TABLE OF CONTENTS

Chapter 11: Design

Section 11-1 Introduction
11-1-1 .....General Design Introduction
1.1.....Originator
1.2.....General Introduction
11-1-5 .....Asset Management by a Practical Design System Preservation Approach
5.1.....Federal Highway Administration (FHWA) Perspective on Performance-Based Practical Design [3]
5.2.....WisDOT Perspective on Performance-Based Practical Design
11-1-10 .....Application of Design Criteria
10.1.....S-1 Application
10.2.....S-2 Application
10.3.....S-3 Application
Attachment 10.1....Improvement Strategies, Improvement Concepts, and Standard Applications
11-1-15 .....Programmatic Exception to Standards
11-1-20 .....Design Justifications (Formerly Exceptions to Standards)
20.1.....General
20.2.....Applicability
20.3.....Controlling Criteria
20.4.....Approval Authority
20.5.....Procedure
11-1-25 .....Metric to US
25.1.....Metric Units
25.2.....Conversion Guidelines
25.3.....Metric Drafting Standards
11-1-99 .....References
Section 11-2 Alternative Contracting
11-2-1 .....Alternative Contracting
1.1.....Introduction
1.2.....Process for Selecting an Alternative Contracting Method
1.3....."Low Bid" Design Build
1.4.....Flexible Notice-to-Proceed
1.5.....Lane Rental
1.6....."Enhanced" Liquidated Damages
1.7.....Interim Liquidated Damages
1.8.....Incentives / Disincentives
1.9.....Cost Plus Time Bidding
1.10.....Warranty Clauses
Attachment 1.1.....Alternative Contracting Decision Flowchart
Attachment 1.2.....Cost Plus Bidding Examples
Attachment 1.3.....Cost Plus Lane Rental Bidding Examples
Section 11-3 Community Sensitive Design
11-3-1 .....Policy & Principles
1.1.....General
1.2.....Design Policy: “Community Sensitive Design”
1.3.....A Changing Context for Transportation
1.4.....Outcomes of Community Sensitive Design
1.5.....Principles of Community Sensitive Design

11-3-5 .....Decision Making Guidance
5.1.....Introduction
5.2.....Decision Making Steps
5.3.....Project Information, Data Collection and Analyses
5.4.....Things to Consider When Making Decisions on Design Criteria
Attachment 5.1.....CSD Considerations for Horizontal Alignment
Attachment 5.2.....CSD Considerations for Vertical Alignment
Attachment 5.3.....CSD Considerations for Stopping Sight Distance
Attachment 5.4.....CSD Considerations for Intersection Sight Distance
Attachment 5.5.....CSD Considerations for Passing Sight Distance
Attachment 5.6.....CSD Considerations for Decision Sight Distance
Attachment 5.7.....CSD Considerations for Cross Section (Lane)
Attachment 5.8.....CSD Considerations for Cross Section (Shoulder)
Attachment 5.9.....CSD Considerations for Cross Section (Medians)
Attachment 5.10....CSD Considerations for Cross Section (Roadside)
Attachment 5.11....CSD Considerations for Intersections
Attachment 5.12....CSD Considerations for Access Control
Attachment 5.13....CSD Considerations for Pedestrian/Bicycle Accommodations
Attachment 5.14....CSD Considerations for Bridges

Section 11-4 Reports

11-4-1 .....Concept Definition Report
1.1.....General
1.2.....Content
1.3.....CDR Process
1.4.....Community Sensitive Design
1.5.....Notes to Design
Attachment 1.1.....Concept Definition Report
11- 4-3 .....Final Scope Certification
3.1.....General
3.2.....Concurrence
3.3.....Content
Attachment 3.1.....Final Scope Certification Document
11-4-5 .....Location Study Report
5.1.....General
11-4-10 .....Design Study Report
10.1.....General
10.2.....Concurrence Process
10.3.....Distribution
10.4.....Content
Attachment 10.1....Modernization and Rehabilitation Design Study Report Template
Attachment 10.2....New Construction, Reconstruction and Rehabilitation Design Study Report Template
Attachment 10.3....Abbreviated Design Study Report Template
Attachment 10.4....Group III Pavement Strategies Preventative Maintenance Project Design Study Report Template
Attachment 10.5....Perpetuation Design Study Report Template
Attachment 10.6....FHWA Design Justification Approval Signature Page
Attachment 10.7....Local Program Signature Sheet
Attachment 10.8....NHS Local Program Signature Sheet
Attachment 10.9....Sample Cross Sections

Section 11-5 General Design Considerations

11-5-1 .....Scope of Construction Projects
1.1.....Discussion
11-5-2 .....Traffic Demand Forecasts
2.1.....Traffic Forecasts General
11-5-3 .....Highway Capacity
3.1.....General
3.2.....Incremental Improvements for Non-Interstates and Non-Freeways
3.3.....Incremental Improvements for Interstates and Freeways
3.4.....Level of Service Analysis
3.5.....Level of Service Evaluation for Environmental Documentation
3.6.....Traffic Analysis Tool Selection

11-5-5 .....Access Control
5.1.....Introduction
5.2.....State Access Management Plan (SAMP)
5.3.....Spacing
5.4.....Intersecting Roadways
5.5.....Interchange Areas
5.6.....Traffic Impact Analysis
5.7.....References
Attachment 5.1.....Access Spacing Guidelines
Attachment 5.2.....Access Control for Typical Interchange
11-5-10 .....Earthwork
10.1.....Preliminary Design
10.2.....General Considerations
10.3.....Project Scheduling
10.4.....Total Volume Concept for Project Earthwork.
10.5.....Borrow
10.6.....Earthwork Quantities
10.7.....Earthwork Computations
10.8.....Excess Incidental Excavation
10.9.....Soil Compaction
10.10.....Bridge Approach Embankments
10.11.....Geosynthetics
Attachment 10.1....Earthwork Calculation Examples
Attachment 10.2....Compaction of Soils
Attachment 10.3....Bridge Approach Construction Techniques
11-5-15 .....Select Materials in Subgrades
15.1.....Policy
15.2.....Application
15.3.....Design
15.4.....Other Design Considerations
Attachment 15.1....Areas for Inclusion of Select Materials
Attachment 15.2....Standard Select Materials Systems
Attachment 15.3....Typical Half Section with Select Materials
Attachment 15.4....Typical Half Section with Select Materials, 4-Lane Divided Highway, 50 ft Median
Attachment 15.5....Typical Half Section with Select Materials, 4-Lane Divided Highway, 60 ft Median
Attachment 15.6....Median Drain Detail for Select Materials Layer Greater Than cmax
Attachment 15.7....Typical Section for 1-Lane Ramp with Select Materials

Section 11-10 Design Controls

11-10-1 .....Basic Criteria
1.1.....Design Year
1.2.....Traffic
1.3.....Highway Capacity
1.4.....Functional Classification
1.5.....Design Speeds
1.6.....References
11-10-5 .....Geometric Elements
5.1.....Sight Distances
5.2.....Horizontal Alignments
5.3.....Superelevations
5.4.....Vertical Alignments
5.5.....References
Attachment 5.1.....Sight Distance Values
Attachment 5.2.....Sight Distance Categories and Applications
Attachment 5.3.....Maximum Grades by Functional Classification
Attachment 5.4.....Sight Distance for Crest Vertical Curves
Attachment 5.5.....Sight Distance for Crest Vertical Curves - Graphs
Attachment 5.6.....Sight Distance for Sag Vertical Curves
Attachment 5.7.....Sight Distance for Sag Vertical Curves - Graphs
Attachment 5.8.....Passing Sight Distance for Crest Vertical Curves
Attachment 5.9.....Sight Distance on Horizontal Curves
Attachment 5.10....Super-elevation Transition of Two-Lane Highway to the Right
Attachment 5.11....Super-elevation Transition of Divided Highway Curve to Right

Attachment 5.12....Super-elevation Chart for Low Speed Urban Street
Attachment 5.13....Guide Dimensions for Vision Triangles, Stop Control on Minor Road
Attachment 5.14....Sample Problem - Intersection Sight Distance
Exhibit 5.1.....Superelevation Tables (emax = 4% and 6%)

Section 11-15 Cross-Section Elements for Modernization Projects on Rural Highways, Freeways and Interstates

11-15-1.....Modernization Design Guidance for Highways
1.0.....Introduction
1.1.....Overview and Scope of Modernization Projects
1.2.....Safety and Traffic Operations
1.3.....Design Standards Application
1.4.....Shoulders
1.5.....Railroad Crossings
1.6.....Cross Slopes
1.7.....Shoulders
1.8.....Rumble strips
1.9.....Auxiliary Lanes
1.10.....Subgrade Side Slopes and Widths
1.11.....Side Slopes
1.12.....Side Ditches
1.13.....Clear Zones, Horizontal Clearances, and Clear Roadway Widths of Bridges
1.14.....Median
1.15.....Transition from Divided to Two-Way Roadways
1.16.....Marsh Section
1.17.....Local Service
1.18.....Rural Driveways and Entrances
1.19.....Traffic Control Devices/Signing on Interstate Highways
1.20.....Access Control on Interstate Highways
Attachment 1.1.....Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Arterials
Attachment 1.2.....Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Collectors
Attachment 1.3.....Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Local Roads
Attachment 1.4.....Modernization Design Standards for Town Roads (New Construction Only)
Attachment 1.5.....Rural State Trunk Highway Modernization Paved Shoulder Width Criteria
Attachment 1.6.....Typical Modernization Cross Sections for Rural 2-Lane Highways
Attachment 1.7.....Typical Modernization Cross Sections for Divided Highways and 1-Lane Ramps
Attachment 1.8.....Modernization Roadway Sections in Rock Cut
Attachment 1.9.....Modernization Clear Zone Distance Tables and Recovery Area Width Determination
Attachment 1.10....Modernization Horizontal Curve Correction Factors
Attachment 1.11....Modernization Ditch Traverseability Evaluation Charts
Attachment 1.12....Typical Modernization 2- to 4-Lane Transition
Attachment 1.13....Typical Modernization Marsh Sections
Attachment 1.14....Lateral Clearance on Modernization Rural Roadways
Attachment 1.15....Modernization Design Criteria for County Trunk Highways Functionally Classified as Arterials
Attachment 1.16....Modernization Design Criteria for County Trunk Highways Functionally Classified as Collectors
Attachment 1.17....Modernization Design Criteria for County Trunk Highways Functionally Classified as Local Roads
Attachment 1.18....Modernization Design Criteria for Interstate Highways
11-15-5.....Design Criteria for the Great River Road
5.1.....Introduction
5.2.....Design Criteria
5.3.....Shoulder Width
5.4.....Special Design Features
5.5.....Application of Design Criteria
Attachment 5.1.....Great River Road Map
11-15-10.....Passing Lanes and Climbing Lanes
10.1.....Passing Lanes
10.2.....Climbing Lanes
Attachment 10.1....Rural STH Passing Lane Corridors

Attachment 10.2....Warrant for Considering Passing Lanes

Section 11-20 Cross Section Elements for Modernization of Urban Highways

11-20-1 .....Modernization Dimensions and Design Classes
1.0.....General
1.1.....Cross Slopes
1.2.....Curbs or Curb and Gutters
1.3.....Design Criteria Guidance
1.4.....Medians
1.5.....Travel Lanes
1.6.....Auxiliary and Parking Lanes
1.7.....Borders
1.8.....Slopes and Ditches
1.9.....Clearances for Urban Roadways
Attachment 1.1.....Urban Streets Modernization Roadway Design Criteria for Posted Speed Limits of 40 mph or less
Attachment 1.2.....Typical Street Cross Sections, Classes 1b, 2a, 2b & 3
Attachment 1.3.....Typical Street Cross Sections, Class 4 and Class 5
Attachment 1.4.....Factors Used for Highway Capacity Manual LOS Thresholds
Attachment 1.5.....Transitional and High Speed Urban Roadway Criteria for Posted Speed Limits of 45 -55 mph
Attachment 1.6.....Typical Transitional / High-Speed Urban Street Cross Sections
Attachment 1.7.....Required Lateral Clearance
Attachment 1.8.....Run Off the Road Frequency Calculator
11-20-5 .....One -Way Streets
5.1.....Guidelines
11-20-10 .....Driveways
10.1.....Introduction
10.2.....Driveways for Parcels
10.3.....Design Criteria
10.4.....Driveway Pavement Materials
10.5.....Plan Preparation
Attachment 10.1....Conceptual Driveway Profiles
Attachment 10.2....Driveway Design Concepts for Type X, Type Y, and Type Z
11-20-50 .....References

Section 11-25 Intersections at Grade

11-25-1 .....General
1.1.....Design Consideration
1.2.....Urban Intersections
1.3.....Rural Intersections
1.4.....Truck Routes and Routes for Oversized-Overweight (OSOW) Vehicles
1.5.....References
Attachment 1.1.....Selection Criteria for Rural High-Speed Intersections
11-25-2……Design Criteria and Guidelines
2.1.....Design Vehicles
2.2.....Physical and Functional Areas of an Intersection
2.3.....Turn Bays
2.4.....Taper Design
2.5.....Corner Clearance to Driveways
2.6.....Intersection Vertical Alignment
2.7.....Intersection Sight Distance
2.8.....Angle of Intersection
2.9.....Intersections on Curves
2.10.....References
Attachment 2.1.....WisDOT Vehicle Inventory of Oversized Overweight (OSOW) Vehicles
Attachment 2.2.....WisDOT Interim Policy on Checking Criteria for OSOW-ST and OSOW-MT Vehicles at Intersections
Attachment 2.3.....Taper Length Criteria
11-25-3……..Intersection Control Evaluation
3.1.....Intersection Control Evaluation (ICE)
3.2.....ICE Process
Attachment 3.1.....Relationship between the Facilities Development Process and the ICE Process
Attachment 3.2.....Intersection Control Evaluation (ICE) Process Flow Chart

Attachment 3.3.....Traffic Control Summary Tables
Attachment 3.4.....Phase I: ICE Memorandum
Attachment 3.5.....Phase I: ICE Brainstorming Guide
Attachment 3.6.....Phase II: ICE Worksheets
Attachment 3.7.....ICE Submittal Checklist
11-25-5 .....Left Turn Lanes
5.1.....Introduction
5.2.....Warranting Criteria
5.3.....Design Criteria
5.4.....Special Designs
5.5.....Tee Intersection Bypass Lane
5.6.....References
Attachment 5.1.....Urban Median Opening and Intersection Guidelines
Attachment 5.2.....Median Openings and Left Turn Lanes in Urban Roadways
Attachment 5.3.....Details for Slotted Left Turn Lanes and Median Opening Openings at Urban Intersections
Attachment 5.4.....Median Opening with Left Turn Lane on Rural High-Speed 4-Lane Divided Highway
11-25-10 .....Right-Turn Lanes
10.1.....Introduction
10.2.....Intersections in Rural and Developing Areas
10.3.....Two-Way Stop-Controlled Intersections on Urban Low Speed and Transitional Roads
10.4.....Signalized Intersection Considerations
10.5.....References
11-25-15 .....Turning Roadways (Channelized Right)
15.1.....Criteria
15.2.....Speed and Curvature
15.3.....Design Guides
15.4.....References
11-25-20 .....Median Openings
20.1.....Introduction
20.2.....U-Turns
20.3.....Length of Opening
20.4.....Spacing
20.5.....References
11-25-25 .....Channelization
25.1.....General
25.2.....Islands
25.3.....Pavement Markings
25.4.....References
11-25-35 .....Auxiliary Lanes
35.1.....Auxiliary Lanes
35.2.....Acceleration Lanes
35.3.....Bus Stops
11-25-40 .....Railroad Crossings
40.1.....General
40.2.....References
11-25-45 .....Frontage Roads
45.2.....References
11-25-50 .....Master Reference List
Section 11-26 Roundabouts
11-26-1 .....General
1.1.....General
1.2.....Modern Roundabout vs. Other Circular Intersections
1.3.....Advantages and Disadvantages
1.4.....Defining Physical Features
1.5.....Roundabout Categories
1.99.....References
11-26-5 .....Design Process and Qualifications
5.1.....Roundabout Design Process and Qualifications
5.2.....Roundabout Designer Requirements
5.3.....Intersection Control Evaluation, Program Level Scoping Phase
5.4.....The 3-Stage Roundabout Design Process
Attachment 5.1.....Roundabout Critical Design Parameters Document

11-26-10 .....User Considerations
10.1.....Pedestrian and Bicyclist Accommodations
10.2.....Transit, Large Vehicle, Oversize Vehicles and Emergency Vehicle Considerations
10.99.....References
11-26-15 .....Agency & Public Coordination
15.1.....Public Meetings
15.2.....Public Outreach Resources & Methods
15.99.....References
11-26-17 .....System Considerations
17.1.....System Considerations
17.2.....Adjacent Intersections and Highway Segments and Coordinated Signal Systems
17.3.....Roundabouts in an Arterial Network
17.4.....Closely Spaced Roundabouts
17.5.....Roundabout Interchange Ramp Terminals
17.6.....Traffic Signals at Roundabouts
17.7.....At-Grade Rail Crossings
17.99.....References
11-26-20 .....Operations
20.1.....Operational Analysis References and Methods
20.2.....Roundabout Operation
20.4.....Operational Analysis Methodology
20.5.....Supplemental Tools for Operational Analysis and Design
20.6.....Capacity Analysis of an Existing Roundabout
20.99.....References
Attachment 20.1....Roundabout Traffic Flow Worksheet
11-26-25 .....Access Control
25.1.....Access Management
25.2.....Functional Intersection Area
25.3.....Corner Clearance and Driveway Location Considerations
25.4.....Parking near Roundabouts
25.5.....Interchange Ramps
25.99.....References
11-26-30 .....Principle Based Design Guidance
30.1.....Introduction
30.2.....Design Principles
30.3.....Roundabout Design Process
30.4.....General Design Steps & Explanation
30.5.....Design Considerations
30.6.....Plan Preparation
30.99.....References
11-26-35 .....Signing and Pavement Marking
35.1.....Signing
35.2.....Pavement Marking
Attachment 35.1....Example Pavement Markings for Typical Designs
Attachment 35.2....Sample Signing Layout for Single-lane Roundabout
Attachment 35.3....Sample Signing Layout for a Multilane Roundabout
Attachment 35.4....Sample Signing Plan for Roundabout Ramp Terminals
Attachment 35.5....Sample Signing Plan for Roundabout Ramp Terminals
11-26-40 .....Landscaping and Maintenance
40.1.....Central Island Landscaping
40.2.....Landscape Design
40.3.....Landscape Maintenance
40.4.....Shared-Use Path Maintenance
11-26-45 .....Work Zone Traffic Control
45.1.....Work Zone Traffic Control
45.99.....References
11-26-50 .....Design Aides
50.1.....Example Plan Sheets
50.2.....Creating Roundabout Fastest Paths (B-spline Curves) and Using AutoTurn software
50.3.....OSOW Vehicle Inventory Evaluation Overview
Attachment 50.1....Creating Roundabout Fastest Paths (Spline Curves) in AutoCAD Civil 3D
Attachment 50.2....Creating Roundabout Fastest Paths (Spline Curves) in Microstation Version 8i
Attachment 50.3....Guide for Using AutoTURN in AutoCAD Civil 3D and MicroStation Version 8i

Section 11-30 Interchange

11-30-1 .....Design Elements
1.1.....Warranting Guidelines
1.2.....General Design
1.3.....Interchange Type and Selection
1.4.....Ramps
1.5.....Intersection Sight Distance
1.6.....Grades and Profile
1.7.....Superelevation and Cross Slope
1.8.....References
Attachment 1.1.....Single Lane Entrance Terminal
Attachment 1.2.....Typical Entrance and Exit Ramp Terminal Details
Attachment 1.3.....Single Lane Exit Terminal
Attachment 1.4.....Typical Details of Ramp - Mainline Intersections
Attachment 1.5.....Details of Ramp - Mainline Intersections with Special Turn Lanes
Attachment 1.6.....Layout for Turning Volumes
11-30-5 .....Cross Section, Ramp and Crossroad
5.1.....Interchange Ramp Roadway Widths
5.2.....Interchange Ramp Median (Two-Way Operations)
5.3.....Intersecting Road
11-30-10 .....Collector Distributor Roads
10.1.....Collector-Distributor Roads

Section 11-35 Structures

11-35-1 .....Widths, Clearances, Sidewalks and Protective Screening
1.1.....Structure Survey Reports
1.2.....Clear Roadway Width of Bridges
1.3.....Lateral Underclearances to Structures [2,3]
1.4.....Parapets on Structures
1.5.....Vertical Clearances [1-3]
1.6.....Sidewalks, Bicycle Accommodations, Shared Use Paths and Roundabout Sidepaths
1.7.....Touchdown Points on Local Program Bridge Projects
1.8.....Protective Screening
1.9.....References
Attachment 1.1.....Structure Roadway Widths and Approach Details
Attachment 1.2... ..4 - Lane Divided Highway Structure Widths (w/Acceleration Lanes)
Attachment 1.3... ..4 - Lane Divided Highway Structure Widths (w/Deceleration Lanes)
Attachment 1.4.....2, 4, and 6 - Lane Structure Widths (Special Situations)
Attachment 1.5.....Lateral Underclearance to Structure for Rural Highways, Expressways, and Freeways
Attachment 1.6.....Lateral Underclearance to Structure for Urban Streets
Attachment 1.7.....Examples of Lateral Underclearance to Structure
Attachment 1.8.....Minimum Vertical Clearance for New Bridges and Replacement Bridges
Attachment 1.9.....Minimum Vertical Clearance for Bridges to Remain
11-35-5 .....Temporary Bridges
11-35-10 .....Three Lane Bridge Criteria
10.1.....General
10.2.....Bridge Widening Warrants
10.3.....Bridge Rehabilitation and Widening Practices
10.4.....Other Factors to Consider

Section 11-38 Safety Certification Process

11-38-1 .....General
1.1.....Overview
1.2.....Acronyms and Definitions
11-38-3 .....Policy
11-38-5 .....Overview of Safety Quantification in the Project Development Process
11-38-10 .....WisDOT Safety Certification Process
10.1.....General
10.2.....Sites of Promise by System Screening
10.3.....Crash Vetting for the Sites of Promise
10.4.....Contributing Geometric Analysis (CGA)
10.5.....Safety Mitigation Certification
10.6.....Safety Certification Document
Attachment 10.1....Safety Certification Process Flowchart

Attachment 10.2....Safety Certification Worksheet
Attachment 10.3....Sites of Promise by System Screening Process Flowchart
Attachment 10.4....Geometric Features
Attachment 10.5....Safety Improvement Prompt List
Attachment 10.6....Design Elements Covered in HSM Predictive Methods
Attachment 10.7....Flowchart for Choosing a Safety Mitigation Method
Attachment 10.8....Safety Certification Document
11-38-15 .....Examples for Safety Certification Process
15.1.....General
11-38-99 .....References

Section 11-40 Perpetuation and Rehabilitation Requirements for Highways

11-40-1 .....General Perpetuation and Rehabilitation Requirements for Highways
1.0.....Introduction
1.1.....Overview of Perpetuation and Rehabilitation Projects
1.2.....Safety Analysis
1.3.....Design Criteria Application
1.4.....Bridge Improvements
1.5.....Pavement Design
1.6.....Traffic Control Devices and Pavement Marking
1.7.....Rumble Strips
1.8.....Passing Sight Distance for Vertical Curves
1.9.....Passing and Truck Climbing Lanes
1.10.....Bicycle and Pedestrian Accommodations
1.11.....Roadside Design
11-40-6.....Design Standards for Perpetuation Projects
6.0.....General
6.1.....General Perpetuation Design Criteria with S-1 Application
6.2.....Intersections
6.3.....Roadway Cross Section Elements
11-40-7 .....Design Standards for Rehabilitation Projects
7.0.....General
7.1.....References
Attachment 7.1.....S-2 Application of Design Criteria for Rehabilitation Projects
Attachment 7.2.....Design Standards for Rehabilitation Projects on Rural State Trunk Highways Functionally Classified as Arterials
Attachment 7.3.....Design Standards for Rehabilitation Projects on Rural State Trunk Highways Functionally Classified as Collectors and Locals
Attachment 7.4.....Design Standards for Rehabilitation Projects on Town Roads
Attachment 7.5.....Design Standards for Rehabilitation Projects on Rural County Trunk Highways Functionally Classified as Arterials
Attachment 7.6.....Design Standards for Rehabilitation Projects on Rural County Trunk Highways Functionally Classified as Collectors and Locals
11-40-8 .....Design Standards for 3R Projects on Expressways and Freeways (Non-Interstate)
11-40-99 .....References

Section 11-45 Other Elements Affecting Geometric Design

11-45-10 .....Roadside Design Application – Improvement Strategy
10.1.....Introduction
10.2.....Application of Improvement Strategy
10.3.....Roadside Hazard Analysis and Treatments
10.4.....Roadside Hardware Evaluation and Treatments
Attachment 10.1....Existing Guardrail Post Sampling Procedure

11-45-15 .....Roadside Barrier - General
15.1.....Introduction
11-45-20 .....Roadside Hazard Analysis
20.1.....Introduction
20.2.....Project Applicability
20.3.....Roadside Hazard
20.4.....Areas of Concern
20.5.....Area of Analysis
20.6.....Roadside Hazard Analysis (RHA) Documentation
Attachment 20.1....Roadside Design Factors to Consider
Attachment 20.2....AASHTO's Warrant for Shielding Foreslopes

Attachment 20.3….FHWA Warrants for Shielding Foreslopes
Attachment 20.4….Shielding Hazardous Cross-Drains
Attachment 20.5….Shielding Hazardous Water
Attachment 20.6….Roadway Segments with High Tree Crash Rates
Attachment 20.7….Shielding Hazardous Trees
Attachment 20.8….Median Barrier Warrant for New Freeways
Attachment 20.9….Shielding Hazardous Fixed Objects
Attachment 20.10….Scoping/Preliminary Roadside Hazard Design Review List
Attachment 20.11….Roadside Hazard Analysis Sheet Template
Attachment 20.12….Roadside Hazard Analysis Sheet Example
11-45-30 .....Roadside Barrier Design Guidance
30.3.....Barrier System Design
30.4.....End Treatments
30.5.....Existing Barrier System Evaluation
30.6.....Drainage Features and Cattle Passes
30.7.....Safety Edge
30.8.....Cross-Median Crash (CMC)
Attachment 30.1 Example Problem 1: West Side of Structure
Attachment 30.2 Example Problem 2: Rock Wall
Attachment 30.3 Example Problem 3: Outside of Curve Cattle Pass
Attachment 30.4 Example Problem 3: Inside of Curve Cattle Pass
Attachment 30.5 Example Beam Guard Plan Sheet
Attachment 30.6 Beam Guard Analysis
Attachment 30.7 Beam Guard Bullnose
Attachment 30.8 Sloped Concrete End Treatment
Attachment 30.9 Grading Area for Hazardous Cross-Drain
Attachment 30.10 Grading Area for Hazardous Parallel Drain
Attachment 30.11 Crash Cushion Selection Tables
Attachment 30.12 Length of Barrier and Working Width Examples
Attachment 30.13 Barrier Working Width Table
Attachment 30.14 Barrier Length Examples
Attachment 30.15 Minimum Barrier Length Table
Attachment 30.16 Shielding Large Fixed Objects in a Median with Cable Barrier and Other Barrier Systems
Attachment 30.17 Median Cable Barrier on a Curve
Attachment 30.18 Median Cable Barrier by an Interchange or Bridge
Attachment 30.19 Median Cable Barrier by a Maintenance Cross Over
Attachment 30.20 Underground Obstructions and Shifting Beam Guard
Attachment 30.21 Crash Test Photos Sequence Beam Guard Attached to Rigid Barrier
Attachment 30.22 Thrie Beam Transitions to Rigid Barrier Installations
Attachment 30.23 Partial Removal of a Middle Section of an Older Barrier Section Details
Attachment 30.24 Short Radius
Attachment 30.25 Long-Span
Attachment 30.26 Beam Guard Retaining Wall
Attachment 30.27 Beam Guard Terminal Earthwork
11-45-40 .....Fencing
40.1.....Introduction
40.2.....Application of Improvement Strategy
40.3.....Roadside Hazard Analysis and Treatments
40.4.....Roadside Hardware Evaluation and Treatments
11-45-99 .....References
Section 11-46 Bicycle and Pedestrian Accommodations
11-46-1 .....Bicycle and Pedestrian Elements Affecting Complete Streets
1.1.....Introduction, Purpose, Definitions, Overview
1.2.....Bikeways and Sidewalks
1.3.....Project Development / Scoping Process
1.4.....References
Attachment 1.1.....FHWA letter
Attachment 1.2.....DOJ/DOT Joint Technical Assistance on the ADA Title II Requirements to Provide Curb Ramps when Streets, Roads, or Highways are Altered through Resurfacing
Attachment 1.3.....Glossary of Terms for DOJ/FHWA Joint Technical Assistance on the ADA Title II Requirements to Provide Curb Ramps when Streets Roads or Highways are Altered Through Resurfacing

11-46-5.....Pedestrian Facilities
5.1.....Introduction
5.2.....Urban Borders and Zone System
5.3.....References
Attachment 5.1.....Sidewalk Design Considerations
11-46-10 .....Curb Ramps
10.1.....General
10.2.....Curb Ramps and Detectable Warning Fields
10.3.....Curb Ramp Design Considerations
10.4.....Other Considerations
10.5.....Curb Ramp Adjacent to Historically Significant Resources
10.6.....References
Attachment 10.1....Legal Crosswalk and Crosswalk Closure Figures
Attachment 10.2....Curb Ramp Options with Restricted Right-of-Way
Attachment 10.3....Accessible Pedestrian Signals & Push Button Locations
Attachment 10.4....On-Street Parking for People with Mobility Impairments
11-46-15 .....Bicycle Facilities
15.1.....Introduction to Bicycle Facilities
15.2.....Design Guidelines and Basic Improvements
15.3.....Urban On-road Bicycle Accommodations
15.4.....Rural On-road Bicycle Accommodations
15.5.....Shared Roadways
15.6.....Shared-use Paths
15.7.....Bicycle Accommodations on Highway Structures
15.8.....Inlet, Manhole and Utility Covers
15.9.....At-Grade Railroad Crossings
15.10.....Signing and Marking
15.11.....References
11-46-20 .....Permanent Public Trail Crossing Rural Public Roads
20.1.....Introduction
20.2.....Engineering Warrants for Trail-Highway Crossings
20.3.....Freeways and Expressways
20.4.....At-Grade Treatments
20.5.....Grade Separation Structure Guidance
20.6.....Financial and Cost Share Responsibilities
Attachment 20.1....Grade Separation Warrants
Attachment 20.2....Grade Separation Warrant Worksheet
Attachment 20.3....Sample Grade Separation Warrant Determination
Attachment 20.4....Sight Distance for Trail Crossing
11-46-99 .....References

Section 11-50 Traffic Control

11-50-1 .....Work Zone Policy Statement
11-50-5 .....Transportation Management Plan Process
5.1.....Introduction
5.2.....What is a TMP?
5.3.....Project Development Process
5.4.....Work Zone Impacts Assessment
5.5.....TMP Development
5.6.....TMP Type Selection Matrix
5.7.....Mitigation Contracts
5.8.....Implement TMP
5.9.....Monitor TMP
5.10.....Documentation of Changes to TMP
5.11.....Post Construction Project Evaluation
5.99.....References
Attachment 5.1.....Project Initiation Process & Project Management Plan
Attachment 5.2.....Standard Work Zone Strategy Matrix
Attachment 5.3.....Standard Public Information and Motorist Mitigation Strategy Matrix
Attachment 5.4.....Standard Incident Management Approval Strategy Matrix
Attachment 5.5.....Non-Standard Mitigation Strategy Form
Attachment 5.6.....Law Enforcement Process Flowchart
11-50-10 .....Components of a Transportation Management Plan
10.1.....Components of a Transportation Management Plan

10.2.....Public Information & Outreach Plan (PIOP)
10.3.....Work Zone Incident Management Plan (IMP)
Attachment 10.1....Public Information & Outreach Plan Checklist
Attachment 10.2....Transportation Operations Plan Checklist
Attachment 10.3....Example Communications Flow Diagram
Attachment 10.4....Example Emergency Alternatives Route Maps
Attachment 10.5....Example Emergency Access, Pullout and Traveler Information Equipment Location Map
11-50-15 .....Work Zone Traffic Control Plan Process
15.1.....Project Scope
15.2.....Traffic Control Scope
15.3.....Construction Under Traffic
15.4.....Detour Determination
15.5.....Develop Staging Plan
15.6.....SDDs
15.7.....Prepare Preliminary Traffic Control Plan & Details
15.8.....Preliminary Plan & Details Review
15.9.....Finished Traffic Control Plan & Review Meeting
15.10.....Contractor Involvement
15.11.....Bureau of Traffic Operations Involvement
Attachment 15.1....Work Zone Traffic Control Plan Process
11-50-20 .....Safety and Design in Work Zones
20.1.....General Requirements
11-50-21 .....Safety and Design in Work Zones
21.1.....Signing
21.2.....Pavement Marking
21.3.....Channelizing Devices
21.4.....Temporary Portable Rumble Strips
21.5.....Work Area Ingress and Egress
21.6.....Pavement Drop-off Protection
21.7.....Freight Consideration
21.8.....Traffic Control Quantities
21.9.....Design of Traffic Control Plans
21.10.....Speed Limits During Construction
21.11.....Detours
21.99.....References
11-50-22 .....Traffic Control Plans for Divided Highways
22.1.....Traffic on Divided Roadways
22.2.....Lane Shifts
22.3.....Lane Closures
22.4.....Lane Width
22.5.....Entrance and Exit Ramps within Lane Closures
22.6.....Crossover Design (Construction)
22.99.....References
11-50-23 .....Traffic Control Plans for Undivided Highways
23.1.....Traffic on Undivided Roadways
23.2.....Lane Shifts
23.3.....Lane Closures
23.4.....Flagging
23.5.....Temporary Signals
23.6.....Full Closures and Detours
11-50-25 .....Smart Work Zones
25.1.....Smart Work Zones
25.2.....Dynamic Late Merge System
25.3.....Queue Warning System
25.4.....Digital Speed Limit Sign Assembly
25.5.....Construction Truck Entering and Exiting System
25.99.....References
11-50-30 .....Statewide Freeway and Expressway Lane Closure and Delay Guidelines
30.1.....Introduction
30.2.....Lane Closure System (LCS)
30.3.....Special Events and Holiday Work Restrictions

30.4.....Peak Hour Restrictions
30.5.....Estimate Capacity Under Proposed Lane Closure
11-50-31 .....Temporary Pedestrian Accommodations
31.1.....Introduction
31.2.....Project Scoping/Planning
31.3.....Transportation Management Plan / PS&E
31.4.....Design Considerations
31.99.....References
11-50-32 .....Road User Costs
32.1.....Introduction
32.2.....Road User Cost Computation
11-50-35 .....Concrete Barrier Temporary Precast in Work Zone
35.1.....Introduction
35.2.....Factors to Consider
35.3.....Guidelines for CBTP Use
35.4.....CBTP Anchoring Requirement/Deflection Distance
35.5.....Intersection Sight Distance
35.6.....CBTP End Treatments
11-50-45 .....Pavement Marking
45.1.....General
45.2.....Pavement Marking Selection
11-50-50 .....Signals
50.1.....General
50.2.....Traffic Signal Investigation
50.3.....Design Standards
11-50-55 .....Signing
55.1.....General
55.2.....Reflective Sheeting and Replacement Guidelines for Highway Signs
11-50-60 .....Lighting
60.1.....General

Section 11-52 Traffic Engineering and Operations

11-52-1 .....Intelligent Transportation Systems (ITS) Guidance
11-52-5 .....Traffic Engineering, Operations and Safety Manual (TEOpS)
11-52-10 .....Traffic Signal Design Manual (TSDM)

Section 11-55 Special Features

11-55-1 .....Boat Ramps
1.1.....Site Layout
1.2.....Launching Ramps
1.3.....Parking Lots
1.4.....Miscellaneous Design
Attachment 1.1.....Boat Ramp Details
Attachment 1.2.....Pier Details
Attachment 1.3.....Boat Ramp Example Parking Layouts
Attachment 1.4.....Boat Ramp Example Parking Layouts
11-55-3 .....Timber Management
11-55-5 .....Retaining Walls
5.1.....General
5.2.....Minor Retaining Wall
5.3.....Barriers on Top of Retaining Walls
5.4.....Right-Of-Way Requirements
11-55-10 .....Cattle Pass Design
10.1.....General
10.2.....Criteria
10.3.....Design Guidelines
10.4.....Other Considerations
Attachment 10.1....Documentation for Cattle Pass
11-55-20 .....Overhead Sign Structures
20.1.....General
20.2.....OSS Selection and Usage Criteria
20.3.....OSS Design and Plan Submittal Process
20.4.....OSS Design Types
20.5.....Subsurface Investigation and Information
20.6.....Roadside Design Guidelines

Attachment 20.1....WisDOT Overhead Sign Structure Types
Attachment 20.2....Overhead Sign Structure Selection Examples
Attachment 20.3....Overhead Sign Structure Design Process Flow Chart
11-55-25 .....Ramp Gates
25.1.....Background
25.2.....Deployment and General Considerations
25.3.....Guideline Compliance Documentation
25.4.....Other Design Considerations
25.5.....Identification Plaques
25.6.....Barricades in Conjunction with Ramp Closure Gates
25.7.....Additional Information
Attachment 25.1....Wisconsin Ramp Gate Maintenance and Inspection Guideline
Attachment 25.2....Inspection Form for Manual Ramp Gates
Attachment 25.3....Example Ramp Closed Use Alternative Route (R11-54F) Sign Details

FDM 11-1-1 General Design Introduction

August 15, 2019

1.1 Originator

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1.2 General Introduction

This Chapter includes the established policies, design criteria and guidelines for application on all highways and streets being designed by or for WisDOT. The design information presented is based primarily on policies, design criteria, and specifications adopted by the American Association of State Highway and Transportation Officials (AASHTO). AASHTO publications are frequently referred to throughout this Chapter and are intended to supplement the design information presented. The letters GDHS will be used to represent various editions of the AASHTO publication "A Policy on Geometric Design of Highways and Streets."

The basic criteria that govern the design and selection of traffic control devices are found in the latest edition of the U.S. DOT publication, "Manual on Uniform Traffic Control Devices for Streets and Highways" (MUTCD). This publication defines national design criteria and provides the necessary uniformity in application of control devices. The provisions of the MUTCD are further interpreted or modified by the Wisconsin DOT supplement to the MUTCD, and by specific provisions of this Facilities Development Manual. The purpose of traffic control devices and the warrants for their use, as stated in the MUTCD, is to help ensure highway safety by providing for the orderly and predictable movement of all traffic.

Safety is a prime consideration in the development of all designs. A performance-based safety engineering analysis and economic appraisal must be used to determine cost and safety effectiveness. See FDM 11-38.

Regarding Wisconsin State Statutes, design criteria are design standards.

FDM 11-1-5 Asset Management by a Practical Design System Preservation Approach May 15, 2019

5.1 Federal Highway Administration (FHWA) Perspective on Performance-Based Practical Design [3]

State Departments of Transportation (DOT) are increasingly challenged with addressing their system performance, mobility, and safety needs in the current era of financial limitations.

The Federal Highway Administration (FHWA) conducted an in-depth review of the Practical Design concept, including interviewing several States about their practices.

Though the name, definition, and approach of Practical Design vary from state to state, most states with a Practical Design program emphasize a renewed focus on scoping projects to stay within the core purpose and need. By exercising a greater level of discipline, agencies may eliminate nonessential project design elements resulting in lower cost and improved value. This approach enables states to deliver a greater number of projects than otherwise possible under their previous project development approaches. By implementing Practical Design, states realized cost savings by utilizing flexibility that exists in current design guidance and regulations.

Some states implementing Practical Design, as well as FHWA, have expressed concern that there may have been an overemphasis on short-term cost savings without a clear understanding of how such decisions could impact other objectives (such as; safety performance, context sensitivity, life-cycle costs, long-range corridor goals, livability, and sustainability).

To address this concern, agencies can make more informed decisions by evolving towards a Performance Based Practical Design (PBPD) approach grounded in a performance management framework. PBPD can be articulated as modifying the traditional design approach to meet both project and system objectives. PBPD uses appropriate performance-analysis tools and considers both short and long-term project and system goals while addressing project purpose and need.

The key to addressing geometric design and safety elements of a projects purpose and need is knowledge of the past safety performance of the location. This is essential for evaluating risk. Designers need a full knowledge of the expected substantive safety performance of the project locations. A project location exhibiting acceptable, long-term safety performance relative to expectation, despite having design features that do not meet current criteria, may indicate a lower level of risk.

See FDM 3-5-1 for asset management information and guidance.

5.2 WisDOT Perspective on Performance-Based Practical Design

The term Performance-Based Practical Design consists of two components:

- Performance-based means that any engineering changes to a highway are based on the actual performance benefits to that highway, rather than whether it is built to a certain standard or criteria.
- Practical design is an approach that starts with addressing only those issues that have been identified as being needed to meet the project specific purpose and need.

Substandard is not the same as deficient. If no discernable safety issues exist in a roadway segment, then the existing configuration can be maintained.

Upgrading to a certain standard may not be the most cost-effective solution. If discernable safety issues are present, project level engineering, standardized safety screening, and appropriate economic analysis is required to ensure the potential design elements will provide the appropriate performance and most reasonable financial cost benefit.

The Department utilizes a PBPD tool for pavement treatments and safety-driven geometric alterations. It includes safety screening to identify safety flags, but also applies a safety certification process that uses performance-based engineering and system-based economic analysis to ensure the right solutions are implemented at the right time, in the right locations.

The flexibility in design guidance and regulations provided in PBPD as described by FHWA is founded in having the appropriate analysis of past and expected future safety performance. PBPD considers individual project investment decisions within the broader context of overall system-wide performance. The engineering methods and documentation that correlates that safety analysis to appropriate design is the key to successfully executing PBPD.

FDM 11-1-10 Application of Design Criteria May 18, 2020

Application of geometric design criteria to a project will depend upon the type of facility and the nature of the project. The design criteria in this chapter apply to state-funded and Federal-Aid projects. FHWA also accepts the values given in the following documents that can be applied when the criteria are not addressed in this

chapter:

1. Interstate Highways
   - A Policy on Design Standards - Interstate System, 2016, AASHTO (see FHWA web-site, "Geometric Design", https://www.fhwa.dot.gov/programadmin/standards.cfm, under "Regulation")
2. Non-Interstate Highways
   - A Policy on Geometric Design of Highways and Streets (GDHS), 6th edition, 2011 AASHTO (see FHWA web-site, "Geometric Design", https://www.fhwa.dot.gov/programadmin/standards.cfm, under "Information")
3. Off System Roads
   - Refer to Chapter 5, GDHS.

10.1 S-1 Application

S-1 application involves the retention and restoration of the roadways existing geometric and cross-sectional features to satisfy the purpose and need of the project.

S-1 will be applied if no discernable safety issues are present as determined by the Safety Certification Document (SCD). Restore existing highway features to satisfy project purpose and need. S-1 will also be applied where safety issues will be mitigated by the addition of low-cost counter measures.

Projects using S-1 applications include Perpetuation and portions of some Rehabilitation Improvement Strategies as defined in FDM 3-5-1.

FDM 11-1 Attachment 10.1 shows the relationship between Improvement Strategies, Improvement Concepts and Application of Design Criteria.

10.2 S-2 Application

S-2 application will involve use of the lower end of the design criteria ranges (where a range exists) as a starting point for the features contributing to safety issues. Apply PBPD principles using the Safety Certification Process (SCP) to satisfy project purpose and need and achieve acceptable safety performance.

Projects using S-2 applications include Rehabilitation and some Modernization Improvement Strategies as defined in FDM 3-5-1. Use S-1 applications on portions of the project that do not have discernable safety issues.

FDM 11-1 Attachment 10.1 shows the relationship between Improvement Strategies, Improvement Concepts and Application of Design Criteria.

10.3 S-3 Application

Use upper end of the design criteria ranges (where a range exists) as a starting point. Apply PBPD principles to satisfy project purpose and need.

Projects using S-3 applications include Modernization Improvement Strategies as defined in FDM 3-5-1.

FDM 11-1 Attachment 10.1 shows the relationship between Improvement Strategies, Improvement Concepts and Application Criteria.

10.4 Ancillary Factors

During scoping and design, potential needs may be identified that require further analysis and possible design alterations or additions. These are referred to as Ancillary Factors. Identification of these factors likely are or may be independent of safety analysis. These factors will require additional analysis to determine their validity. If they are found valid, they may require alterations or additions to the current design. They include:

- Remaining Pavement Life-cycle service life (Assessed by Pavement Design)
- System continuity considerations and user expectancy considerations
- Existing or proposed bicycle or pedestrian routes
- Existing or proposed oversize-overweight (OSOW) routes
- Traffic calming measures, traffic stratification measures or corridor classification changes
- Regional or municipal planning documents showing:
  - Intended future development needs, especially if imminent
  - Land use zoning changes

- County or local government concern
- Concern by other agencies or governmental entities, safety commission comments made
- Public input and/or concern
- Known detour or work zone traffic staging/operations issues
- Environmental impact or commitments
- Sociological or societal factors
- Consistency of intersection/interchange types in the area (driver expectancy)
- Ripple effects (i.e. when addressing one issue inadvertently creates another issue; unintended consequences)

Presence of one or more of these factors may require addition of alignment, profile, cross-sectional or other feature changes or additions to a highway project.

Presence of a given factor or factors does not *require* the designer to address them by including changes or additions. Careful consideration should be given to the magnitude and immediacy of the need balanced against the purpose and need for the current project. For example: a given factor may not be addressed with a current project if a more substantial subsequent project is expected.

Ultimately all potential additions to a design should ensure theme compliance and consistency with program effectiveness. Coordination and consultation should occur between the region, BPD and DTIM Office of Asset and Performance Management (OAPM) to ensure program effectiveness and theme compliance. Where possible project staff should develop a numerically quantifiable evaluation to demonstrate a cost benefit to a proposed improvement based on safety, operation, or quality improvement.

Absence of these factors should indicate that no further consideration of project feature or geometric and cross-sectional changes are required.

Discussion of Ancillary Factors analysis should be included in the Final Scope Certification if identified during scoping (preferred), otherwise discuss in the Design Study Report. Any action taken to address these, or decisions taken to eliminate their consideration should be included as part of this discussion.

LIST OF ATTACHMENTS

Attachment 10.1 Improvement Strategies, Improvement Concepts, and Application of Design Criteria

FDM 11-1-15 Programmatic Exception to Standards *November 30, 2018*

Programmatic Exception to Standards (PES) process has been superseded with the Safety Certification Process (SCP) (FDM 11-38). During the implementation of the SCP, projects that are at LC11 or higher which have a completed Safety Screening Analysis (SSA) and been determined to meet PES based on the former SSA/PES procedures, do not need an SCD. The applicability of the PES should be documented in the Design Study Report (DSR) and the SSA should be attached to the DSR.

FDM 11-1-20 Design Justifications (Formerly Exceptions to Standards) *May 15, 2019*

20.1 General

Design Justifications are required for engineering decisions which fall outside design criteria and are not recommended by the Safety Certification Document (SCD). SCD decisions which fall outside the criteria do not require additional documentation as design justifications.

For any project that does not use the Safety Certification Process (SCP), Design Justifications are required for all engineering decisions which fall outside of ranges.

20.1.1 Justification (Exception) Process

A Design Justification (exception to standards) is a documented decision to design a highway element or a segment of highway to design criteria that fall outside design criteria established for that highway or project (FHWA (1), page 3).

From “FHWA-SA-07-011: Mitigation Strategies for Design Exceptions.” (1), page 3:

- “Designers and engineers are faced with many complex tradeoffs when designing highways and streets. A good design balances cost, safety, mobility, social and environmental impacts, and the needs of a wide variety of roadway users. Good design is also context-sensitive - resulting in streets

and highways that are in harmony with the natural and social environments through which they pass.

- Highway design criteria that have been established through years of practice and research form the basis by which roadway designers achieve this balance. These criteria are expressed as minimum dimensional values or ranges of values for various elements of the three-dimensional design features of the highway. The criteria are intended to deliver an acceptable, generally cost-effective level of performance (traffic operations, safety, maintainability, and constructability). The criteria are updated and refined as research and experience increase knowledge in the field of highway engineering, traffic operations, and safety.
- Designers are trained to use accepted design criteria throughout the project development process. Striving to meet design criteria is important because it is the primary means by which a resultant high-quality roadway will be produced. A highway or roadway that reflects full compliance with accepted design criteria decreases the probability that safety problems will develop. Using design values that lie within typical ranges thus provides a high degree of quality control and reduced risk.
- It must be recognized, however, that to achieve the balance described above, it is not always possible to meet design criteria. There is a wide variety of site-specific conditions and constraints that designers encounter. Roadways have a multitude of contexts. Establishing design criteria that cover every possible situation, each with a unique set of constraints and objectives, is not possible. On occasion, designers encounter situations in which the appropriate solution may suggest that using a design value or dimension outside the normal range of practice is necessary. Arriving at this conclusion requires the designer to understand how design criteria affect safety and operations. For many situations, there is sufficient flexibility within the design criteria to achieve a balanced design and still meet minimum values. However, when this is not possible, that is when a design exception may be considered."

Despite the range of flexibility that exists with respect to virtually all the major road design features, there are situations in which the application of even the lowest end of the design criteria would result in unacceptably high costs or major impacts to the human or natural environment. In these situations, Design Justification allows for the use of criteria below those specified as lowest values in Chapter 11 of the FDM for the controlling criteria listed in Table 20.1. Projects on the National Highway System (NHS) must conform to the FHWA prescribed standards (as specified in 23 C.F.R. 625) regardless of the source of funding.

The determination to approve a project design that does not conform to the lowest criteria is to be made only after due consideration is given to all project conditions such as:

- Maximum service and safety benefits for the dollar invested,
- Compatibility with adjacent sections of roadway, and
- The probable time before reconstruction of the section due to increased traffic demands or changed conditions.

Design Justifications may be given on a project basis to designs that do not conform to the lowest criteria, as set forth in the FDM or other applicable design manual, for:

- Experimental features on projects; and
- Projects where conditions warrant that exceptions be made.

The FHWA and WisDOT Stewardship & Oversight Agreement, and its amendments, specify project responsibilities, including approval authority for Design Justification (exceptions to standards) (see FDM 5-2-1 and its Exhibits).

20.2 Applicability

The provisions of this procedure apply to improvements[1] on the following roads, regardless of who is designing, constructing, or administering the improvement, including improvements resulting from permits, Traffic Impact

[1] Section 84.06, Wis. Statutes Highway construction. (1) DEFINITIONS. In this section: (a) Subject to par. (b), "improvement" or "highway improvement" includes all of the following: 1. Construction, reconstruction, rehabilitation, and processes incidental to building, fabricating, or bettering a highway or street. 2. Highway operations or activities that are life−cycle or investment driven and that are based on an asset management philosophy in which taking action adds service life by preventing or delaying deterioration of highway system functionality. (b) "Improvement" or "highway improvement" does not include any of the following: 1. Maintenance activities described in s. 84.07 (1). 2. The installation, replacement, rehabilitation, or maintenance of highway signs, highway lighting, or pavement markings or the maintenance of traffic control signals or intelligent transportation systems, unless incidental to building, fabricating, or bettering a highway or street.

Analysis Reports, etc.:

- National Highway System (NHS) routes[2]., regardless of system, regardless of funding source; (https://www.fhwa.dot.gov/planning/national_highway_system/nhs_maps/wisconsin/index.cfm)
- STH, USH and Interstate routes, regardless of funding source;
- Connecting Highways[3], regardless of funding source;
- Business Routes[4], regardless of funding source;
- CTH routes, regardless of funding source;
- Town Roads, regardless of funding source;
- City or Village roads for improvements that have state or federal funding. (NOTE: City or Village roads that are not part of one of the above listed systems do not require WisDOT or FHWA approval for Design Justifications on improvements that are 100% locally funded (i.e., no state or federal funding)).

20.3 Controlling Criteria

On May 5, 2016, FHWA issued a memo, https://www.fhwa.dot.gov/design/standards/160505.cfm, revising and reducing the number of Controlling Criteria.

Design Justifications shall be processed whenever the controlling criteria shown in Table 20.1a and Table 20.1b cannot be met. For those criteria that are related to speed, the Design Justification shall be based on the design criteria for the design speed for the appropriate segment of the project.

Table 20.1a Controlling Criteria for Freeway / Expressway Projects regardless of Design Speed, and for Non-Freeway / Non-Expressway Projects with a Design Speed of 50 mph or Greater

Controlling Criteria	Speed Related
Design Speed	*
Lane Width	
Shoulder Width	
Horizontal Curve Radius	*
Superelevation Rate	*
Stopping Sight Distance	*
Maximum Grade	*
Cross Slope	
Vertical Clearance	
Design Loading Structural Capacity	

[2] FDM 5-2 Project Action Responsibility Matrix (Appendix A of FHWA and WisDOT Stewardship & Oversight Agreement, September 2015).

[3] Section 84.03(10), Wis. Statutes "Federal aid; state and local funds. IMPROVEMENT OF CONNECTING HIGHWAYS. All connecting highways shall be constructed or reconstructed by the state in the same manner as portions of the state trunk highway system. It shall not be compulsory for the state to construct or reconstruct any such highway to a greater width than those portions of the state trunk system connecting therewith."

[4] Section 84.02 (6), Wis. Stats "State trunk highway system. ALTERNATE ROUTES THROUGH CITIES, VILLAGES AND TOWNS. In cases where any state trunk highway passes near but not through the central or business portion of any city, village or town, the department may upon petition of any city, village or town designate an alternate route through such central or business portion, and shall install suitable marking to guide travelers over such alternate route. No such designation shall be made unless the department finds that public travel will be benefited. Any such designation may be revoked on 30 days' notice to the city, village or town if the department finds that public travel is not benefited. Such designation shall impose no responsibility on the state, except the cost of marking in the first instance. Such alternate routes shall be constructed and maintained and kept clear of snow, in a condition satisfactory to the department without expense to the state, and the department may require assurances to that effect before making such designation."

***Table 20.1b* Controlling Criteria for Non-Freeway / Non-Expressway Projects with a Design Speed of Less than 50 mph**

Controlling Criteria	Speed Related
Design Speed	*
Design Loading Structural Capacity	

See chapter 3 of FHWA SA-07-011(1) for additional technical information on the controlling criteria, including clarifications on when Design Justification (formal design exceptions) are required and the potential impacts to traffic operations or substantive safety that a designer should consider when evaluating Design Justifications (design exceptions) and mitigation strategies. Also, see NCHRP Report 783 (2) for information on Design Criteria, Traffic Operational and Safety Effects, and Mitigation Strategies for the Controlling Criteria.

20.4 Approval Authority

Table 20.2 illustrates the level of approval that must be obtained for Design Justifications. These levels of approval are determined based on the highway system on which the project is located.

The Federal-Aid Oversight Agreement that is included as Attachment A of the FHWA and WisDOT Stewardship Agreement specifies that FHWA has approval authority for all Design Justifications on the NHS. An amendment to this agreement delegates additional approval actions to WisDOT, including approval authority for some Design Justification on the NHS. FHWA has not delegated approval authority on projects defined as either "Projects of Corporate Interest" (PoCI), or "Projects of Division Interest" (PoDI). A PoDI could be either a Mega-PoDI or a non-Mega PoDI. All other projects, including those on the NHS, are defined as "Delegated Projects" on which WisDOT has final approval of Design Justifications[5].

NOTE: FHWA's approval of design justifications (formerly exceptions) for all highway improvement projects on the NHS or Interstate System is considered to be a Federal Administrative Action (as specified in 23 CFR 771.107). The approval of design justifications (formerly exceptions) by FHWA is a Federal Administrative Action even if:

- The project does not utilize Federal-Aid highway funding, and
- FHWA is not involved in the review and approval of project level environmental documentation for the purposes of complying with the National Environmental Policy Act (NEPA) requirements.

[5] FDM 5-2 Exhibit 1.1, FH*WA and WisDOT Stewardship & Oversight of Projects through Implementation of a Risk-Based Approach,* Attachment 2, "Project Approval Responsibilities List" under Detailed/Final Design: Design Exceptions (13 controlling criteria) (23 CFR 625.3), page 14

***Table 20.2* Approvals for Design Justifications**

Highway or Road		Funding Source	Project Defined As				
			Delegated		non-Mega-PoDI		PoCI or Mega-PoDI
			Approval(s)		Approval(s)		Approval(s)
			Initial	Final	Initial	Final	
NHS route	STH, USH, Interstate [A]	ANY [B]	Region [C]	BPD [D]	Region [C]	(1) BPD [D] (2) FHWA [E]	Per Project Agreement
	Connecting Highway	ANY [B]	(1) City or Village (2) Region [C]		(1) City or Village (2) Region [C]		
	Business Route on City, Village or Town road	ANY [B]	(1) City, Village or Town (2) Region [C]		(1) City, Village or Town (2) Region [C]		
	City or Village Road, non-Business Route, non- Connecting Highway	ANY [B]	(1) City or Village (2) Region [C]		(1) City or Village (2) Region [C]		
	CTH	ANY [B]	(1) County (2) Region [C]		(1) County (2) Region [C]		
	Town Road, non-Business Route	ANY [B]	(1) Town (2) Region [C]		(1) Town (2) Region [C]		
Non-NHS route	STH, USH	ANY [B]	Region [C]	BPD [D]	Region [C]	(1) BPD [D] (2) FHWA [E]	
	Connecting Highway	ANY [B]	(1) City or Village (2) Region [C]		(1) City or Village (2) Region [C]		
	Business Route on City, Village or Town road	ANY [B]	(1) City, Village or Town (2) Region [C]		(1) City, Village or Town (2) Region [C]		
	City or Village Road, non-Business Route, non- Connecting Highway	State or Federal	(1) City or Village (2) Region [C]		(1) City or Village (2) Region [C]		
	CTH	State or Federal	(1) County (2) Region [C]		(1) County (2) Region [C]		
	Town Road, non-Business Route	State or Federal	(1) Town (2) Region [C]		(1) Town (2) Region [C]		
	City or Village Road, non-Business Route, non- Connecting Highway	City, Village, or Private	City or Village	City or Village	(1) City or Village (2) Region [C]	(1) BPD [D] (2) FHWA [E]	
	CTH	County or Private	County	Region [D]	(1) County (2) Region [C]		
	Town Road, non-Business Route	Town or Private	Town	Region [D]	(1) Town (2) Region [C]		

(1) First Signature

(2) Second Signature

(A) The National Highway System (NHS) includes the Interstate Highway System.

(B) This includes funding from any source whatsoever, for example, the federal government, state government, local government(s), grants, private citizens and businesses.

(C) The Region Project Development Section (PDS) Chief is the Department's initial approval authority for projects that are not administered by the Local Program Unit.

The Region Local Project Manager is the Department's initial approval authority for projects that are administered by the Local Program Unit.

The Region Director is the Department's initial approval authority for Design Justifications on non-Mega PoDI Projects on County Trunk Highways financed totally by a County (in accord with Administrative Code TRANS 205.04); and for Design Justifications on non-Mega PoDI Projects on non-Business Route Town Roads financed totally by a Town (in accord with Section 82.50(2) Wis. Stats.)

(D) The DTSD BPD Project Services Section Chief is the Department's final approval authority, except that the Region Director is the Department's final approval authority for Design Justifications on Delegated Projects on County Trunk Highways financed totally by a County (in accord with Administrative Code TRANS 205.04); and for Design Justifications on Delegated Projects on non-Business Route Town Roads financed totally by a Town (in accord with Section 82.50(2) Wis. Stats.)

(E) FHWA is the final approval authority for Design Justifications on non-Mega PoDI projects, regardless of funding source.

20.5 Procedure

Requests for Design Justification shall be documented as part of the Design Study Report (DSR). See FDM 11-4-10.

FDM 11-1-25 Metric to US

November 30, 2018

WisDOT no longer uses metric units for highway design. However, there are numerous Metric as built plans because many projects were designed using metric design criteria. WisDOT used metric units for highway design during the1990's and early 2000's.

WisDOT used the International System of Units (SI). An international standard, called "ASTM E380," provides guidelines for the proper use of SI metrics. WisDOT used that standard, except that the American spelling of liter and meter were used, rather than the French litre and metre.

25.1 Metric Units

25.1.1 Basic Units

All units are based on decimal mathematics. Basic units that apply to highway design are:

1. **Meter** (m): The basic measure of distance in the metric system.
2. **Liter** (L): The metric system's basic measure of liquid.
3. **Gram** (g): For weighing small quantities.
4. **Time** (s): The second, the basic measure of time, remains the same as in the U.S. system.
5. **Temperature** (°C): The basic unit of temperature is the degree Celsius. This scale defines the freezing point of water as 0°C and the boiling point as 100°C.
6. **Angles**: Although the radian is the metric unit of angular measure, WisDOT continued to measure plane angles using degrees (°), minutes (') and seconds (").

25.1.2 Special Units

These basic metric units have been used to develop special units of measure to describe other measurable attributes as listed in Table 25.1.

Table 25.1 Special Metric Units

Measurable Attribute	Unit	Symbol	Expression
Frequency of periodic phenomena	hertz	Hz	$Hz = s^{-1}$
Force	newton	N	$N = kg \cdot m/s^2$
Energy or work	joule	J	$J = N \cdot m$
Power	watt	W	W = J/s
Pressure or stress	pascal	Pa	$Pa = N/m^2$

25.1.3 Derived Units

Other measurable attributes were expressed as combinations of the metric units listed above rather than creating more special units. Some of these are shown in Table 25.2.

Table 25.2 Derived Units

Measurable Attribute	Unit	Expression
Acceleration	Meters per second squared	m/s^2
Area	square meter	m^2
Density	kilogram per cubic meter	kg/m^3
Velocity	meters per second	m/s
Volume	cubic meter	m^3

25.1.4 Multiplication Factors

Sometimes, the units shown above are too large or too small to be practical for use in engineering calculations. To remedy this, metrics uses a series of prefixes to adjust the order of magnitude of its units. Some of the more common prefixes are listed in Table 25.3.

Table 25.3 Common Metric Prefixes

Prefix	Symbol	Order of Magnitude	Examples
mega	M	1000000	megapascal (MPa), megagram (Mg)
kilo	k	1000	kilogram (kg), kilometer (km)
milli	m	0.001	millimeter (mm), milliliter (mL)

25.2 Conversion Guidelines

Conversion from metric to US can be either exact ("soft"), or a suitable approximation ("hard"). A soft conversion transforms a metric value to an exact US equivalent (e.g., 3.6m X 39.37/12 = 11.8'). A hard conversion transforms the metric value to a rounded, rationalized US value that is convenient to work with (e.g., AASHTO has hard converted the 3.6 m to a 12-ft lane lane).

25.2.1 Conversion Factors

The factors listed in Table 25.4 allow the conversion of metric values to US. Note that the metric unit centimeter does not appear in the conversion factor tables. The SI system does not recognize this as a standard unit of measure. Therefore, the unit centimeter was not used in WisDOT projects.

***Table 25.4* Conversion Factors (based on US Survey Foot*)**

Class	Multiply	By	To Get
Length	in	25.4	mm
	U.S. survey ft.	12/39.37**	m
	yd.	36/39.37	m
	mi	1.609 347	km
Area	ft2	(12/39.37)2	m2
	yd2	(36/39.37)2	m2
	acre	4046.873	m2
	acre	0.404 687 3	hectares (ha)
	mi2	2.590 00	km2
Volume	ft3	(12/39.37)3	m3
	yd3	(36/39.37)3	m3
	gal	3.785 412	L
	acre ft.	1233.489	m3
Mass	lb	0.453 592 4	kg
	ton	0.907 184 7	Mg
Mass/unit length	lb/ft	1.488 161	kg/m
Mass/unit area	lb/ft2	4.882 408	kg/m2
Density	lb/ft3	16.018 37	kg/m3
	lb/yd3	0.593 272 9	kg/m3
Force	lb	4.448 222	N
Pressure	psi	6894.730	Pa
Velocity	mph	0.447 040 9	m/s
Temperature	°F	(°F - 32) x 5/9	°C

* State Statute designates the U.S. Survey Foot (not the International Foot) as the recognized measure for length in Wisconsin. The U.S. survey foot is, by definition, exactly 12/39.37 of a meter.

** When used to convert U.S. coordinates (x, y, and z) or stationing to metric, this factor shall be carried to ten decimal places or 0.3048006096.

25.3 Metric Drafting Standards

WisDOT plans were prepared on the following metric-size sheets:

Full size: Metric sheet A1 (594 mm X 841 mm)

Reduced size: Metric sheet A3 (297 mm X 420 mm)

Stationing was based on 1000 meters per station with each station subdivided into twenty-five increments of 40 m each (rural) and 50 increments of 20 m each (urban).

Table 25.5 presents metric scales which were used in lieu of the corresponding U.S. scales shown.

***Table 25.5* Equivalent English and Metric Scales**

Metric Scale	Engineer's Scale	% enlargement or reduction using metric scale
1:20	1"= 2'	+20
1:50	1" = 5'	+20
1:100	1" = 10'	+20
1:250	1" = 20'	- 4
1:500	1" = 30'	-28
	1" = 40'	- 4
	1" = 50'	+20
1:1000	1" = 60'	-28
	1" = 100'	+20
	Architect Scale	
1:2	1:2	-
1:5	3" = 1'0"	-20
1:10	1 1/2 " = 1'-0	-20
	1" = 1'-0	+20
1:20	3/4" = 1'-0	-20
	1/2" = 1'-0	+20
1:50	3/8" = 1'-0	-36
	1/4" = 1'-0	- 4
	3/16" = 1'-0	+28
1:100	1/8" = 1'-0	- 4

Cross sections were provided at 40 m intervals in rural areas and 20 m intervals in urban areas. Cross sections were also provided for special situations such as the locations of side roads, driveways or culverts.

Pavement cross slope and superelevation were shown as percentages.

Side slopes were expressed in non-dimensional ratios with the vertical component shown first.

For slopes <45°, the ratio was expressed as 1:X.

For slopes >45°, the ratio was expressed as Y:1 because the metric system does not use fractions.

Angular measurements were shown in degrees, minutes and seconds.

Curves were defined in terms of radius rather than degree of curvature.

Curves originally defined by degree had their radius specified to the nearest millimeter.

Curves to be based on metrics initially had their radii established in 5 m increments.

The normal contour interval for aerial-based topographic maps is 500 mm.

Construction plans showed only metric units.

Right-of-way plats were dual dimensioned with metric values shown first followed by U.S. values in parentheses.

FDM 11-1-99 References

November 30, 2018

1. Stein, W.J. and T. R. Neuman. FHWA-SA-07-011: Mitigation Strategies for Design Exceptions. Federal Highway Administration, Office of Safety, Washington, DC, 2007. https://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/fhwa_sa_07011.pdf
2. Harwood, D.W., J. M. Hutton, C. Fees, K. M. Bauer, A. Glen, H. Ouren, MRIGlobal, Quincy Engineering, and HQE, Inc. NCHRP Report 783: Evaluation of the 13 Controlling Criteria for Geometric Design. Transportation Research Board of the National Academies, Washington, DC, 2014. https://www.trb.org/Publications/Blurbs/171358.aspx
3. Federal Highway Administration; “Performance-Based Practical Design”; https://www.fhwa.dot.gov/design/pbpd/general_information/index.cfm; 1200 New Jersey Avenue, SE; Washington, DC 20590; 2017

	From PMM 5-10-5			Geometrics				Roadside			
Improvement Strategies	Improvement Type	Improvement Concept Code	Improvement Concept Definition	Safety Certification Documentation Required?	Standard Application	Alignments (Horizontal and Vertical)	Cross Section Revisions (e.g. outside of existing shoulder subgrade points)? [6]	Evaluate bike & ped (outside of ADA curb ramps)? [1]	Improve Curb Ramps? [1]	Potential for R/W Acquisition (other than ADA and beam guard needs)	Encroachment Report Required?
Perpetuation	Preservation / Restoration	PSRS10 PSRS20 PSRS30	**PRESERVATION / RESTORATION** - preservation/restoration treatments may address cracks, joints and surface imperfections, seal and protect the road surface, improve friction and/or remove and apply a minimal riding surface (code varies by treatment type)	No	S-1	Existing	No	See FDM 11-46	Based on work type defined as alteration [4]	No	No
		PSRS40		Yes				See FDM 11-46	Yes		
Perpetuation	Resurfacing	RSRF10 RSRF15 RSRF20 RSRF25 RSRF30 COLD10 COLD20	**RESURFACING** - placing a new surface on an existing roadway to provide a better all-weather surface, a better riding surface, and to extend or renew the pavement life (code varies by thickness of resurface.) Cold-in-place recycling when applicable.	Yes	S-1	Existing	No	See FDM 11-46	Yes	No	No
Perpetuation	Bridge Preventive	BRPVTV	**BRIDGE PREVENTIVE** – preserves the structure, retards future deterioration, and maintains or improves the functional condition	No[8]	S-1	Existing	No	See FDM 11-46	Based on work type defined as alteration [4]	No	No
Perpetuation	Bridge Rehabilitation	BRRHB	**BRIDGE REHABILITATION** - the preservation or restoration of the structural integrity of an existing bridge as well as work to correct safety defects.	Yes[8]	S-1	Existing	No	See FDM 11-46	Yes	No	No
Rehabilitation	Reconditioning	RCND10 RCND20	**RECONDITIONING** - work in addition to resurfacing. Minor reconditioning (10) includes intersection work, pavement widening and/or shoulder paving. Major reconditioning (20) includes improvement of an isolated grade, curve, intersection or sight distance problem to improve safety.	Yes	S-1/S-2[7]	Existing with minor realignment or improvements based on safety certification document	Yes, S-2 areas only	See FDM 11-46	Yes	Yes [3]	Yes [5]
Rehabilitation	Pavement Replacement	PVRPLA PVRP_O COLD30	**PAVEMENT REPLACEMENT** - structural improvement of the pavement structure or removal of the total thickness of all paving layers from an existing roadway and providing a new paved surface without changing the subgrade. PVRP_O includes operational improvements. Full depth Cold-in-place recycling where applicable.	Yes	S-1/S-2[7]	Existing with minor improvements based on safety certification document	Yes, S-2 areas only	See FDM 11-46	Yes	Yes [3]	Yes [5]
Rehabilitation	Bridge Replacement	BRELIM BRRPLE BRRPL	**BRIDGE ELIMINATION, BRIDGE REPLACEMENT EXPANSION & BRIDGE REPLACEMENT PRESERVATION** - the building of a new bridge to replace an existing bridge.	Yes	S-1/S-2[7]	Existing with minor improvements based on safety certification document	Yes, S-2 areas only	See FDM 11-46	Yes	No	Yes [5]
Modernization	Reconstruction	RECST BRNEW	**RECONSTRUCTION PRESERVATION** - total rebuilding of an existing highway to improve maintainability, safety, geometrics and traffic service.	Yes	S-2	Realignment generally necessary. Utilize as much of existing alignments as practical. Make improvements based on safety certification document.	Yes	Yes [2]	Yes	Yes	Yes
Modernization	Expansion	RECSTE BRNEW	**RECONSTRUCTION EXPANSION AND NEW BRIDGE** - includes the same types of work associated with reconstruction, but also involves the construction of additional through travel lanes or new structures.	S-3 Application - see appropriate FDM chapters and other resources							

[1] See FDM 11-46 for ADA curb ramp requirements
[2] Per state statutes; see FDM 11-46
[3] Typically minimal strip takings and intersection corners
[4] Refer to FDM 3-5-5 Exhibit 5.1 for pavement strategies meeting ADA alteration definition
[5] Within areas that involve improvements extending outside the subgrade shoulder points or curb and gutter
[6] Exciudes widening for guardrail end terminal grading
[7] S-1/S-2 , S-1 Standard Application applies to project corridor, S-2 Standard Application applies to the features contributing to crash problem areas identified in the safety certification
[8] SCD is required at locations which widen, replace or overlay the entire deck or approach slabs with concrete or asphalt.

FDM 11-2-1 Alternative Contracting

May 15, 2019

1.1 Introduction

Most of the improvement projects will continue to be designed and constructed using the traditional design-bid-build method, where cost determines the winning bid. Some alternative contracting techniques (flexible notice to proceed, lane rental that does not unduly delay traffic) might be useful in conjunction with many of the traditional projects. However, for a limited number of projects, due to their adverse impact on traffic, other alternative contracting methods may be appropriate. The alternative contracting methods discussed below are techniques to allow the department to stay in compliance with the Work Zone Policy Statement (FDM 11-50-1). As background on determining traffic impacts, see FDM 11-50-30 - Statewide Freeway and Expressway Lane Closure and Delay Guidelines.

The Moving Ahead for Progress in the 21st Century Act (MAP-21), was signed into law in July 2012. Among other items, MAP-21 provides an array of provisions designed to increase innovation and improve efficiency, effectiveness, and accountability in the planning, design, engineering, construction and financing of transportation projects. Building on FHWA's "Every Day Counts" initiative, MAP-21 changes will speed up the project delivery process, saving time and money for individuals and businesses, and yielding broad benefits nationwide. (See http://www.fhwa.dot.gov/map21/ for more information.) The alternative contracting methods discussed in this section are an integral part of MAP-21.

Current department practice, in the case of construction projects that exceed the contact time, liquidated damages are applied per standard spec 108.11. These liquidated damages are only expected to recoup the added administrative costs (staff time) due to the construction work extending beyond the time stated in the contract. The department already uses some other alternative contracting methods (sometimes allowing the free use of lanes during "off peak" hours - a basic form of lane rental - and sometimes using interim liquidated damages and incentive/disincentive provisions to assure timely completion of some or all of the work). Similarly, the new concept of "enhanced" liquidated damages (recovering road user costs at the conclusion of a project in addition to administrative costs) is another possibility for alternative contracting.

FHWA evaluated a number of methods for improving the efficiency of delivering transportation improvement projects under the Special Experimental Project 14 Program. Four formerly experimental techniques are now operational;

- cost-plus-time bidding
- lane rental
- design/build contracting
- and warranty clauses.

Currently, Wisconsin statutes do not allow design/build contracting. The department has a lot of experience with lane rentals and warranties and has used cost-plus-time bidding on a limited basis in the past. Variations of cost plus time bidding (cost plus lane rentals and accelerated bridge construction) are relatively new to the department.

Road User Costs:

Road user costs (see FDM 11-50-32) play an important role in computing the lane rental fee assessments for the failure to open a lane (or shoulder) in;

- Lane Rental specifications (FDM 11-2-1.5)
- "Enhanced" Liquidated Damages (FDM 11-2-1.6)
- Interim Liquidated Damages (FDM 11-2-1.7)
- Incentives/Disincentives (FDM 11-2-1.8)
- cost per unit of time specified in Cost-Plus-Time bidding (FDM 11-2-1.9).

The monies specified are based on a portion of the calculated road user costs. Contact your Region Traffic Unit Supervisor or the Supervisor of the Traffic Design Unit in the Bureau of Traffic Operations for the current information on computing road user costs.

Other Work Zone Effects:

Other work zone effects that impact businesses and the community at-large are generally hard to quantify and therefore should be considered as non-monetary or qualitative factors in the decision-making process. Work zones can affect accessibility to local business premises, thus adversely impacting local commerce. Many business owners are concerned about the potential negative impacts on their businesses. Local communities have similar concerns, such as issues related to resident access, decrease in property and land values, noise, and air pollution. There is some variance in the process to calculate road user costs and the calculation generally results in a range of possible costs. If the businesses and the community at-large concerns are judged to be sufficiently severe, the monies specified may be placed at a slightly higher portion of the calculated road user cost range.

The potential use of alternative contracting methods should be considered in the early stages of project planning, as part of the scoping process (see FDM 3-1-10). This will allow any potential additional monies due the contractor for meeting or exceeding contract deadlines to be included in the project estimate. Unless noted otherwise, projects contemplated for alternative contracting methods should be free of third party conflicts and design uncertainties.

Sample special provisions for most of the alternative contracting methods discussed below are available in FDM 19-15-2.

There are other alternative contracting techniques that are presently considered experimental by the FHWA. To be approved for use of federal funds, the department or local public agency would have to submit a SEP-14 work plan through the local FHWA Division Office.

1.2 Process for Selecting an Alternative Contracting Method

The alternative contracting decision flowchart is shown in Attachment 1.1. The Overview (page 1) shows the process in general terms with more detail included in pages 2 through 8. The questions asked in the diamond boxes on the flowchart are addressed in discussions below.

Most of the techniques discussed below are based on assuming a normal design engineering process, then relying on either a normal or an accelerated construction process. In some rare cases, when the design time is extremely limited or construction of a project needs to be started quickly, a possible alternative contracting technique is “low bid” design/build. The “low bid” design/build concept could be constructed with normal or accelerated construction projection rates. See the discussion below in FDM 11-2-1.3.

Another type of alternative contracting is the use of Flexible Notice-to-Proceed specifications. It is useful when there are not any constraints on when the project needs to start and there is more than enough time available in the construction season than is needed for the project. The flexible notice-to-proceed concept is intended for a project that is expected to be constructed using normal construction production rates. See the discussion in FDM 11-2-1.4.

1.2.1 Alternative Contracting Methods for Projects Constructed with Normal Production Rates

The discussions below are not intended to apply to “low bid” design/build contracts, contracts with flexible notice-to-proceed special provisions, or lane rentals (long term or off-peak) when traffic is not delayed.

In order to consider the use of the alternative contracting methods discussed below, the proposed project must be relatively free of third party conflicts and design uncertainties, if not, normal contracting methods should be used (see page 4 of Attachment 1.1). The project must demonstrate a need to minimize traffic inconvenience. The project should also be able to be completed using normal construction production rates (FDM 19-10-30).

Utility conflicts, design uncertainties, or right-of-way issues which may impact the bid letting date or the project schedule complicate construction administration. The completion dates in the contract must accurately reflect the impacts of utility relocations, design uncertainties, and right-of-way constraints that may restrict construction operations. To consider alternative contracting methods, the project should not have significant conflicts or design uncertainties.

The project would in most cases be classified as a transportation management plan (TMP) Type 3 or Type 4 (see FDM 11-50-5) and should also meet at least some of the following criteria to demonstrate a need to minimize traffic inconvenience:

- Completion time constraint; this could include weather limitations or a potential interference with major public events
- Safety Considerations
    - School zone in or adjacent to project
    - Impairment of emergency vehicle response (hospital, police or fire)

    - Basic need for project is to alleviate accidents
    - Heavy pedestrian/bike usage; or
    - High worker exposure.
- Projects on OSOW routes (see FDM 11-25-1)
- Projects which have multiple activities occurring which do not necessarily have to be done sequentially.

Once the need to minimize traffic inconvenience is determined and third-party conflicts have been assessed, the following alternative contracting methods can be considered:

- FDM 11-2-1.5 Lane Rental (Long Term), when traffic is delayed on remaining lane(s)
- FDM 11-2-1.6 Lane Rental (Off-Peak), when traffic is delayed on remaining lane(s)
- FDM 11-2-1.7 “Enhanced” Liquidated Damages, with normal construction production rates
- FDM 11-2-1.8 Interim Liquidated Damages, with normal construction production rates.

1.2.2 Alternative Contracting Methods for Projects Constructed with Accelerated Production Rates

In order to be a candidate for the alternative contracting methods discussed below, the project must demonstrate a need to be constructed with accelerated production rates; it must be relatively free of third party conflicts; and the agency responsible must have necessary resources to accommodate an accelerated construction schedule.

As above, the project would in most cases be classified as a TMP Type 3 or Type 4 (see FDM 11-50-5). In addition to meeting some of the criteria discussed above under projects constructed with normal production rates (FDM 11-2-1.2.1) the project should also meet at least some of the following criteria to demonstrate a need for accelerated construction:

- Current level of service below “C”
- Major bridge or roadway out of service due to a natural calamity, such as earthquake or flood
- Projects where access to retail business will be restricted or inconvenienced because of reconstruction and as a result significant business loss can be expected to occur
- Motorists' delay time waiting in line is 15 minutes above normal recurring traffic delays between major city nodes and within each major city
- Road User Costs (RUC) related to detours or due to delays caused by congestion/capacity problems exceed 20% of the project construction cost, but are a minimum of $100,000
- The calculated RUC exceeds $40,000 per day. Traffic restrictions, lane closures, or detours result in high RUC. Some causes of high road user-costs are:
    - lengthy detours
    - high traffic volumes
    - major reconstruction or rehabilitation on an existing urban facility.
- Highly sensitive project (political issues, significant public interest and benefit, completion of a gap in a significant highway system)
- Traffic control phasing can be structured to maximize a contractor's ability to reduce the duration of construction and the department seeks contractors’ expertise to facilitate an earlier completion.

Similar to projects to be constructed with normal production rates, utility conflicts, design uncertainties, or right-of-way issues which may impact the bid letting date or interfere with the critical path schedule complicate contract administration on projects to be constructed with accelerated production rates. As above, the completion dates in the contract must accurately reflect the impacts of utility relocations, design uncertainties, and right-of-way constraints that may occur during the duration of the project.

Although the number of administrative staff-hours for a project using accelerated construction production rates is generally less or about the same as the same project bid conventionally, the responsible agency needs to be aware that the contractor will likely work longer hours. This will require an increase in staff-hours per day; overtime, weekend work, multi-shifts should be expected.

Once the need for accelerated construction is determined, the third-party conflicts and construction administration staffing issues have been assessed, the following alternative contracting methods can be considered:

- FDM 11-2-1.6 “Enhanced” Liquidated Damages, with accelerated construction production rates
- FDM 11-2-1.7 Interim Liquidated Damages, with accelerated construction production rates

- FDM 11-2-1.8 Incentives/Disincentives
- FDM 11-2-1.9 Cost Plus Time Bidding
    - A + B (and A + B1 + B2 + B3) bidding
    - A + Lane Rental (Long Term) bidding or A + Lane Rental (Off-Peak and Peak Hour) bidding
    - Accelerated Bridge Construction

Warranties (FDM 11-2-1.10) are an alternative contracting method which can be used to increase project quality by protecting the department's investment.

1.3 "Low Bid" Design Build

The "Low Bid" Design-Build method is shown schematically in page 2 of Attachment 1.1.

The department has used a "low bid" design-build method one time on a bridge project (to rehabilitate the Wisconsin Avenue and Juneau Avenue bridges in the City of Milwaukee). Federal law provides that federally funded design-build projects may be procured using "any process permitted by applicable State and local law." The department is normally awards construction contracts through a competitive bidding process but is not subject to any requirement to use a particular method to procure engineering services contracts. It is therefore possible to bundle design and construction services into a single contract awarded to the "lowest competent and responsible bidder."

Although the design engineering process timeline is compressed with the "low bid" design/build concept, the construction work may or may not need to be accelerated to complete the entire project in the available time.

This contracting method should not solely be used to obligate funds nor to compensate for inadequate agency resources.

"Low Bid" Design/Build Advantages:

"Low bid" design/build allows the department to tap into the primary advantage of a design/build contract, allowing the construction to begin before the final design is complete, thus reducing the overall project time.

"Low Bid" Design/Build Disadvantages:

Use of this technique might limit the number of firms available to do both the design and construction work or might require firms to form partnerships to qualify for consideration.

"Low Bid" Design/Build Criteria for Selection:

The primary reason to consider a "low bid" design/build contract is a lack of time available to use the normal design process. Construction could be accomplished with normal or accelerated construction production rates.

1.4 Flexible Notice-to-Proceed

The Flexible Notice-To-Proceed method is shown schematically in page 3 of Attachment 1.1.

One type of alternative contracting is the use of Flexible Notice-to-Proceed specifications. It is useful when there are not any constraints on when the project needs to start and there is more than enough time available in the construction season than is needed for the project. However, once started, the project would be required to be completed in a certain amount of time or by a specified date. In those cases, it is possible to allow the contractor to pick the start date, within certain parameters such as the soonest and the latest it can start.

The contractor is expected to complete the work using normal construction production rates.

Flexible Notice-to-Proceed Advantages:

Using this concept allows a contractor to have more flexibility in scheduling the use of their equipment and manpower. Contractors seem to like this flexibility as it allows them to use their resources better. The result may be lower bid prices and perhaps reduced contract time.

Flexible Notice-to-Proceed Disadvantages:

It is somewhat more difficult to communicate the start date and end date with local communities, businesses, and utilities.

Flexible Notice-to-Proceed Criteria for Selection:

In order to use this concept, the project start date and end date must be able to be "floated". If the estimated construction time for the project is appreciably less than the available construction window, this technique may be appropriate to use.

Refer to FDM 19-15-2 Attachment 15.1 for a listing of standardized special provisions available for use to

specify flexible notice-to-proceed techniques.

1.5 Lane Rental

The Lane Rental methods are shown schematically in page 5 (for lane rental long term) and page 6 (for lane rental off peak) of Attachment 1.1.

Even though the possibility of closing the road to through traffic (and using a detour) is always available, in many cases the proposed construction can be accomplished by restricting the traffic to portions of the existing or reconstructed roadway. Common examples of these traffic restrictions are reducing a four-lane facility to two lanes of counter-directional traffic (while reconstructing the other two lanes) or reducing two lanes in one direction on a four-lane facility to a single lane (for construction activities on the closed lane). While these restrictions are defined as lane rentals, there is not always a lane rental fee assessment for using the lane for construction. Lane rental fee assessments are associated with a lane rental which unduly causes a “delay” (see definition below) in traffic.

Undue traffic delays as a result of lane rentals are defined in FDM 11-50-30: a “delay” occurs when the projected traffic volumes on the reduced lanes results in a traffic delay of more than 15-minutes above the normal travel time between city nodes and within each city node. If the 15-minute threshold is not exceeded, it would not be considered a delay warranting special specifications. The designer should coordinate with the region Traffic Section and State Traffic Operations Center (STOC) early in the project to identify impacts of lane closures and the hours such closures will be allowed.

The department defines two types of lane rentals - long term and off peak. Off peak lane rentals are defined as using a lane (or lanes) for a portion of a 24-hour period that has lower traffic volumes, then re-opening the lane (or lanes) when peak traffic volumes are present. Long term lane rentals are defined as using a lane (or lanes) for a defined number of consecutive 24-hour periods.

Off-Peak Lane Rentals:

In the simplest case, for a project that will temporarily reduce two lanes in one direction on a four-lane facility to a single lane, the existing traffic volume may be so low that the single remaining lane will handle the volume without delay at all times (peak and off-peak hours). This might occur for projects classified as TMP Type 2 (see FDM 11-50-5). Current WisDOT practice in this case is to allow lane (or shoulder) closures without charge. However, for higher traffic volumes, it may be that the peak hour traffic would be “delayed” while the off-peak would not. This might occur for projects classified as TMP Type 3 or Type 4 (see FDM 11-50-5). In this case, current WisDOT practice is to allow construction during off peak/night time hours without charge but restrict the use of the through traffic lanes during peak hours. For even higher traffic volumes, the off-peak traffic might be “delayed” and then the use of both the peak and off-peak use of a lane would be limited to the amounts shown in the special provisions.

When using off peak lane rentals, the designer shall make sure that the contractor will have a minimum of eight (8) hours of contract time per off-peak period, not including work zone setup and removal. If this is not considered, the letting may result in a no bidder scenario or extremely high unit prices.

As noted above, if traffic delays are expected, use of the lanes (during peak hour or off-peak) should be limited by specification. The specification should include a “failure to open” clause with associated costs if the lane is not re-opened when scheduled. Off peak and peak hour lane rentals could be daily, hourly or fractions of an hour. The lane rental fee assessments are dependent on the number and type of lanes closed and can vary for different hours of the day. For example: the rush hour periods (say 6:30 to 9:00 am and 3:00 to 6:00 pm) could have an hourly rental fee assessment of $2000 for closing one lane while a lane could be closed at off-peak times for an hourly rental fee assessment of $500. The fee assessments could begin to be charged when the lane is not open for a quarter hour. Assessments can only be charged by the day in AASHTOWare Project Construction Administration System (CAS)™; assessments by the hour (or portion thereof) can be entered in FieldManager™ using the administrative item Failing to Open Road to Traffic (see CMM 2-38). Lane rental fee assessments that are more than the amounts shown as Liquidated Damages in standard spec 108.11 shall be approved by the Supervisor of the Traffic Design Unit in the Bureau of Traffic Operations and, if the project is on the National Highway System or subject to FHWA oversight, by the FHWA.

Projects that include restrictions on the use of lanes during peak hours typically push the contractor into nighttime operations. The designer will need to coordinate with local officials to determine if there is any conflict with these operations and local noise or light ordinances. Though it would be the responsibility of the contractor to coordinate with the locals on these ordinances, the designer needs to make sure that the proposed construction staging and timeframes are achievable.

For a few projects that have a demonstrated need to minimize traffic inconvenience and a need for accelerated construction production rates, off-peak and peak hour lane rental may be used as a variation of the “Cost Plus

Time Bidding" method. See the A + Lane Rental portion of FDM 11-2-1.9 for further information.

Long Term Lane Rentals:

On a project that will reduce two lanes in one direction on a four-lane facility to a single lane for a number of consecutive days, the traffic volumes may be so low that the remaining lane will handle the volumes without delay at all times. This might occur for projects classified as TMP Type 2 (see FDM 11-50-5). Current WisDOT practice in this case is to allow lane (or shoulder) closures without charge. However, for larger traffic volumes, it may be that the traffic on the remaining lane would be "delayed". This would usually occur for projects classified as TMP Type 3 or Type 4 (but maybe for TMP Type 2). In this case, current WisDOT practice is to limit by specification the maximum time of the long-term lane rental.

If traffic delays are expected, use of the lane should be limited by specification and include a "failure to open" clause with associated costs if the lane is not re-opened when scheduled. Lane rental fee assessments could be daily or fractions of a day. A long-term lane rental could have a lane rental fee assessment of $10,000 per day or more if the lane is not reopened. The lane rental fee assessments are based on a portion of the calculated road user costs (see FDM 11-50-32). The costs could begin to be charged when the lane is not open for a quarter day. Lane rental fee assessments can be charged by the day in AASHTOWare Project Construction Administration System (CAS)™. Lane rental fee assessments that are more than the amounts shown as Liquidated Damages in standard spec 108.11 shall be approved by the Supervisor of the Traffic Design Unit in the Bureau of Traffic Operations and, if the project is on the National Highway System or subject to FHWA oversight, by the FHWA.

In some limited cases when the project has a demonstrated need to minimize traffic inconvenience and a need for accelerated construction production rates, long term lane rental may be used as a variation of the "Cost Plus Time Bidding" method. See the A + Lane Rental portion of FDM 11-2-1.9 for further information.

When provisions for lane rental fee assessments are added to the contract, it is a method of transferring a portion of the road user cost (RUC) to the contractor. The lane rental fee assessment is usually a portion of the estimated cost of delay or inconvenience to the road users during the rental period. The fee is assessed for the time that the contractor occupies or obstructs part of the roadway and is deducted from the progress payments. See FDM 11-50-32 for a discussion of road user costs. Road user costs that are more than the amounts shown as Liquidated Damages in standard spec 108.11 shall be approved by the Supervisor of the Traffic Design Unit in the Bureau of Traffic Operations and, if the project is on the National Highway System or subject to FHWA oversight, by the FHWA.

Lane Rental Advantages:

The intent of lane rental is to encourage contractors to schedule their work to keep traffic restrictions to a minimum, both in terms of duration and number of lane closures. The lane rental concept has merit for use on projects that significantly impact the traveling public. Projects on major urban commuter routes are prime candidates for this approach.

Lane Rental Disadvantages:

Lane rental can increase the cost of a project, as contractors may need to apply more resources to or work more quickly on lane rental jobs and require additional bond coverage.

Lane Rental Criteria for Selection:

Lane Rental is particularly applicable to projects where the contractor can adjust or design the traffic control plan to reduce lane closure durations, or take lanes out of service during periods of the day or night when impacts to traffic are minimal.

Refer to FDM 19-15-2 Attachment 2.1 for a listing of standardized special provisions available for use to specify lane rentals.

1.6 "Enhanced" Liquidated Damages

If the contractor does not complete all contract work within the contract time, or within the extra time allowed under engineer-granted time extensions, the department will assess final liquidated damages. Final liquidated damages recover department costs to provide additional engineering and supervision to keep the project open longer. The department will deduct a specified sum from payments due the contractor for every calendar day on calendar day contracts and completion date contracts, or for every working day on working day contracts, that the work remains incomplete. See standard spec 108.11 of the standard specifications for daily liquidated damages that reflect only the cost of engineering and supervision.

On projects that meet some of the criteria in FDM 11-2-1.2.1, it may be appropriate to amend the definition of final liquidated damages (from standard spec 108.11) to recover not only the cost of engineering and

supervision but also a portion of the calculated road user costs (see FDM 11-50-32). The department has chosen to call the amended definition "enhanced" liquidated damages. This concept would be useful for projects that need to be substantially complete before the road user impacts are gone.

"Enhanced" liquidated damages are used to motivate the contractor to complete the project early to discontinue the use of a detour and reopen the highway to through traffic. The designer must decide how much flexibility the department can give the contractor to complete the project and the level to which the contract time must be controlled. Generally, if the contractor has flexibility in determining the contract's timeframe, bid prices will be lower.

As noted in FDM 11-2-1.2.1, the use of "enhanced" liquidated damages is typically intended for projects expected to be constructed with normal construction production rates. It could, however, be used on projects expected to be constructed with accelerated construction production rates. "Enhanced" liquidated damages could be considered for projects classified as TMP Type 3 or Type 4 (see FDM 11-50-5).

"Enhanced" Liquidated Damages Advantages:

Using "enhanced" liquidated damages allows the department to recoup some of the road user costs. Also, the contractor may be more inclined to finish the project on time to avoid the higher assessments.

"Enhanced" Liquidated Damages Disadvantages:

It is possible that all the contractors bidding on a project may decide to bid some of the contract items slightly higher as a hedge against the higher "enhanced" liquidated damages.

"Enhanced" Liquidated Damages Criteria for Selection:

This technique is useful for projects that have a demonstrated need to minimize traffic inconveniences.

Refer to FDM 19-15-2 Attachment 15.1 for a listing of standardized special provisions available for use to specify "enhanced" liquidated damages.

1.7 Interim Liquidated Damages

As noted in FDM 11-2-1.2.1, the use of interim liquidated damages is intended for projects expected to be constructed with normal production rates. As discussed below, interim liquidated damages could sometimes be used on project expected to be constructed with accelerated production rates when no Incentive is included. Interim liquidated damages could be considered for projects classified as TMP Type 3 or Type 4 (see FDM 11-50-5) or any project with multiple stages or projects containing interim completion dates or interim stages.

Interim liquidated damages are not considered a penalty, but are fixed and agreed-to damages that the contractor owes the state for not completing the work within the time specified in the contract. Not completing contract work within the specified time may result in:

- Public inconvenience due to detours and delays caused by increased traffic or lower highway speeds
- Excessively high vehicle operating costs if traffic is routed over a long detour
- Additional project costs due to maintaining the detour and using traffic control items for a longer period of time than anticipated
- Delay to remaining stages of the project.

Interim liquidated damages are used to motivate the contractor to complete a portion of the construction early in order to discontinue the use of a detour and reopen a section of highway to through traffic or ensure that the remainder of the project stays on track.

When using an interim liquidated damage provision in a contract, the preferred contract type is either a completion date or calendar day contract. Do not mix calendar day or completion date provisions with working day contracts.

The designer must decide how much flexibility the department can give the contractor to complete the project and the level to which the contract time must be controlled. Generally, if the contractor has flexibility in determining the contract's timeframe, bid prices will be lower. Interim deadlines specified in the contract must be realistic and not be subject to third-party delays that are beyond his control. Unrealistic timeframes increase risks and costs to both the department and contractors, and add significant tension to contract administration.

When specifying interim liquidated damages, the designer may eliminate all excusable delays or restrict the number of weather delays, in addition to the conditions specified in section 108 of the standard specifications. Eliminating all excusable delays should be taken seriously, as it may not always be appropriate to do so. For example, do not eliminate all excusable delays if there is a strong likelihood of utility or other third-party delays that are beyond the control of the contractor. By increasing the number of adverse weather days allowed during

the road closure period when interim liquidated damages are specified in a contract, the likelihood of granting the contractor a weather delay for the road closure period is reduced, since time extensions are granted when the number of adverse weather days actually occurring exceeds the number of adverse weather days listed in the contract. More guidance on how to complete a special provision for interim liquidated damages that restricts the number of weather delays is provided in the Technical Notes of the STSP Index spreadsheet located at:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/stsp.aspx

Interim liquidated damages are useful for projects that do not need to be substantially complete before the road user impacts are gone. Avoid using a deadline for interim liquidated damages that is the same as the deadline for completing all contract work. For example, suppose it is critical to open a roadway in front of a high school before the 2013 school year begins on September 3, 2013, and, because all major project work must be completed within the summer time period that school is not in session, the project has a short construction timeframe. Instead of specifying that interim liquidated damages will be assessed if all contract work is not completed by September 3, 2013, consider assessing interim liquidated damages if the roadway is not paved and open to through traffic on September 3, 2013, and then provide the contractor another week or two to complete work, such as landscaping, that can be completed with the highway open to traffic.

Interim Liquidated Damages by the Hour:

Interim liquidated damages can only be charged by the day in AASHTOWare Project Construction Administration System (CAS)™; damages cannot be charged by the hour. Interim liquidated damages assessed by the hour can be entered in FieldManager™ using the administrative item Failing to Open Road to Traffic (see CMM 2-38). Very few projects need interim liquidated damages assessed by the hour.

Interim Liquidated Damages Advantages:

Using interim liquidated damages allows the department to recoup some of the road user costs. Also, the contractor may be more inclined to finish the project on time to avoid the higher assessments.

Interim Liquidated Damages Disadvantages:

Utility conflicts, design uncertainties, or right-of-way issues complicate contract administration on projects to be constructed with accelerated production rates. Special care must be used to assure that the completion dates in the contract accurately reflect the impacts of utility relocations, design uncertainties, and right-of-way constraints that may occur during the duration of the project.

Accelerated construction production rates generally require an increase in construction administration staff-hours per day; overtime, weekend work, multi-shifts should be expected.

1.7.1 Interim Liquidated Damages Criteria for Selection

The degree to which contract time is critical varies from project to project, and may vary between different construction stages or roadway sections of the same contract. In most contracts, it isn't necessary to add interim liquidated damages; standard spec 108 will suffice. Use interim liquidated damages with care and only when necessary. The "damages" in interim liquidated damages are developed from considering road user costs of delay occurring in subsequent stages.

1.7.2 Interim Liquidated Damages - Multiple Project Contract

Sometimes several small projects are combined into one contract, such as small bridge and approach projects, to obtain more competitive bids. In these contracts, it may be necessary to complete one or more of these projects at a specified date or within a specified time period within the overall contract time.

When this is necessary, use an interim liquidated damage provision for each project that has to be completed by a specified date or within a specified time period. If not completed within the time frame, assess the contractor interim liquidated damages.

This provision may be necessary to:

- Reduce public inconvenience
- Shorten the detour time
- Reduce disruption to traffic
- Reduce effects on businesses, tourism, etc.
- Reduce road user costs

An STSP provision to specify interim liquidated damages on a multiple-project contract is provided as part of the STSP template located at:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/stsp.aspx

After opening the general template, select the tab Completion Date, and use the button Eliminate Excusable Delays Multiple Projects.

It is important to make a clear distinction between the intent of I/D provisions and interim liquidated damages. Although they have some common elements and similar mechanisms, the purpose or function of each provision is different.

Common features of both I/D and interim liquidated damages provisions are:

1. Both provide a specified contract date for the critical work to be completed to open the highway to traffic.
2. Both are used to recover some or all road user costs of detours and delays if the roadway is not opened on the specified date.
3. Both should be used with care and only when necessary.
4. Both can be used to keep subsequent stages on track.

Unique elements of Interim Liquidated Damages:

1. Is typically used when the work necessary to open highway can be completed with reasonably normal production rates.
2. Are used more frequently than I/D on projects where it is necessary to open a highway stage to traffic on a specific date, or within a prescribed time frame.
3. Could be used on projects with accelerated construction production rates when no Incentive is provided.

Unique elements of I/D Provisions:

1. This provision is used when the work necessary to open highway to traffic cannot be completed with normal production rates.
2. Provides significant financial motivation to complete critical work on a highly accelerated schedule.
3. Should be used very judiciously.

Refer to FDM 19-15-2 Attachment 15.1 for a listing of standardized special provisions available for use when using interim liquidated damages provisions.

1.8 Incentives / Disincentives

As noted in FDM 11-2-1.2.2, the use of incentives/disincentives is intended for projects expected to be constructed with accelerated production rates. Incentives/disincentives could be considered for projects classified as TMP Type 3 or Type 4 (see FDM 11-50-5).

Incentives/Disincentives Criteria for Selection:

See the criteria in FDM 11-2-1.2.2.

- The Incentive/Disincentive (I/D) provision is intended to motivate the contractor to complete the work faster than normal.
- The provision should be limited to projects where construction will severely disrupt highway traffic, significantly increase road users' costs.
- I/D provisions should be used judiciously and only on critical projects. Excessive use of the provision is detrimental to both WisDOT and contractors.
- When using the I/D provision in a contract, the preferred contract type is a completion date contract although a calendar day contract may be used.
- Federal funds can be used as part of the incentive provisions. FHWA policy recommends a cap of 5% of the total contract amount for the maximum incentive payment and no cap for the disincentive amount. In the past, WisDOT has not exceeded 2.5% on the contract amount for disincentives.

It is important to make a clear distinction between the intent of I/D provisions and interim liquidated damages. Although they have some common elements and similar mechanisms, the purpose or function of each provision is different.

Common features of both I/D and interim liquidated damages provisions are:

1. Both provide a specified contract date or time duration for the critical work to be completed to open the highway to traffic.

2. Both are used to recover some or all road user costs of detours and delays if the roadway is not opened on the specified date.
3. Both should be used with care and only when necessary.

Unique elements of Interim Liquidated Damages:

1. Is typically used when the work necessary to open highway can be completed with reasonably normal production rates.
2. Are used more frequently than I/D on projects where it is necessary to open a highway to traffic on a specific date.
3. Could be used on projects with accelerated construction production rates when no Incentive is provided.

Unique elements of I/D Provisions:

1. This provision is used when the work necessary to open highway to traffic cannot be completed with normal production rates.
2. Provides significant financial motivation to complete critical work on a highly accelerated schedule.
3. Should be used very judiciously.

Incentives/Disincentives Description

An incentive/disincentive (I/D) provision is part of a contract that compensates the contractor a certain amount of money for completing critical work on or ahead of schedule, and assesses a deduction for work not completed on time. This provision is intended for critical projects where traffic inconvenience and delay is to be kept to a minimum and access is to be restored as soon as possible.

I/D provisions are applicable to projects that require accelerated construction production rates.

I/D provisions may be used to assure completion of interim stages or completion of the entire project to the point where road user impacts are gone but some other contract work remains. I/D provisions are also useful for projects that need to be substantially complete before the road user impacts are gone. Although labeled “Incentive/Disincentive for Interim Completion of Work”, the current incentive/disincentive special provision has been used for completion of the project as well for completion of interim stages. To resolve this inconsistency, the designer is encouraged to use a new special provision called Incentive/Disincentive for Final Completion of Work when the work under the contract needs to be substantially complete by a certain time.

On many projects, it is better to list the bid items or portion of bid items that may remain incomplete in order for the contractor to receive the incentive. This list would generally be much shorter than a list of items that must be completed.

Incentives/Disincentives Advantages

Using interim incentives/disincentives allows the department to recoup some of the road user costs. Also, the contractor may be more inclined to finish the project on time to avoid the higher assessments.

Incentives/Disincentives Disadvantages

Utility conflicts, design uncertainties, or right-of-way issues complicate contract administration on projects to be constructed with accelerated production rates. Special care must be used to assure that the completion dates in the contract accurately reflect the impacts of utility relocations, design uncertainties, and right-of-way constraints that may occur during the duration of the project.

Accelerated construction production rates generally require an increase in construction administration staff-hours per day; overtime, weekend work, multi-shifts should be expected.

1.8.1 Project Types Appropriate for Incentives/Disincentives

On projects where delays will occur, the current peak hourly volumes must be used to determine the number of lanes required to handle the traffic.

The project must then be analyzed by region Traffic Section and State Traffic Operations Center (STOC) staff to determine whether a shortening of the construction time can be accomplished on the project and whether the I/D provision will achieve the desired result.

Avoid selecting projects where contractor’s production can be adversely affected due to the following conditions which are outside their control:

1. Utility conflicts/relocations
2. Hazardous materials coordination and clean up.
3. Major items of work with quantities that may vary considerably such as joint repairs and base patching in pavement rehabilitation work.

Project Development

The following information/steps will be helpful to designers at the project development stage:

1. It is important to define clearly the "work" which is subject to the I/D provision. See the sample Special Provision in FDM 19-15-2. The following is a list of items which should be considered:
    a. The number of driving lanes open to traffic. This may include some discussion of whether traffic flow must be completely unrestricted when reopened or if some defined minor temporary traffic restrictions may be allowed:
    b. Opening the bridge to unrestricted four lane traffic.
    c. The contractor will not be allowed to interrupt traffic once the bridge is re-opened except between 3:00 AM and 6:00 AM as approved by the engineer.
    d. Completion of shoulder work.
    e. Pavement markings completed. Specify whether permanent or temporary.
    f. Installation of bridge rail.
    g. Installation of beam guard.
    h. Completion of signing (all or just critical signing.)
2. To avoid claims during construction, the designer should make an extra effort to ensure compatibility of design, plans, specifications, and schedule. This may require conduction of more thorough design field reviews, and collecting more field data rather than relying on as-built plans.
3. Consider pre-bid meetings to explain I/D provisions.
4. Make sure I/D dates are compatible with other contract dates, such as environmental dates, for migratory birds and fish spawning.
5. On staged projects with multiple contracts, coordinate I/D dates with other contract completion dates for compatibility.
6. When using I/D provisions on a single contract extending over more than one construction season, provide a clear explanation in the special provisions regarding the suspension of work time used as the basis for setting an I/D date in a future season. It is best to specify a firm suspension date.
7. Coordinate with locals on projects to determine their cost share for the I/D provision and to define the "work." Inform the locals of the implications of making the I/D provision too restrictive.
8. For projects that may experience a long delay between design completion and PS&E submittal, the I/D provisions should be reviewed for need and changed conditions prior to the letting.
9. Computations and justifications for I/D should be forwarded to the appropriate project design oversight engineer in the BPD, prior to the PS&E, who will ensure that the report is placed in the file for the project.
10. For steel bridge projects, be sure to account for lengthy fabrication time when determining the I/D date.

The I/D provision has a maximum dollar amount for the incentive payment but no maximum dollar amount for disincentive.

Local Participation

Generally, the department requests local participation in projects where local needs are served in addition to the needs of the through traveler. The goal of the cost sharing agreements is to reflect the reason for the project so those who benefit from the project also contribute to the cost of the project. Cost sharing of the I/D provision should have the same goal. Local governments should pay that portion of the I/D provision that corresponds to the benefit they will receive. Local participation in I/D provisions can vary widely. Some communities have paid 100% of the I/D provision on urban projects where early completion primarily benefited the local government. A municipality contributed 50% of the I/D provision on a rural interstate project because they felt it would benefit

their tourism industry.

Whenever a local government asks for an I/D provision, the department should begin by requesting 100% local contribution and require a minimum of 50% local contribution. The department should only contribute to the I/D provision in this situation if there is a “significant benefit” to through travelers for early completion.

Refer to FDM 19-15-2 Attachment 15.1 for a listing of standardized special provisions available for use to specify incentives/disincentives.

1.9 Cost Plus Time Bidding

The Cost Plus Time Bidding methods are shown schematically in Attachment 1.1, page 7 (for A + Lane Rental bidding) and page 8 (for A + B bidding and Accelerated Bridge Construction).

Projects to be considered for cost plus time bidding should have a demonstrated need to minimize traffic inconvenience (see criteria in FDM 11-2-1.2.1) and a need for accelerated construction production rates (see criteria in FDM 11-2-1.2.2). The project should also be clear of third party conflicts and construction administration staffing issues assessed. Cost plus time bidding could be considered for projects classified as TMP Type 3 or Type 4 (see FDM 11-50-5).

Cost Plus Time Bidding Criteria for Selection

In some cases, additional emphasis on reducing traffic inconvenience is needed beyond including incentive/disincentive provisions in the contract. For critical projects that have very high road user delay impacts, the cost plus time bidding method can be an effective technique to significantly reduce these impacts. On projects that have used the cost plus time bidding method, contract times have been reduced, costs have been acceptable, and quality has been maintained.

It is appropriate to consider cost-plus-time bidding when the project has flexibility in the methods and means of construction. The following situations are appropriate to a project:

- Projects which allow alternate solutions where one solution may take significantly less time to construct, yet designers are hesitant to specify methods and means of construction or a proprietary solution.
- Projects in which innovative solutions from the contracting industry are sought (specialty work) which may be beyond the designer’s expertise.

If it is determined that accelerated construction production rates are needed but there is no apparent flexibility in the methods and means of construction, an incentive provision could be included to reward the contractor if the work is completed and the roadway reopened earlier than the time specified in the contract.

The cost plus time method generally includes three types of bidding.

1. The basic type is A + B bidding, where the contractor bids both items (A) and contract time (B).
2. The second type is A + Lane Rental, where the time component is the number of lane closures.
3. A third type is Accelerate Bridge Construction, where the maximum time specified in the contract is so restrictive that pre-fabricated bridge elements and systems, state-of-the-art equipment, material technologies, and innovative contracting methods would be needed.

All types of cost plus time bidding include a maximum time that could be bid and the cost (or costs) per unit (or units) of time bid that will be used to evaluate the bids.

1.9.1 A + B Bidding

The A+B bidding method, involves time, with an associated cost, in the low bid determination. Under the A+B bidding method, each bid submitted consists of two components:

- The "A" component is the traditional bid for the contract items and is the dollar amount for all work to be performed under the contract.
- The "B" component is a "bid" of the total number of calendar days required to complete the project, as estimated by the bidder (Calendar days are used to avoid any potential for controversy which may arise if work days were used). The bidding documents would specify the maximum number of days a contractor can bid.

The total bid for award consideration is based on a combination of the bid for the contract items and the associated cost of the time, according to the formula:

(A) + (B x Road User Cost / Day)

The above formula is only used to determine the lowest bid for award and is not used to determine payment to

the contractor. A contract would be awarded for the bid amount for the bid items (A) with the time bid specified in the contract. See Attachment 1.2 for a Cost + Time bidding example.

As noted above, the "B" component is generally a "bid" of the total number of calendar days required to complete the project. The “B” component could also be the time to do interim stages of a contract. B1 could be the time to complete the first stage of a project, B2 the second stage, B3 the third stage, etc. It is normal to have the same road user cost for each of the interim stages although different road user costs could be used. The combination of the bid for the contract items and the associated cost of the time would normally then be:

(A)+ [(B1 + B2 + B3) x (Road User Cost / Day)]

Or, if there are different road user costs:

(A) + (B1 x RUC1 / Day) + (B2 x RUC2 / Day) + (B3 x RUC3 / Day)

The above formula is only used to determine the lowest bid for award and is not used to determine payment to the contractor. A contract would be awarded for the bid amount for the bid items (A) with the interims times bid specified in the contract. See Attachment 1.2 for a Cost + Time bidding example with interim stages.

The road user costs listed in the bidding proposal are some portion of the calculated road user costs. The listed costs are stated in dollars per day. The maximum number of days allowed to be bid is also written into the bidding proposal. Road user costs that are more than the amounts shown for Liquidated Damages in standard spec 108.11 shall be approved by the Supervisor of the Traffic Design Unit in the Bureau of Traffic Operations and, if the project is on the National Highway System or subject to FHWA oversight, by the FHWA.

When the A+B bidding method is used, a liquidated damages provision (that assesses road user costs) is usually incorporated into the contract to discourage the contractor from overrunning the time "bid" for the project. Consider A+B bidding without an incentive provision if:

- The project is not required to finish ahead of a specific completion date.
- RUC is not severe but other factors warrant expediting the project.

In addition, an incentive provision can be included to reward the contractor if the work is completed earlier than the time bid. If a project is especially time-critical and it is cost-beneficial to use them, incentive provisions will motivate contractors to further shorten the construction duration. Consider using A+B bidding with an incentive provision if:

- The RUC is high, and the monetary benefit to the highway user equals or exceeds the contractor’s costs to finish early and earn the maximum incentive.
- It is in the public interest to complete the project as soon as possible.

1.9.2 A + Lane Rental Bidding

As noted above (in FDM 11-2-1.5), if traffic delays are expected, temporary use of the lanes (during peak hour or off-peak) or a lane (during long term lane rental) would be limited by specification. Limited use should also include a “failure to open” clause with associated costs if the lane is not re-opened when scheduled. These limitations are applied assuming normal construction production rates.

However, if it is determined that accelerated construction production rates are needed and there is flexibility in how the lanes may be closed for construction, either type of lane rental could be used as part of the bid process similar to the “A + B” discussed above. Instead of the “time” portion being the total contract time, it could be the number of consecutive days (for long term lane rental) or the number of off-peak (or even peak hour) lane rentals multiplied by specified road user costs. See Attachment 1.3 for Cost + Lane Rental bidding examples.

(A) + (LR x Road User Cost / (Day or Hour))

Similar to A+B bidding, the contract would be signed for the sum of the quantities in the plan times the unit prices bid (the A portion of the bid) with the number of lane rental periods from the successful bid written into the contract.

Lane rental rates are stated in the bidding proposal in dollars per lane (or per shoulder) per time period. The maximum number of lane rentals allowed is written into the proposal.

Cost + Lane Rental bidding could be considered for projects classified as TMP Type 3 or Type 4 (see FDM 11-50-5).

Each of the two types of lane rental should include a “failure to open” clause with associated costs if the lane is not re-opened when scheduled (either at the end of the contract indicated period for long term lane rentals or at the start of the peak hour traffic period for off peak lane rentals) to discourage the contractor from overrunning the time "bid" for the lane rental. The associated costs are based on a portion of the calculated road user costs (see FDM 11-50-32). The costs could begin to be charged when the roadway is not open for a quarter day (at

the end of a long-term lane rental) or a quarter hour (for an off-peak lane rental). Costs can only be charged by the day in AASHTOWare Project Construction Administration System (CAS)™; costs by the hour (or portion thereof) can be entered in FieldManager™ using the administrative item Failing to Open Road to Traffic (see CMM 02-38).

If it is determined that accelerated construction production rates are needed but there is no apparent flexibility in how lanes may be closed for construction, an incentive provision could be included to reward the contractor if the work is completed and the lanes reopened earlier than the time specified in the contract. See the above discussion under A + B bidding for considerations of when or when not to use incentives.

1.9.3 Accelerated Bridge Construction Bidding

The normal (cast-in-place) reconstruction of some structures can create extreme hardship on the traveling public. A special type of cost plus time bidding which severely limits the time the bridge may be closed to traffic could be useful for those projects. If the bidding proposal provides an extremely tight timeframe, the result would be an accelerated bridge construction contract which would greatly minimize the contract time and impact on the public. Accelerated bridge construction emphasizes pre-fabricated bridge elements and systems, state-of-the-art equipment, material technologies, and innovative contracting methods, with a potential of using various construction materials. Sometimes precast bridge elements are moved using a self-propelled modular transporter (SPMT).

The accelerated bridge construction concept of providing an extremely short timeframe could also be used for projects (other than bridges) that would create extreme hardships. An example of this would be reconstruction of a high-volume intersection.

Cost Plus Time Bidding Advantages

The major benefit of the cost plus time bidding method is time savings, an important issue with the traveling public. The cost plus time bidding method is used to motivate the contractor to minimize the overall time on high priority and high usage projects.

It encourages potential contractors to analyze, develop and carefully plan operations that minimize contract time. Since the time bid by contractors is based on their capabilities to perform the work, the more efficient contractor can generally bid shorter times. This method allows the contractors to maximize efficiency in scheduling their work crews and equipment in order to meet the time bid. The method:

- Encourages contractors to work overtime, double shifts and at night to reduce construction time.
- Encourages contractors to develop or use existing innovative construction methods and procedures.
- Minimizes road user costs and inconvenience.
- Reduces the number of congestion related complaints from the road users and local communities.
- Reduces congestion related pollution and environmental impacts.

Cost Plus Time Bidding Disadvantages

Drain on Agency Human Resources

Since the project duration is shortened, cost plus time reduces the time that personnel are required on the project. However, the agency must be ready to work the construction schedule as determined by the contractor. Therefore, this method often extends the work schedules (hours/day and days/week).

Increased Construction Costs

The bid cost (A) on cost plus time contracts may be slightly higher than traditional contracts of similar scope and size. Also cost plus time projects with incentives tend to have a higher cost overrun than similar traditionally built projects. However, when the savings on road user costs is considered in the total cost of the project, the cost is almost always less than that of a traditional bid contract.

Unbalanced Bidding

Cost plus time bidding could lead to the contractor unbalancing the bid by increasing ‘A’ portion of the bid and take all the mobilization advances up front, use them, and return them at project’s end as liquidated damages. Also, there is some documentation that many agencies tend to be lenient when assessing liquidated damages.

Refer to FDM 19-15-2 Attachment 15.1 for a listing of standardized special provisions available for use to specify cost-plus-time bidding.

1.10 Warranty Clauses

Warranties have been successfully used, in other countries and by some States on non-Federal projects, to protect investments from early failure. The 1991 Highway Act, referred to as ISTEA, permitted a State to exempt

itself from FHWA oversight for Federal-aid projects located off the National Highway System. For projects under these conditions, warranty clauses may be used in accordance with State procedures.

On August 25, 1995, FHWA published an Interim Final Rule (IFR) for warranties for projects on the National Highway System. The IFR states that warranty provisions shall be for a specific construction product or feature. Routine maintenance items are not eligible. The IFR also prohibits warranties for items not within the control of contractors. The warranty Final Rule was published in the April 19, 1996 Federal Register and the interim final rule remains unchanged.

See FDM 19-15-3 for further discussion of warranties.

Warranty Clauses Advantages

Warranties are intended to increase the quality of a product by giving the contractor responsibility for replacement or repair of deficiencies. Warranties have been successfully used to protect investments from early failure and to improve overall construction quality.

Warranty Clauses Disadvantages

Warranty clauses have a couple of disadvantages:

- They become an additional expense for the contractor and the extra cost is passed along to the responsible agency.
- Adding a warranty to a project will complicate and delay the finals process.

Warranty Clauses Criteria for Selection

Warranty provisions shall be for a specific construction product or feature. A general warranty for the entire project is unacceptable since the contractor does not control the design process or make decisions during that phase.

Warranties may not cover items of maintenance not eligible for Federal participation. An example of this might be a warranty for guardrail construction where it would be inappropriate to warrant routine damage done to the guardrail by vehicle impacts.

Contractors are not to be required to warrant items over which they have no control.

Currently, the regulations do not restrict the duration of the warranty. However, practical experience has shown that 2 to 5-year warranties are common, and warranties beyond 5 years may not be as cost effective due to bonding or surety concerns. Warranty provisions have been used for bridge painting, traffic striping, and bridge expansion joints.

Prior approval by the FHWA Division Administrator of a warranty provision and its subsequent revisions are required for NHS projects. The clause must not require a contractor to warrant items over which they do not have control. Maintenance items ineligible for Federal-aid funding are not allowed to be warranted.

Use of warranty provisions for non-NHS projects will be governed by the individual State written procedures.

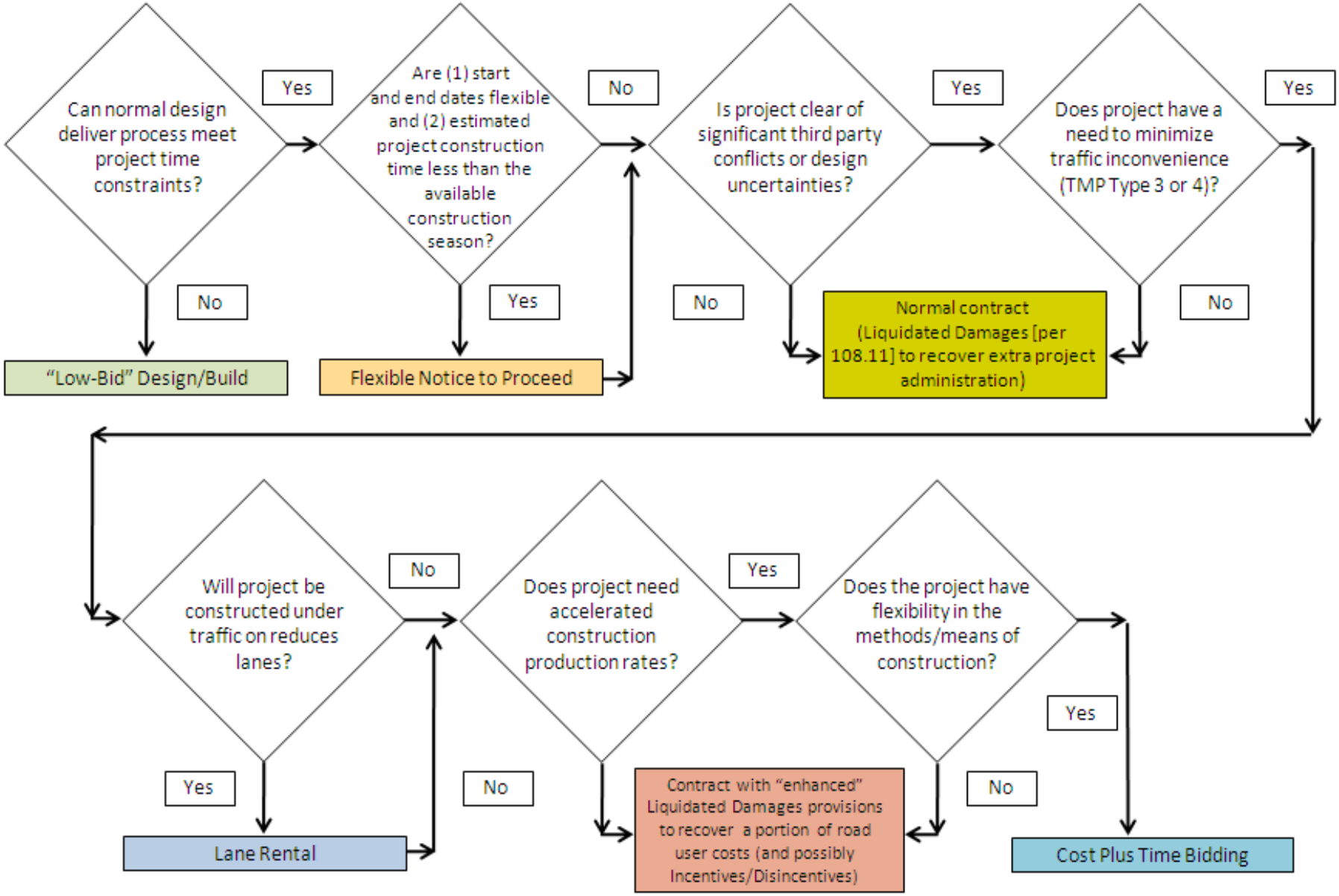
LIST OF ATTACHMENTS

Attachment 1.1 Alternative Contracting Decision Flowchart

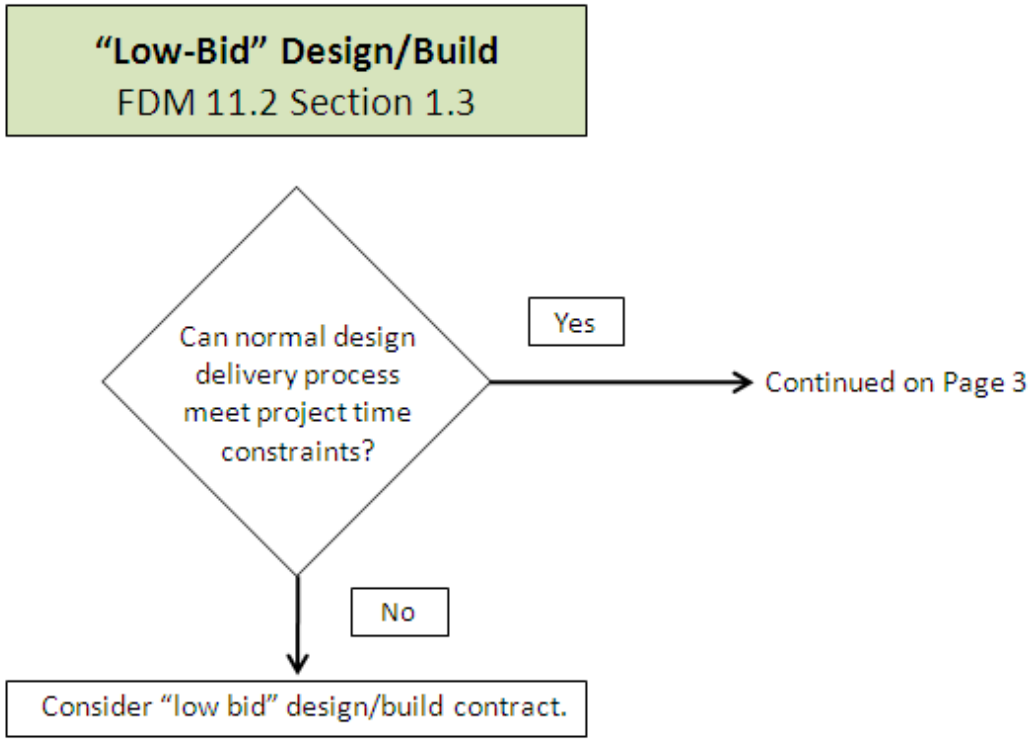
Attachment 1.2 Cost Plus Bidding Examples

Attachment 1.3 Cost Plus Lane Rental Bidding Examples

Alternative Contracting Overview



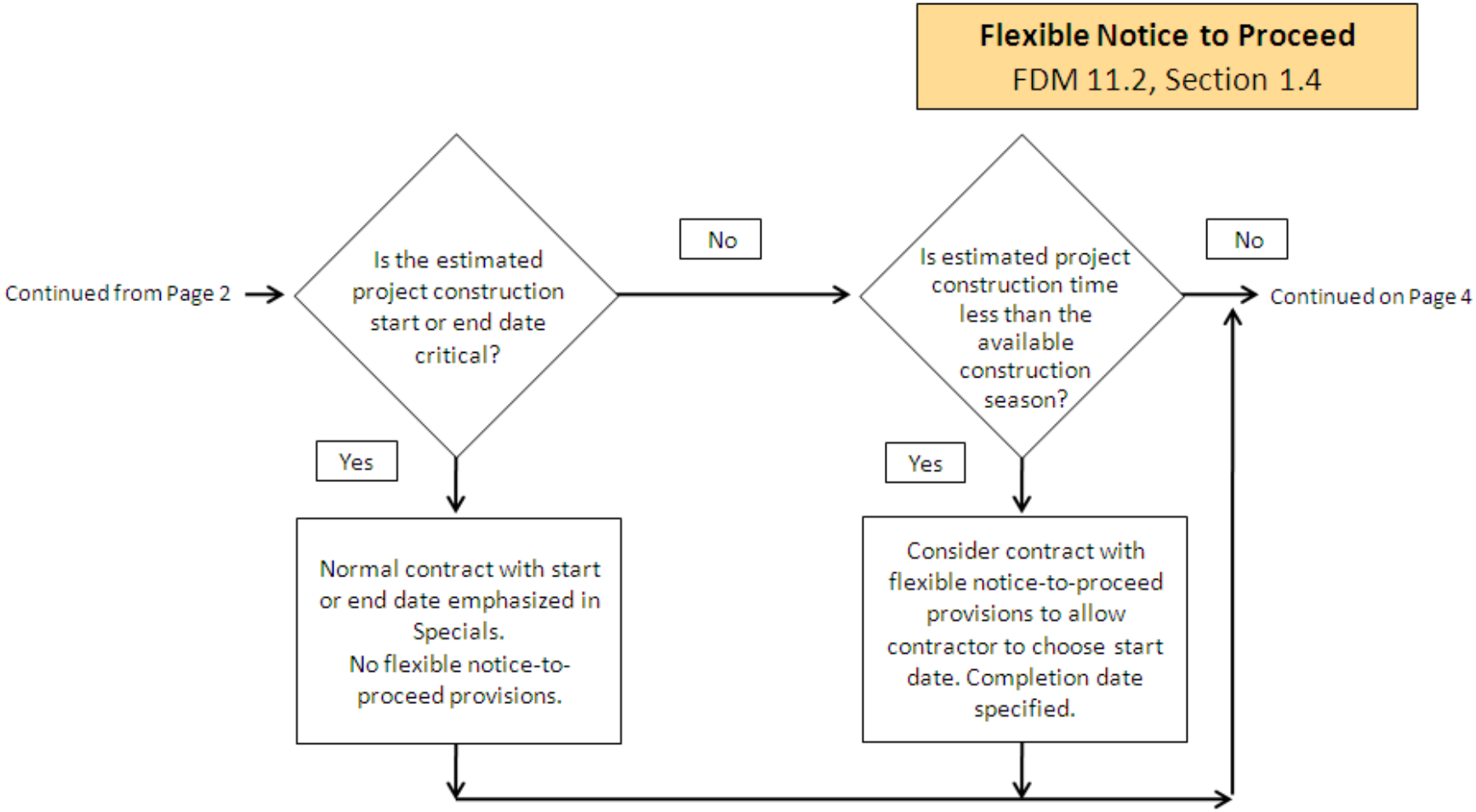
"Low-Bid" Design Build Details



Notes:

1. This Alternative Contracting method assumes an accelerated design delivery process.
2. This Alternative Contracting method assumes either normal or accelerated construction production rates.
3. This Alternative Contracting method will normally only seek to recover construction administrative costs.

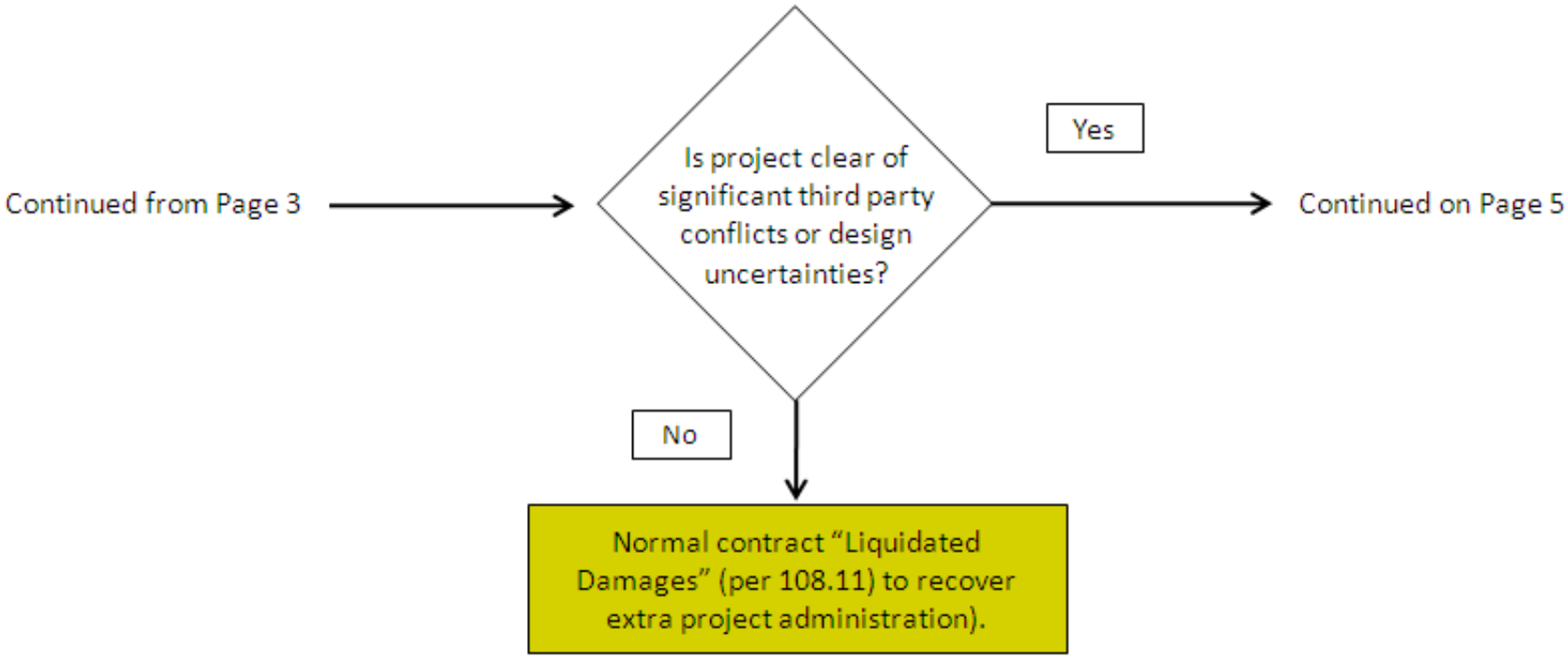
Flexible Notice to Proceed Details



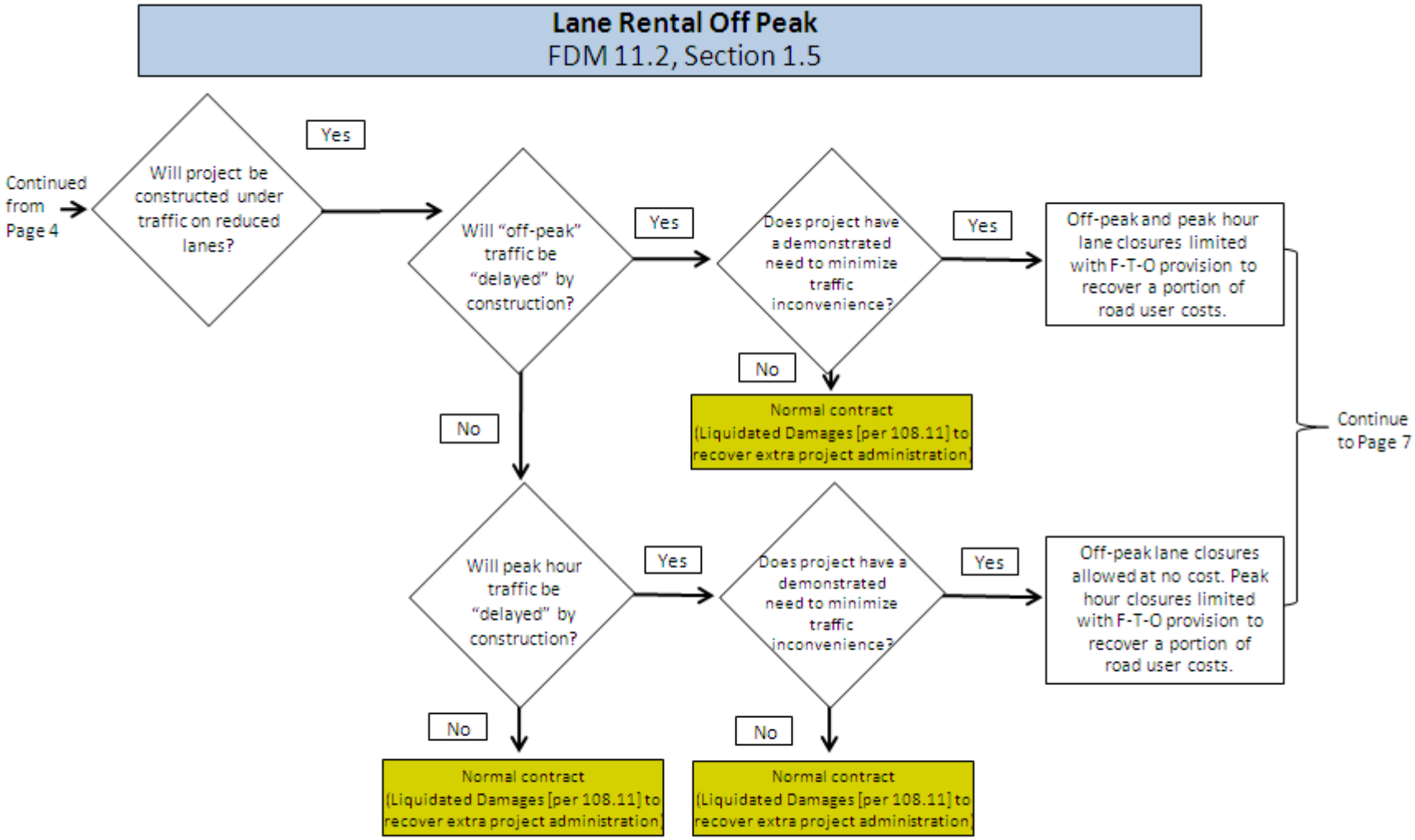
Notes:

1. This Alternative Contracting method assumes a normal design delivery process.
2. This Alternative Contracting method assumes normal construction production rates.
3. This Alternative Contracting method will only seek to recover construction administrative costs.

Normal Contract Details



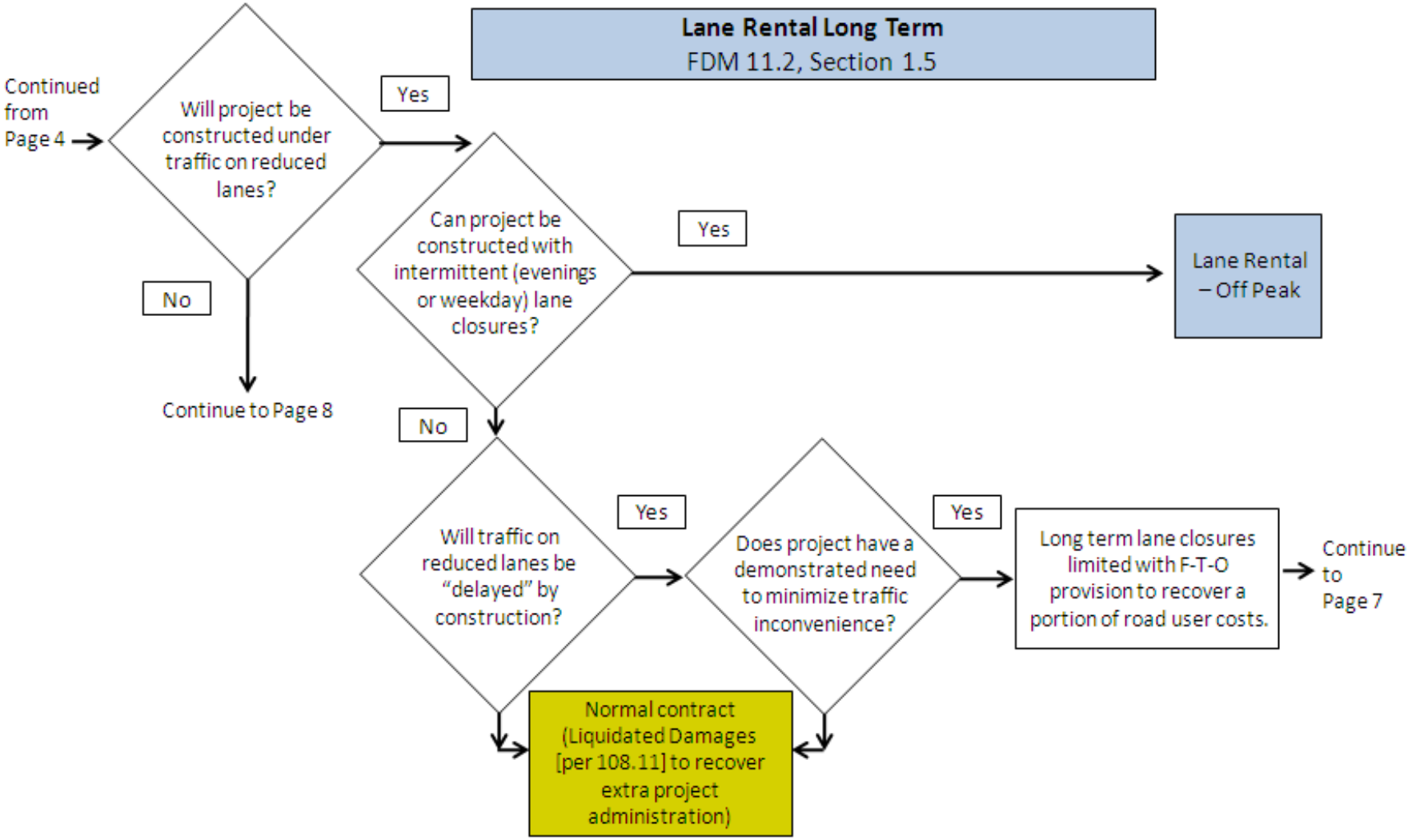
Lane Rental Long Term Details



Notes:

1. This Alternative Contracting method assumes a normal design delivery process.
2. This Alternative Contracting method assumes normal construction production rates.
3. If traffic is "delayed", this Alternative Contracting method will seek to recover a portion of road user costs.

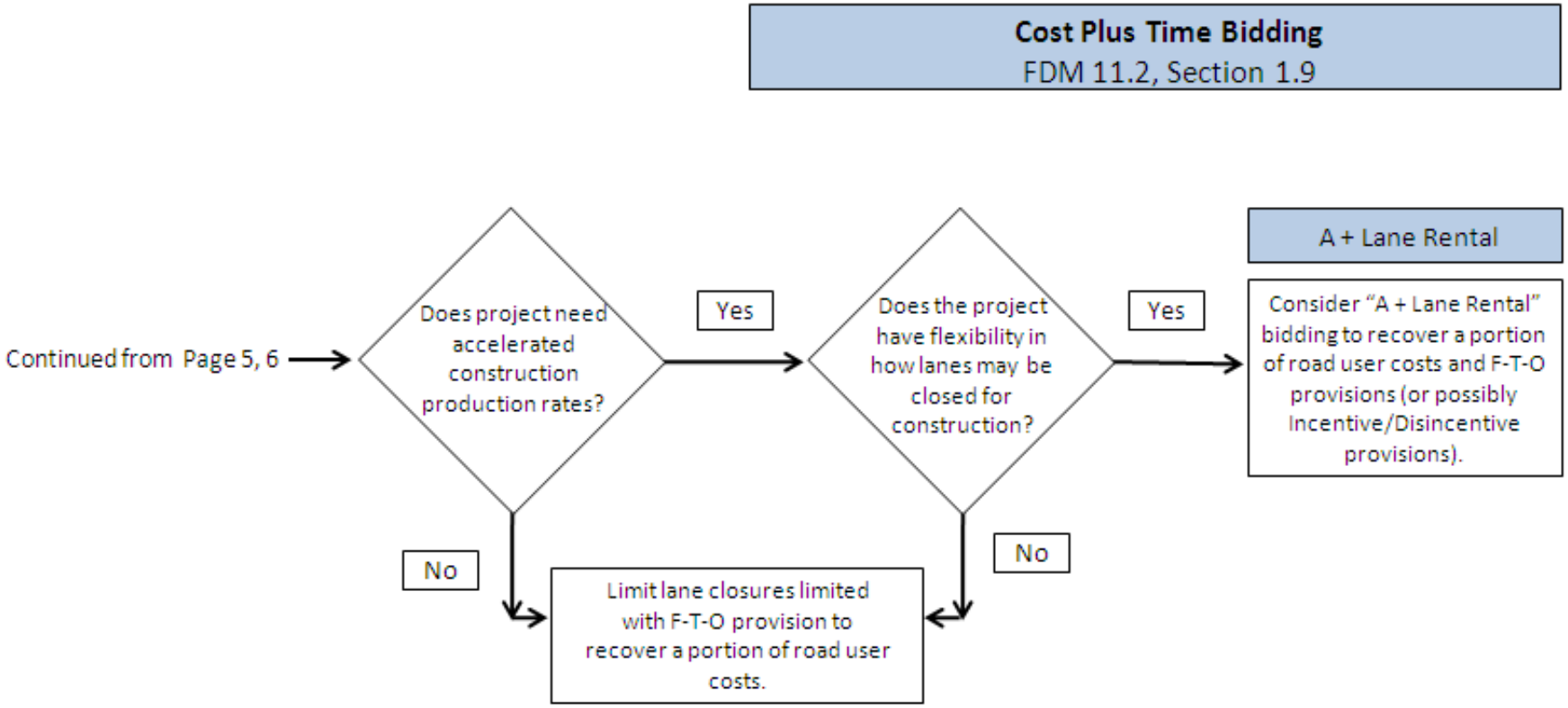
Lane Rental Long Term Details



Notes:

1. This Alternative Contracting method assumes a normal design delivery process.
2. This Alternative Contracting method assumes normal construction production rates.
3. If traffic is "delayed", this Alternative Contracting method will seek to recover a portion of road user costs.

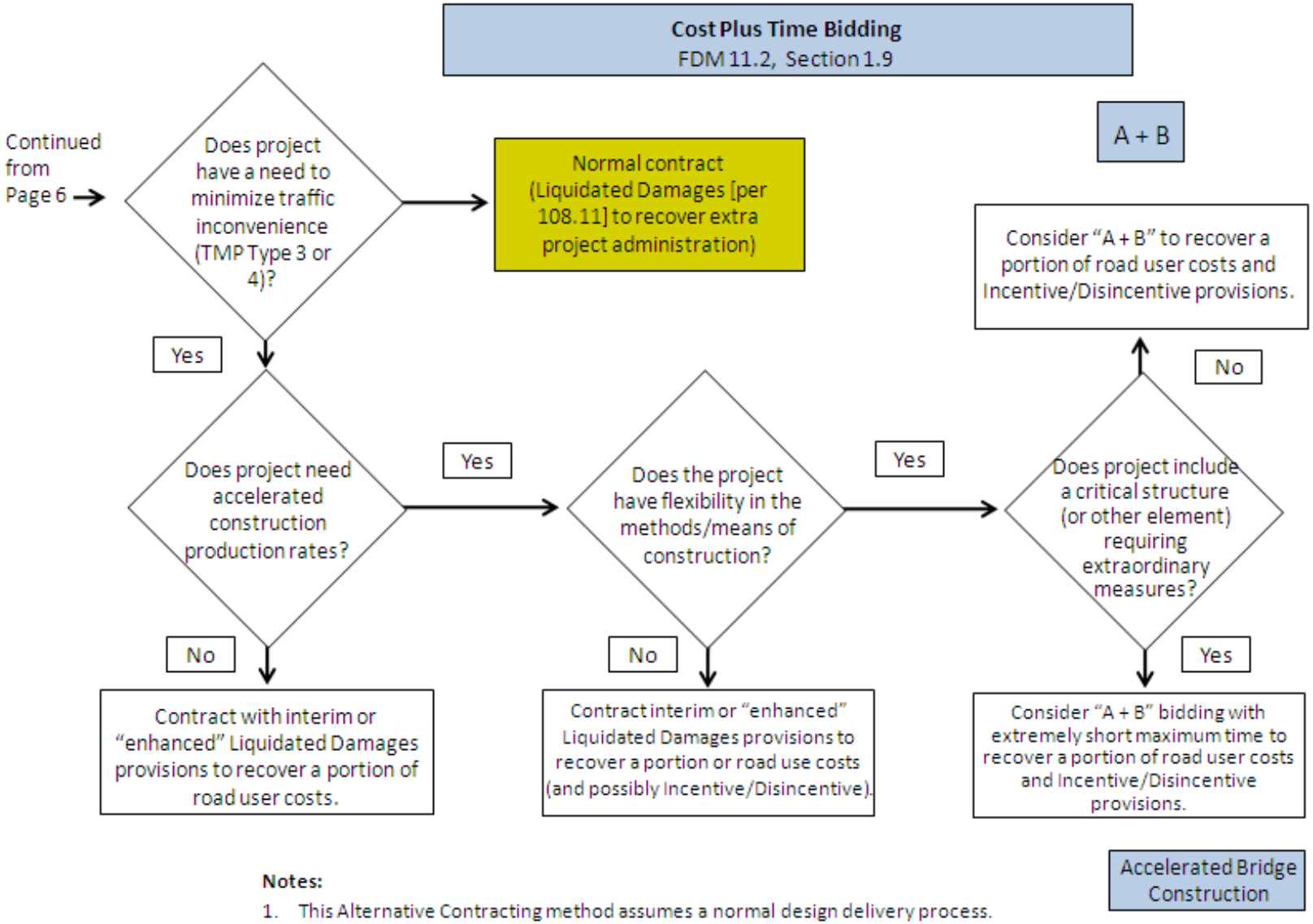
Cost Plus Time Bidding Details



Notes:

1. This Alternative Contracting method assumes a normal design delivery process.
2. This Alternative Contracting method assumes accelerated construction production rates.
3. This Alternative Contracting method will seek to recover a portion of road user costs.

Cost Plus Time Bidding Details (continued)



Notes:

1. This Alternative Contracting method assumes a normal design delivery process.
2. This Alternative Contracting method assumes accelerated construction production rates.
3. This Alternative Contracting method will seek to recover a portion of road user costs.

Cost Plus Time Bidding Example (Entire Contract):

CONTRACTOR	BID ITEMS TOTAL (A)	DAYS BID	ROAD USER COSTS	TIME TOTAL (B)	A + B TOTAL
X	$4,900,000	110	$10,000	$1,100,000	$6,000,000
Y	$4,300,000	130	$10,000	$1,300,000	$5,600,000
Z	$4,400,000	115	$10,000	$1,150,000	$5,550,000

In the example above the proposal listed a maximum allowable contract time of 130 days and a road user cost (RUC) of $10,000 per day. Contactor Z had the lowest combined bid. A contract for $4,400,000 would be awarded to Contractor Z with a maximum of 115 days specified in the contract.

Cost Plus Time Bidding Example (Interim Stages):

CONTRACTOR	BID ITEMS TOTAL (A)	STAGE 1 DAYS BID	STAGE 2 DAYS BID	STAGE 3 DAYS BID	TOTAL DAYS BID	ROAD USER COSTS	TIME TOTAL (B)	A + B TOTAL
U	$4,900,000	20	30	25	75	$10,000	$750,000	$5,650,000
V	$4,300,000	25	30	30	85	$10,000	$850,000	$5,150,000
W	$4,400,000	20	30	40	90	$10,000	$900,000	$5,300,000

In the example above the proposal listed a maximum allowable contract time of 25 days for Stage 1, 30 days for Stage 2 and 40 days for Stage 3, with a RUC of $10,000 per day. Contactor V had the lowest combined bid. A contract for $4,300,000 would be awarded to Contractor V with a maximum of 85 days specified in the contract (25 for stage 1, 30 for stage 2, and 30 for stage 3).

Cost Plus Lane Rental Bidding Example (Long Term):

CONTRACTOR	BID ITEMS TOTAL (A)	LANE RENTAL DAYS BID	ROAD USER COSTS	LANE RENTAL TOTAL (B)	A + LR TOTAL
R	$4,450,000	30	$10,000	$300,000	$4,750,000
S	$4,300,000	50	$10,000	$500,000	$4,800,000
T	$4,400,000	45	$10,000	$450,000	$4,850,000

In the example above the proposal listed a maximum allowable long term lane rental of 50 days and a RUC of $10,000 per day. Contactor R had the lowest combined bid. A contract for $4,450,000 would be awarded to Contractor R with a maximum of 30 days of long term lane rental specified in the contract.

Cost Plus Lane Rental Bidding Example (Off Peak):

CONTRACTOR	BID ITEMS TOTAL (A)	OFF-PEAK HOURS BID	OFF-PEAK RUC	OFF-PEAK B (PART)	PEAK HOURS BID	PEAK HOUR RUC	PEAK B (PART)	TIME TOTAL (B)	A + B TOTAL
M	$4,500,000	480	$500	$240,000	160	$2000	$320,000	$560,000	$5,160,000
O	$4,300,000	640	$500	$320,000	280	$2000	$560,000	$880,000	$5,180,000
P	$4,400,000	560	$500	$280,000	300	$2000	$600,000	$880,000	$5,280,000

In the example above the proposal listed a maximum allowable off-peak lane rental of 640hours (with a RUC of $500 per hour) and peak hour lane rental of 300 hours (with a RUC of $2,000 per hour). Contactor M had the lowest combined bid. A contract for $4,500,000 would be awarded to Contractor M with a maximum of 480 hours of off-peak lane rentals and 160 hours of peak hour lane rental specified in the contract.

FDM 11-3-1 Policy & Principles

May 15, 2019

1.1 General

This procedure has been prepared to explain the Department's beliefs and approach to design policy and aesthetics for community-sensitive design during project development.

Transportation projects are not an end in themselves, but a vital means to reach many end points. WisDOT's vision is to deliver a comprehensive transportation network that provides safe, user-friendly access and mobility, and, at the same time, responds to the values of Wisconsin citizens.

1.2 Design Policy: "Community Sensitive Design"

It is WisDOT policy to use a "Community Sensitive Design" (CSD) approach to enhance transportation project development and resulting solutions. CSD is an approach of creating public works projects that function safely, efficiently, and are pleasing to both the users and the neighboring communities.

CSD is also known as Context Sensitive Solutions (CSS) in National literature and engineering guides.

Community Sensitive Design is a collaborative interdisciplinary approach that includes early involvement of all stakeholders to ensure that transportation projects not only provide safety and mobility but are also in harmony with communities and the natural, social, economic, and cultural environments. All projects shall include a CSD approach, however the application of the various CSD elements will vary significantly based on project complexity and scope. All projects shall include an appropriate level of public involvement to ensure that stakeholder issues relevant to the project scope are addressed. However, limited scope projects, such as Perpetuation (S-1) and some Rehabilitation (S-2) projects will mainly have CSD elements implemented by the Department limited to work within the shoulder to shoulder or face to face curb points. S-1 (Perpetuation), S-2 (Rehabilitation and Reconstruction-Type Modernization) and S-3 (Modernization) are defined in FDM 11-1-10. This integration of projects into the community and environment requires careful planning. Consequences from differing perspectives must be balanced, and the design tailored to fit a project's circumstances and scope.

In accomplishing this, a variety of design, construction and safety analyses must be considered, along with environmental considerations. Justifications to design criteria may be used, where appropriate and necessary. These will be documented as alternatives in the Safety Certification Document (SCD) and a final alternative will be selected and approved in the Final Scoping Document (FSD) or in some cases outside of the scoping process with documentation provided in Design Study Report (DSR) Design Justifications (DJs) sections. The selection of an alternative will contain the necessary analysis of the consequences and tradeoffs involved.

1.3 A Changing Context for Transportation

The impacts from delivering transportation facilities and dealing with community expectations are causing transportation agencies to do their work within a broader framework or context. Traditional transportation needs such as access to land and markets, mobility, and safety in travel continue to grow. However, added to the traditional needs are concerns about where and how the transportation facilities are to be developed, designed and funded. The impacts of growth and transportation can be either positive or negative and increasingly hard to balance.

Society expects these agencies to be more sensitive to the context within which transportation facilities exist. This has led to a significant number of laws, rules, and regulations designed to protect society and the natural world from the impacts of growth, and transportation facility changes.

This context requires that many perspectives and interests be considered in the project development and design process before major design decisions are made. These perspectives include environmental considerations and community values and interests. Federal legislation consisting of ISTEA in 1991, TEA-21 in 1998, SAFETEA-LU in 2005, MAP-21 in 2012 and FAST in 2015 recognized this need for balance, and for consideration of many interests and issues.

As a result, transportation agencies have found it necessary to adapt and transform the transportation project development process in such a way that it acknowledges the legitimacy of these many players and perspectives but does not conflict with providing needed safe and efficient transportation facilities. FHWA's "Flexibility in Design" document (https://www.fhwa.dot.gov/environment/publications/flexibility) was prepared considering the changing context of design decisions.

1.4 Outcomes of Community Sensitive Design

The outcomes of a community sensitive design approach are as follows:

- The project is a safe facility both for the user and the community.
- The project satisfies the purpose and need and involves the appropriate range of stakeholders. This agreement is forged in the earliest phase of project planning or project development and amended as warranted as the project develops. Include the Purpose and Need in the Environmental Document.
- The project is in harmony with the community and preserves environmental, scenic, aesthetic, historic and natural resource values of the area.
- The project meets the expectations of both designers and stakeholders and achieves a level of acceptance in people's minds.
- The project involves an efficient and effective use of resources (time, budget, community).
- The project is designed and built with minimal disruption to the community.
- The project adds value to the community.

1.5 Principles of Community Sensitive Design

Project development is successful when it leads to public works projects that fit the community and environmental context through which they pass. The following principles are the cornerstone of WisDOT's project development philosophy.

1. Involve customers and stakeholders early and continuously.
2. Use an interdisciplinary project development approach.
3. Emphasize good project management.
4. Be sensitive to environmental issues.
5. Provide an appropriately balanced, aesthetically pleasing quality product.
6. Provide safe and efficient facilities.
7. Deliver quality projects on time and within budget.

The above principles must be understood and applied if WisDOT is to be a leader in project and transportation development.

Integrating these principles into project development is more of an art than a science. No two projects are alike, and no engineering formula will guarantee successful project development. However, these guiding principles can provide some direction for what successful project development looks like.

1.5.1 Involve Customers and Stakeholders Early and Continuously

Community Sensitive project development starts with people and ends with people, i.e., customers and stakeholders, who use or reside along the improved facilities. Involving people before decisions are made is vital to obtaining trust and participation and helps to ensure that the transportation facility fits the community context and meets all aspects of environmental justice.

A public/agency participation thought process must be developed for all projects, while a formal public/agency participation plan is needed for large, complex projects. The Facilities Development Process guidance (especially the public/agency involvement sections) is a major resource available for use.

Customers may be hard to attract to meetings and creative means to involve them are often necessary. Stakeholders are often easier to involve because of their immediate concerns about access or impacts.

1.5.2 Use an Interdisciplinary Project Development Approach

Engineers are key players in delivering public works projects. Their discipline and expertise are critical to building facilities that will last and function safely and efficiently. However, engineers cannot do it all. Historians, archeologists, landscape architects, biologists, foresters, planners and other disciplines also contribute to the project development process.

A team approach is necessary to ensure that the project is considered in context with the land use, environment, and culture in which it is built. The disciplines that are brought to bear on an individual project will vary depending on the type and scope of project and its impacts. The collective eyes and creative energies of the team members may see opportunities that a single discipline may overlook. Early team involvement during scoping is often the key to a later successful integration of the various elements that contribute to project success.

1.5.3 Emphasize Good Project Management

The project manager (**PM**) is the key person who can ensure good customer, stakeholder, and interdisciplinary involvement. The PM can take a broad view of a project because he/she knows both the internal and external perspectives shaping the project and can integrate them into a well-balanced design. The PM is recognized as the external and internal contact and focal point for projects.

A project manager needs to be well trained in the project development process, as well as in the project management scheduling tools available. A PM also must recognize that he/she can't do the project development alone, but rather serves as the coordinator, decision maker or facilitator of decisions.

1.5.4 Be Sensitive To Environmental Issues

The impact of roadways on the environment need not be negative. Design and enhancement opportunities exist if creatively sought. The main principle is to identify, avoid, minimize, and mitigate social, environmental or economic impacts.

1.5.5 Provide an Aesthetically Pleasing Quality Product

The aesthetic and visual quality of highways and transportation facilities are important in a community sensitive design approach. Scenic views, community image, and roadside landscaping can play an important part in the driving experience. The aesthetic design of bridges can leave a lasting impression on communities, daily users, and tourists. As such, the design process should provide the opportunity for communities and other stakeholders to participate in a discussion about aesthetic treatments that might be incorporated on the project and what the cost participation responsibilities are.

Department policy on Perpetuation (S-1) Rehabilitation and Reconstruction-Type Modernization (S-2) projects is to make improvements to the facility without changing the existing geometric and cross-sectional features except where justified by a safety analysis performed as part of the Safety Certification Process (SCP). Appurtenant features (such as curb & gutter, sidewalks, drainage structures, etc.) will typically not be altered on these projects having a pavement treatment service life of 17 years or less. Maintaining existing roadway features minimizes the projects impacts on the natural and societal landscape and thus existing aesthetics will usually remain unaffected by the project. Correspondingly however, the addition of new aesthetic treatments will typically be beyond the scope of these projects. Aesthetic treatments appropriately fitting within the project scope, including the existing right of way, environmental impact footprint and project cost and schedule, may be needed in some cases as mitigation paid for with project funding if justified as part of the environmental process or may be included at the request of the locals, but with local commitment to its cost and maintenance.

However, projects having a pavement treatment service life of 18 years or more, whether Perpetuation (S-1) and Rehabilitation and Reconstruction-Type Modernization (S-2) projects or Modernization (S-3) projects [Reconstruction (S-2) and New Construction (S-3)], will typically replace some or all the appurtenant features and thus aesthetic treatments are more easily incorporated within the project scope. The scope of these projects is more likely to involve the acquisition of right of way and impacts to the natural and societal landscape and thus more likely to impact existing aesthetics along the project. The environmental process will determine what the project impacts are and what aesthetic mitigation is justified. Aesthetics outside of those deemed as environmental mitigation, can be discussed and typically integrated on the project, but will require local commitment for cost and maintenance.

Comprehensive aesthetics planning is a process that integrates the roadway with the community and creates a wealth of goodwill. Aesthetic design and design success must flow directly from the design process so that transportation public works projects complement communities, provide safety and mobility, and enhance visual quality.

1.5.6 Provide Safe and Efficient Facilities

Concern about customers, stakeholders, the environment, and aesthetics must not preclude safe and efficient design. The project and its elements must all be designed and constructed so that they function well and last through their design life.

The challenge is to be flexible, so that safety and operational integrity are in proper balance with other contextual factors. The use of appropriate safety performance analyses of existing roadway elements that will be performed as part of the SCP will help to facilitate this flexibility (See FDM 11-38).

1.5.7 Deliver Quality Projects on Time and Within Budget

Program delivery in a timely and cost-effective manner is a department objective. There is some concern about whether a community sensitive design approach will add to the time and cost of project delivery. Quality in the customer's eyes may be enhanced, but at what cost? The main goal is to make wise decisions during project development. Designers must consider the context of the project from the outset and to budget accordingly. This

includes the opportunity for public participation in discussions about such things as aesthetic or trail improvements. It may include a less costly design if a lower design speed or improvement treatment is appropriate for the project.

The time to develop the project is likely to be longer in the early stages but quicker in the labor-intensive detail design/right-of-way acquisition phase. This is because the rework cycle is minimized through better involvement and agreement early in the process.

The cost and time elements need to be carefully considered so that the CSD approach is in balance with the project complexity, context and scope. There probably isn't a single formula one can apply since the tradeoffs between quality, cost, and time will largely be project and situation dependent.

FDM 11-3-5 Decision Making Guidance

May 15, 2019

5.1 Introduction

As described in FDM 11-3-1, an important aspect of CSD is to deliver transportation projects that not only provide safety and mobility but are also in harmony with communities and the environment. This requires balancing design, construction and safety elements with impacts to the natural, social, economic and cultural environment.

Pursuant to Wis. Stat. 85.0205 (https://docs.legis.wisconsin.gov/statutes/statutes/85/0205/2) there is a limit on how much of the cost of a highway improvement project can be spent on elements determined to be aesthetic preferences of a community impacted by the improvement project. Refer to the Program Management Manual document number 03-25-15 for additional information and a list of eligible items.

This procedure provides guidance to help designers more comfortably make the appropriate design choices. Attachment 5.1 through 5.14 consist of decision-making matrices showing the following:

- Steps to follow,
- Project information and data to collect,
- Types of analyses to be completed, and
- Things to consider when applying flexibility in design, construction and safety elements.

Consult AASHTO's GDHS (https://www.fhwa.dot.gov/programadmin/standards.cfm) FHWA's "Flexibility in Highway Design" (https://www.fhwa.dot.gov/environment/publications/flexibility) and the AASHTO Bridging Document (http://sp.design.transportation.org/Documents/SCOD,Neuman,CH2MHill,FlexibilityGuide.pdf) for additional guidance.

5.2 Decision Making Steps

The decision-making steps are as follows:

1. Use the design criteria values recommended in the SCD for Perpetuation (S-1), Rehabilitation (S-2), appropriate Reconstruction Type Modernization (S-2) Projects or within the FDM design criteria and guidance for Modernization (S-3) projects for initial preliminary designs and design alternative alignments. Layout horizontal and vertical alignments to best fit the "lay of the land," and to reduce or soften impacts to community and environmentally sensitive areas. The design should meet the safety and mobility needs of the project at a financially acceptable cost, as indicated in the projects purpose and need.

2. For Rehabilitation (S-2) and those Reconstruction-Type Modernization (S-2) project segments not passing the SCP, begin by using the lowest end of the design criteria ranges in the FDM above the existing design criteria that are contributing to crashes first and then proceed to use upper values if needed to meet safety performance needs. For all other Modernization (S-3) projects, consider using the lower values for Reconstruction (S-2) Types and the higher values for New Construction (S-3) Types in the FDM design criteria or guidance first, and then only proceed to analyzing lower values if further flexibility in design criteria is needed to reduce impacts and to develop the best overall design. The use of lower design criteria values shall be justified, documented and approved through either the Department SCD or a Design Justification in the Design Study Report. This documentation will typically include such things as a description of the impacts that are being avoided or reduced, and a description of the crash history and other analyses completed to address safety concerns.

3. Consideration may be given to maintaining or using design criteria outside of FDM design criteria in situations where even the lowest FDM design criteria will cause excessive impacts to community or environmentally sensitive areas, and where it can be proven from the existing crash history or a predictive crash safety analysis that unacceptable safety problems do not or will not exist. For

controlling and non-controlling criteria, the use of design criteria outside of FDM values for existing design criteria with crash history problems or for the incorporation of new design criteria outside of FDM values requires an approved DJ. See FDM 11-1-20 and FDM 11-4-10 for information on preparing DJs.

The introduction of new values outside of FDM and AASHTO design criteria requires great care to ensure that the safety and operational characteristics of the new roadway design are compatible with the operational characteristics of the original roadway. These operational characteristics consist of such things as meeting driver expectations and maintaining existing vehicle operating speeds and consistency of operating speeds throughout the project. Appropriate mitigation measures should be used to warn drivers and to maintain consistent operating characteristics. Examples of mitigation measures for various design features are listed in Attachment 5.1 through 5.13.

5.3 Project Information, Data Collection and Analyses

To ensure that design criteria are applied appropriately, the following project information and data should be collected and analyzed:

5.3.1 Project Information

5.3.1.1 Type of Improvement

Appropriately choose the type of improvement (Modernization (S-2 & S-3), Rehabilitation (S-2), Perpetuation (S-1), etc.) that best reflects the purpose and need of the project. Design criteria flexibility is generally greater for Perpetuation (S-1) and Rehabilitation (S-2) projects than for Modernization (S-2 & S-3) projects.

5.3.1.2 Roadway Functional Classification

Flexibility in design criteria increases as the functional classification of roadways decreases. Based on functional classifications the following philosophies in applying design criteria should be followed:

Interstates, Other Freeways, and Expressways

There is the least design criteria flexibility for these facilities. CSD is applied mostly to the extent that the safety and mobility needs, and existing or new design criteria allow. CSD is largely achieved on these projects through roadway location selection, horizontal and vertical alignments that follow the “lay of the land,” aesthetic features that soften roadway impacts, and by use of roadside and median safety barriers to reduce roadway widths. Both FDM and AASHTO guidance generally consist of higher design criteria values. When alternatives are generated in the SCP, they should always begin within the range of values prior to going outside the ranges and only when needed to address unique circumstances.

Corridors 2020 Multilane and Two-lane Roadways

Follow a similar philosophy as the Interstate, Freeways and Expressways; but also include urban roadway design criteria in addition to rural roadway design criteria. Outside of the design criteria ranges of SCP alternatives with safety issues should be considered only under very unique circumstances, such as those pertaining to justifiable environmental impacts or excessive costs. Design criteria flexibility for these facilities generally consist of some lower widths for median shoulders on rural projects, some lower median and outside shoulder/curb offset widths on transitional/high speed urban roadways and some lower travel, parking lane and median widths on low speed urban roadways.

Non-Corridors 2020 Principal and Minor Arterials

The CSD philosophy is applied by making informed choices between the safety and mobility needs of the roadway and the social and environmental needs. Crash history is analyzed on these projects to determine where safety improvements are needed. Crash history and other data, such as vehicle operating speeds, can be used to make informed choices between geometric upgrades and social and environmental impacts.

The lowest design criteria should not be used if existing or predictive safety analyses show or determine that safety will be degraded as an outcome or if driver expectations will be violated. For example, proposing to upgrade lane and shoulder widths on a highway without proper consideration given to also upgrading the horizontal or vertical features could give drivers the impression that the entire roadway has been upgraded. This could encourage them to drive faster than the horizontal and vertical features can handle and thereby potentially increase crash rates.

Design criteria flexibility for rural roadways generally includes narrower shoulder widths and, in rolling terrain conditions, narrower lane widths on roadways with lower volumes or lower design speeds. Design criteria flexibility for urban roadways generally includes narrower median and outside shoulder/curb offset widths and narrower lane widths on lower volume transitional/high speed urban roadways and narrower travel and parking

lane and median widths on low speed urban roadways.

Increased levels of congestion, above AASHTO guidance, are allowed per FDM 11-5-3.

Collectors, Locals and Town Roadways

Apply a similar CSD Philosophy to collectors, locals and town roads as described above for the Non-Corridors 2020 principal and minor arterials. The difference is that collectors, locals and town roads have additional flexibility available in design criteria and are more commonly allowed to operate at even higher congestion levels. Design Justifications to design criteria may be submitted as needed to avoid or reduce impacts to socially or environmentally sensitive areas.

5.3.1.3 Type of Terrain

The AASHTO policy for level, rolling, and mountainous terrain conditions reflects design practices related to cost and operational efficiency. Steep upward grades reduce vehicle operating speeds at the approach to crest vertical curves. The lower design speeds provided in the rolling terrain tables reflect these lower operating speeds and the economic constraints that are imposed in the construction of roadways under these conditions. Be cautious when designing sag vertical or sharp horizontal curves at the bottom of steep downgrades because vehicle operating speeds at these locations tend to increase. This can create difficulties, especially for large trucks, affecting their ability to decelerate safely. Level terrain is the predominant terrain in Wisconsin, but there are areas in the state that have rolling terrain.

5.3.1.4 Project Design Speed

Horizontal, vertical and cross-sectional design features are all affected by the project design speed. Lower design speeds allow increased flexibility in the ranges of design criteria values. The selection of design speed should generally be compatible with the operating characteristics, functional classification and predominant use (e.g., high mobility, local access, “Scenic Byway,” etc.) of the highway. See FDM 11-10-1 for guidance on the selection of design speed.

5.3.2 Data Collection

5.3.2.1 Existing and Projected Traffic Volumes

Traffic volumes affect the flexibility available in cross sectional design criteria. As traffic volumes increase the potential number of conflicts between vehicles and between vehicles and objects increases. This, in turn, increases the potential for a crash. Wider lane and shoulder widths provide additional lateral separation between vehicles and vehicles and roadside objects. This generally provides drivers with more room to perform avoidance and deceleration maneuvers. Review projected traffic volumes to be sure that they adequately reflect future development plans.

5.3.2.2 Operating Speeds

These tend to indicate how a highway is being driven and whether individual geometric elements meet driver expectations. Use this data to aid in selecting project design speeds, and when considering the use of the lowest design criteria. Consult with region’s traffic section when collecting and analyzing operating speed data.

5.3.2.3 Crash History

This indicates the types of safety improvements that should be considered in the design of a project. It also indicates the relative safety performance of various geometric elements or roadside safety features. Crash history information and analysis is to be documented in all SCDs and DJs when the use of design criteria values outside of the ranges are proposed.

5.3.2.4 Roadside Conditions

Field reviews and photo log observations of roadside conditions can help to identify and evaluate potential safety impacts of existing geometric elements or roadside features. Such things as vehicle tracks and skid marks and damage to roadside barriers or other roadside objects may indicate potential safety hazards that may not show up in the crash history data.

5.3.2.5 Pavement Friction

An assessment of existing or proposed pavement surface friction can help to evaluate the safety impacts associated with the use of lower curve radii or super-elevation rates. If a decision is made to retain or use a curve radius outside of the design criteria based on a thorough analysis of crash history, operating speeds and roadside conditions, construction of a pavement surface with an increased coefficient of friction in combination with the use of maximum super-elevation is a good mitigation measure.

5.3.3 Analyses

5.3.3.1 Operating Speed Analysis

Inspection of vehicle operating speeds can help to evaluate how the existing roadway is being driven and as to how well existing geometrics are meeting driver expectations. An ideal analysis would include the measurement of existing operating speeds at various locations throughout the project with special measurements made at locations where geometric features are of most concern. On projects with a complex or controversial decision-making process, actual measurements of operating speeds may be needed to help to generate or defend a final decision. In many cases however, the time and effort required to collect this data may not be cost effective. In those cases, the designer can get a feel for the effects of existing geometric features on vehicle operating speeds by:

- Driving the roadway or soliciting comments from other staff who have driven the roadway,
- Making field observations of vehicle operating speeds on various sections of the project or at individual geometric features that are of concern,
- Soliciting comments from law enforcement officials, other local officials or public citizens that drive or live near the highway,
- Calculating the average running speed from driving the project and comparing it to the posted speed limit and design speed,
- Reviewing crash history reports for those crashes in which excessive operating speeds were cited as a cause of the crash.

5.3.3.2 Crash History Analysis

Close inspection of crash history data is needed to evaluate the overall safety performance of the roadway and to assess which improvements to implement on a project when considering maintaining lower existing or propose new lower design criteria values. The safety analysis should go beyond the customary project crash rate comparisons to statewide averages to include a performance-based crash analysis. Performance based crash analyses consist of looking at individual crash types at concentrated locations and levels of severity, like is completed in the SCP. For instance, when evaluating the decision to use lower curve radii, the crash history should be reviewed at the curve location being analyzed to see if a crash history exists and to determine what may have caused the crashes. Documentation for DJs when needed, shall include an analysis of crash history as one of the justifications for approval.

The SCP analyses performed for Perpetuation (S-1), Rehabilitation (S-2) and Reconstruction Type Modernization (S-3) projects (See FDM 11-38) should be referred to for this effort.

5.3.3.3 Traffic Capacity and Level of Service Analysis

An analysis of a highways capacity and level of service is important to determine a highways ability to handle current and future traffic volumes. As a highway nears its capacity and the level of service decreases, the safety and mobility of a highway can become compromised. Use accepted traffic analysis formulas and models, such as the Highway Capacity Manual, to determine the incremental improvements or level of capacity expansion needed to meet the traffic needs for the project. See FDM 11-5-3 for more guidance on traffic analyses and recommended traffic analysis models and software

5.4 Things to Consider When Making Decisions on Design Criteria

Under Community Sensitive Design, designers should attempt to make geometric and other design elements conform to the “lay of the land” in order to minimize community and environmental impacts. These design elements are listed in Table 5.1.

Table 5.1 Design Elements

Design Elements	Description
Highway Capacity and Traffic Control	Level of service (LOS), intersection traffic control warrants, signing and marking criteria
Horizontal	Tangents, curves, super-elevations and transitions and sight distances
Vertical	Grades, vertical curves, vertical clearances and sight distances

Design Elements	Description	
Sight Distance	Stopping sight distances (SSDs), intersection sight distances (ISDs), passing sight distances (PSDs), decision sight distances (DSDs), approach sight distances (ASDs), driveway sight distances (DWSDs)	
Cross section	Lanes and Shoulders	Number of lanes, lane widths, shoulder widths, cross slopes, super-elevations, lateral clearances, curb and gutters, auxiliary lanes, passing and climbing lanes, horizontal clearances, shy distances, clear roadway widths of bridges, pavement structures, truck routes
	Medians	Types (raised, flush, or ditched), widths, slopes, lateral clearances and barriers
	Roadside	Side slopes, clear zones, sidewalk widths, sidewalk cross-slopes, driveway side-slopes, driveway culverts, terrace slopes, side ditches, culvert end treatments, retaining walls, roadside safety barriers and fencing
Intersections, RR Crossings, Interchanges, and Driveways	Locations, intersection angles, turning radii, horizontal and vertical roadway alignments, left/right turn lanes and tapers, median openings, channelization, approach grades, traffic controls, approach sight distances, intersection sight distances, vision triangles, design vehicles, parking and frontage road offsets	
Clearances	Clear roadway widths of bridges, clear zones, lateral clearances, horizontal clearances, vertical clearances and shy distances	
Drainage and Erosion Control	Design storms, drainage basin sizes and characteristics, hydrology, hydraulic characteristics (ditches, gutters, culverts, storm sewer pipes and inlets)	
Access Control	Controls (Ch. 84.09, 82.25, 84.295 stats, Trans 233, driveway permits, state access management system plans), access spacings, intersections, driveway locations, driveway uses and driveway design vehicles	
Bicycle accommodations	Locations, widths, cross slopes, longitudinal slopes, pavement structures, sight distances, vertical clearances, road crossings, driveway crossings, grates and median refuges	
Pedestrian and Handicap Accommodations	ADA requirements, locations, widths, cross slopes, longitudinal slopes, landings, handicap accessibility, pedestrian characteristics, curb zones, planter/furniture zones, pedestrian zones, frontage zones, surface textures, ramp designs, road crossings, driveway crossings, grates and median refuges	
Bridge	Clear roadway widths of bridges, cross slopes, super-elevations, horizontal clearances, vertical clearances, structural capacities, freeboards, hydraulic capacities, railings and roadside safety barriers.	
Other	Trail crossings	Trail uses and hourly exposure factors
	Cattle passes	Numbers of cattle, sizes of openings, longitudinal grades and lengths of structures
	Construction traffic control	Speeds, detour routes, traffic control devices: sizes, spacings and placements, delays, traffic control zone components: advance warning areas, transition areas, activity areas (longitudinal and lateral buffer spaces, work spaces, traffic spaces), termination areas and all applicable previously discussed design elements

Decision to use design criteria outside the FDM design criteria should be made informatively and based on thorough considerations of many factors. The types of factors that could be considered for all of the various geometric features involved on projects can be numerous, and not always readily apparent. To help guide

designers through this decision-making process, Attachments 5.1 through 5.14 provide checklists of factors, titled “Things to Be Considered.” These are lists of factors to consider when making these design criteria decisions.

LIST OF ATTACHMENTS

Attachment 5.1	CSD Considerations for Horizontal Alignment
Attachment 5.2	CSD Considerations for Vertical Alignment
Attachment 5.3	CSD Considerations for Stopping Sight Distance
Attachment 5.4	CSD Considerations for Intersection Sight Distance
Attachment 5.5	CSD Considerations for Passing Sight Distance
Attachment 5.6	CSD Considerations for Decision Sight Distance
Attachment 5.7	CSD Considerations for Cross Section (Lane)
Attachment 5.8	CSD Considerations for Cross Section (Shoulder)
Attachment 5.9	CSD Considerations for Cross Section (Medians)
Attachment 5.10	CSD Considerations for Cross Section (Roadside)
Attachment 5.11	CSD Considerations for Intersections
Attachment 5.12	CSD Considerations for Access Control
Attachment 5.13	CSD Considerations for Pedestrian/Bicycle Accommodations
Attachment 5.14	CSD Considerations for Bridges

Horizontal Alignment (Tangents, Curves, & Superelevation)

Factors Affecting Design:

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway functional classification
- Type of terrain (level or rolling)
- Existing/projected traffic volumes
- Selection of design speed
- Operating speeds
- Crash history at curves
- Roadside conditions in curve vicinity – particularly on the outside of curves
- Available pavement friction

Things to Consider When Making Decisions on Design Criteria

Before deciding to apply lower, curve design criteria consider the following:

- Design Justifications – Horizontal alignment, superelevation, and stopping sight distance are controlling criteria for roadways with a design speed of 50 mph or greater. Design values that are outside of the FDM design criteria require design justification.
- DSR documentation – Document any design justifications in the DSR.
- Traffic volumes - The risk is lower for lower volume highways and higher for higher volume highways.
- Number of unfamiliar drivers - The risk is higher on roads with a higher percentage of unfamiliar drivers (such as on long distance traveler and tourist route highways).
- Vehicle operating speeds - The risk may generally be acceptable if the effective or nominal speed on the proposed curve is within 5 to 10 mph of the project design speed.
- Amount of truck traffic - The risk increases as truck volumes increase due to trucks' propensity to overturn on curves (try to stay within 5 mph of project design speed when truck traffic is a factor).
- Length of curve - The longer the curve the higher the risk (short, flat curves are best).
- Vehicle entry speeds at curves - The risk varies as a function of the approach speed distribution.
- Cross section - The risk is reduced when wider lanes, shoulders and clear zone are provided along curves.
- Sight distance - The risk is reduced when sight distance is increased along curves.
- Presence of intersections and driveways - The risk increases when intersections and driveways are present on curves.
- Number of geometric elements - The overall risk of a sharp horizontal curve increases when the combination of other geometric elements in the vicinity of the curve are designed to lower design criteria values.
- Use full range of curvature to establish the best alignment - Rigid adherence to lower radius curvature is not recommended, instead use the full range of curvature to fit terrain, land use constraints and desired operating speeds.
- Mitigation measures - Use these when lower radius values are used to mitigate potential safety impacts.
- Reductions to vehicle speeds - Use transition curves to "step down" operating speeds prior to sharp curves.
- Provide adequate justification for lesser design criteria - Thoroughly document why FDM and AASHTO criteria are not being met and what analysis of crash history was performed to minimize safety concerns.

Possible Mitigation Measures If Lower Design Criteria Are Used

- Widening the lanes or shoulders along curves
- Improving the roadside (clear zone/side slopes) on curves
- Relocating or closing intersections or driveways on curves
- Spot pavement resurfacing or "wedging" to increase friction
- Advanced warning signing prior to curves
- Delineation (signing or pavement marking) on curves
- Use of spiral curve transitions
- Increased super-elevation (up to a maximum) on curves
- Shoulder paving along curves

Vertical Alignment (Grades, Crest Vertical Curves & Sag Vertical Curves)

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway functional classification
- Type of terrain (level or rolling)
- Existing/projected traffic volumes
- Selection of design speed
- Operating speeds
- Crash history on grades & curves
- Truck percentage data
- Roadside conditions in grade vicinity
- Drainage analysis

Things to Consider When Making Decisions on Design Criteria

Before deciding to apply steeper, grade design criteria consider the following:

- Design Justifications – Grades, vertical clearance, and stopping sight distance are controlling criteria for roadways with a design speed of 50 MPH or greater. Design values that are less than or greater than the FDM design criteria require a design justification.
- DSR documentation - Document, justify, and solicit approval for design justifications in the DSR.
- Drainage needs - Flat grades may require steeper cross-slopes and other special drainage considerations in order to avoid "ponding" of water.
- Traffic volumes and percentage of trucks - The risk is reduced on roadways having lower traffic volumes, especially lower truck volumes.
- Length of grade - Longer, steeper grades affect vehicle deceleration and acceleration operations, especially trucks, whereas shorter steeper grades have very little effect.
- Type of terrain - Select the appropriate type of terrain for the project to determine the appropriate grade criteria to apply. See FDM 11-10-5 and FDM 11-15-1.
- Truck climbing lanes - Consider when the truck percentage is significant, and grades are long and steep
- Shoulders and clear zones - Consider using wider shoulders and clear zones at the bottom of steep grades to provide additional safety measures to compensate for higher vehicle operating speeds.
- Curves at the bottom of steep grades - Use higher curve radii and increase super-elevation to compensate for higher vehicle operating speeds.
- Provide adequate justification for lesser design criteria - Thoroughly document why FDM and AASHTO criteria are not being met and what analysis of crash history was performed to minimize safety concerns.

Before deciding to apply flatter, grade design criteria consider the following:

- Use of flat grades - consider drainage needs. Steeper cross-slopes and other special drainage considerations may be needed to avoid "ponding" of water.
- Provide adequate justification for lesser design criteria - See above

Possible Mitigation Measures If Lower Design Criteria Are Used

- Wider shoulders or climbing lanes
- Design of truck escape ramps
- Increased shoulder and clear zones at the bottom of grades
- Increased curve super-elevation at the bottom of grades
- Use flatter horizontal curves at the bottom of grades

When using flatter grades, consider the following mitigation measures:

- Increased cross slope and other special drainage designs
- Careful design of pavement edges at superelevation transitions

Sight Distance (Stopping Sight Distance (SSD)

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway functional classification
- Type of terrain (level or rolling)
- Existing/projected traffic volumes
- Selection of design speed
- Operating speeds
- Crash history at vertical curves
- Roadside conditions in vicinity of vertical curves (intersections, driveways, etc.)

Things to Consider When Making Decisions on SSD Design Criteria

Before deciding to apply lower SSD design criteria consider the following:

- Design Justifications –Stopping sight distance is a controlling criterion for roadways with a design speed of 50 MPH or greater. Design values that are less than the FDM design criteria require a design justification.
- DSR documentation - Document, justify, and solicit approval for design justifications in the DSR.
- Traffic volumes - The risk of a sight restriction is related to the traffic volume exposed to it.
- Features within sight restrictions - The risk is greater where other features such as intersections, narrow bridges, high-volume driveways or sharp curvature occur within the sight restriction.
- No high-risk features in sight restriction - Nominal deficiencies as great as 5 to 10 mph may not create undue risk of increased crashes in sight restricted areas without high-risk features.
- Eye heights - Greater eye-heights associated with trucks, recreational vehicles and other similar vehicles provide a greater margin of safety for vertical sight restrictions.
- Horizontal sight restrictions - Horizontal sight restrictions such as large buildings, signs, tree lines, etc. affect all vehicle types equally.
- Shorter sag vertical curves - When faced with a choice, use shorter sag vertical curves in favor of providing the longest crest vertical curve possible.
- Modernization of existing highways - Study known crash history of the highway and the locations to determine the extent of actual safety risk.
- Provide adequate justification for lesser design criteria - Thoroughly document why FDM and AASHTO criteria are not being met and what analysis of crash history was performed to minimize safety concerns.

Possible Mitigation Measures If Lower, Design Criteria Are Used

- Relocate or remove features within sight-restriction
- Spot widening to increase room for collision avoidance
- Appropriate signing, lighting and delineation treatments

Sight Distance (Intersection Sight Distance (ISD)

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway functional classification
- Existing/projected traffic volumes
- Selection of design speed
- Intersection approach operating speeds
- Intersection crash history
- Roadside conditions at intersection
- Intersection design vehicle
- Intersection traffic control (signal, all-stop, etc.)

Things to Consider When Making Decisions on Design Criteria

Before deciding to apply lower ISD design criteria consider the following:

- Design speed - Higher approach design speeds require more sight distance than approaches with lower design speeds.
- DSR documentation – ISD is not a controlling criterion and does not require a Design Justification if it is not provided where no crash problems exist. However, if ISD is needed, but cannot be provided where crash problems do exist, this must be documented, justified, and approved in a design justification in the DSR.
- Vehicle type - ISD computations should be based on the appropriate design vehicle type.
- Intersection control - Certain types of intersection control (I.e. signal, all stop) require less stringent sight lines.
- Sight restrictions - Strive to eliminate sight restrictions such as trees, vegetation, signs and movable obstacles.
- Vertical geometry sight restrictions – Removing sight restrictions may include alignment reconstruction, but also may include relocation of the intersection away from the sight restriction, closure of intersection, or turn restrictions that eliminate higher risk movements.
- Urban roadway sight restrictions - Viable solutions may include creative use of turn restrictions or focusing traffic on safer (perhaps signal-controlled) intersections.
- Advance signing – advance signing can be used on the unstopped approach to warn of the intersection.
- Traffic signal control - Where volumes are high, sight restrictions significant, and a pattern of crashes related to the sight restriction is evident, traffic signal control may be a solution.
- Provide documentation in a Design Justification in the DSR when ISD should be provided, but cannot be provided

Possible Mitigation Measures if lower, Design Criteria Are Used.

- Remove objects to eliminate sight restrictions
- Relocate or close the intersection
- Impose turn restrictions to eliminate higher risk movements
- Place advance signing on the unstopped approach(es) to the intersection
- Install traffic signal control at high volume intersections

Sight Distance (Passing Sight Distance (PSD)

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway functional classification
- Existing/projected traffic volumes
- Selection of design speed
- Operating speeds
- Crash history due to lack of PSD
- Existing % passing/no passing

Things to Consider When Making Decisions on Design Criteria

Before deciding to apply PSD design criteria consider the following:

- DSR documentation – PSD is not a controlling criterion and does not require a Design Justification if it is not provided in situations where no crash problems exist. However, if PSD is needed but cannot be provided, this should be documented, justified, and approved in a design justification in the DSR.
- PSD is not a requirement in the FDM or AASHTO
- Effects of Insufficient PSD– Insufficient PSD can degrade operations and increase risk taking by drivers. The effects of insufficient PSD may not be evident except where traffic volumes approach the capacity of a two-lane highway, or where the volume of heavy vehicles is usually great.
- DSR documentation - If PSD is needed, but cannot be provided, document why in the DSR.

If PSD cannot be provided, consider the following:

- Construction of passing lanes
- Construction of truck auxiliary lanes on long upgrades
- Construction of intermittent turn-outs for slower vehicles

Sight Distance (Decision Sight Distance (DSD)

Things to Consider When Making Decisions on Design Criteria

Before deciding to use DSD design criteria consider the following:

- DSR documentation – DSD is not a controlling criterion and does not require a Design Justification if it is not provided where crash problems do not exist. However, if DSD is needed, but cannot be provided, it should be documented, justified, and approved in a design justification in the DSR.
- DSD is not a requirement of the FDM or AASHTO
- Location and circumstances - Provide DSD where complex or instantaneous decision-making and unusual maneuvers are required, such as complex intersections, exit ramps, lane drops, etc.
- Three-dimensional design - Strive to provide three dimensional alignments that produce DSD as part of location planning and studies for new alignment and in considering proposals to add new intersections and interchanges to existing highways.

Where DSD should be available and is needed but cannot be provided consider the following:

- Traffic control devices
- Advance warning signs

Cross Section (Lane)

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway functional classification
- Type of terrain (level or rolling)
- Existing/projected traffic volumes
- Selection of design speed
- Operating speeds
- Crash history due to lane width
- Roadside conditions

Things to Consider When Making Decisions on Design Criteria

Before deciding to apply narrower, lane widths consider the following:

- Design Justifications – Lane width, pavement cross slope, and superelevation are controlling criteria for roadways with a design speed of 50 MPH or greater. Any lane widths that are outside of FDM width criteria require design justifications.
- DSR documentation - Document, justify, and solicit approval for lower design criteria in the DSR.
- Design speed - Wider lane widths are associated with higher speed roadways such as freeways, suburban arterials and two-lane arterial and collector highways.
- Traffic volumes - Wider lanes are desirable to accommodate variations in the lateral placement of vehicles within lanes.
- Vehicle type - Wider lanes better accommodate wider vehicles.
- Drainage – Flat cross slopes, particularly in conjunction with flat grades, may lead to ponding of water.
- Driveway Operation – Steep pavement cross slopes can contribute to vehicles “bottoming out” when entering and leaving driveways.
- Capacity - Wider lanes marginally increase the capacity of the roadway
- Horizontal curves - Adequate lane width is very important for vehicle "off-tracking" on horizontal curves.
- Vehicle separation - Narrow lanes reduce vehicle separation and separation from bicyclists.
- Urban cross section - Total cross sections that consider left turning vehicles, medians, and pedestrian and bicyclist needs should be considered.
- Narrow lane widths on urban streets - Lessen pedestrian crossing distances, enable provision for on-street parking and transit stops, enable development of left turn lanes for safety and can sometimes encourage lower operating speeds.

Possible Mitigation Measures If Lower Design Criteria Are Used

- Wider shoulders
- Improved roadside (slopes & clear zones)
- Lane widening through sharp horizontal curves
- Special centerline and edge line delineation (pavement marking)
- Use of shoulder rumble strips
- Improved stopping sight distance
- Flush or raised medians on 4 or 6 lane urban roadways

Cross Section (Shoulder)

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway functional classification
- Type of terrain (level or rolling)
- Existing/projected traffic volumes
- Selection of design speed
- Operating speeds
- Crash history due to shoulder width
- Roadside conditions

Things to Consider When Making Decisions on Design Criteria

Before deciding to apply narrower, shoulder widths consider the following:

- Design Justifications - Shoulder width is a controlling criterion for roadways with a design speed of 50 MPH or greater. Shoulder widths outside of FDM shoulder width criteria require a Design Justification.
- DSR documentation - Document, justify, and solicit approval for lower design criteria in the DSR.
- Design Speed - Wider shoulder widths are associated with higher speed roadways such as freeways, suburban arterials and two-lane arterial and collector highways.
- Traffic Volumes and Vehicle Type - Wider shoulders are desirable to enable collision avoidance maneuvers and store disabled vehicles.
- Shoulder Side Slope - Side slopes that are steeper than 4:1 reduce the effective width of finished shoulder.
- Capacity - Wider shoulders marginally increase the capacity of the roadway
- Horizontal Curves - Adequate shoulder width is important for vehicle off-tracking on horizontal curves.
- Drainage - Wider, paved shoulders increase drainage runoff.
- Bicycles and Pedestrians - Give due consideration to wider, paved shoulders for bicycle and pedestrian accommodations.

Possible Mitigation Measures if Lower Design Criteria Are Used

- Provide a wider clear slope or roadside
- Use traversable ditch designs
- Provide adequate shy distance at safety barriers

Cross Section (Medians)

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway functional classification
- Existing/projected traffic volumes
- Selection of design speed
- Operating speeds
- Posted speed
- Rural versus urban categories
- Crash history due to median or lack of
- Roadside conditions
- Alignment consistency
- Truck type and %
- Left turn movements
- Intersection traffic controls

Things to Consider When Making Decisions on Design Criteria

Before deciding to apply lower median widths or no median at all, consider the following:

- DSR documentation - For all roadways, provide documentation and solicit approval in the DSR when median width criteria cannot be provided.
- Tradeoffs - Balance median widths with other elements of the total roadway cross section. Wider medians require more right-of-way and may result in greater environmental effects or increased construction costs.
- Intersection operation - Care should be taken in selecting a median width that provides for safe intersection operations. Special consideration should be given to whether room for truck storage in the median is needed.
- Safety benefits - Research strongly supports the safety benefits of four-lane divided urban streets versus undivided urban streets with no median.

Possible Mitigation Measures if Lower Design Criteria Are Used

- Use of median safety barriers
- Where medians do not exist, or cannot be provided:
    - Consider left-turn restrictions
    - Consider access controls
- Where narrow medians exist in urban areas
    - Consider re-allocation of cross section width
    - Consider use of turn-arounds or jug-handles

Cross Section (Roadside)

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway functional classification
- Existing/projected traffic volumes
- Selection of design speed
- Operating speeds
- Crash history due to clear zone
- Roadside conditions
- Roadside slopes
- Horizontal alignment

Things to Consider When Making Decisions on Design Criteria

Before deciding to apply lower clear zones consider the following:

- DSR documentation – Clear zone and Lateral Clearance are not controlling criteria and do not require a Design Justification if they are not provided. However, if clear zone or lateral clearance is needed, but cannot be provided, they should be documented, justified, and approved in the DSR.
- Design Speed - High design speeds require larger clear zones, however avoid setting artificial design speeds.
- Traffic Volumes - The higher the traffic volume the greater the probability of a vehicle leaving the roadway and thus the greater the clear zone needed.
- Roadside Slope and Ditch Designs - The design of recoverable and traversable slopes and ditches reduces the size of the clear zone needed.
- Consistency - Apply a consistent roadside treatment approach for any project.
- Flexibility - Avoid the establishment of a uniform clear zone. Width does not necessarily need to be uniform. Adjust clear zone to match roadway needs.
- Removal or Relocation - Encourage the removal or relocation of objects in the clear zone to improve safety and aesthetics.
- Extreme hazard areas - Provide extra protection when the obstacle is a cliff, a deep body of water, a flammable liquids tank, or some other similar feature that is equally dangerous regardless of the travel speed.
- Grading - Modify objects by flattening embankment slopes, re-grading the surrounding ground to safely redirect an errant vehicle over or around a feature or back onto the road, or redesigning the feature to be traversable or re-directive.
- Barriers - Barriers should be crashworthy for speeds at which they will likely be struck, regardless of the project's overall design speed, since operating speeds may vary along a highway.
- Landscaping - Encourage safe landscaping, paying special attention to trees placed within the clear zone, sight triangles at intersections, and bushes or other treatments in medians.

Possible Mitigation Measures if Lower Design Criteria Are Used

- Removal or relocation of severe hazards and as many other hazards as possible
- Modification of objects such as:
    - Flattening slopes
    - Re-grading to safely redirect errant vehicles
    - Redesigning features to be traversable or re-directive

If clear zone cannot be provided, then the following treatments should be considered for hazardous objects

- Removing objects
- Relocating objects
- Making objects break-away
- Shielding objects with safety barriers

Intersections

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway functional classification
- Existing/projected traffic volumes
- Selection of design speed
- Operating speeds
- Crash history due to median or lack of
- Roadside conditions
- Design vehicle(s)
- Alignment consistency
- Truck type and %
- Turning movements
- Traffic control

Things to Consider When Making Decisions on Design Criteria

Before deciding on Intersection design criteria consider the following:

- DSR documentation - Document, justify, and solicit approval for Design Justifications in the DSR.
- Sight Distance - Provide sufficient sight distance in advance of the intersection and on all approaches to the intersection.
- Traffic Control - Use appropriate traffic control.
- Skew angle – Skew angles that are greater than 15 degrees off of 90 degrees may inhibit the ability of drivers on a side road to see traffic approaching on the mainline. This is particularly true for older drivers.
- Left Turns - Provide safe and efficient handling of left turning vehicles.
- Alignments - Avoid unusual or confounding alignments near intersections. Intersections located within a mainline horizontal curve appear to be more crash prone than intersections located on a tangent.
- Capacity - Provide sufficient capacity at intersections to reduce adverse operational effects on the adjacent street system.
- Design Vehicles - Select the appropriate design vehicle.
- Traffic Control Devices – The Manual on Uniform Traffic Control Devices specifies practice regarding the design and placement of traffic control devices, including traffic signals, stop and other regulatory signs and warning signs.

Possible Mitigation Measures if Lower Design Criteria Are Used

- Placement of roadside objects farther from pavement edge
- Use of mountable or painted end treatments on raised barriers
- Use of different traffic control schemes where turn lanes cannot be provided:
    - Turn prohibitions
    - Special signal phasing
    - Rumble strips
    - Other measures

Access Control

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway type & functional class.
- Existing and projected traffic volumes
- Selected design speed
- Operating speeds

Things to Consider When Making Decisions on Design Criteria

Access management is the key to a highway's two primary functions: 1) mobility and 2) access to adjacent lands.

Before deciding on access control criteria consider the following:

- WisDOT policy and guidance - Follow WisDOT policy and guidance for access control - see FDM Chapter 7.
- Existing and Proposed Controls – Consult with the Region Access Administrator and review records, plans, plats, and the State Access Management System Plan for existing and proposed access controls such as: §83.027 - County Administrative Access Control, §84.09 – Purchased Access Control, §84.25 - Administrative Access Control, §84.295 – Freeway or Expressway Designation, TRANS 233 – Land Division Review, driveway permits.
- Local requirements - Work with communities when deciding on the appropriate access control measures to provide. Work with communities to develop a highway system in which access needs are provided within the context of each road's function.
- Limit the number of conflict points - This includes using non-traversable medians to manage left-turn and crossover movements. Judicious use of median treatments, driveway permits, and driveway geometry can improve the operation of the road without undue burden on landowners accessing their property.
- Separate conflict points - This includes preserving the functional area of intersections and interchanges.
- Separate turning movements from through movements.
- Locate traffic control signals to facilitate traffic movement.
- Maintain a hierarchy of roadways by current and planned function - An important part of this is to provide an adequate supporting street and circulation system.
- Limit access to state highways and other major roads when there is an opportunity for alternative access to lower-functioning roads.
- DSR documentation - If access control should be provided and is needed (based on crash history etc.), but cannot be provided, document why in the DSR
- Access control is among the most useful tools available to maintain safe and efficient operations

Pedestrian/Bicycle Accommodations

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway type & functional class.
- Existing and projected traffic volumes
- Bicycle and pedestrian counts
- Selected design speed
- Operating speeds
- Bicycle/pedestrian related crash history
- Drainage grate types

Things to Consider When Making Decisions on Design Criteria

Before deciding on pedestrian and bicycle design criteria consider the following:

- DSR documentation - Give Due Consideration to Pedestrian or Bicycle Accommodations except where prohibited (i.e. freeways), or where it isn't feasible. Document in the DSR whenever they are not provided.
- Location – Ideally, construct pedestrian and bicycle facilities outside the clear zone of high speed, high-volume highways.
- Curbing - Curbing has little, if any, re-directive capacity at medium and high speeds and consequently affords little, if any, protection for pedestrians.
- Designated routes
- Pedestrian/Bicycle volumes
- Shared versus exclusive facilities
- Existence of parking
- Regular versus integral curb and gutter
- Accommodations on bridges

Bridges

Factors Affecting Design

- Improvement type (Modernization, Rehabilitation, Perpetuation)
- Roadway functional classification
- Existing/projected traffic volumes
- Selection of design speed
- Operating speeds
- Bridge crash history
- Roadside conditions
- Bicycle/pedestrian accommodations

Things to Consider When Making Decisions on Design Criteria

Before deciding to apply Lower SSD design criteria consider the following:

- Design Justifications - Lane width and vertical clearance are controlling criteria for roadways with a design speed of 50 MPH or greater, and Structural Capacity is controlling criteria on all roadway regardless of the design speed. Note that Bridge Width is now covered by Lane Width in the ten controlling criteria. Design values that are outside of FDM Design Criteria require a design justification.
- DSR documentation - Document, justify, and solicit approval for design justifications in the DSR.
- Historic or very low volume bridges - Replacement or retention of bridges having historic or aesthetic value or design of bridges on very low volume roads may justify widths less than the indicated minimum AASHTO values (although this may still require a design justification).
- Pedestrian and bicycle needs.

FDM 11-4-1 Concept Definition Report

August 17, 2020

1.1 General

The concept definition phase of the process begins with the decision that "… something must be done . . .” From this point on, the designer formulates recommendations based upon what is already known about the problem area under consideration. The first action taken in this regard is the region's preparation of a decision document called the Concept Definition Report (CDR). Its purpose is to establish initial agreement between the Region Project Development (PD), System Planning and Operations (SPO), Technical Services (TS) and other sections as to the timing and scope of the project, and to initiate authorization to incur engineering charges. The CDR also provides various central office sections information about the project and an opportunity to offer their comments and perspectives.

The Concept Definition Report also identifies whether the project is located on a National Highway System route and whether the project will be subject to oversight by the Federal Highway Administration. FDM 5-5-15 describes the WisDOT-FHWA relationship in the development of federally-funded projects.

On local road projects, the CDR or approved application establishes initial agreement between the WisDOT and the Municipality. For local road projects, the approved application may serve as the initial CDR.

Prior to Final Scope Certification, Region and BPD Design Oversight Engineers shall review all previous documentation and agreements that fall within the proposed project limits. These include past Design Study Reports (DSRs), Design Justifications (DJs), Exceptions to Standards, etc. and when they exist; Interstate Conversions, Municipal Agreements, etc. where available. The objective of this review is to identify and incorporate any previous commitments to external agencies and evaluate any previously identified deficiencies or intended enhancements to the facility.

1.2 Content

Limit the length of the CDR to one sheet and present the basic project concepts in as brief and concise a manner as possible. The necessary elements of a CDR are as follows:

1. Where - Describe the project location.
2. Why - State the justification for establishing a project.
3. What - State the project concepts that the region is proposing.

Bicycle and pedestrian needs and the potential type(s) of accommodations should be made part of this report.

Attachment 1.1 is a recommended format for presenting the text information required in a CDR.

Include a map that is appropriate to the scope of the project within the report. For rural projects, this should be a county map showing the project termini. For urban projects, this should be a street map, again showing project termini. For spot improvements like bridge projects, it can be either a county or street map with the project location circled. Typically, this map is printed on the reverse side of the CDR.

1.3 CDR Process

The CDR is typically prepared by region SPO staff for regular improvement projects, based on information gathered during program development (needs identification, evaluation, etc.). Procedures for acceptance vary among regions, but generally indicate agreement between SPO, PDS, TSS, and others involved. A statement of anticipated environmental documentation type serves to alert FHWA, Bureau of Technical Services Environmental Section, and other central office sections of the extent of involvement or, in the case of Categorical Exclusions, completes the documentation.

Updated CDR's are prepared and distributed when there is a change in concept, such as project description (revised length or limits), scope of improvement or improvement type (e.g. Perpetuation to Rehabilitation) or a significant change in combined scope, special features, or cost that could cause a change in federal oversight status. For local road projects, the approved updated application may serve as the updated CDR.

Treat CDRs written before project scoping is completed as an initial document until the scoping process is completed. At that time, the project manager shall decide if the current CDR is accurate or if it needs to be updated to reflect pertinent changes in project scope resulting from the scoping process.

The region should forward copies of the completed CDR to the individuals listed below for purposes indicated.

Table 1.1 CDR Distribution

Organization, Attention	Which Projects	Purpose
Bureau of Project Development, Design Standards and Oversight Section Chief	All	Information and comment. This copy and notation will be maintained in C.O. File.
Bureau of Structures, Structures Design Section Chief	Projects involving bridgework	Information and comment.
Bureau of Traffic Operations, Traffic Engineering and Safety Section Chief	Projects involving signals, lighting, special traffic issues	Information and comment.
Bureau of Highway Maintenance, Highway Maintenance and Roadside Management Section Chief	All projects.	Information and comment
Region Railroad Coordinator (RRC)	All projects with a railroad crossing located within the project limits or within 1000 feet of the project location. All projects with grade separations between highway and railroad. All projects that parallel a railroad on adjacent right of way.	Information and comment. Begin railroad coordination efforts. The RRC will send a copy to the affected railroads and to the Bureau of Railroads and Harbors.
Bureau of Technical Services - Environmental Section Chief	All	Preparation of "quarterly listing" of ER and pER
USDA - Forest Service	All projects located within the Chequamegon and Nicolet National Forest	Information and Comment (see FDM 5-5 Attachment 5.1, M.O.U.)
FHWA, "Point of Contact"	All projects located on the National Highway System with an estimated project cost of $2,000,000 or more intended to be eligible for federal participation in any phase.	Information, reference, and to establish responsibility for oversight of 23 USC requirements.

NOTE: TOIPS or other special interest projects may warrant wider or targeted distribution as appropriate. See the Maintenance or Traffic Manuals regarding these.

1.4 Community Sensitive Design

Community Sensitive Design (CSD) is a philosophy of involving the "community" impacted by an improvement project early in the design process. See FDM 11-3-1 for a detailed explanation of Community Sensitive Design.

During the Concept Definition phase, meetings with the public should be used to determine the "community values" which will be used to assess various alternatives. At the same time, the community should be informed that there are certain physical and legal requirements that WisDOT and other agencies must meet when developing an improvement project. Each party needs to learn the issues important to the others. WisDOT and their consultant should host the meeting and both the public and other key agencies affected by the project should be invited to attend. At the public meeting:

WisDOT reports: "This is what the design criteria suggest we do" by providing a range of alternatives.

Other agencies report: "These are the non-highway related legal requirements for a project of this type."

Community reports: "This is what is important to us."

The goal of a public meeting held during this phase is to reach consensus on the project scope.

1.5 Notes to Design

The region Systems Planning & Operations Section will, include a "Notes to Design" document as an attachment to the CDR. The "Notes to Design" document is a means of providing the people involved in scoping and design with background information that was gathered by SPO staff in the development of the project CDR.

It also describes the local desires and commitments that may have been made when a project was put into the program. The document consists of 1 or 2 pages of text providing information on the most important factors affecting the projects schedule, cost and concept. Subjects that it might address are:

- Community growth, planning and development issues
- Corridor-specific issues that the community or public may have with this route
- Summary of public inquiries received or Safety Commission comments made
- Current pavement condition and history and where it is in its life cycle
- Any known desires on pavement type or roadway treatments requested by local government
- Any legislative interest in the project
- Any known detour issues
- A generic statement on guidelines in place at the time the project was originally programmed
- Any traffic capacity or access control issues
- Any other information relevant to project development, cost or schedule
- Recommendations to incorporate or not incorporate bicycle and pedestrian accommodations.

LIST OF ATTACHMENTS

Attachment 1.1 Concept Definition Report Template

FDM 11-4-3 Final Scope Certification

May 18, 2020

3.1 General

The purpose of the Final Scope Certification (FSC) document is to establish final agreement between the Region System Planning and Operations (SPO-PLN and SPO-OPS), Project Development (PDS), Technical Services (TSS), and the Bureau of Project Development (BPD) Design Standards and Oversight Section as to the scope, schedules, and budgets of the project. The FSC also provides various Statewide Bureaus and Division Offices with information about the project.

The Final Scope Certification is to be completed prior to moving a project to Life Cycle 11.

The Final Scope Certification includes confidential estimate information that should be redacted prior to sharing the document outside WisDOT (including design consultants).

Attachment 3.1 shows the format for the FSC.

3.2 Concurrence

Region SPO-Planning/Programming chief approves the FSC after concurrence from PDS, SPO-Ops, TSS, and BPD chiefs or their delegates.

3.3 Content

3.3.1 Cover Sheet

The cover sheet includes project identification information and approval signatures. The signature page includes the concurrence by the chiefs or their delegates as determined by the regions, with the SPO-Planning/Programming chief approval being the final signature.

3.3.2 Performance Measure Compliance

This checklist is a series of questions related to the status of the project as compared to certain performance measures and initiatives. Explanations and identification of mitigation strategies are included depending on the status of the criteria.

Performance Measures

Program Effectiveness – Is the project in compliance with the Department's current asset management theme for appropriate highway treatment?

Balanced program – Does the project estimate allow the region to stay within its assigned program funding levels?

Delivery Risk - Is the project scheduled to be compliant with current PLP and APLP programmatic completion goals for LC 12 and LC 15 Delivery Risk?

Design on Budget (DOBI) – Is the established project delivery budget compliant with EDCI goals for that

project treatment type? Only include a link to the delivery budget that is saved in a secure location. Do not enter a value in the FSC as delivery budget should be kept confidential.

Design on Time (DOTI) - Does milestone schedule allow project to meet APLP and PLP LC12 and LC15 performance measures?

3.3.3 Certifications

Safety Certification Document (SCD) - enter link to the SCD and provide a summary of recommended safety countermeasures from Safety Certification Document (SCD) - FDM 11-38.

Bridge or Structure Certification Document (BOSCD) – enter date of BOSCD, include link to applicable document, and provide additional information as appropriate.

Pavement Design Report– enter date of the signed Pavement Design Report, include link to the report and provide additional comments as appropriate.

Risk Based Environmental Scoping Template – enter link to the Risk Based Environmental Scoping Template.

Native American Lands of Interest (NALI) scoping determination - describe coordination and indicate if Native American Hiring Provision is needed. Contact Region Tribal Liaison. See Environmental Document Forms and Tools.

Resiliency F4R – See FDM 3-22

3.3.4 Project Information

Purpose and need – enter description of the project's purpose and need.

Summary of recommended safety countermeasures from Safety Certification Document (SCD) - FDM 11-38.

Summary of scope of work – For Perpetuation projects, list improvements beyond pavement that are included with this project. For Rehabilitation projects, list improvements beyond pavement and SCD identified mitigations that are included with this project.

These are items that may have come up through the environmental process or other FDM required actions. Items may include but not be limited to:

- Sidewalk
- Curb and gutter
- ADA improvements
- Bike and pedestrian accommodations
- Drainage
- Structures
- Local/municipality requested work

Milestone Schedule (milestones shown in FDM 3-1 attachment 1.1) – enter dates. See FDM 3.1 for definitions of milestone dates.

Non-Let schedules and estimates – include FIIPS values for RE, RR and UTL non-let components.

3.3.5 Supplemental Data

Region process will determine the format and content of the supplemental data to be linked to the document. This may include but not limited to:

- Scoping notes
- Supporting documents (Intersection Control Evaluation, technical memos, preliminary drawings)
- Detail work breakdown schedules
- Project estimates (MBI, others as applicable, etc.)

ATTACHMENTS

Attachment 3.1	Final Scope Certification Template

FDM 11-4-5 Location Study Report *May 15, 2019*

5.1 General

One report used for major projects is a Location Study Report. This is used to document the factors affecting the

selection of an alignment alternative and to solicit concurrence with that selection.

Concurrence in the corridor selection is required by the Administrators of the Divisions of Transportation System Development (DTSD) Regions, the Division of Transportation System Development, and the Division of Transportation Investment Management. The preferred method of securing concurrence is to prepare and forward to the Design Standards and Oversight Section of the Bureau of Project Development a Location Study Report containing a map which shows the alternative corridors or alignments, very briefly describes them, identifies the selected alternative, describes any controversial issues, and indicates which issues have and have not been resolved as well as the nature of the resolution. The report should be brief, no more than 2-3 typewritten pages plus maps. If the administrators did not attend the selection meeting, the cover letter should indicate whether a meeting with the administrators is recommended at this point. That recommendation should be based primarily on whether unresolved controversy still exists.

The staff of the Design Standards and Oversight Section will contact the three administrators, provide them with a copy of the Location Study Report and determine whether they desire to meet. If a meeting is not desired, the Chief of the Design Oversight and Standards Section will sign the report indicating that he and the administrators have been informed of the selected alternatives and concur with them.

If the administrators do wish to meet, the Design Standards and Oversight Section will schedule the meeting. The region should be prepared to discuss the scope of the project, the alternatives, their pros and cons and the controversial issues. They should also discuss timing of the notification of local and state elected officials prior to announcing the preferred location to the public.

If there is significant controversy associated with the preferred corridor, the concurrence of the Secretary of the Department is required prior to announcing the choice to the public. The coordination with the Secretary will be handled by the Administrator of the DTSD who will advise the region what information is necessary and whether or how they will be expected to participate. After concurrence of all parties has been secured, the Chief of the Design Standards and Oversight Section will sign the report as noted above.

FDM 11-4-10 Design Study Report *August 17, 2020*

10.1 General

All projects in the improvement program require a Design Study Report (DSR) to be completed. The purpose of the DSR is to document the decisions and rationale for decisions in the development of an improvement project. The DSR, at a minimum, shall address the following:

- Design criteria proposed.
- Geometric and Safety aspects to be addressed by the project improvements
- Summary and Synopsis of important project approvals and decisions and rationale for decisions

Other things about DSRs to be aware of:

- Must be approved before Final Project Delivery can begin on a project. See FDM 3-1 for project phases.
- Must be approved before Real Estate Relocation Orders can be approved and Real Estate acquisition can begin on a project
- Will be kept in the Central Office files per records retention policy, or until a future DSR replaces it, as defense against potential legal actions
- Serves as the bridging document between Project Definition and Project Delivery phases.
- Serves as a good “check box” for designers as to what needs to be completed in Project Definition phase.
- Serves as a good summary of project decisions and source of project information when staff changes occur.

A DSR is approved upon completion of the hearing(s) or hearing opportunity(ies) and finalization of the environmental document and approval of the initial Transportation Management Plan (TMP). For those projects not requiring a hearing or an opportunity for a hearing, the final DSR can be submitted shortly after the approval of the environmental document and Transportation Management Plan (TMP). When the DSR originates outside the department, the report shall be signed and sealed by the professional engineer in responsible charge of its preparation. Draft DSRs can be submitted to the WisDOT region office and Bureau of Project Development staffs for review at any time for comments. This can be especially important when review comments are needed before significant effort or time is expended in finishing the preliminary right-of-way plats and design plans for a project.

The regions will develop DSRs for improvement projects designed in-house and will involve the appropriate region and bureau personnel while doing so. The regions will also review and approve DSRs for improvement projects on the STH system that are designed by consultants or local municipalities.

10.2 Concurrence Process

Region Project Development Chiefs will approve all DSRs for STH improvement projects within their region. Concurrence with the DSR from the Bureau of Project Development, Design Standards and Oversight Section, is required for all state trunk highway (STH) and National Highway System (NHS) projects. Project oversight engineers in the Design Standards and Oversight Section have been delegated authority to concur with these DSRs.

Local Program Sponsor (LPS) will approve all DSRs for Local improvement projects. The Region Local Program Project Manager (LPPM) will concur on all DSRs on Local highway improvement projects [(a)].

Table 10.1 Authorizing Signature

Project Type	Authorizing Signatures Required
Local	Regional Local Program Sponsor approval and Region Local Program Project Manager concurrence [(a)]
STH and NHS (local and state)	Region approval and Bureau of Project Development (BPD), Design Standards and Oversight Section concurrence [(b)]

(a) Final concurrence on DSRs for Local Improvement projects on NHS routes shall be by the Bureau of Project Development (BPD), Design Standards and Oversight Section.

(b) The regions shall provide a minimum of one (1) original signed copy to the BPD, Design Standards and Oversight Section as shown in the table. Send additional signed copies if the region, locals or consultant desire a signed copy for their files. Otherwise, a photocopy of the signed cover sheet will be sent back to the region and the region will need to provide additional photocopies if desired.

If the Design Standards and Oversight Section Oversight Engineer or Chief, or Region Project Develop Section Project Manager or Chief, or Region Local Program Project Manager or Local Program Section Chief do not concur in a DSR then section staff will initiate discussions with the appropriate region staff to resolve the differences. This shall begin within thirty days of receipt of the DSR in the Design Standards and Oversight Section or Local Program Section. If the issue cannot be resolved at the staff level, the Bureau Director shall seek resolution with the appropriate Region Director. Add an additional 30 days to the concurrence timeline if FHWA signature is required for a Design Justification within a DSR.

These concurrences are required prior to proceeding with the delivery of final design plans or approval of the relocation order. Under certain circumstances right of way may be appraised or acquired prior to concurrence in the DSR. See Real Estate Program Manual Chapter 3 for further guidance.

10.3 Distribution

BPD Design Standards and Oversight Section and Region Local Program Project Management staff will forward to FHWA points of contact electronic copies of all signed DSR's for all projects that have been designated for Federal Oversight in accordance with the Federal Oversight Agreement. Region staff must check FIIPs or consult with their Region Planning section to determine if a project has been designated as Federal Oversight or not.

10.4 Content

The following is intended to explain in more detail the DSR topics. Separate DSR format documents have been created as attachments for the following project types:

Attachment 10.1 - Modernization and Rehabilitation

Attachment 10.2 - New Construction, Reconstruction and Rehabilitation

Attachment 10.3 - Abbreviated

Attachment 10.4 - Group III Pavement Strategies Preventative Maintenance Project

Attachment 10.5 - Perpetuation

The difference between the attachments are that Attachments 10.1 and 10.5 will be used on projects which follow the Asset Management Scoping Process which apply the Safety Certification Process (SCP) per FDM 11-38, whereas Attachments 10.2, 10.3 and 10.4 will be used on projects which have moved through the scoping process prior to implementation of the new Asset Management Scoping Process and as such have not gone

through the Safety Certification Process (SCP) and have not completed the Safety Certification Documents (SCDs) and Final Scoping Certifications (FSCs).

Use the DSR format attachments in the following ways:

1. **Modernization and Rehabilitation DSR format (Attachment 10.1)** - Use for Modernization (FDM 11-10, FDM 11-15 and FDM 11-20) and Rehabilitation (FDM 11-10 and FDM 11-40) projects which, by definition, contain S-2 or S-3 Segments/Locations. See FDM 11-1-10 for definitions of Modernization S-2 and S-3 and Rehabilitation S-2 Segments/Locations. All sections of Attachment 10.1 DSR format need to be filled out completely for all these project types except for the following:

    - Only fill out Section 2.0 Subsections 2.2, 2.3 and 2.4 for Modernization and Rehabilitation Project features located in S-2 Segment(s)/Location(s) that are either outside of the range of design criteria regardless of safety performance history or within the range of design criteria but having safety performance history issues identified in the SCD. For Modernization Projects without any S-2 Segments/Locations either remove these tables or just state “None” in these sub-sections. If the SCD or FSC contain the required documentation to fully justify the retention or use of outside of the range design criteria, then just refer to those documents for the applicable information. If there are any features proposed to be retained or improved which will be outside of design criteria and which are not fully documented in the SCD or FSC or in which the proposed roadway improvements have been significantly changed from what is documented in the SCD or FSC then provide further required documentation in the respective DSR sections.

    - Section 4.0 - fill out most of the Section 4.0 Subsections for Modernization Projects S-2 and S-3 Segments/Locations and Rehabilitation S-2 Segments/Locations. The exception to this being that Subsections 4.3.1 and 4.3.2 only need to be filled out if Design Justification (DJ) documentation is required for the project. If no DJs are required for the project, then eliminate or just state “None” in these sub-sections.

    - Section 5.0 - fill out all Section 5.0 Subsections for Modernization Projects S-2 and S-3 Segments/Locations and all Rehabilitation S-2 Segments/Locations generally documenting the proposed cross-sectional, geometric, intersection, or interchange improvements proposed. S-1 Segments/Locations on Rehabilitation Projects require no documentation in these subsections, unless any of the originally assigned S-1 segments/locations get re-assigned as S-2 Locations/Segments later in the design process. If the SCD or FSC contain all the required documentation, then just refer to those documents. Any information not fully documented in the SCD or FSC, such as documentation associated with new or significant changes to proposed improvements due to newly obtained information not realized during scoping or due to environmental document process evaluations not covered in the SCD or FSC, need to be further documented as needed in these sections.

2. **New Construction, Reconstruction and Rehabilitation (Attachment 10.2, formerly known as New Construction/Reconstruction or 3R/4R) DSR format** - Use for Modernization (formerly referred to as New Construction and Reconstruction) (See FDM 11-10, FDM 11-15 and FDM 11-20) and Rehabilitation (formerly known as 3R Recondition) (See FDM 11-10 and FDM 11-40) Type Projects which have moved beyond the Scoping Phase prior to implementation of the Asset Management Scoping Process and thus did not have a Scoping Certification Document (SCD) or Final Scoping Certification (FSC) completed during scoping. See FDM 11-1-10 for definitions of Modernization New Construction S-3, Reconstruction S-2 and Rehabilitation S-2 Projects. All sections of the DSR need to be filled out completely for all these project types except for the following:

    - Section 4.0 - If no improvements are required to any existing roadway cross-sectional, geometric, intersection or interchange features on the project, either because there are none on the project outside of design criteria or where a SSA/CGA design justification (formerly known as a Programmatic Exception to Standards (PES)) applies to any or all features outside of design criteria. In these cases, just state that a SSA/CGA design justification applies and then provide the documentation as an attachment to the DSR. Any features outside of design criteria in which the SSA/CGA design justification does not apply, need to either be upgraded to within the appropriate design criteria, or have the required justification to be upgraded, or even retained to lesser than design criteria based on an approved safety benefit/cost analysis and approved DJ(s) documented in Subsections 4.3.1 or 4.3.2.

3. **Abbreviated DSR format (Attachment 10.3)** - Generally use on stand-alone structure, traffic signal, lighting, pavement marking or signing type projects. Also use on Perpetuation (formerly 3R Resurface) (FDM 11-40) Projects which have moved beyond the Scoping Phase prior to the implementation of the

Asset Management Scoping Process and thus did not have a Scoping Certification Document (SCD) or Final Scoping Certification (FSC) completed during scoping. See FDM 11-1-10 for definitions of Perpetuation S-1 Projects. As such, the project must follow the SSA/CGA design justification (formerly known as a Programmatic Exception to Standards (PES)) process to maintain existing features outside of design criteria. For a project to be eligible to use this DSR format, the project must either have no roadway cross-sectional, geometric, intersection or interchange features outside of design criteria or have no crash history contributable to all the features on the project that are outside of design criteria. Any roadway features outside of design criteria which have crashes contributed to them must be identified as S-2 Segments/Locations and the project must use the Attachment 10.2 New Construction, Reconstruction and Rehabilitation (formerly known as New Construction/Reconstruction or 3R/4R) DSR format. All sections of Attachment 10.2 DSR format need to be filled out completely for these project types.

4. **Group III Pavement Strategies Preventative Maintenance (PM) DSR format (Attachment 10.4)** - Use for Group III PM Projects (FDM 3-5-5) which have moved beyond the Scoping Phase prior to the implementation of the Asset Management Scoping Process and thus do not have a Scoping Certification Document (SCD) or Final Scoping Certification (FSC) completed. All sections of Attachment 10.2 DSR need to be filled out completely for all these project types.
5. **Perpetuation DSR format (Attachment 10.5)** - Use for Perpetuation (FDM 11-40) Projects which, by definition, only contain S-1 Segments/Locations. See FDM 11-1-10 for definition of Perpetuation S-1 Projects. All sections of Attachment 10.5 DSR need to be filled out completely for these project types.

For the Group III Pavement Strategies PM, Abbreviated and Perpetuation DSR format documents, only provide the information asked for in those sections shown in Attachment 10.3, Attachment 10.4, or Attachment 10.5. The Abbreviated, Group III Pavement Strategies PM and Perpetuation DSR format documents follow the same format as the Modernization and Rehabilitation and New Construction, Reconstruction and Rehabilitation DSR formats except that the sections not applicable to these types of projects were removed, thus the numbering of the sections are not always in sequential order. However, all these DSR formats refer to the same sections of this FDM chapter for information related to filling them out. It is not necessary to address every topic in depth for every DSR. Label topics that do not apply to the project as either;

- Do not exist on the project (e.g. no railroads exist within the project limits),
- Will not be affected by the project,
- Is not required for the project.

Information may be provided in either text, tabular or attachment form as explained in the topic sections that follow or as shown in Attachment 10.1, Attachment 10.2, Attachment 10.3, Attachment 10.4 and Attachment 10.5. Any tables shown in Attachment 10.1, Attachment 10.2, Attachment 10.3, Attachment 10.4 and Attachment 10.5 that do not apply to the project or in which the information is provided on an attachment (e.g. typical cross sections) may be deleted if not needed. Just note “See Attachment __” under the section titles where tables are deleted.

Design Justifications (DJs) are required for engineering decisions which fall outside design criteria and are not justified to remain by the Safety Certification Document (SCD). SCD decisions which fall outside design criteria do not require additional documentation as DJs. For any project that does not use the Safety Certification Process (SCP), DJs are required for all engineering decisions which fall outside design criteria. Department and region approvals of DJs are integrated in the approvals of the DSR. FHWA approvals of DJs require a separate signature on the DSR title page. See FDM 11-1-20.

Attach a map that is appropriate to the project as an appendix to every DSR. That would typically be a county map with termini marked on it for a rural project, a city street map for an urban project, or a county map with the location circled for a bridge or spot location project. If desired to convey information, attach individual typical cross sections, as-built or preliminary plan sheets, encroachment reports, etc. as appendices rather than verbally describing this information within the text or tables of the DSR. Do not include attachments that duplicate information that is chosen to be documented in the DSR unless needed to better convey information.

Transmittal/ Cover Letter Sheet

A transmittal/ cover letter sheet from the Region to Bureau of Project Development (BPD) is required. If WisDOT personnel prepare the DSR, this is the only cover sheet required. It will contain two to three signature blocks, one for either the Region Project Development Chief or Local Program Sponsor, one for either the BPD Design Standards and Oversight Section or Local Program Section’s concurrence signature, and one, if required, for either BPD Design Standards and Oversight Section for Local Program Projects on NHS Routes or for FHWA approval of Controlling Criteria Design Justifications for projects with Federal Oversight. Attachment 10.1, Attachment 10.2, Attachment 10.3, Attachment 10.4 and Attachment 10.5 provide a format for these memos

with imbedded Word shells. Use the titles of Region Project Development Chief or Local Program Sponsor and Design Standards and Oversight Section Chief or Local Program Section Chief even though others may be authorized to sign for them. Do not place these signature blocks within the report.

Title Sheet - All DSR's prepared by consultants must contain their seal. The purpose of this sheet is to identify the project and provide a separate location for the seal. If DOT personnel prepare the DSR, this sheet is not required. Project identification on this sheet should include the design I.D. number, route number or road name, Structure ID number (when structures are part of the project), termini, and county.

1.0 Project Description and Need

1.1. Federal Oversight – State if project is a Federal oversight project (Yes or No). Check FIIPs or with Region Planning Sections to determine if a project has been designated as Federal Oversight.

1.2. Project Length and Termini - State the length of the project. If generalized termini are used on the cover sheet define the limits more precisely here or attach a map or project overview with the termini labeled. Also provide beginning and ending stations for the project if stationing will be used in the document to describe locations of various features in the DSR.

1.3. Existing Roadway Information - Indicate whether the roadway is an arterial, collector, or local service facility; whether the project or segments of the project are Rural, Urban or Transitional and whether the roadway is a Corridors 2030 Backbone Route or Connector Route. Indicate if the road is an NHS route: http://www.fhwa.dot.gov/planning/nhs/maps/wi/index.htm (click on the city name for a local map) or not, part of a Federal (http://www.fhwa.dot.gov/legsregs/directives/fapg/cfr06581.htm) or State (https://wisconsindot.gov/Documents/dmv/shared/truck-routes.pdf) Long Truck Route or not, and what Access Control Tier Category (see FDM 7-5-1) the project falls under. Also note if the roadway is on an approved bicycle or pedestrian transportation plan:

https://wisconsindot.gov/Documents/projects/multimodal/bike/coord-map.pdf

1.4. Need for Project - Describe those deficiencies in the present facility that caused the project to be programmed. Generally, focus on pavement condition, safety, or traffic capacity. The list below describes some of these.

- Age and condition of roadway, pavement, bridges, etc.
- Traffic congestion (levels of service, operating conditions, etc.)
- Significant crash locations and crash patterns
- Other safety considerations
- High maintenance costs
- Public concern
- Construction staging (one phase of a much bigger improvement)
- Other considerations

1.5 Proposed/Selected Alternative, Improvement Type and Description – Indicate the Selected Alternative, Improvement Type and give a brief description of the project.

2.0 Existing Facility Information

2.1. Posted Speed - State the regulatory speed limit(s) and provide any advisory speeds.

2.2. Geometrics (S-2 Segments Information Only in Attachment 10.1 DSR format) - Identify any features that are outside design criteria (for Attachment 10.1 DSR format) only provide information or any additional information required for S-2 Segment(s) in which information is not already documented in the Safety Certification Document (SCD) or Final Scoping Certification (FSC), how many of each there are, how much outside design criteria they are and where they are located relative to physical features. If a project contains only S-3 New Construction segments, or S-2 Segments that do not require additional information beyond what is provided in the SCD and FSC, or where there are no geometric features outside design criteria, then remove this table or just state "None".

The information for these features may either be given in the text/tables of the DSR or on individual as-built plan sheets attached to the DSR with the required feature information labeled.

2.2.1. For horizontal alignment feature information required in this table, provide feature type (curve, P.I. deflection, etc.), location, size (radius, P.I. deflection, etc.), super-elevation rate and speed rating.

2.2.2. For vertical alignment feature information required in this table, provide feature type (curve, grade deflection, etc.), location, whether sag or crest, grades, K value or grade deflection, speed rating and whether stopping sight distance and decision sight distance is met or not.

2.2.3. For vertical grades and clearance feature information required in this table, provide the location, % grade and vertical clearance for steep tangent grades and low vertical clearance locations. For the Abbreviated, Preventative Maintenance and Perpetuation DSRs, documentation of grade information is not required. Provide vertical clearances as measured from the roadway to bridges passing over the mainline, to overhead trusses on bridges carrying the mainline, and as measured from the bottom of mainline bridges to the surface of features below (e.g., RR tracks, water level in streams, etc.).

2.3. Side roads / Intersection / Interchanges Information/Geometrics (S-2 Location Information Only in Attachment 10.1 DSR format) – Provide existing side road, intersection and interchange information in the DSR. If there are either no S-2 location features contributing to crash issues or no side roads, intersections, or interchanges on the project then either remove the appropriate tables or just state "None".

The intersection information for these features may either be given in the text/tables of the DSR or on individual as-built plan sheets attached to the DSR with the required feature information labeled.

2.3.1. Side road information (S-2 Locations Information Only in Attachment 10.1 DSR format) should include roadway name, functional classification, posted speed, existing traffic (AADT), intersection approach grade and whether pedestrian or bicycle facilities are present. If existing traffic volumes are not known, state whether the AADT is assumed to be < 100 or > 100.

2.3.2. Intersection information (S-2 Locations Information Only in Attachment 10.1 DSR format) (For Attachment 10.1 DSR format only provide information or any additional information required at S-2 Location(s) in which information is not already documented in the Safety Certification Document (SCD) or Final Scoping Certification (FSC)) should include intersecting roadway names, intersection types (Rural (A1/A2/B1/B2/C/D), urban, roundabout, etc. as described in FDM 11-25-1 and FDM 11-26-1), intersection angles, traffic control (2 or 4-way stop, signal, roundabout, etc.), stopping sight distance, intersection sight distance, decision sight distance, vision triangles, and corner clearance to driveways.

2.3.3. Interchange information (S-2 Locations Information Only in Attachment 10.1 DSR format) (For Attachment 10.1 DSR format, only provide information or any additional information required on S-2 Location(s) in which information is not already documented in the Safety Certification Document (SCD) or Final Scoping Certification (FSC)) should include intersecting roadway names, interchange types (diamond, cloverleaf, etc. as described in FDM 11-30-1), ramp types (exit or entrance and whether tapered, parallel, collector/distributor, left side ramps, etc.), ramp design speed(s), what horizontal or vertical curves exist on the ramp, ramp grades, stopping sight distance and decision sight distance.

2.4. Cross Section(s) Information – Identify cross section features (S-2 Location Information Only in Attachment 10.1 DSR Format) (For Attachment 10.1 DSR format only provide information or any additional information required on S-2 Segment(s) in which information is not already documented in the Safety Certification Document (SCD) or Final Scoping Certification (FSC) by either attaching individual existing typical cross section(s) as an attachment(s) to the DSR or by providing the information in the text of the DSR. Indicate ranges where applicable. Identify on-road bicycle facilities (bike lanes, paved shoulders, or wide lanes for bicyclists). Identify presence of sidewalks and curb ramps or shared-use paths. Identify widths outside design criteria. See Attachment 10.9 for the format of information to be provided on attached typical cross sections[1].

2.5. Pavement Structure / Condition - Provide types and thickness of pavement layers, including base course. Give a physical description of the pavement (e.g. rutting, transverse/longitudinal cracking, etc.) Information on type and thickness of pavement layers can be shown on either individual attached existing typical cross section(s) or in the text or tables of the DSR. See Attachment 10.9 for the format of information to be provided on attached typical cross sections.

2.6. Right of Way - For projects with TTP or ROW plat, attach the project's list of encroachments (see FDM 12-1-20). Identify any existing R/W issues that are unique to the project.

2.7. Structures - Indicate existing structure I.D. number, feature crossed, type of structure, sufficiency rating, clear roadway width, and railing type. Large drainage structures (box culverts and multiple pipe

[1] The cross sections in Attachment 25.4 and others are available as CADDS cells in a folder called cdtyps.cel.

installations) with span lengths less than 20 feet should also be described and their condition noted if they are to be replaced. Also, identify other types of structures such as sign bridges, tunnels, etc.

2.8. Utilities - List names, types and general locations of existing utility facilities and whether underground or overhead. Any utilities that will add to the complexity of the project or are attached to an existing bridge should be mentioned in the comments section.

2.9. Railroad Crossings - Indicate where they exist on the project and provide the name of the railroad, the number of tracks, their function (e.g., mainline, siding or spur, switching, etc.), and crossing type (arms, signals, cross-buck signing, grade separation, etc.). If a run-out lane is present at the crossing, then provide a description of its design in the comments section.

2.10. Special Soils Conditions – Describe only special or unique soils conditions (such as rock, marsh, or frost susceptible soils) that have a direct effect on the design features chosen for the project. If there are no special soil conditions, then state "None".

2.11. Unique Project Features - Describe features of environmental significance on the project including historic, archeological, hazardous materials, or things that have been identified by a community or the public as being important to their community's identity or vitality.

3.0 Traffic Information

3.1. Traffic Volumes / Conditions

3.1.1. The need to develop a traffic forecast varies according to facility location and project type.

If a forecast is required, attach the forecast report to the DSR. See FDM 11-5-2 for more information on traffic forecasting. If a forecast is not required, just provide the current AADT volume(s) in the DSR, section 3 Traffic information. Current Annual Average Daily Traffic (AADT) can be found at the Traffic Counts webpage in TCMap.

3.1.2. If a highway capacity analysis was completed for the project, provide the existing and design year levels of service. (See FDM 11-5-3, FDM 11-15-1, and FDM 11-20-1 for guidance on when a level of service analysis needs to be completed.). For the Abbreviated DSR, use the Meta-manger LOS data for the existing, construction year and construction year + 10-year level of service information.

3.2. Crash Analysis (For projects which have moved through scoping prior to the new Asset Management Scoping Process and which did not apply the Safety Certification Process (SCP) need to provide the information requested in the tables, otherwise answer questions found in Attachments 10.1 and 10.5).

3.2.1. Provide the crash rates for the project, using a minimum of the most current 5-year period available, and compare it to the most current statewide crash rates for that type of facility (e.g. two-lane rural, rural interstate, etc.) over the same years. Include the number and severity of crashes for each year. See the region Traffic Section to obtain the most current 5-year crash information for the project site. To find the statewide average crash rates go to:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/manuals.aspx

Consultants can also request this information from the region project development staff.

3.2.2. Even with a crash rate lower than the average statewide crash rate, identify other crash patterns (e.g. locations with crash concentrations, crash types, weather/road/light conditions, etc.). Identify any significant crash concentration locations (e.g. intersections or short sections of highway) or other crash patterns that might exist and explain the possible causes of the crashes. If no patterns are found, that should be stated so it is known that the crashes were examined.

4.0 Proposed Design Criteria (S-2/S-3 segments only for Attachment 10.1)

Any items listed under "Section 1.0 Project Description and Need, Sub-Section 1.4 Need for Project" should be resolved by the project proposal or this section should explain why the project cannot correct them.

4.1. Design Class - Indicate appropriate design class from:

- FDM 11-15-1, for rural Modernization projects

- FDM 11-20-1, for urban Modernization projects
- FDM 11-40-1, for rural and urban Perpetuation and Rehabilitation projects

4.2. Design Speed(s) - Indicate design speeds and posted speeds pertinent to the various portions of the facility. Features outside design criteria retained through SCD or DJs do not establish the design speeds.

4.3. Design Justifications (DJs) - Identify all features for which DJs are proposed. Document why the DJs are proposed.

4.3.1 Controlling Design Criteria DJs - For Controlling Design Criteria DJs include the following information:

- Document the existing highway conditions and proposed improvement project in general terms. Discuss type and extent of work, project length, existing and design year AADT, percent trucks, anticipated future work, etc. Indicate if the road in question is a Long-Truck Route.
- Thoroughly describe the feature(s) which fall outside the design criteria, providing specific data identifying the degree of deficiency. Proposed design features should be compatible with programmed improvements of adjacent roadway segments.
- Provide crash data and indicate the time-period for which the data applies. A 5-year minimum period should be used, and it should be the latest period for which data is available. Breakdown crashes into property damage, injury, and fatality types when pertinent. Review crash reports as necessary.
- Identify any high hazard locations.
- Provide crash numbers and rate for the overall project, and for highway segments on the project. Compare the rate to the statewide average for that type of facility.
- Provide numbers and severity (fatal, injury or property damage) of crashes attributable to each individual feature outside design criteria.
- Provide applicable cost data for alternative solutions.
- Give the overall cost of the improvement project as proposed.
- Present the additional cost to bring each individual feature within design criteria. Include construction, real estate and utility costs as applicable.
- Describe other adverse impacts that would result from upgrading each feature to be within design criteria.
- Describe safety enhancements that will be made by the project. Specifically describe improvements that will address high crash locations. Include low cost mitigation features such as improved signing and marking, delineation, etc. Restoration of existing markings, etc., do not constitute enhancements. Discuss compatibility of the proposed improvement with adjacent roadways.
- Include maps, charts, photographs, tables or other graphical data as necessary to enhance clarity and understanding and to reduce the length of the discussion.
- See chapter 2 of FHWA SA-07-011(1) (https://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/fhwa_sa_07011.pdf) for information on the Design Justification (design exception) process.

4.3.2 Non-Controlling Design Criteria DJs - For Non-Controlling Design Criteria DJs include the following information:

- The social/environmental factors and impacts involved.
- Estimated cost to upgrade existing features to meet design criteria or estimated cost comparisons between different options using design criteria within or outside of design criteria or both.
- Review of crash history to assess the relative safety of existing roadway features.
- Any other information necessary to justify the use of design criteria outside of FDM values.
- Any mitigation measures proposed for use in conjunction with the DJs.
- If bicycle and pedestrian facilities are not being proposed, the reasons for not providing the facilities documented in this section. The documentation must show that these facilities were given due consideration but were later eliminated due to such factors as significant right-of-way constraints or community impacts, excessive costs to construct the facilities, complete lack of anticipated use (not uncommon for rural projects, especially sidewalks).

4. 4. Typical Cross Section Alternative Features Considered – On Modernization and Rehabilitation and New Construction, Reconstruction and Rehabilitation projects where not discussed in the SCD or FSD, describe typical cross section alternative features considered and explain what was chosen and what was not and why. Some of the most common typical cross section alternative features to consider are number of driving lanes, paved shoulders, parking lanes, median or no median, median widths, turn lanes, two-way left turn lanes (TWLTLs), bicycle lanes or accommodations, sidewalks and terrace widths. For Perpetuation projects, this section may be left blank. The extent of this section should be proportional to the magnitude of the project.

5.0 Proposed Design Improvements

If the clearest and efficient method of providing the required geometric design information is on attached individual preliminary plan sheets, then these sheets should label the following information:

- Mainline information: horizontal geometrics (radii, bearings, P.I. deflections, etc.), vertical geometrics (curve lengths, k values, grades, vertical clearance under structures, etc.),
- Side road / intersection / interchange information: intersection angles, side-road alignments and profiles, lane widths, median widths, shoulder widths or curb & gutter type, turn lane information (widths, bay lengths and taper lengths).

If the information is shown and labeled on the proposed plan sheets, the same information is not required to be included in the text or tables of the DSR.

5.1. Improvement Type(s) - Provide the FIIPs Legislative program number and improvement program type definition (See PMM 5-10-5 for improvement program type definitions).

5.2. Proposed Geometrics Information (For Attachment 10.1 only provide for S-2/S-3 segments) - Provide the information for the sections listed below on any attached plan sheets or as text/tables in the DSR

5.2.1. Horizontal alignments - list any information not shown on any attached plan sheets

5.2.2. Vertical alignments/stopping sight distances - list any information not shown on any attached plan sheets

5.2.3. Grades and Vertical Clearances - list any information not shown on any attached plan sheets

5.3. Side-roads / Intersections / Interchanges Information (For Attachment 10.1 only provide for S-2/S-3 locations) - In locations where work is proposed at or alongside-roads, provide the proposed side-road, intersection and interchange information shown below. Information is not needed at those locations where no work at or alongside-roads is proposed (i.e. milling and resurfacing the mainline pavement across an intersection without any work along the side-road).

5.3.1. Side-road information should include the roadway name, functional classification, design speed, design year traffic (AADT), design class, approach grades and pedestrian and bicycle facilities proposed. If design year traffic volumes are not known, state whether the AADT is assumed to be < 100 or > 100.

5.3.2. Intersection information should include names of intersecting roadways, intersection types [Rural (A1/A2/B1/B2/C/D), Urban, Roundabout, etc. as described in FDM 11-25-1 and FDM 11-26-1], proposed intersection angles, proposed traffic control (2 or 4-way stop, signal, roundabout, etc.), stopping sight distance, intersection sight distance, decision sight distance, vision triangles, and corner clearances to driveways.

5.3.3. Interchange information should include the names of intersecting roadways, interchange types (Diamond, Cloverleaf, etc. as described in FDM 11-30-1), ramp types (exit or entrance, tapered, parallel, collector/distributor, left handed ramps, etc.), ramp design speeds, ramp grades, Stopping Sight Distance, Decision Sight Distance and Vision Triangles.

5.4. Roundabout(s) Information – State if the construction or reconstruction of a roundabout(s) is part of the recommended design. If so, then include the critical design parameters chart as an attachment to the DSR. See FDM 11-26-20 for definitions of the parameters. A template of this chart is shown in FDM 11-26 Table 5.1. The values to be shown are those determined at the 60% plan complete stage. This chart may be omitted if a roundabout is not part of the recommended design or there are no changes proposed in the geometric features of a pre-existing roundabout (e.g., for resurfacing or pavement replacement projects).

5.5. Cross Section / Pavement Structure Information (For Attachment 10.1 only provide for S-2/S-3 segments) - Describe those features listed in Attachment 10.1 or Attachment 10.4. Provide types and thickness of pavement layers for both driving lanes and shoulders. Note what type of bicycle and

pedestrian accommodation (paved shoulders, bicycle lanes, wide curb lanes, paths, sidewalks, etc.) are being provided. Discuss the project with the region bicycle and pedestrian coordinators for assistance on facility selection:

https://wisconsindot.gov/Documents/projects/multimodal/bike/coord-map.pdf

The information may either be described in the written text of the DSR or provided on individual attached finished/proposed typical cross section(s). See Attachment 10.9 for the format of information to be provided on attached typical cross sections.

5.6. Street Lighting Improvements - If street lighting is proposed for the project, describe its' general location(s) and type and identify any breakaway requirements for light poles within the clear zone. (see FDM 11-50-15)

5.7. Structure Improvements Information - Provide the information requested below for all structures on which work is to be completed on the project. Information is not required for existing structures on which no work is to be completed on the project.

5.7.1. Bridge Structures – For each bridge structure provide the structure I.D. #, location, type, length, clear roadway width, number of spans, vertical clearance, horizontal clearance under the structure and proposed improvement. Describe the proposed treatment of existing deficient bridges. Also address the inclusion and location of items such as pedestrian over-passes, and bicycle and pedestrian accommodations.

5.7.2. Box Culverts and Multiple Pipe Structures – For each box culvert or multiple pipe structure, provide the structure I.D. #, location, size/type, length, number of culverts or pipes and proposed improvement. Also address the inclusion and location of items such as cattle passes, pedestrian under-passes and bicycle and pedestrian accommodations.

5.7.3. Retaining Walls and Noise Barrier Structures - For each retaining wall or noise barrier structure, provide structure I.D. #, location, type, length, height and proposed improvement.

5.7.4. Sign Bridge Structures – For each sign bridge structure, provide the structure I.D. #, location, type, length, clear roadway width, vertical clearance, horizontal clearance, clear zone width under the structure and proposed improvement.

5.7.5. Tunnel Structures – For each tunnel structure, provide the structure I.D. #, location, type (vehicular, bicycle, pedestrian, etc.) length, type of lighting, vertical clearance and horizontal clearance in the tunnel, safety features required (stand pipes, video surveillance, ventilation, call boxes, etc.) and proposed improvement. State what coordination has occurred with local emergency responders.

5.7.6. Touchdown Points on Local Bridge Program Projects - For each local bridge project that is included in the Local Bridge Program, provide the approach lengths calculated in accordance with the Policy on Local Program Bridge Approaches (FDM 3-20 Attachment 1.1). For "short" approaches, document the lengths on the DSR template in the "Comments" area of 5.7.1, Bridge Structures. For "medium" and "long" approaches, document the justification and approvals for the lengths in the same area.

5.8. Permanent Traffic Control – Indicate whether permanent signs will be installed as part of the project. Indicate if non-standard sign layout details are needed. (Examples of signs needing layout details are large freeway/expressway guide signs and other signs with unique messages.)

5.9. Safety Enhancements/Mitigation Measures - Describe features expected to improve safety and address crash patterns on the facility. Some of the more important features are increased lane widths, increased shoulder widths, wider clear zones, longer turning radii, intersections upgraded to higher types or roundabouts, safety barrier installation or upgrades, etc. Safety enhancements/mitigation measures must be addressed for all areas on the project where crash problems exist or where DJs are proposed.

5.10. Real Estate – If no real estate is required on the project then just state that.

5.10.1. If real estate is required on the project, then provide the R/W Plat I.D. #. If known, indicate general acreage to be acquired and whether permanent or temporary. Include easements and construction permits as well as fee acquisitions. If acreage is not known, provide some other indicator of the extent of acquisitions (i.e. strip takings). Indicate the number and type of relocations.

5.10.2. Attach a list of encroachments to the DSR, if applicable. Describe access control proposals, if

applicable. (see FDM 12-1-20)

5.11. Utilities – State whether the project is a Trans 220 utility project or not. Explain any unique or special design features that result from the need to accommodate any existing or planned utility facilities. Identify major utility agreements when required. A description of proposed utility locations need not be given unless they are unique or add significantly to the complexity of the project.

5.12. Railroads - Describe any improvements to railroad facilities needed. If a run-out lane is needed at the crossing, then provide a description of its design. Identify railroad agreements when required.

5.13. Financing and Scheduling – Provide construction ID #s, most recent project cost estimate, the type of funding and their percentages (Federal, State, Local, etc.), proposed time frame for construction, ties to other work or projects (tied contracts), description of Alternative Contracting; and any major amounts of non-participating work and any deferred construction work on PM projects.

5.14. Unique Project Features

5.14.1. Hazardous Waste - Include a statement regarding known or potential hazardous waste areas required for construction. Describe proposed remediation efforts as well as any new or unusual products or techniques.

5.14.2. Environmental Commitments – Describe features incorporated due to historic, archeological, or other environmental commitments. Attach the Environmental Commitments Basic Sheet of the Environmental Screening Worksheets as an appendix to the DSR when applicable. Identify and describe the locations of environmentally sensitive areas and any unusual erosion control and storm water management measures.

5.14.3. Community Sensitive Design/Public Involvement - Describe any features to be incorporated into the project due to community sensitive design/public involvement coordination.

5.14.4. Value Engineering - Describe the results of any value engineering (V.E.) studies and what V.E. recommendations are to be incorporated on the project.

6.0 Synopsis

Provide completion/approval dates for the following. Provide other relevant information as needed.

- Concept Definition Report (CDR) (see FDM 11-4-1)
- Safety Certification Document (SCD) (See FDM 11-38)
- Bridge or Structure Certification Document Approval (BOSCA) (If Needed)
- Risk Assessment (RA) (If Needed)
- Signed Pavement Design Report (PDR) (see FDM 14-15-1)
- Public Involvement Plan (PIP)
- Structure Survey Report (SSR)
- Public Hearing/Public Information Meetings (PH/PIM) (see FDM 6-10-1 and FDM 6-5-10)
- Signed State Municipal Agreement (SMA(s)) (If Needed)
- Final Scope Certification (FSC) (See FDM 11-4-3)
- Historical/Archaeological Coordination Complete (Section 106, etc.) (SHPO) (see FDM 5-10-5)
- DNR Coordination Acceptance (401 Cert., etc.) (DNR) (see FDM 5-10-1)
- Preliminary Plan Review Complete (PPRC)
- Preliminary Structure Plan Review Complete (PSPRC) (If Needed)
- Signed Environmental Document (ED) – Indicate document type (see FDM 20-15-1)
- Transportation Management Plan (TMP) (see FDM 11-50-5)
- Freight/OSOW Accommodations Coordination (FOAC)
- Roadside Hazard Analysis Sheet (RHA) (If Needed)
- Drainage Design Report (DDR) (If Needed)
- Status of Statutory Actions (If needed) (e.g. STH change) - Indicate type of action and who approved or accomplished it. (see FDM 4-5-1, FDM 4-5-5, FDM 4-5-10, and FDM 4-5-15)

7.0 Attachments

- Project Location / Overview Map
- Existing Typical Cross Section(s)/ Finished / Proposed Typical Cross Section(s)

- Encroachment Report (If applicable) (see FDM 12-1-20)
- Safety Certification Document (SCD) with Contributing Geometric Analysis (CGA) (If applicable) (see FDM 11-38)
- Traffic Forecast Report (see FDM 11-5-2)
- Preliminary Plan Sheet(s)
- Critical Design Parameters Chart for each proposed roundabout (If applicable) (see FDM 11-26-5)
- Environmental Commitments Basic Sheet (If applicable) Include coordination letter
- Roadside Hazard Analysis form template (if applicable) (see FDM 11-45-20)
- ADA Technically Infeasible documentation
- Non-Compliant Roadside design

LIST OF ATTACHMENTS

Attachment 10.1	Modernization and Rehabilitation Design Study Report Template
Attachment 10.2	New Construction, Reconstruction and Rehabilitation Design Study Report Template
Attachment 10.3	Abbreviated Design Study Report Template
Attachment 10.4	Group III Pavement Strategies Preventative Maintenance Project Design Study Report Template
Attachment 10.5	Perpetuation Design Study Report Template
Attachment 10.6	FHWA Design Justification Approval Signature Page
Attachment 10.7	Local Program Signature Sheet
Attachment 10.8	NHS Local Program Signature Sheet
Attachment 10.9	Sample Cross Sections

CONCEPT DEFINITION REPORT (a working file of this template: FDM 11-4 A1.1 File 1)

Date:_____ **To:** _____ **From:** Region _____

I. Design ID:_____ Related ID(s): _____

Highway No. or Local Road Name: _____

Title: _____

County: _____ Length: _____

Functional Class: _____ Current AADT: _____

LOCATION: _____

II. A. Roadway Conditions:

Pavement: Type: _____ Width:_____ Year: _____

IRI: _____ PDI: _____

Shoulder: Type: _____ Width: _____

Crash Rate: _____ Year: _____

Improvement Flags: From RP _____ to RP _____

From RP _____ to RP _____

Alignment Features Outside of Design Criteria:

Horizontal: _____

Vertical: _____

B. Structure: Type: _____

Bridge Number: _____Year Constructed: _____

Clear roadway width: _____ SR: _____ RS: _____

C. Railroad: _____ Existing Facility _____

JUSTIFICATION: _____

_____

_____

III. PROPOSED IMPROVEMENT: _____

_____

Environmental documentation type: _____

Improvement Type: _____ PMSID: _____

Cost: _____ Program Year: _____ Program: _____

Local Participation: _____ Access Control: _____

Real Estate: _____ R/E Cost: _____

NATIONAL HIGHWAY SYSTEM: _____ EXEMPT: _____

Railroad Crossing/Structure: _____

Project Supervisor: _____ Recommend Acceptance: _____

Accepted By: _____ Date: _____

The following instructions are for use in completing the standardized Concept Definition Report (CDR) format. A CDR can be prepared by simply filling out the form shown (type or print please). The information requested is the minimum needed to show the "where", "why" and "what" aspects of the project as well as give some preliminary indications about critical issues such as local participation, environmental document type, access control, etc.

Top Portion:	**Date**: Date the CDR is completed or submitted.
	From: Region number.
Section I.	**Design ID.** 8 - digit FOS ID number. This will usually be completed by DOT if a consultant prepares the report.
	Related Design ID(s) - FOS ID's for associated design projects; that is, projects tied to this one for bidding purposes. This most commonly occurs with bridges.
	Highway No. or Local Road Name - Self-explanatory (e.g. USH 12)
	Title: Project limits or termini (i.e. CTH "X" - Sunset drive) or common name for the project (e.g. Crandon Overhead) when termini are not applicable.
	County - Self-explanatory.
	Length - In miles to nearest one hundredth for most highway projects and number of feet for bridges.
	Functional Class - Self-explanatory (e.g. Principal Arterial)
	Current ADT - Average daily traffic for most recent year counted. If counts were made at more than one location on the project, list the range of values.
	Location - General description of the area (e.g. north of the City of Whitewater in northwestern Walworth County). This is required only if the location is not readily discernible from the description under Title above.
Section II	**Pavement Type** - Indicate whether the existing pavement is concrete (PCC) or asphaltic (AC) or road mix.
	Pavement: Width - Total width of existing travel lanes in feet. Gutter widths should be included for urban roadways but indicate "F-F" after the dimension. Do not include shoulder paving.
	Pavement Year - Year the existing pavement was constructed.
	Pavement: IRI - Latest International Roughness Index. This is required for rural STH projects only but should be included for local projects also if the data is available.
	Pavement: PDI - Latest Pavement Distress Index rating. This is required for STH projects only but should be included for local projects also if the data is available.
	Shoulder Type - Surface type: turf, aggregate, asphalt paving (AC), or concrete paving (PCC).
	Shoulder Width - Total width. If paved also indicate the paved width.
	Crash Rate - Number of crashes per 100 million vehicle miles of travel. This is required for STH projects only but should be included for local projects also when the data is available.
	Crash Year - Year(s) for which the crash rate was computed. This should generally be the average for the latest five years for which crash data is available.
	Alignment Features Outside of Design Criteria: Horizontal and Vertical - At a minimum provide a "yes" or "no" response. If information is available indicate the number of curves by speed rating (in **5 mph** increments) which are outside of design criteria (below posted speed).
	Safety Flags: For Perpetuation and Rehabilitation projects, identify those highway segments that have been assigned Safety Flags by the Safety Metamanager Process described in FDM 11-1-4.

Section II - cont.	
	Structure Type - Existing bridge type as commonly described by bridge engineers (e.g. steel girder, slab span, haunched slab, concrete box culvert, etc.)
	Bridge Number - WisDOT assigned bridge number(s) (e.g. B-28-0064). If there are bridges within the project limits, complete this section whether or not they are proposed for improvement. List all bridges within the project.
	Bridge: Year Constructed - Year construction of the existing structure was completed.
	Clear Roadway Width - Distance between sidewalk curbs or parapet walls.
	SR - Latest Sufficiency Rating for the structure.
	RS - Latest Rate Score for the structure.
	Railroad - Name of railroad.
	Existing Facility - At grade crossing or grade separation. If crossing, specify current warning device (cross bucks only, flashing light signals, cantilevers, gates.)
	Justification - Brief statement describing problems with the existing facility. This is required only if data showing the deficiencies is not available or if the deficiencies are not readily apparent from the data given (e.g. PDI may be fairly low even though there is severe pavement rutting or faulting).
Section III	**Proposed Improvement** - Narrative recommendation; a description of the major elements of the proposed project (e.g. Perpetuation, Rehabilitation, Modernization, reconstruct, resurface and, widen shoulders to 6 feet, overlay bridge deck, etc.). The proposed improvement would logically address the deficiencies stated in "Justification."
	Environmental Document Type - Proposed environmental action type as defined in Facilities Development Manual and FDM 20-15-1.
	Improvement Type - Program name for the type of improvement. These are identified in FDM 3-5-2.
	PMSID - Program Management System ID number. This is a 10-digit program identifier assigned by the Region SPO Section. This is required for STH project only.
	Cost - Anticipated cost of construction, real estate, utilities, and railroads.
	Program Year - Fiscal year for which construction dollars are included in the applicable program.
	Program - Title of the applicable program (i.e. Interstate, HES, Local Bridge, etc.) or (some prefer to show Program Code, or both).
	Local Participation - Identify whether cost sharing is expected to apply or there will be substantial amounts of non-participating work (i.e. parking lanes). Indicate "yes" or "no". This is required for STH projects only.
	Access control - Identify whether or not access control will be acquired as part of the project. If it will, indicate whether the route is TIER I or TIER II. If it won't, write "N/A". If existing, write "Exist." This is required for STH projects only.
	Real Estate: Right of Way Acquisition**.** Anticipated "None", "Minor" or "Yes".
	National Highway System - Identify if the project is located on the NHS by entering "yes" or "no."
	Exempt - If the project is on the NHS and based on the estimated construction dollar value (including estimated right-of-way costs) and the improvement type, determine whether project development will be subject to FHWA oversight, or exempt, and identify by entering "Yes" (exempt) or "No" (oversight). See Facilities Development Manual FDM 5-5-15.
	Railroad Crossing/Structure: Identify what work is proposed at each existing crossing on (or within 1000 feet of) the project or if new crossings are being proposed.

Bottom Portion	**Project Supervisor** - Provide the name of the Region supervisor who will be responsible for the project.
	Recommended for Acceptance - Provide the name of the Region SPO or PD Supervisor who is responsible for preparing the Concept Definition Report.
	Accepted By - Region Director, Manager, or Designee, Date.
	Other acknowledgements.

Final Scope Certification

(For a working file of this template: FDM 11-4 A3.1 File 1)

Date: Click or tap to enter a date.

Project I.D. (design/construction): Click or tap here to enter text.

Route:Click or tap here to enter text.

Title/Limits Click or tap here to enter text.

Bridge # (if applicable):Click or tap here to enter text.

County:Click or tap here to enter text.

Having considered the criteria and documentation attached we concur and approve the Final Scope.

Concurrence:

Region Project Development Chief or delegate:	
Region Technical Services Chief or delegate:	
Region Operations Chief or delegate:	
Bureau of Project Development – Design Standards and Oversight Chief or delegate:	

Approval:

_____ _____

Region Programming/Planning Chief Date

Performance Measure Compliance

Program Effectiveness – Is the project in compliance with the Department's current asset management theme for appropriate highway treatment?

Theme recommended improvement (PEM): Choose an item.

Proposed improvement: Choose an item.

Is proposed improvement within one level on the Program Effectiveness scale? ☐Yes ☐No

If no, explain:

Click or tap here to enter text.

Balanced program

Programmed LC10 construction estimate: Click or tap here to enter text.

Proposed LC11 construction estimate: Click or tap here to enter text.

Does the project estimate allow the region to stay within its assigned program funding levels?

☐Yes ☐No

If no, have other programmatic changes been identified to stay within guidelines for program balance?

Click or tap here to enter text.

Delivery Risk - Is the project scheduled to be compliant with current PLP and APLP programmatic completion goals for LC 12 and LC 15 Delivery Risk?

PLP:
Proposed letting month: Click or tap here to enter text.

PLP guidelines for that month ($): Click or tap here to enter text.

Current region programmed amount for that month ($): Click or tap here to enter text.

APLP:

Proposed earliest letting month (advanceable projects): Click or tap here to enter text.

APLP guidelines for that quarter ($): Click or tap here to enter text.

Current advanceable programmed amount for that month: Click or tap here to enter text.

LC12 and LC15 Delivery Risk:

Does the milestone schedule allow for the project to reach LC12 and LC15 in accordance with Delivery Risk Guidelines?
☐Yes ☐No

If outside PLP, APLP, or LC12 and LC15 Delivery Risk guidelines, explain why and what mitigations will be made?

Click or tap here to enter text.

Design on Budget (DOBI)

Delivery Budget Worksheet (link):Click or tap here to enter text.

Is the established project delivery budget compliant with EDCI goals for that project treatment type?

☐Yes ☐No

If no, has the appropriate exception process been followed to allow the established delivery budget to stay as is?

Click or tap here to enter text.

Design on Time (DOTI)

Does milestone schedule allow project to meet APLP and PLP LC12 and LC15 performance measures? ☐Yes ☐No
If no, does the region program remain compliant to APLP and PLP without the project? ☐Yes ☐No

If no, what action is the region taking to ensure overall programmatic compliance to APLP and PLP performance expectations.

Click or tap here to enter text.

Certifications

Safety Certification Document (SCD)
(enter link and give summary of recommended geometric improvements or countermeasures from Safety Certification Document) Click or tap here to enter text.

Bridge or Structure Certification Document (BOSCD) Date: Click or tap to enter a date.

(enter link) Click or tap here to enter text.

Pavement Design Report Date Click or tap to enter a date.

(enter link) Click or tap here to enter text.

Risk Based Environmental Scoping Template or draft environmental document (enter link) Click or tap here to enter text.

Native American Lands of Interest (NALI) scoping determination: Click or tap here to enter text.

Resiliency F4R (enter link) Click or tap here to enter text.

Final Scope Certification (enter link) Click or tap here to enter text.

Project Information

Purpose and need:

Click or tap here to enter text.

Summary of scope of work (For Perpetuation projects, list improvements beyond pavement that are included with this project. For Rehabilitation projects, list improvements beyond pavement and SCD identified mitigations that are included with this project)
Click or tap here to enter text.

Milestone Schedule (milestones shown in FDM 3-1 attachment 1.1)

Project Initiation Complete (actual)	Click or tap to enter a date.
Preliminary Scope Complete (actual)	Click or tap to enter a date.
Final Scope Certification (actual)	Click or tap to enter a date.
Final Resourcing/Start Final Design	Click or tap to enter a date.
Design Study Report	Click or tap to enter a date.
Early PS&E	Click or tap to enter a date.
PS&E	Click or tap to enter a date.
Project Let (Programmed)	Click or tap to enter a date.
Project Award (based on Programmed)	Click or tap to enter a date.

Non-Let schedule and estimates:

RE	**$** Click or tap here to enter text.	**Schedule date** Click or tap to enter a date.
RR	**$** Click or tap here to enter text.	**Schedule date** Click or tap to enter a date.
UTL	**$** Click or tap here to enter text.	**Schedule date** Click or tap to enter a date.
MISC	**$** Click or tap here to enter text.	**Schedule date** Click or tap to enter a date.

Supplemental Data

Scoping notes (enter link) Click or tap here to enter text.

ICE (enter link) Click or tap here to enter text.

Tech memos (enter links) Click or tap here to enter text.

Preliminary drawings/preliminary plan (enter link) Click or tap here to enter text.

Detail schedule (enter link) Click or tap here to enter text.

Major Bid Item estimate (enter link) Click or tap here to enter text.

SAMPLE TRANSMITTAL LETTER

(For a working file of this template: FDM 11-4 A10.1 File 1)

CORRESPONDENCE/MEMORANDUM_____State of Wisconsin

Date: _____, 20___

To: _____
Director, Bureau of Project Development
Attn: (Design Standards and Oversight Chief)

From: _____
_____ Region

Subject: MODERNIZATION AND REHABILITATION DESIGN STUDY REPORT
Project I.D. (design) _____
(STH, IH, USH (choose one)) _____
Bridge # (if applicable) _____
_____ County

Having considered the economic and social effects of this project, its impact on the environment, and its consistency with the goals of community planning, we request your approval of the attached design study report.

_____ _____
Region Project Development Chief Date

Concur:

_____ _____
Bureau of Project Development Date
Design Standards and Oversight Chief

SAMPLE TITLE SHEET

MODERNIZATION AND REHABILITATION DESIGN STUDY REPORT

Project I.D. (design) _____
(STH, IH, USH, CTH, Local (choose one)) _____
Bridge # (if applicable) _____
_____ County

CONSULTANT'S SEAL

MODERNIZATION AND REHABILITATION DESIGN STUDY REPORT

1.0 Project Description and Need

1.1 Federal Oversight Project (Yes or No):

1.2 Project Length and Termini

Project Length: XX.XXX

Termini/Limits:

1.3 Existing Roadway Information

Roadway	Functional Class (Principal or Minor Arterial, Collector or Local)	Surrounding Development Type? Rural, Urban or Transitional	Corridors 2030 or Backbone (No or State Which)	NHS Route (Yes or No)	Long Truck Route (No or State Federal or State)	Access Control Tier	On Ped. Trans. Plan (Yes or No)	On Bike Trans. Plan (Yes or No)

Comments:

1.4 Need for Project

1.5 Proposed/Selected Alternative (State the Improvement Type and add brief description).

2.0 Existing Facility Information

2.1 Posted Speed

Roadway or Roadway Segment	Posted Speed	Advisory Speed

2.2 Segments Information/Geometrics (S-2 Location only)

2.2.1 Horizontal Alignment Features Outside Design Criteria Not Documented in SCD/FSC (S-2 Location only)

Horizontal Feature* (Curve, P.I. Deflection, etc.)	Location (Stationing)	Size* (Radius, P.I. Deflection, etc.)	Super-Elevation* (S.E.)	Speed Rating

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

2.2.2 Vertical Alignment Features/SSD* Outside Design Criteria Not Documented in SCD/FSC (S-2 Location only)

Vertical Feature (Curve, Vertical Grade Deflection, etc.)	Location (Stationing)	Sag or Crest	% Grades*	K Value/ Grade Deflection	Speed Rating	SSD** Met *(Yes or No) Length	DSD Met (Yes or No) Length

* Controlling Criteria for Design Speed ≥ 50 mph, **SSD = Stopping Sight Distance

Comments:

2.2.3 Grades* and Vertical Clearances* Outside Design Criteria Not Documented in SCD/FSC (S-2 Location only)

Location (Stationing, Overpass Structures, etc.)	% Grade*	Vertical Clearance*

*Controlling Criteria for Design Speed ≥ 50 mph

Comments:

2.3 Side-Roads/ Intersections/ Interchanges Information/Geometrics (S-2 Location only)

2.3.1 Side-Roads Design Information (S-2 Location only)

Roadway	Functional Class	Posted Speed (MPH)	Existing Traffic*** (AADT)	Approach Grades	Pedestrian Facilities (Yes or No)	Bicycle Facilities (Yes or No)

*** If Existing Traffic volumes are not available, then state at a minimum whether AADT is assumed to be <100 or >100.

Comments:

2.3.2 Intersections Geometrics Outside Design Criteria Not Documented in SCD/FSC (S-2 Location only)

Intersecting Roadway	Intersect. Type	Intersect. Angle	Traffic Control	SSD** Met* (Y/N)/ Length	ISD** Met (Y/N)/ Length	DSD** Met (Y/N)/ Length	Vision Triangle (Y/N)	Corner Clearance to Driveways Present (Y/N)

* Controlling Criteria for Design Speed ≥ 50 mph

** SSD=Stopping Sight Distance, ISD=Intersection Sight Distance, and DSD=Decision Sight Distance (See FDM 11-25-1).

Comments:

Has intersection control evaluation (ICE) worksheet been coordinated (Yes or No)? _____

2.3.3 Locations Interchanges Geometrics Outside of Design Criteria Not Documented in SCD/FSC (S-2 Location only)

Intersecting Roadways	Interchange Type	Ramp Types	Ramp Design Speed	Horizontal Curve on Ramp	Vertical Curve on Ramp	Ramp Grades	SSD** Met* (Y/N) Length	DSD** Met (Y/N) Length

* Controlling Criteria for Design Speed ≥ 50 mph

**SSD = Stopping Sight Distance, DSD = Decision Sight Distance (See FDM 11-25-1).

Comments:

2.4 Cross Section(s) Information (S-2 Segments Cross Section Geometrics Outside of Design Criteria Not Documented in SCD/FSC)

- Number of roadways
- Number of lanes
- Median width
- Lane width*
- Shoulder width* (Total and Paved or Curb and Gutter)
- Bicycle facility type
- Sidewalk and curb ramps
- Cross slope*
- Super-elevation*
- Horizontal clearance
- Clear zone
- Vertical clearance*
- Side-slopes/Ditch sections

* Controlling Criteria for Design Speed ≥ 50 mph

2.5 Pavement Structure/Condition

Roadway	Pavement Types and Thicknesses	Physical Description

Comments:

2.6 Right-of-Way

2.6.1 Encroachments – Attach Encroachment Report

2.6.2 Unique Right-of-Way Issues

2.7 Structures

Existing Structure I.D. #	Feature Crossed	Structure Type	Sufficiency Rating	Clear Roadway Width*	Railing Type

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

2.8 Utilities

Utility Name	Type of Utility	General Location	Underground/ Overhead/Both

Comments:

2.9 Railroad Crossings

Location (Sta.)	Railroad Name	No. of Tracks	Function	Crossing Type

Comments:

2.10 Special Soils Conditions

2.11 Unique Project Features

3.0 Traffic Information

3.1 Traffic Volumes/Conditions

3.1.1 Traffic Forecast Report - Attachment

3.1.2 Highway Capacity Analysis

Location (Roadway Segment or Intersection)	Existing Level of Service	Design Year Level of Service Under Existing Roadway	Design Year Level of Service Under Proposed Roadway

Comments:

3.2 Crash Analysis

Was a Region Safety Certification Document completed?	☐ Yes	☐ No
Were any crash problems identified?	☐ Yes	☐ No
If Yes, did you discuss safety mitigation measures with the Region Safety Engineer?	☐ Yes	☐ No

Comments:

4.0 Proposed Design Criteria (S-2/S-3 Locations only)

4.1 Design Class (S-2/S-3 Locations only)

Roadway or Roadway Segment	Design Class

4.2 Design Speed(s)* (S-2/S-3 Locations only)

Roadway or Roadway Segment	Design Speed*	Posted Speed

* Controlling Criteria for all Design Speeds

4.3 Design Justifications (DJs) (S-2/S-3 Locations only)

4.3.1 Controlling Criteria Design Justifications (DJs)

4.3.2 Non-Controlling Criteria Design Justifications (DJs)

4.4 Typical Cross Section(s) Alternative Features Considered (S-2/S-3 Locations only)

5.0 Proposed Design Improvements

5.1 Improvement Type(s)

5.2 Proposed Geometrics Information (S-2/S-3 Locations only)

5.2.1 Horizontal Alignment* Information (S-2/S-3 Locations only)

5.2.2 Vertical Alignment/Stopping Sight Distance* Information (S-2/S-3 Locations only)

5.2.3 Grades* and Vertical Clearances* Information (S-2/S-3 Locations only)

*Controlling Criteria for Design Speed ≥ 50 mph

5.3 Sideroads/Intersections/Interchanges Information (S-2/S-3 Locations only)

5.3.1 Side-Roads Information (S-2/S-3 Locations only)

Roadway Name	Functional Class	Design Speed (MPH)	Design Year Traffic (AADT)	Design Class	Approach Grades	Ped. Facilities (Y/N)	Bike Facilities (Y/N)

Comments:

5.3.2 Intersections Information/Proposed Geometrics (S-2/S-3 Locations only)

Intersecting Roadway Names	Intersect. Type	Intersect. Angle	Traffic Control	SSD** Met* (Y/N)/ Length	ISD** Met (Y/N)/ Length	DSD** Met (Y/N)/ Length	Vision Triangles Proposed (Y/N)	Corner Clearance to Driveways Met (Y/N)

* Controlling Criteria for Design Speed ≥ 50 mph

** SSD = Stopping Sight Distance, ISD = Intersection Sight Distance, DSD = Decision Sight Distance (See FDM 11-25-1).

Comments:

Has intersection control evaluation (ICE) worksheet been coordinated (Yes or No)? _____

5.3.3 Interchanges Information/Proposed Geometrics (S-2/S-3 Locations only)

Name of Intersecting Roadways	Interchange Type	Ramp Type	Ramp Design Speed	Ramp Grades	SSD** Met* (Y/N)/ Length	DSD** Met (Y/N)/ Length	Vision Triangle (Yes or No)

*Controlling Criteria for Design Speed ≥ 50 mph

**SSD = Stopping Sight Distance, DSD = Decision Sight Distance (See FDM 11-25-1).

Comments:

5.4 Roundabout(s) Information

5.5 Segments Proposed Cross Section/Pavement Structure Information (S-2/S-3 Locations only)

- Number of roadways
- Number of lanes
- Median width/type
- Lane width*/type (Driving, Parking, Bike Lane, etc.)
- Shoulder width* (Total & Paved or Curb and Gutter)
- Bike facilities proposed
- Pedestrian facilities/sidewalk proposed
- Cross slope*
- Super-elevation*
- Horizontal clearance
- Vertical clearance*
- Pavement structure
- Clear zone
- Side-slope/Ditch sections

*Controlling Criteria for Design Speed ≥ 50 mph

5.6 Street Lighting Improvements

Location	Type	Break-away Requirements

5.7 Structure Improvements Information

5.7.1 Bridge Structures

Structure I.D. #	Location	Structure Type	Length	Clear Width	No. of Spans	Vertical Clearance*	Horizontal Clearance
	Proposed Improvement:						
	Proposed Improvement:						
	Proposed Improvement:						

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

5.7.2 Box Culverts and Multiple Pipe Structures

Structure I.D. #	Location	Type	Length	No. Pipes
	Proposed Improvement:			
	Proposed Improvement:			

Comments:

5.7.3 Retaining Walls and Noise Barrier Structures

Structure I.D. #	Location	Type	Length	Height
	Proposed Improvement:			
	Proposed Improvement:			

Comments:

5.7.4 Sign Bridge Structures

Structure I.D. #	Location	Type	Length	Clear Roadway Width	Vertical Clearance*	Horizontal Clearance	Clear Zone Under
	Proposed Improvement:						
	Proposed Improvement:						

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

5.7.5 Tunnel Structures

Structure I.D. #	Location	Type (Veh., Ped., Bicycle, etc.)	Length	Lighting Type	Vertical Clearance*	Horizontal Clearance
	Safety Features			Coordination with Local Emergency Responders		
	Proposed Improvement:					
	Safety Features			Coordination with Local Emergency Responders		
	Proposed Improvement:					

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

5.7.6 Touchdown Points on Local Bridge Program Projects

5.8 Permanent Traffic Control

Will permanent signs be installed (Yes or No)? _____

Are non-standard sign layout details needed (Yes or No)? _____

Comments:

5.9 Safety Enhancements/Mitigation Measures

5.10 Real Estate

5.10.1 Real Estate Acquisition

Plat I.D.:

Relocations		Land (Acres)	Permanent Easements	Temporary Easements	Construction Permits
Type	Number				

Comments:

5.10.2 Encroachments and Access Control, if applicable (Attach Encroachment Report and describe Access Control)

5.11 Utilities

Is Project Trans 220 Utility Project (Yes or No)? _____

Describe any special design features to accommodate utilities:

Major Utility Agreements:

Comments:

5.12 Railroads

Describe improvements to Railroad Facilities:

Railroad Agreements:

Comments:

5.13 Financing and Scheduling

Construction I.D.	Cost Estimate	Type of Funding			Proposed Timeframe for Construction	Ties to Other Work or Projects	Alternative Contracting (Yes or No)
		% Fed.	% State	% Local			

Describe Alternative Contracting:

Non-participating Work:

Deferred Construction Work (Preventative Maintenance projects):

5.14 Unique or Non-Standard Features

5.14.1 Hazardous Waste

5.14.2 Environmental Commitments

5.14.3 Community Sensitive Design/Public Involvement

5.14.4 Value Engineering

6.0 Synopsis

Reports, Documents and Coordination	Completion/ Approval Dates (xx/xx/xxxx)	Status of Coordination or Other Information as Needed
Concept Definition Report (CDR)		
Safety Certification Document (SCD)		
Bridge or Structure Certification Document Approval (BOSCA) (if needed)		
Risk Assessment (RA) (if needed)		
Signed Pavement Design Report (PDR)		
Public Involvement Plan (PIP)		
Structure Survey Report (SSR) (if needed)		
Public Information Meeting(s) (PIM(s))		
Signed State Municipal Agreement(s) (SMA(s)) (if needed)		
Native American Lands of Interest (NALI) Scoping Determination		
Final Scope Certification (FSC)		
SHPO Coordination Acceptance (Section 106, etc.) (SHPO)		
DNR Coordination Acceptance (401 Cert., etc.) (DNR)		
Preliminary Plan Review Complete (PPRC)		
Preliminary Structure Plan Review Complete (PSPRC) (if needed)		
Signed Environmental Document (ED) (Type: ?)		
Interstate Access Justification Report (IAJR)		
Transportation Management Plan (TMP(s)) (Type: ?)		
Freight/OSOW Accommodations Coordination (FOAC)		
Roadside Hazard Analysis Sheet (RHA) (if needed)		
Drainage Design Report (DDR) (if needed)		
Status of Statutory Actions (if needed)		

Comments:

7.0 Attachments

- Project Location/Overview Map
- As-built Plan Sheet(s) (for Rehabilitation S-2 segments only)
- Existing Typical Cross Section(s)/ Finished/Proposed Typical Cross Section(s)
- Encroachment Report (If applicable) (see FDM 12-1-20)
- Safety Certification Document (SCD) with Contributing Geometric Analysis (CGA) (If applicable) (see FDM 11-38)
- Traffic Forecast Report
- Preliminary Plan Sheet(s)
- Critical Design Parameters Chart for Each roundabout proposed (if applicable)
- Environmental Commitments Basic Sheet (if applicable) (include coordination letters)
- Roadside Hazard Analysis Form Template
- ADA Technically Infeasible documentation
- Non-Compliant Roadside design

SAMPLE TRANSMITTAL LETTER

(For a working file of this template: FDM 11-4 A10.2 File 1)

CORRESPONDENCE/MEMORANDUM_____State of Wisconsin

Date: _____, 20___

To: _____
Director, Bureau of Project Development
Attn: (Design Standards and Oversight Chief)

From: _____
_____ Region

Subject: NEW CONSTRUCTION, RECONSTRUCTION AND REHABILITATION DESIGN STUDY REPORT
Project I.D. (design) _____
(STH, IH, USH (choose one)) _____
Bridge # (if applicable) _____
_____ County

Having considered the economic and social effects of this project, its impact on the environment, and its consistency with the goals of community planning, we request your approval of the attached design study report.

_____ _____
Region Project Development Chief Date

Concur:

_____ _____
Bureau of Project Development Date
Design Standards and Oversight Chief

SAMPLE TITLE SHEET

NEW CONSTRUCTION, RECONSTRUCTION AND REHABILITATION DESIGN STUDY REPORT

Project I.D. (design) _____
(STH, IH, USH, CTH, Local (choose one)) _____
Bridge # (if applicable) _____
_____ County

CONSULTANT'S SEAL

NEW CONSTRUCTION, RECONSTRUCTION AND REHABILITATION DESIGN STUDY REPORT

1.0 Project Description and Need

1.1 Federal Oversight Project (Yes or No): _____

1.2 Project Length and Termini

Project Length:

Termini/Limits:

1.3 Existing Roadway Information

Roadway	Functional Class (Principal or Minor Arterial, Collector or Local)	Surrounding Development Type? Rural, Urban or Transitional	Corridors 2030 or Backbone (No or State Which)	NHS Route (Yes or No)	Long Truck Route (No or State Federal or State)	Access Control Tier	On Ped. Trans. Plan (Yes or No)	On Bike Trans. Plan (Yes or No)

Comments:

1.4 Need for Project

1.5 Proposed/Selected Alternative (State the Improvement Type and add brief description).

2.0 Existing Facility Information

2.1 Posted Speed

Roadway or Roadway Segment	Posted Speed	Advisory Speed

2.2 Geometrics

2.2.1 Horizontal Alignment Features Outside of Design Criteria

Horizontal Feature* (Curve, P.I. Deflection, etc.)	Location (Stationing)	Size* (Radius, P.I. Deflection, etc.)	Super-Elevation* (S.E.)	Speed Rating

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

2.2.2 Vertical Alignment Features/SSD* Outside of Design Criteria

Vertical Feature (Curve, Vertical Grade Deflection, etc.)	Location (Stationing)	Sag or Crest	% Grades*	K Value/ Grade Deflection	Speed Rating	SSD** Met *(Yes or No) Length	DSD Met (Yes or No) Length

* Controlling Criteria for Design Speed ≥ 50 mph, **SSD = Stopping Sight Distance

Comments:

2.2.3 Grades* and Vertical Clearance* Outside of Design Criteria

Location (Stationing, Overpass Structures, etc.)	% Grade*	Vertical Clearance*

*Controlling Criteria for Design Speed ≥ 50 mph

Comments:

2.3 Side-Roads/ Intersections/ Interchanges Information/Geometrics

2.3.1 Side-Roads Design Information

Roadway	Functional Class	Posted Speed (MPH)	Existing Traffic*** (AADT)	Approach Grades	Pedestrian Facilities (Yes or No)	Bicycle Facilities (Yes or No)

*** If Existing Traffic volumes are not available, then state at a minimum whether AADT is assumed to be <100 or >100.

Comments:

2.3.2 Intersections Geometrics Outside of Design Criteria

Intersecting Roadway	Intersect. Type	Intersect. Angle	Traffic Control	SSD** Met* (Y/N)/ Length	ISD** Met (Y/N)/ Length	DSD** Met (Y/N)/ Length	Vision Triangle (Y/N)	Corner Clearance to Driveways Present (Y/N)

* Controlling Criteria for Design Speed ≥ 50 mph

** SSD=Stopping Sight Distance, ISD=Intersection Sight Distance, and DSD=Decision Sight Distance (See FDM 11-25-1).

Comments:

Has intersection control evaluation (ICE) worksheet been coordinated (Yes or No)? _____

2.3.3 Interchange Geometrics Outside of Design Criteria

Intersecting Roadways	Interchange Type	Ramp Types	Ramp Design Speed	Horizontal Curve on Ramp	Vertical Curve on Ramp	Ramp Grades	SSD** Met* (Y/N) Length	DSD** Met (Y/N) Length

* Controlling Criteria for Design Speed ≥ 50 mph

**SSD = Stopping Sight Distance, DSD = Decision Sight Distance (See FDM 11-25-1).

Comments:

2.4 Cross Section Geometrics Outside of Design Criteria

- Number of roadways
- Number of lanes
- Median width
- Lane width*
- Shoulder width* (Total and Paved or Curb and Gutter)
- Bicycle facility type
- Sidewalk and curb ramps
- Cross slope*
- Super-elevation*
- Horizontal clearance
- Clear zone
- Vertical clearance*
- Side-slopes/Ditch sections

* Controlling Criteria for Design Speed ≥ 50 mph

2.5 Pavement Structure/Condition

Roadway	Pavement Types and Thicknesses	Physical Description

Comments:

2.6 Right-of-Way

2.6.1 Encroachments – Attach Encroachment Report

2.6.2 Unique Right-of-Way Issues

2.7 Structures

Existing Structure I.D. #	Feature Crossed	Structure Type	Sufficiency Rating	Clear Roadway Width*	Railing Type

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

2.8 Utilities

Utility Name	Type of Utility	General Location	Underground/ Overhead/Both

Comments:

2.9 Railroad Crossings

Location (Sta.)	Railroad Name	No. of Tracks	Function	Crossing Type

Comments:

2.10 Special Soils Conditions

2.11 Unique Project Features

3.0 Traffic Information

3.1 Traffic Volumes/Conditions

3.1.1 Traffic Forecast Report Attachment

3.1.2 Highway Capacity Analysis

Location (Roadway Segment or Intersection)	Existing Level of Service	Design Year Level of Service Under Existing Roadway	Design Year Level of Service Under Proposed Roadway

Comments:

3.2 Crash Analysis

3.2.1 Project Crash Information

Roadway	Crash Rate (1) (Year)	Statewide Crash Rate (1) (Year)	Number and Severity of Crashes			
			Fatal	Injury	Property Damage	Total No. Crashes

(1) Crash rate based on 100 million vehicles miles traveled (100 MVMT)

Comments:

3.2.2 Significant Crash Locations or Patterns

Location or Pattern	Year	Number and Severity of Crashes				Crash Rate(2)	Possible Factors Contributing to Crashes
		Fatal	Injury	Property Damage	Total		

(2) Crashes per million entering vehicles (MEV)

Comments:

4.0 Proposed Design Criteria

4.1 Design Class

Roadway or Roadway Segment	Design Class

4.2 Design Speed(s)*

Roadway or Roadway Segment	Design Speed*	Posted Speed

* Controlling Criteria for all Design Speeds

4.3 S-2/S-3 Design Justifications (DJs)

4.3.1 Controlling Criteria Design Justifications (DJs)

4.3.2 Non-Controlling Criteria Design Justifications (DJs)

4.4 Typical Cross Section(s) Alternative Features Considered

4.5 Safety and Contributing Geometric Analysis (CGA) Design Justification (FDM 11-38), 3R projects and Preventive Maintenance (PM) Group I and Group II pavement strategy projects (FDM 3-5 Exhibit 5.1)

See attached Safety Screening and Contributing Geometric Analysis worksheets for locations and details of Crash Flags, Improvement Flags, and Design Justifications within the project limits.

National Highway System (NHS) Roadway - Geometric Features Outside of Controlling Design Criteria Covered by Design Justifications (3R & PM projects) *

NHS Roadway Name:_____

Location				Feature Type	Magnitude of Variance
Sta.	to Sta.	RP	to RP		

** This documentation is required only for 3R projects on the National Highway System.

These geometric features outside of controlling design criteria are located on highway segments containing no flags or only crash type flags. These features do not contribute significantly to the crash situation on these segments of highway, so these highway segments are covered by Design Justifications.

See attached map.

Comments:

Geometric Features Outside of Controlling Design Criteria NOT Covered by Design Justifications and NOT corrected as part of PM project (PM Group I and Group II pavement strategy projects)

Roadway Name: _____

Location				Feature Type	Magnitude of Variance	Operational Improvements
Sta.	to Sta.	RP	to RP			

Construction is required for safety improvements or to correct the above controlling geometric features outside of design criteria. The region will either consider this construction for HSIP funding or address this construction with future programming. Operational improvements will be incorporated into the PM project at these locations that are consistent with the scope of the preventive maintenance work and appropriate based on the analysis of crash types.

Comments:

5.0 Proposed Design Improvements

5.1 Improvement Type(s)

5.2 Proposed Geometrics Information

5.2.1 Horizontal Alignment* Information

5.2.2 Vertical Alignment/Stopping Sight Distance* Information

5.2.3 Grades* and Vertical Clearances* Information

*Controlling Criteria for Design Speed ≥ 50 mph

5.3 Side-roads/Intersections/Interchanges Information

5.3.1 Side-Road(s) Information

Roadway Name	Functional Class	Design Speed (MPH)	Design Year Traffic (AADT)	Design Class	Approach Grades	Ped. Facilities (Y/N)	Bike Facilities (Y/N)

Comments:

5.3.2 Intersection(s) Information/Proposed Geometrics

Intersecting Roadway Names	Intersect. Type	Intersect. Angle	Traffic Control	SSD** Met* (Y/N)/ Length	ISD** Met (Y/N)/ Length	DSD** Met (Y/N)/ Length	Vision Triangles Proposed (Y/N)	Corner Clearance to Driveways Met (Y/N)

* Controlling Criteria for Design Speed Limits ≥ 50 mph

** SSD = Stopping Sight Distance, ISD = Intersection Sight Distance, DSD = Decision Sight Distance (See FDM 11-25-1).

Comments:

Has intersection control evaluation (ICE) worksheet been coordinated (Yes or No)? _____

5.3.3 Interchange(s) Information/Proposed Geometrics

Name of Intersecting Roadways	Interchange Type	Ramp Type	Ramp Design Speed	Ramp Grades	SSD** Met* (Y/N)/ Length	DSD** Met (Y/N)/ Length	Vision Triangle (Yes or No)

*Controlling Criteria for Design Speed ≥ 50 mph

**SSD = Stopping Sight Distance, DSD = Decision Sight Distance (See FDM 11-25-1).

Comments:

5.4 Roundabout(s) Information

5.5 Cross Section/Pavement Structure Information

- Number of roadways
- Number of lanes
- Median width/type
- Lane width*/type (Driving, Parking, Bike Lane, etc.)
- Shoulder width* (Total & Paved or Curb and Gutter)
- Bike facilities proposed
- Pedestrian facilities/sidewalk proposed
- Cross slope*
- Super-elevation*
- Horizontal clearance
- Vertical clearance*
- Pavement structure
- Clear zone
- Side-slope/Ditch sections

*Controlling Criteria for Design Speed ≥ 50 mph

5.6 Street Lighting Improvements

Location	Type	Break-away Requirements

5.7 Structures Improvements Information

5.7.1 Bridge Structures

Structure I.D. #	Location	Structure Type	Length	Clear Width	No. of Spans	Vertical Clearance*	Horizontal Clearance
	Proposed Improvement:						

	Proposed Improvement:						
	Proposed Improvement:						

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

5.7.2 Box Culverts and Multiple Pipe Structures

Structure I.D. #	Location	Type	Length	No. Pipes
	Proposed Improvement:			
	Proposed Improvement:			

Comments:

5.7.3 Retaining Walls and Noise Barrier Structures

Structure I.D. #	Location	Type	Length	Height
	Proposed Improvement:			
	Proposed Improvement:			

Comments:

5.7.4 Sign Bridge Structures

Structure I.D. #	Location	Type	Length	Clear Roadway Width	Vertical Clearance*	Horizontal Clearance	Clear Zone Under
	Proposed Improvement:						
	Proposed Improvement:						

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

5.7.5 Tunnel Structures

Structure I.D. #	Location	Type (Veh., Ped., Bicycle, etc.)	Length	Lighting Type	Vertical Clearance*	Horizontal Clearance
	Safety Features			**Coordination with Local Emergency Responders**		
	Proposed Improvement:					
	Safety Features			**Coordination with Local Emergency Responders**		
	Proposed Improvement:					

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

5.7.6 Touchdown Points on Local Bridge Program Projects

5.8 Permanent Traffic Control

Will permanent signs be installed (Yes or No)? _____

Are non-standard sign layout details needed (Yes or No)? _____

Comments:

5.9 Safety Enhancements/Mitigation Measures

5.10 Real Estate

5.10.1 Real Estate Acquisition

Plat I.D.:

Relocations		Land (Acres)	Permanent Easements	Temporary Easements	Construction Permits
Type	Number				

Comments:

5.10.2 Encroachment Actions

Encroachment Location	Encroachment Type	What is to be Done? (Removed, Revocable Permit, etc.)

Comments:

5.11 Utilities

Is Project Trans 220 Utility Project (Yes or No)? _____

Describe any special design features to accommodate utilities:

Major Utility Agreements:

Comments:

5.12 Railroads

Describe improvements to Railroad Facilities:

Railroad Agreements:

Comments:

5.13 Financing and Scheduling

Construction I.D.	Cost Estimate	Type of Funding			Proposed Timeframe for Construction	Ties to Other Work or Projects	Alternative Contracting (Yes or No)
		% Fed.	% State	% Local			

Describe Alternative Contracting:

Non-participating Work:

Deferred Construction Work (Preventative Maintenance projects):

5.14 Unique Project Features

5.14.1 Hazardous Waste

5.14.2 Environmental Commitments

5.14.3 Community Sensitive Design/Public Involvement

5.14.4 Value Engineering

6.0 Synopsis

Reports, Documents and Coordination	Completion/ Approval Dates (xx/xx/xxxx)	Status of Coordination or Other Information as Needed
Concept Definition Report (CDR)		
Risk Assessment (RA) (if needed)		
Signed Pavement Design Report (PDR)		
Public Involvement Plan (PIP)		
Structure Survey Report (SSR) (if needed)		
Public Information Meeting(s) (PIM(s))		
Signed State Municipal Agreement(s) (SMA(s)) (if needed)		
Native American Lands of Interest (NALI) Scoping Determination		
SHPO Coordination Acceptance (Section 106, etc.) (SHPO)		
DNR Coordination Acceptance (401 Cert., etc.) (DNR)		
Preliminary Plan Review Complete (PPRC)		
Preliminary Structure Plan Review Complete (PSPRC) (if needed)		
Signed Environmental Document (ED) (Type: ?)		
Interstate Access Justification Report (IAJR)		
Transportation Management Plan (TMP(s)) (Type: ?)		

Freight/OSOW Accommodations Coordination (FOAC)		
Roadside Hazard Analysis Sheet (RHA) (if needed)		
Drainage Design Report (DDR) (if needed)		
Status of Statutory Actions (if needed)		

Comments:

7.0 Attachments

- Project Location/Overview Map
- As-built Plan Sheet(s) (for Rehabilitation projects only)
- Existing Typical Cross Section(s)/ Finished/Proposed Typical Cross Section(s)
- Encroachment Report (If applicable) (see FDM 12-1-20)
- Safety Certification Document (SCD) with Contributing Geometric Analysis (CGA) (Formerly known as PES) (if applicable)
- Traffic Forecast Report
- Preliminary Plan Sheet(s)
- Critical Design Parameters Chart for Each roundabout proposed (if applicable)
- Environmental Commitments Basic Sheet (if applicable) (include coordination letters)
- Roadside Hazard Analysis Form Template
- ADA Technically Infeasible documentation
- Non-Compliant Roadside design

SAMPLE TRANSMITTAL LETTER
(For a working file of this template: FDM 11-4 A10.3 File 1)

CORRESPONDENCE/MEMORANDUM_____**State of Wisconsin**

Date: _____, 20___

To: _____
Director, Bureau of Project Development
Attn: (Design Standards and Oversight Chief)

From: _____
_____ Region

Subject: ABBREVIATED DESIGN STUDY REPORT
Project I.D. (design) _____
(STH, IH, USH (choose one)) _____
Bridge # (if applicable) _____
_____ County

Having considered the economic and social effects of this project, its impact on the environment, and its consistency with the goals of community planning, we request your approval of the attached design study report.

_____ _____
Region Project Development Chief Date

Concur:

_____ _____
Bureau of Project Development Date
Design Standards and Oversight Chief

SAMPLE TITLE SHEET

ABBREVIATED DESIGN STUDY REPORT

Project I.D. (design) _____
(STH, IH, USH, CTH, Local (choose one)) _____
Bridge # (if applicable) _____
_____ County

CONSULTANT'S SEAL

ABBREVIATED DESIGN STUDY REPORT

1.0 Project Description and Need

1.1 Federal Oversight Project (Yes or No): _____

1.2 Project Length and Termini

Project Length:

Termini/Limits:

1.3 Existing Roadway Information

Roadway Name	Functional Class (Principal or Minor Arterial, Collector or Local)	Surrounding Development Type? (Rural, Urban or Transitional)	Corridors 2030 or Backbone (No or State Which)	NHS Route (Yes or No)	Long Truck Route (No or State Federal or State)	Access Control Tier	On Ped Trans. Plan (Yes or No)	On Bike Trans. Plan (Yes or No)

Comments:

1.4 Need for Project

1.5 Proposed/Selected Alternative (State the Improvement Type and add brief description)

2.0 Existing Facility Information

2.1 Posted Speed

Roadway or Roadway Segment	Posted Speed	Advisory Speed

2.2 Existing Geometrics

2.2.3 Vertical Clearance* Outside of Design Criteria

Location (Stationing, Overpass Structures, etc.)	Vertical Clearance*

* Controlling Criteria for Design Speed ≥50 mph

Comments:

2.4 Cross Section Information - Number of roadways

- Number of lanes
- Median width
- Lane width*
- Shoulder width* (Total and Paved or Curb & Gutter)
- Bicycle facility type
- Sidewalk and curb ramps
- Cross slope*
- Super-elevation*
- Horizontal clearance
- Clear zone
- Vertical clearance*
- Side-slopes and ditch sections

* Controlling Criteria for Design Speed ≥50 mph

2.5 Pavement Structure/Condition

Roadway	Pavement Types and Thicknesses	Physical Description

2.6 Right-of-Way

2.6.1 Encroachments – Attach Encroachment Report (if applicable)

2.7 Structures

Existing Structure I.D. #	Feature Crossed	Structure Type	Sufficiency Rating	Clear Roadway Width*	Railing Type	Design Loading Structural Capacity

* Controlling Criteria for Design Speed ≥50 mph

Comments:

2.8 Utilities

Utility Name	Type of Utility	General Location	Underground /Overhead/ Both

Comments:

2.9 Railroad Crossings

Location (Sta.)	Railroad Name	No. of Tracks	Function	Crossing Type

Comments:

2.11 Unique Project Features

3.0 Traffic Information

3.1 Traffic Volumes/Conditions

3.1.1 Existing Average Annual Daily Traffic (AADT) Volume

3.1.2 Highway Capacity Analysis

Location (Roadway Segment or Intersection)	Existing Level of Service	Construction Year Level of Service	Construction Year + 10 Level of Service

Comments:

3.2 Crash Analysis

3.2.1 Project Crash Information

			Number and Severity of Crashes			
Roadway	**Crash Rate (1) (Year)**	**Statewide Crash Rate (1) (Year)**	**Fatal**	**Injury**	**Property Damage**	**Total No. Crashes**

(1) Crash rate based on 100 million vehicles miles traveled (100 MVMT)

Comments:

4.0 Proposed Design Criteria

4.3 Design Justifications

4.3.1 Controlling Criteria Design Justifications

4.3.2 Non-Controlling Criteria Design Justifications

4.5 Safety and Contributing Geometric Analysis Design Justifications (FDM 11-1-40) 3R projects and Preventive Maintenance (PM) Group I and Group II Pavement Strategy Projects (FDM 3-5 Exhibit 5.1)

See attached Safety Screening and Contributing Geometric Analysis worksheets for locations and details of Crash Flags, Improvement Flags, and Design Justifications within the project limits.

National Highway System (NHS) Roadway - Controlling Geometric Features Outside of Design Criteria Covered by Design Justifications (3R & PM Projects) **

NHS Roadway Name: _____

Location				Feature Type	Magnitude of Variance
Sta.	**to Sta.**	**RP**	**to RP**		

** This documentation is required only for 3R projects on the National Highway System.

These controlling geometric features outside of design criteria are located on highway segments containing no flags or only Crash Type Flags. These features do not contribute significantly to the crash situation on these segments of highway, so these highway segments are covered by Design Justifications.

See attached map

Comments:

Controlling Geometric Features Outside of Design Criteria NOT Covered by Design Justifications and NOT Corrected as Part of PM Project (PM Group I and Group II Pavement Strategy Projects)

Roadway Name: _____

Location				Feature Type	Magnitude of Variance	Operational Improvements
Sta.	to Sta.	RP	to RP			

Construction is required for safety improvements or to correct the above controlling geometric features outside of design criteria. The region will either consider this construction for HSIP funding or address this construction with future programming. Operational improvements will be incorporated into the PM project at these locations that are consistent with the scope of the preventive maintenance work and appropriate based on the analysis of crash types.

Comments:

5.0 Proposed Design Improvement

5.1 Improvement Type(s)

5.5 Cross Section/Pavement Structure Information

- Number of roadways
- Number of lanes
- Median width/type

- Lane width*/type (Driving, Parking, Bike Lane, etc.)
- Shoulder width* (Total & Paved or Curb & Gutter)
- Bike facilities proposed
- Pedestrian facilities / sidewalk proposed
- Cross slope*
- Super-elevation*
- Horizontal clearance
- Vertical clearance*
- Pavement structure
- Clear zone
- Side-slope/Ditch Sections

* Controlling Criteria for Design Speed ≥ 50 mph

5.6 Street Lighting Improvements

Location	Type	Break-away Requirements

5.7 Structures Improvements Information

5.7.1 Bridge Structures

Structure I.D. #	Location	Structure Type	Length	Clear Width	No. of Spans	Vertical Clearance*	Horizontal Clearance
	Proposed Improvement:						
	Proposed Improvement:						
	Proposed Improvement:						

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

5.7.2 Box Culverts and Multiple Pipe Structures

Structure I.D. #	Location	Type	Length	No. Pipes
	Proposed Improvement:			
	Proposed Improvement:			

Comments:

5.7.3 Retaining Walls and Noise Barrier Structures

Structure I.D. #	Location	Type	Length	Height
	Proposed Improvement:			
	Proposed Improvement:			

Comments:

5.7.4 Sign Bridge Structures

Structure I.D. #	Location	Type	Length	Clear Roadway Width	Vertical Clearance*	Horizontal Clearance	Clear Zone Under
	Proposed Improvement:						
	Proposed Improvement:						

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

5.7.5 Tunnel Structures

Structure I.D. #	Location	Type (Veh., Ped., Bicycle, etc.)	Length	Lighting Type	Vertical Clearance*	Horizontal Clearance
	Safety Features			**Coordination with Local Emergency Responders**		
	Proposed Improvement:					
	Safety Features			**Coordination with Local Emergency Responders**		
	Proposed Improvement:					

* Controlling Criteria for Design Speed ≥ 50 mph

Comments:

5.8 Permanent Traffic Control

Will permanent signs be installed (Yes or No)? _____

Are non-standard sign layout details needed (Yes or No)? _____

Comments:

5.9 Safety Enhancements/Mitigation Measures

5.10 Real Estate

5.10.2 Encroachments – Attach Encroachment Report (if applicable)

5.11 Utilities

Is Project Trans 220 Utility Project (Yes or No)? _____

Describe any special design features to accommodate utilities:

Major Utility Agreements:

Comments:

5.12 Railroads

Describe improvements to Railroad Facilities:

Railroad Agreements:

Comments:

5.13 Financing and Scheduling

Construction I.D.	Cost Estimate	Type of Funding			Proposed Timeframe for Construction	Ties to Other Work or Projects	Alternative Contracting (Yes or No)
		% Fed.	% State	% Local			

Describe Alternative Contracting:

Non-participating Work:

Deferred Construction Work (Preventative Maintenance Projects):

5.14 Unique or Non-Standard Features

5.15.1 Hazardous Waste

5.14.2 Environmental Commitments

5.14.3 Public Involvement

6.0 Synopsis

Reports, Documents and Coordination	Completion/ Approval Dates (xx/xx/xxxx)	Status of Coordination or Other Information as Needed
Concept Definition Report (CDR)		
Safety Certification Document (SCD) or SSA/CGS (PES)		
Bridge or Structure Certification Document Approval (BOSCA) (if needed)		
Signed Pavement Design Report (PDR)		
Public Involvement Plan (PIP)		
Structure Survey Report (SSR) (if needed)		
Public Information Meeting(s) (PIM(s))		
Signed State Municipal Agreement(s) (SMA(s)) (if needed)		
Native American Lands of Interest (NALI) Scoping Determination		
Final Scope Certification Document (FSC)		
SHPO Coordination Acceptance (Section 106, etc.) (SHPO)		
DNR Coordination Acceptance (401 Cert., etc.) (DNR)		

Preliminary Plan Review Complete (PPRC)		
Preliminary Structure Plan Review Complete (PSPRC) (if needed)		
Signed Environmental Document (ED) (Type: ?)		
Interstate Access Justification Report (IAJR)		
Transportation Management Plan (TMP(s)) (Type: ?)		
Freight/OSOW Accommodations Coordination (FOAC)		
Roadside Hazard Analysis Sheet (RHA) (if needed)		
Drainage Design Report (DDR) (if needed)		
Status of Statutory Actions (if needed)		

Comments:

7.0 Attachments

- Project Location/Overview Map
- Existing Typical Cross Section(s)/ Finished/Proposed Typical Cross Section(s)
- Encroachment Report (If applicable) (see FDM 12-1-20)
- Safety Certification Document (SCD) with Contributing Geometric Analysis (CGA) (if applicable) (see FDM 11-38)
- Preliminary Plan Sheet(s)
- Environmental Commitments Basic Sheet (if applicable) (include coordination letters)
- Roadside Hazard Analysis Form Template
- ADA Technically Infeasible documentation
- Non-Compliant Roadside design

SAMPLE TRANSMITTAL LETTER
(For a working file of this template: FDM 11-4 A10.4 File 1)

CORRESPONDENCE/MEMORANDUM_____State of Wisconsin

Date: _____, 20___

To: _____

Director, Bureau of Project Development

Attn: (Design Standards and Oversight Chief)

From: _____

_____ Region

Subject: GROUP III PAVEMENT STRATEGIES, DRAINAGE RESTORATION, SAFETY APPURTENANCES AND OTHER PREVENTIVE MAINTENANCE PROJECT DESIGN STUDY REPORT

Project I.D. (design) _____

(STH, IH, USH (choose one)) _____

Bridge # (if applicable) _____

_____ County

Having considered the economic and social effects of this project, its impact on the environment, and its consistency with the goals of community planning, we request your approval of the attached design study report.

_____ _____

Region Project Development Chief Date

Concur:

_____ _____

Bureau of Project Development Date

Design Standards and Oversight Chief

SAMPLE TITLE SHEET

GROUP III PAVEMENT STRATEGIES PREVENTIVE MAINTENANCE PROJECT DESIGN STUDY REPORT

Project I.D. (design) _____
(STH, IH, USH, CTH, Local (choose one)) _____
_____ County

CONSULTANT'S SEAL

ABBREVIATED GROUP III PAVEMENT STRATEGIES PREVENTIVE MAINTENANCE PROJECT DESIGN STUDY REPORT

1.0 Project Description and Need

1.1 Federal Oversight (Yes or No):

1.2 Project Length and Termini

Project Length: XX.XXX

Termini/Limits:

1.4 Need for Project

2.0 Existing Facility Information

2.5 Pavement Structure/Condition

Roadway	Pavement Types and Thicknesses	Physical Description

Comments:

5.0 Proposed Design Improvement

5.1 Improvement Type(s)

5.13 Financing and Scheduling

Construction I.D.	Cost Estimate	Type of Funding			Proposed Timeframe for Construction	Ties to Other Work or Projects	Alternative Contracting (Yes or No)
		% Fed.	% State	% Local			

Describe Alternative Contracting

Non-participating Work

5.14 Unique Project Features

5.14.1 Hazardous Waste

5.14.2 Environmental Commitments

5.14.3 Community Sensitive Design/Public Involvement

6.0 Synopsis

Reports, Documents and Coordination	Completion/ Approval Dates (xx/xx/xxxx)	Status of Coordination or Other Information as Needed
Concept Definition Report (CDR)		
Safety Certification Document (SCD)		
Bridge or Structure Certification Document Approval (BOSCA) (if needed)		
Signed Pavement Design Report (PDR)		
Public Involvement Plan (PIP)		
Structure Survey Report (SSR) (if needed)		
Public Information Meeting(s) (PIM(s))		
Signed State Municipal Agreement(s) (SMA(s)) (if needed)		
Native American Lands of Interest (NALI) Scoping Determination		
Final Scope Certification Document (FSC)		
SHPO Coordination Acceptance (Section 106, etc.) (SHPO)		
DNR Coordination Acceptance (401 Cert., etc.) (DNR)		
Preliminary Plan Review Complete (PPRC)		
Preliminary Structure Plan Review Complete (PSPRC) (if needed)		

Signed Environmental Document (ED) (Type: ?)		
Interstate Access Justification Report (IAJR)		
Transportation Management Plan (TMP(s)) (Type: ?)		
Freight/OSOW Accommodations Coordination (FOAC)		
Roadside Hazard Analysis Sheet (RHA) (if needed)		
Drainage Design Report (DDR) (if needed)		
Status of Statutory Actions (if needed)		

Comments:

7.0 Attachments

- Project Location/Overview Map
- Existing Typical Cross Section(s)/ Finished/Proposed Typical Cross Section(s)
- Preliminary Plan Sheet(s)
- Environmental Commitments Basic Sheet (if applicable) (include coordination letters)
- Roadside Hazard Analysis Form Template
- ADA Technically Infeasible document if required.

SAMPLE TRANSMITTAL LETTER
(For a working file of this template: FDM 11-4 A10.5 File 1)

CORRESPONDENCE/MEMORANDUM_____State of Wisconsin

Date: _____, 20___

To: _____
Director, Bureau of Project Development
Attn: (Design Standards and Oversight Chief)

From: _____
_____ Region

Subject: PERPETUATION DESIGN STUDY REPORT
Project I.D. (design) _____
(CTH, Local (choose one)) _____
Bridge # (if applicable) _____
_____ County

Having considered the economic and social effects of this project, its impact on the environment, and its consistency with the goals of community planning, we request your approval of the attached design study report.

_____ _____
Region Project Development Chief Date

Concur:

_____ _____
Bureau of Project Development, Date
Design Standards and Oversight Services Chief

SAMPLE TITLE SHEET

PERPETUATION STUDY REPORT

Project I.D. (design) _____
(construction): _____
(STH, IH, USH, CTH, Local (choose one)) _____
Bridge # (if applicable) _____
_____ County

CONSULTANT'S SEAL

PERPETUATION DESIGN STUDY REPORT

1.0 Project Description and Need

1.2 Project Length and Termini

Project Length: XX.XXX

Termini/Limits:

1.3 Existing Roadway Information

Roadway	Functional Class (Principal or Minor Arterial, Collector or Local)	Surrounding Development Type? Rural, Urban or Transitional	Corridors 2030 or Backbone (No or State Which)	NHS Route (Yes or No)	Long Truck Route (No or State Federal or State)	Access Control Tier	On Ped. Trans. Plan (Yes or No)	On Bike Trans. Plan (Yes or No)

Comments:

1.4 Need for Project

1.5 Proposed/Selected Alternative (State the Improvement Type and add brief description).

2.0 Existing Facility Information

2.1 Posted Speed

Roadway or Roadway Segment	Posted Speed (MPH)	Advisory Speed (MPH)

Comments:

2.4 Cross Section(s) Information

See attached Existing Typical Section(s)

3.0 Traffic Information

3.1 Traffic Volumes/Conditions

Roadway or Roadway Segment	AADT[1]

[1] AADT = Average Annual Daily Traffic

3.2 Existing Crash Analysis

Was a Region Safety Certification Document completed? ☐ Yes ☐ No

Were any crash problems identified? ☐ Yes ☐ No

If Yes, did you discuss safety mitigation measures with the Region Safety Engineer? ☐ Yes ☐ No

Comments:

5.0 Proposed Design Improvements

5.1 Improvement Type:

5.5 Proposed Cross Section/Pavement Structure Information

See attached Proposed Typical Section(s)

5.8 Permanent Traffic Control Information

Will permanent signs be installed? ☐ Yes ☐ No

5.9 Safety Enhancements/Mitigation Measures

Are Safety Mitigation Measures to be Implemented in these Crash Location Areas? ☐ Yes ☐ No

If so, Describe:

5.11 Utilities

Is Project Trans 220 Utility Project (Yes or No)? _____

Describe any special design features to accommodate utilities:

Major Utility Agreements:

Comments:

5.13 Financing and Scheduling Information

Construction I.D.	Cost Estimate	Type of Funding			Proposed Timeframe for Construction	Ties to Other Work or Projects	Alternative Contracting (Yes or No)
		% Fed.[14]	% State	% Local			

[14]Fed. = Federal

Does Project Require a State/Municipal Agreement? ☐ Yes ☐ No

5.14 Unique Project Features

5.14.1 Does Project Require any Hazardous Waste Mitigation? ☐ Yes ☐ No

Comments:

5.14.2 Does Project contain any Environmental Commitments? ☐ Yes ☐ No

Comments:

6.0 Synopsis

Reports, Documents and Coordination	Completion/ Approval Dates (xx/xx/xxxx)	Status of Coordination or Other Information as Needed
Concept Definition Report (CDR)		
Safety Certification Documentation (SCD)		
Bridge or Structure Certification Document Approval (BOSCA) (if needed)		
Signed Pavement Design Report (PDR)		
Public Involvement Plan (PIP)		
Structure Survey Report (SSR) (if needed)		
Public Information Meeting(s) (PIM(s))		
Signed State Municipal Agreement(s) (SMA(s)) (if needed)		

Native American Lands of Interest (NALI) Scoping Determination		
Final Scope Certification Document Approval (FSC)		
SHPO Coordination Acceptance (Section 106, etc.) (SHPO)		
DNR Coordination Acceptance (401 Cert., etc.) (DNR)		
Preliminary Plan Review Complete (PPRC)		
Preliminary Structure Plan Review Complete (PSPRC) (if needed)		
Signed Environmental Document (ED) (Type: ?)		
Interstate Access Justification Report (IAJR)		
Transportation Management Plan (TMP(s)) (Type: ?)		
Freight/OSOW Accommodations Coordination (FOAC)		
Roadside Hazard Analysis Sheet (RHA) (if needed)		
Drainage Design Report (DDR) (if needed)		
Status of Statutory Actions (if needed)		

Comments:

7.0 Attachments

- Project Location/Overview Map
- Existing Typical Cross Section(s)/ Finished/Proposed Typical Cross Section(s)
- Safety Certification Document (SCD)
- Preliminary Plan Sheet(s)
- Environmental Commitments Basic Sheet (if applicable) (include coordination letters)
- Roadside Hazard Analysis Sheet
- ADA Technically Infeasible documentation
- Non-Compliant Roadside design
- 60% TMP (Transportation Management Plan)

(For a working file of this template: FDM 11-4 A10.6 File 1)

CORRESPONDENCE/MEMORANDUM_____State of Wisconsin

Date: _____, 20___
To: _____
Director, Bureau of Project Development
Attn: (Design Standards and Oversight Chief)

From: _____
_____ Region

Subject: MODERNIZATION AND REHABILITATION DESIGN STUDY REPORT
Project I.D. (design) _____
(STH, IH, USH (choose one)) _____
Bridge # (if applicable) _____
_____ County

Having considered the economic and social effects of this project, its impact on the environment, and its consistency with the goals of community planning, we request your approval of the attached design study report.

_____ _____
Region Project Development Chief Date

Concur:

_____ _____
Bureau of Project Development Date
Design Standards and Oversight Chief

_____ _____
Federal Highway Administration Date
Chief of Design Services Section

(For a working file of this template: FDM 11-4 A10.7 File 1)

CORRESPONDENCE/MEMORANDUM _____ **State of Wisconsin**

Date: _____, 20xx

To: (Name)_____
WisDOT DTSD XX Region, Local Program Project Manager

From: (Name)_____
_____ - Local Public Agency

Subject: DESIGN STUDY REPORT
Project I.D. (design)_____
(CTH, Local (choose one)) _____,
Bridge # (if applicable)
_____County

Having considered the economic and social effects of this project, its impact on the environment, and its consistency with the goals of community planning, we recommend your concurrence of the attached design study report.

Recommended:

_____ _____

Name, PE Date

Local Public Agency

Are there any Design Justifications included in this DSR? Yes ☐ No ☐

Concur:

_____ _____

Name, PE Date

WisDOT DTSD XX Region, Local Program Project Manager

(For a working file of this template: FDM 11-4 A10.8 File 1)

CORRESPONDENCE/MEMORANDUM _____**State of Wisconsin**

Date: _____, 20xx

To: (Name)_____

WisDOT DTSD XX Region, Local Program Project Manager

From: (Name)_____

_____ - Local Public Agency

Subject: DESIGN STUDY REPORT

Project I.D. (design)_____

(CTH, Local (choose one)) _____,

Bridge # (if applicable)

_____County

Having considered the economic and social effects of this project, its impact on the environment, and its consistency with the goals of community planning, we recommend your concurrence of the attached design study report.

Recommended:

_____ _____

Name, PE Date

Local Public Agency

Are there any Design Justifications included in this DSR? Yes ☐ No ☐

Concur:

_____ _____

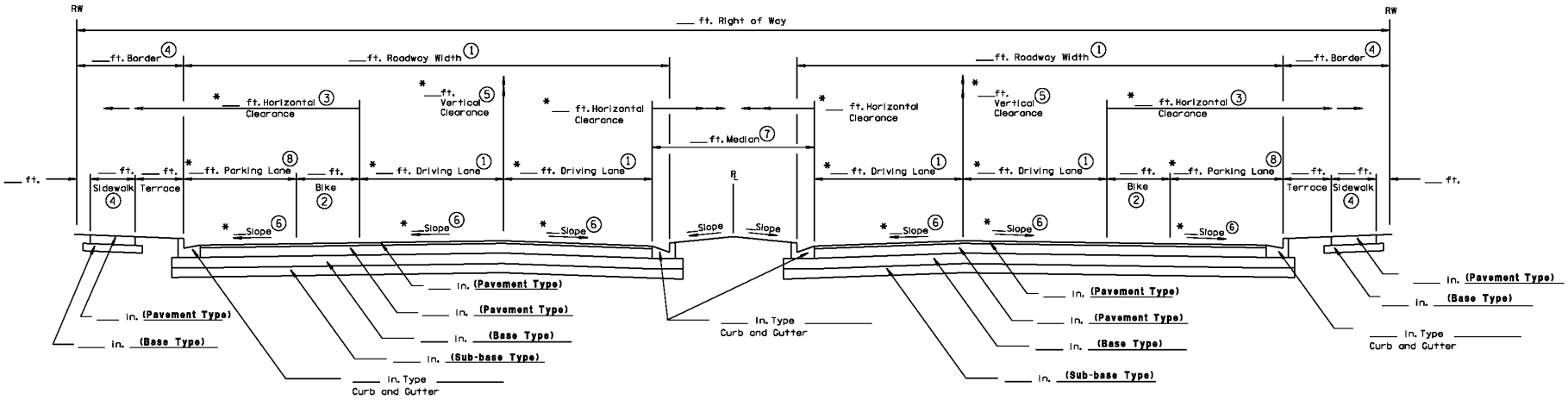
Name, PE Date

WisDOT DTSD XX Region, Local Program Project Manager

_____ _____

Name, PE Date

WisDOT DTSD BPD, Design Standards and Oversight Chief



(EXISTING OR PROPOSED) **URBAN CROSS SECTION FOR** (ROADWAY NAME)

Sta. _____ **to Sta.** _____

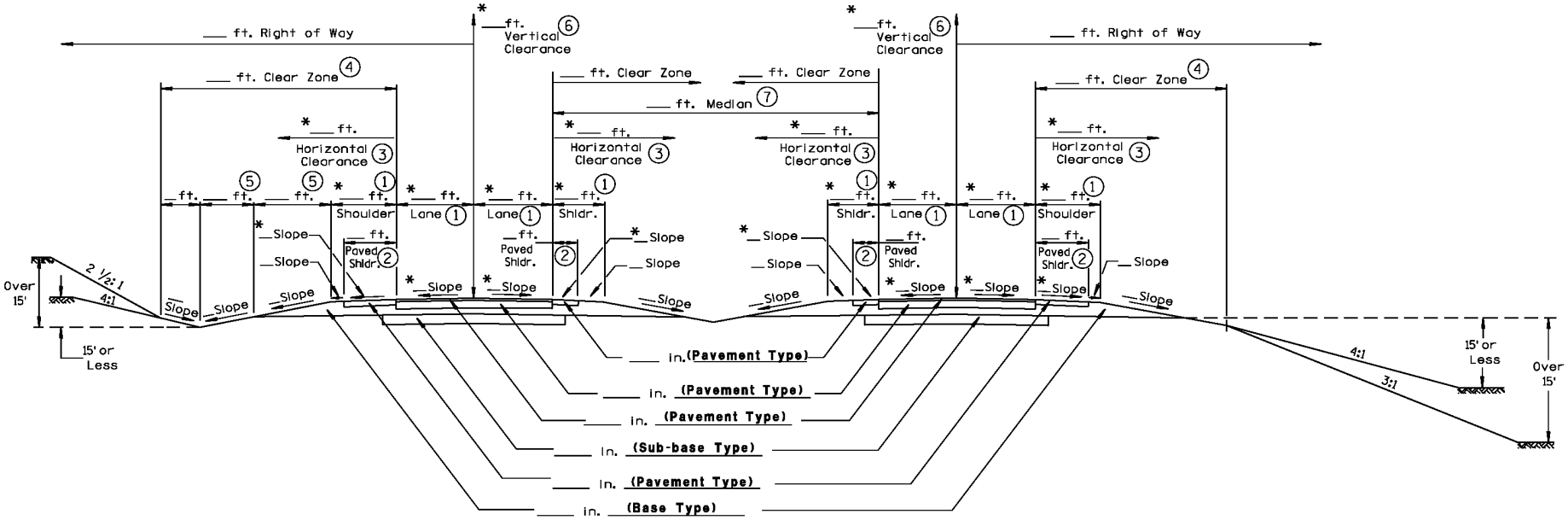
Improvement Type: _____

Design Class 4

* CONTROLLING CRITERIA

1. SEE FDM 11-20 ATTACHMENT 1.1.
2. SEE FDM 11-46-15.
3. SEE FDM 11-20 TABLE 1.5.
4. SEE FDM 11-46-05.
5. SEE FDM 11-35 ATTACHMENTS 1.8 AND 1.9.
6. SEE FDM 11-20 TABLE 1.1.
7. SEE FDM 11-25-1 AND FDM 11-45-2.
8. SEE FDM 11-20 TABLE 1.4.

4-LANE URBAN DESIGN CLASS 4 WITH PARKING



(EXISTING OR PROPOSED) **CROSS SECTION FOR** (ROADWAY NAME)

Sta. _____ **to Sta.** _____

Improvement Type: _____

Design Class: A3

* CONTROLLING CRITERIA

** 6 AND 8 LANE SIMILAR

1. SEE FDM 11-15 ATTACHMENTS 1.1 TO 1.4 AND 1.16 TO 1.18 AND FDM 11-40-2.
2. SEE FDM 11-15 ATTACHMENT 1.5 AND FDM 11-40 TABLE 2.1.
3. SEE FDM 11-15 TABLE 1.1.
4. SEE FDM 11-15 ATTACHMENT 1.9.
5. SEE FDM 11-15 ATTACHMENT 1.7.
6. SEE FDM 11-35 ATTACHMENTS 1.8 AND 1.9.
7. SEE FDM 11-15-1, MEDIAN SECTION AND FDM 11-45-1 MEDIAN BARRIER SECTION.

4-LANE RURAL CROSS SECTION**
DESIGN CLASS A3

FDM 11-5-1 Scope of Construction Projects

September 18, 1992

1.1 Discussion

Construction projects can frequently be organized into a series of separate contracts by major items of work or combined into "package" contracts. Some types of contract composition have proven to be more economical than others. It is generally beneficial to the State, and usually preferred by the contractors, to let separate contracts for each major type of work, i.e., grading, structures, base course, surfacing, or specialty work. When contracts include only items the contractors consider to be within their prime area of expertise, the savings are usually significant enough to warrant structuring projects around those abilities, whenever feasible.

The Region should develop an understanding and concurrence with the appropriate Central Office Design Coordinator on whether or not to package the project, early in the project's development.

Combinations of major work items into package contracts may be advantageous to the State when the project requires unusual considerations, such as complex traffic handling.

Combining box culverts or other small structures with grading work is desirable because of the closely interrelated scheduling of construction operations required.

Large structures should be let as separate contracts. Steel structures should be let to contract six months or more in advance of construction, to allow time for fabrication. When several small structures are to be built in the same general area, including those in adjacent Regions, they may be combined into one contract. Future construction project schedules should be examined to determine whether it would be advantageous to reschedule a project to the same fiscal year or otherwise make an adjustment to allow packaging the project.

The use of separate contracts also allows the opportunity to schedule contracts for letting at appropriate times, as may be required for stage construction.

Contracts for signing and signalization should be let at least six to nine months in advance of the anticipated installation date, to allow adequate time for fabrication. Normally, signing work should be let before the paving contract.

Urban highway and street projects should be let early enough in the year to assure that by the end of the construction season, the condition of the project is suitable to carry traffic during the winter months.

Asphaltic concrete paving contracts should not be scheduled for letting during the months of June through October. This is the period when paving contractors are busy with construction, there is a limited construction season remaining, bids are speculative and must reflect anticipated costs for the following year, and experience has shown that bids during this period are least favorable to the state. Off-season lettings for paving contracts allow the contractors ample time to prepare bids which normally results in more competitive bidding. Asphalt paving contracts should generally require completion of construction during the same calendar year as the fiscal year used for funding the project, i.e. during one construction season.

An economic advantage may be realized through utilization of the alternate proposal bidding procedures, as presented in Chapter 19 under Consideration of Proposals. By using the provisions contained in that procedure, the Department may solicit bids for project A, project B, and project A and B combined.

It should be emphasized that there is no substitute for engineering judgment and common sense. When there is any uncertainty, questions relating to contract format should be directed to the appropriate Central Office Design Coordinator.

FDM 11-5-2 Traffic Demand Forecasts

August 17, 2020

2.1 Traffic Forecasts General

This section discusses traffic forecasting including forecast uses, when a forecast is required, the types of forecasts, and how to request a forecast.

Traffic forecasts are used throughout the project life cycle in several ways, including but not limited to:

1. Determining appropriate highway and bridge design criteria.
2. Designing pavement structures.
3. Evaluating levels of service for improvement needs and project alternatives.
4. Analyzing environmental issues like air quality and noise.
5. Evaluating alternative alignments.

The Transportation Planning Manual (TPM) is a document that outlines traffic forecasting policies, procedures, data and travel demand model use. The TPM is maintained by the Traffic Forecasting Section. See TPM section 1.4 for a summary of traffic forecast requirements.

WisDOT completes two types of forecasts: *project-level* and *planning-level*.

Project-level traffic forecasts are developed or reviewed by the Traffic Forecasting Section. The TRAFFIC FORECAST REQUEST form (DT1601) shall be used to request a project-level forecast. The project schedule should allow sufficient time for the preparation of traffic forecasts as stated in the DT1601 form.

Consultants or Metropolitan Planning Organizations (MPO's) may complete traffic forecasts for State Highway projects in some rare instances, and in those instances the Traffic Forecasting Section shall review the completed forecast. The FORECAST REVIEW REQUEST form (DT1594) shall be used to request a traffic forecast review.

Planning-level traffic forecasts are developed by region staff with data maintained and provided by the Traffic Forecasting Section. Contact the appropriate WisDOT Region forecast liaison to request a planning-level forecast; TPM section 70.1. See the Planning-Level Forecast SharePoint page for more information.

Contact the Traffic Forecasting Section at DOTTrafficForecasting@wi.dot.gov with questions.

FDM 11-5-3 Highway Capacity

August 17, 2020

3.1 General

This chapter discusses the evaluation of highway capacity and Level of Service (LOS). The analysis of existing and future operating characteristics of a facility can be measured using Level of Service to provide an indication of the ability of the facility to satisfy both existing and future travel demand. Level of Service is a nationally recognized quantitative measure that is used to describe the quality of travel on a transportation facility. LOS can be measured for various travel modes that include automobile (autos, trucks, buses, and motorcycles), pedestrian, bicycle and transit modes. This FDM chapter will discuss LOS that applies to the automobile mode. In addition to LOS, there are other measures of effectiveness that can be used to enhance the evaluation of mobility needs for the automobile mode (see FDM 11.5-3.2.1).

The LOS measure is stratified into six letter grades, "A" through "F" with "A" representing excellent operating conditions with traffic flowing freely and "F" representing extremely congested conditions. The capacity of a roadway represents the maximum number of vehicles that can pass a point on a roadway in a given amount of time. Each roadway type has a defined method for assessing capacity and level of service, which is based on a set of performance measures. For example, LOS on a freeway is characterized by the traffic speed, proximity to other vehicles, and the freedom to maneuver within the traffic stream. LOS on a rural two-lane highway is defined by the traveler's speed and the ability to pass slower moving vehicles. LOS on urban arterials is defined by the average travel speed, which includes delay incurred at the controlled intersections.

When evaluating the LOS and capacity of a highway, follow the procedures in the 'Highway Capacity Manual 6th Edition' (HCM6): A Guide for Multimodal Mobility Analysis, published by the Transportation Research Board. For further information on how to obtain this document, write or call:

Transportation Research Board Business Office
500 Fifth Street, NW
Washington, D.C. 20001
(202) 334-3213
www.trb.org

Other references on capacity and LOS include: (1) "A Policy on Geometric Design of Highways and Streets," AASHTO 2011. (2) "A Policy on Design Standards Interstate System", AASHTO 2005.

3.2 Congestion and LOS

3.2.1 Congestion and Facility LOS

The LOS thresholds shown in Table 3.1 are considered desirable degrees of design year congestion on Wisconsin facilities. Facilities are lengths of freeways, multilane highways, two-lane highways and urban streets, which are defined by two endpoints. Table 3.1 does not apply to controlled intersections. Intersection LOS is discussed below in subsection FDM 11-5-3.2.2.

When substantial portions of a facility have a current or projected LOS that is more congested than that shown in Table 3.1 the Department may consider improving the LOS preferably through incremental improvements or capacity expansion. Table 3.1 provides desirable LOS values; however, it may not always be feasible to improve congested facilities to the desirable LOS values shown. For example, consider the case where the primary purpose of an improvement project is system preservation. During the scoping phase of this project it is determined that the design year LOS exceeds the desirable LOS threshold. In this case, safety should be the primary reason to make improvements outside of the existing footprint. The Department may elect to address system preservation with no capacity expansion, due to financial, environmental, or community input considerations.

The Department intends to use the mobility performance information to guide State Highway System improvement planning efforts. Such improvements enhance the economy, reduce congestion, improve safety, avoid and minimize environmental impacts, and serve community objectives.

The designer should strive for the best operating performance conditions practical for the facility. A LOS and capacity analysis can be used by designers to assist in determining the design features, including roadway cross-section, which will allow a facility to operate at the desired LOS. There may be situations where an evaluation of capacity or operational improvements supports a higher quality of service due to safety and operational impacts. There may be other situations where an evaluation of capacity or operational improvement supports a lower quality of service due to environmental or economic considerations. When the study involves an evaluation of a highway expansion, adjustments to the LOS thresholds should be approved by the WisDOT Bureau of State Highway Programs, Program Development and Analysis Section. Coordination with FHWA should be made on any Interstate or NHS NEPA project that evaluates capacity improvement elements or expansion alternatives.

Although the LOS analysis and the Table 3.1 LOS thresholds should be part of the decision to consider capacity and operational improvements, there may be other mobility measures of effectiveness that could be used to demonstrate needs and enhance the roadway design, which include but are not limited to:

- Average Travel Speed
- Vehicle Density
- Hours and Cost of User Delay
- Queue
- Travel Time Reliability

In addition to these measures, there may be other operational and safety factors to consider when evaluating projects for capacity or operational improvements. These important factors listed below could also be considered when determining the purpose and need, or criterion to use for the alternative analysis evaluation in the environmental study.

- Projects being considered for system preservation where the LOS is within a reasonable range of the LOS threshold in the design year and the benefits of the improvements (related to factors such as operation and safety) are greater than the marginal cost of the improvements.
- Projects with substantial safety problems that may not be addressed by spot improvements.
- Short highway segments that provide lane continuity and logical connections to major facilities or areas.

The measures selected to evaluate the operational improvements should be consistent with a project's purpose and need. The environmental document should include an explanation of the measures selected to evaluate purpose and need as well as the criteria used to evaluate the alternative improvements.

***Table 3.1* Desirable Levels of Service**

STH Sub-System	Rural and Small Urban Areas [1]	Urbanized Areas [2] with Population > 50,000
C2030 Backbone and Connector Routes [3]	LOS C (≤ 4.0)	LOS D (≤ 5.0)
National Highway System (NHS) Routes [4] (Non-NHS Backbone and Connector Routes)	LOS D (≤ 5.0)	LOS D (≤ 5.0)
Non-NHS Routes [5] (Other Principal Arterials, Minor Arterials, Collectors and Local Functionally Classified Roads)	LOS D (≤ 5.0)	Mid LOS E (≤ 5.5)

The highest LOS thresholds are applied to the Interstate system routes and other Corridors 2030 system routes in recognition of their importance from a mobility and economic development perspective. The Interstate system within Wisconsin is included in the C2030 Backbone system. Wisconsin C2030 Backbone routes also include a number of other important freeways and expressways. On Corridors 2030 routes, "minimal to moderate" congestion is allowed. Some "severe" congestion is allowed on non-NHS routes in highly urbanized areas. See Table 3.2, which shows the relationship between the LOS alpha value and the numeric value.

3.2.2 Congestion and Intersection LOS

As with roadway facilities, designers should strive to achieve the best intersection level of service (LOS) that is practical given the local land use, economic, social, and environmental characteristics. The designer should aim to balance the level of service for all users of the intersection (e.g., vehicles, pedestrian, bicycles, etc.).

Where practical, on C2030 and NHS routes, strive to provide LOS D or better operations for all movements at the intersection (left, through and right turning movements for each approach) during the peak hours of travel. On non-NHS routes, where practical, strive to provide mid-LOS E or better operations for all movements at the intersection (left, through and right turning movements for each approach) during the peak hours of travel. Where it is not practical to achieve these levels of operation, a reduced LOS may be acceptable for minor street movements or major street non-through movements.

Common scenarios where a reduced LOS may be appropriate include, but are not limited to, the following:

- The minor street is not part of the State Trunk Network (STN)
- The 95th percentile queue for the movement with the reduced LOS is less than four vehicles, or approximately 100 feet, and will not block another major intersection or access point
- Nearby alternate routes are available for drivers to self-divert to a location with lower delay

---

[1] 23 USC 101 (a): "(33) URBAN AREA. The term ''urban area'' means an urbanized area or, in the case of an urbanized area encompassing more than one State, that part of the urbanized area in each such State, or urban place as designated by the Bureau of the Census having a population of 5,000 or more and not within any urbanized area, within boundaries to be fixed by responsible State and local officials in cooperation with each other, subject to approval by *the Secretary*. Such boundaries shall encompass, at a minimum, the entire urban place designated by the Bureau of the Census, except in the case of cities in the State of Maine and in the State of New Hampshire."

[2] 23 USC 101 (a): "(34) URBANIZED AREA. The term ''urbanized area'' means an area with a population of 50,000 or more designated by the Bureau of the Census, within boundaries to be fixed by responsible State and local officials in cooperation with each other, subject to approval by *the Secretary*. Such boundaries shall encompass, at a minimum, the entire urbanized area within a State as designated by the Bureau of the Census." https://www.gpo.gov/fdsys/pkg/USCODE-2012-title23/pdf/USCODE-2012-title23-chap1-sec101.pdf. The Wisconsin Urbanized Area Boundaries are found at:

http://wisconsindot.gov/Pages/projects/data-plan/plan-res/boundaries.aspx

[3] The Corridors 2030 Map is found at:

http://wisconsindot.gov/Documents/projects/data-plan/plan-res/corr2030.pdf

[4] The National Highway System Routes are found at:

http://wisconsindot.gov/Pages/projects/data-plan/plan-res/nhs.aspx

[5] The National Highway System Routes are found at:

http://wisconsindot.gov/Pages/projects/data-plan/plan-res/nhs.aspx

- The intersection is minor street stop-controlled and centered between two signalized intersections on the major street
- Fewer Impacts to other modes of travel (motorized and non-motorized).

An example of a case where a reduced LOS may not be appropriate includes movements at ramp intersections that impact the mainline Interstate or other freeway operations.

WisDOT will consider reduced LOS operations for specific intersection movements during the design year on a case-by-case basis to determine the most practical level of service. The Bureau of Traffic Operations will review the use of a reduced LOS for intersection or turning movement operations.

Describe the rationale for justifying and accepting the lower LOS for these intersection movements. Document the rationale and decision in the Design Study Report or other capacity evaluation reports (e.g., ICE report). WisDOT shall obtain FHWA acceptance for federally-funded new construction, reconstruction and projects that include capacity improvements, on the NHS or on intersections that can impact interstate movements, such as ramp terminals.

3.2.3 Converting LOS Letter Value to Numeric Value

Table 3.2 shows the relationship between the traditional alpha value for LOS and the numeric value for level of service at WisDOT. The LOS is converted from the alpha-character scale to a numeric scale in order to facilitate a more detailed comparison between segments and to compare segment values with threshold values.

Table 3.2 LOS Alpha/Numeric Value Comparison

LEVEL OF SERVICE (Alpha Value)	LEVEL OF SERVICE (Numeric Value)
A - (Excellent conditions)	1.01 to 2.00
B - (Very good conditions)	2.01 to 3.00
C - (Good conditions)	3.01 to 4.00
D - (Moderately congested conditions)	4.01 to 5.00
E - (Severely congested conditions)	5.01 to 6.00
F - (Extremely congested conditions)	≥ 6.00

The numeric value is calculated using the measure that defines the LOS alpha value. For example, the measure used to define LOS on basic freeway segments is density. For the basic freeway segment, the density range for a given LOS alpha value is equal to the numeric range shown in Table 3.2 (e.g., the density range for LOS E is > 35 to 45 passenger cars per mile per lane (pc/mi/ln) and equates to the numeric range of 5.01 to 6.00). Interpolation is used to calculate the numeric LOS value for a density value that falls between the density ranges for a given LOS alpha value, (e.g., a density of 40 pc/mi/ln is halfway between the LOS E minimum and maximum density range and equates to a numeric value of 5.50). The LOS F range can be difficult to estimate. Therefore, it may be appropriate to show a numerical value of 6+ for conditions that exceed the LOS F threshold.

3.3 Incremental Improvements for Non-Interstates and Non-Freeways

One of the most cost effective and safe ways to make highway improvements is through advanced planning and providing incremental improvements to the system. Evaluate incremental improvements for projects that include capacity improvements in the scope of work. Coordinate the evaluation of all phased alternatives with the region environmental staff as outlined in FDM 20-10.

In rural areas consider the following incremental improvements:

- Passing lanes - providing a passing lane on a two-lane rural corridor could improve the LOS. Passing lanes are advantageous where passing opportunities are limited because of traffic volumes, roadway alignment or a high proportion of slower vehicles. FDM 11-15-10 contains design criteria and guidance on potential locations for passing lanes.
- Truck climbing lanes.
- Turn lanes at intersections.
- Intersection sight distance impacts and geometric improvements.
- Vertical and horizontal alignment improvements,

- Widen lanes and shoulder improvements.
- Access Control.

In urbanized areas consider:

- Access control and review traffic operations at intersections.
- Adding left or right turn bays or extending the length of existing turn bays.
- Review island locations.
- Upgrade the signal timing and phasing.
- Upgrade signal equipment.
- Signal coordination and actuated signal control.
- Conversion to a one-way street, from two-way street.
- Selective removal of on-street parking.

3.4 Incremental Improvements for Interstates and Freeways

Evaluate incremental improvements for projects that include capacity improvements in the scope of work. The evaluation of phased alternatives should be coordinated with the environmental staff as outlined in FDM 20-10. Below is a partial list of potential improvements:

- Add auxiliary lanes between ramps.
- Lengthen exit or entrance ramps.
- Provide additional ramp lanes for turning movements at the ramp terminal intersection.
- Provide collector-distributor roads.
- Extend the length of weaving sections where possible.
- Where heavy volumes of bus or truck traffic exist, evaluate dedicated bus or truck lanes.
- Consider incident management sites to reduce congestion and delay.
- Implement appropriate ITS strategies.
- Part-time use of shoulder
- Travel Demand Management

Facilities which experience occasional severe congestion (such as routes with high flows a few days a year resulting from seasonal tourism or special events) may be candidates for temporary operational strategies such as enhanced motorist assistance patrols, deployment of portable variable message signs, or extra bus service. These mitigation strategies may forestall the need for high-cost capacity improvements for a number of years. Implementation of these measures may require coordination between the DOT, local officials, and the businesses or organizations that generate the extra-ordinary demand. Permanent operational strategies should be considered where recurrent congestion occurs.

3.5 Level of Service Analysis

Conduct a level of service analysis to evaluate the need for incremental improvements, or to determine if alternatives with additional lanes should be included in a project's range of alternatives. The following list provides examples of types of projects or project tasks that include a LOS analysis.

- Environmental analysis (EA, PEL, EIS) for a potential Major or Mega project
- A corridor study that includes an operational needs evaluation
- Traffic Impact Study (TIA)
- Intersection Control Evaluation (ICE) (See FDM 11-25-3 for further guidance)
- Project scoping when operational problems are projected to occur.
- Design Study Reports

The types of projects that do not require an operational analysis include, but are not limited to:

- activities that do not lead to construction
- utility installation
- activities included in the state's highway safety plan
- installation of noise barriers, fencing or pavement markings.

LOS can be measured for applications that range from the highly detailed to generalized planning applications. The design criteria tables in FDM 11-15-1 and FDM 11-20-1 contain planning level AADT thresholds that could be used for first glance planning applications. The AADT thresholds in the Arterial Design Criteria Tables in

FDM 11-15-1 are based on Highway Capacity Manual analyses using conservative data for typical 2-lane and multi-lane roadway configurations. The AADT and DHV thresholds in the Urban Streets Criteria in FDM 11-20-1 provide a general indication of when capacity improvements may be needed. These tables are based on the HCM arterial analysis using the assumptions provided. The dynamics of all the factors used in the urban LOS analysis makes the LOS of individual urban roadways complex and highly variable depending upon the geometric and traffic control conditions.

The WisDOT Meta-Manager model output provides LOS information using site-specific forecasts and roadway information that can be used for more specific planning level evaluation of the need for incremental and capacity improvements. The Meta-Manager mobility model output provides LOS information for existing and proposed traffic conditions under current roadway and geometric conditions. This LOS information is provided for through movements on mainline freeways, rural multilane highways, rural two-lane facilities and urban arterials. The Meta-Manager LOS information should not be used to analyze individual signalized intersections, connections with side roads and freeway ramps. The urban arterial analysis uses system averages for traffic signal timing characteristics and should only be used for a planning and preliminary design level analysis of the corridor. The LOS data, traffic forecasts and roadway conditions are stored in an excel table, within the mobility sheet, located in the "Meta Manager" folder on each Highway Region's local area network. The Meta-Manager document (\\mad00fpH\N8public\BSHP\Meta-manager data\Metadata.doc) provides more specific information about the location of the data and the LOS calculations. For questions about the Meta-Manager LOS information, contact the Bureau of State Highway Programs (See the contact information for mobility data on page 2 of the Meta-Manager document).

WisDOT supported traffic analysis software should be used for more specific traffic analysis or design applications. See TEOpS 16-10 for an overview of available traffic analysis tools that can be used to evaluate traffic operations on WisDOT facilities and intersections. The use of the Highway Capacity Manual for the operational analysis of projects on the NHS is not required if another traffic analysis method is determined to be more appropriate by WisDOT to fully identify and evaluate the performance and impacts of the proposed project alternatives. (See FHWA May 6, 2016 LOS Letter https://www.fhwa.dot.gov/design/standards/160506.cfm).

If HCM or other or microscopic simulation analysis is performed for the evaluation and design of transportation improvement projects, a peer review process should be conducted. The Traffic Model Peer Review process is outlined in the Traffic Engineering, Operations and Safety Manual, Chapter 16, Section 25 (TEOpS 16-25).

Traffic analyses can be conducted by WisDOT, consultant, or local unit of government trained in the use of the Highway Capacity Analysis methodology. In general, begin a traffic analyses by evaluating the existing operation of the project using existing data collected in the field such as traffic volumes, roadway geometrics, traffic control operations (i.e., signal timing plans) and other features (i.e. parking stalls and maneuvers, driveway operations, etc.). Once the existing traffic analyses are calibrated and the results are validated, the existing traffic analyses can be modified to model future traffic volumes, operations and geometric improvements to meet an agreed to level of service.

The level of service analysis of a facility should consider traffic characteristics, roadway conditions, and control conditions of the facility.

3.5.1 Design Hour Volume

The level of service analysis focuses on the existing or projected traffic along a highway or intersection during a particular peak hour. The amount of traffic occurring during this hour is called the Design Hour Volume (DHV). The DHV is one of the most important criterion used in the level of service evaluation. The selection of an appropriate hour for planning, design and operational purposes is a compromise between providing an adequate LOS for most hours of the year and providing economic efficiency. Document the rationale and supporting data for determining the DHV in the DSR or capacity evaluation report. Refer to FDM 11-5-3.5.1.1 for guidance with WisDOT DHV approval on Wisconsin facilities. FHWA approval of the DHV should be requested for federally-funded new construction and reconstruction projects on the NHS.

3.5.1.1 Design Hour Volume for Freeways, Multilane Highways, and Two-Lane Highways

WisDOT policy is to use the 30th highest hour volume of the year as the Design Hour Volume for mainline freeways, mainline multilane highways, and rural two-lane facilities. The 30th-highest design hour may be used when the facility has a small number of hours in the year with higher volumes and has many hours that experience only a small reduction in volumes. However, in cases where traffic patterns are significantly different, other design hour volumes can be justified.

For example, there may be circumstances where the 30th highest design hour is not realistic to use because of exceptionally high hourly volume peaking characteristics. These conditions may occur on routes with a higher level of recreational traffic or routes that are in close proximity to a stadium, seasonal shopping mall or other special event traffic generator. These routes tend to have higher volumes on a few select weekends or in other

peak periods, and traffic during the rest of the year has much lower volumes, even during the week-day commute times.

A higher design hour may be justified when the LOS using the 30th highest design hour cannot be achieved because of social and environmental constraints, or if the project is financially cost prohibitive. When higher design hours are justified, the LOS evaluation should also consider the 100th highest design hour for rural or small to medium urban areas and 200th or 250th highest hour for highly urbanized areas (>200,000 population) with heavy daily traffic. Higher design hours (e.g., 200th or 250th highest hours) may also be justified in urban areas where there is usually little difference between the 30th and the 200th or 250th highest hour. In urban areas, a higher design hour may be justified to be consistent with daily AM or PM peak periods.

A project specific evaluation of the appropriate design hour and associated volumes must be made for all LOS evaluations on projects that include lane additions for a roadway facility. The design hour evaluation should be made by analyzing the traffic volume data from the most applicable continuous traffic count site locations. Additionally, other data sources may be used to supplement the determination of the design hour volumes. A summary of the findings, recommended design hour, and associated volumes should be reviewed and approved for those projects that include lane additions, by the WisDOT project team, in conjunction with the Bureau of State Highway Programs, the Bureau of Traffic Operations, and the Traffic Forecasting Section. The Federal Highway Administration must approve deviations from the 30th highest design hour on interstate projects.

The traffic forecast provides the annual average daily traffic (AADT). The K factor and the design hour directional distribution (D) are located on the Traffic Forecast webpage. The K factor is defined as the design hour volume divided by the annual average daily traffic (AADT) that occurs for the design year. Refer to FDM 11-5-2 for guidance on how to obtain traffic forecasts.

If the directional design hour volume (DDHV) is to be computed using the K factor, one of the following formulas can be used:

$$DDHV = AADT * K_{(both\ directions)} * D$$

Where:

DDHV = directional design hour volume (veh/hr)

AADT = annual average daily traffic in both directions (veh/day)

$K_{(both\ directions)}$ = proportion of AADT occurring in the design hour for both directions combined

D = proportion of traffic in the highest direction during the design hour

If the analysis of DDHV includes data from continuous count site locations, the K factor may be computed by direction rather than for both directions.

$$DDHV = AADT * K_{(one\ direction)}$$

Where:

DDHV = directional design hour volume (veh/hr)

AADT = annual average daily traffic in both directions (veh/day)

$K_{(one\ direction)}$ = proportion of AADT occurring in the design hour for one direction only

3.5.1.2 Design Hour Volume for Urban Streets, Intersections and Ramp Terminals

The design hour volume used for a detailed analysis of urban arterials, intersections, ramps, and ramp terminals should be based on the AM or PM peak hour volume for individual turning and through movements. In some cases where significant traffic is occurring on the weekend or mid-day, it may also be appropriate to consider mid-day peaking. In urban corridors, directional traffic patterns and intersection turn volumes are seldom the same in the AM and PM peak hours, so it is usually necessary to analyze the traffic operations for at least two different time periods. Additionally, other data sources may be used to supplement the determination of the design hour volumes.

The traffic forecast provides the AADT and turning movement projections for intersections if needed. The K factor and the design hour directional distribution (D) are located on the Traffic Forecast webpage. Refer to FDM 11-5-2 for guidance on how to obtain traffic forecasts.

3.5.2 Peak Hour Factor (PHF)

The peak hour factor is the ratio of the total hourly volume to the rate of flow during the highest 15-minute period within the hour and is computed by the following equation.

$$PHF = \frac{V}{4\ x\ V_{15}}$$

Where:

PHF = peak hour factor

V = hourly volume (veh/h)

V_{15} = volume during the peak 15 minutes of the analysis hour (vehicles in 15 min)

After the PHF is calculated, it can be used to convert a peak hour volume to a peak hour flow rate (v), using the following formula:

$$v = \frac{V}{PHF}$$

The PHF for controlled intersections is calculated at the intersection level and then the intersection PHF is applied to each of the movements.

3.5.2.1 Facility Segments

The PHF for the existing conditions can be based on existing field data. If field data does not exist, the recommended HCM default can be used. For design year conditions use a PHF of 1.0.

3.5.2.2 Intersections

In most cases, use the PHF derived from the existing field data for intersection LOS analyses. If the existing field-derived PHF is less than 0.92 (the recommended HCM default), however, it may be appropriate to utilize a higher PHF for the analyses of design year conditions. Use of any value other than the field-derived PHF requires coordination with and approval from the regional traffic engineer or the Bureau of Traffic Operations.

In general, apply the PHF to all turning movements and approaches at the intersections. In those cases where one approach to the intersection has significantly different peaking characteristics than the rest of the intersection (e.g., one approach provides direct access to a school), coordinate with region traffic operations or BTO to determine whether it is appropriate to use a different PHF for that one approach.

3.5.3 Percent Heavy Vehicles in the Design Hour

In general, the percentage of trucks in the design hour is lower than the percentage of trucks over an average day. This lower percentage is because there is a higher percent of total vehicles in the design hour. Sometimes trucks try to avoid traveling in peak conditions, thus care must be taken when estimating heavy trucks.

Mainline design hour truck percentages can be found at http://wisconsindot.gov/Pages/projects/data-plan/traf-fore/default.aspx.

3.5.4 Driver Population Factor

The capacity can be adjusted to account for unfamiliar drivers in the traffic stream, using the capacity adjustment factor (CAF). In general, the factor for driver population should be set to 1.0, which assumes the traffic stream is comprised of regular drivers. A lower number may be justified if sufficient empirical data is used to support that a significant amount of the drivers are unfamiliar with the corridor. In those cases where the corridor contains a higher percentage of recreational or unfamiliar drivers, the driver population factor should range between 0.9 and 1.0.

3.5.5 Rural Roadway Conditions

Capacity and LOS on rural highways are at a minimum affected by the following:

- Number and widths of travel lanes
- Shoulder widths
- Percent no-passing zones
- Number of access points or interchange density per mile

- Terrain type
- Free flow speed

Wisconsin highways use only the level and rolling terrain classifications. Level terrain generally includes corridors that contain grades of no more than 3 percent. These corridors include any combination of horizontal and vertical alignment permitting heavy vehicles to maintain approximately the same speed as passenger cars. Within level terrain corridors there may be isolated sections on two-lane highways that require climbing lanes to mitigate the speed variance between passenger cars and trucks. Rolling terrain generally includes grades of significant length greater than 3 percent grade and will cause heavy vehicles to reduce their speed substantially below the speed of passenger cars. Typically, rolling terrain corridors are similar to those found near the Wisconsin River Valley, in the southwestern part of the State. Mountainous terrain is not used in Wisconsin. The Meta-Manager database provides an estimate of segments with rolling terrain that can be used for a planning level analysis.

3.5.6 Urban Roadway Conditions

Capacity and LOS on urban streets are at a minimum affected by the following:

- Presence of exclusive turn lanes.
- Number and lengths of exclusive turn lanes.
- Presence of medians.
- Level of access control.
- Presence of parking and bus stalls and frequency of maneuvers within those stalls.
- Number and widths of travel lanes.
- Free flow speed

3.5.7 Intersection Control Conditions

Capacity and LOS at an intersection will be affected by as the following control conditions:

- Type of intersection control (stop condition, traffic signals, or roundabouts).
- Traffic signal timing characteristics and level of coordination between adjacent traffic signals or within a system of traffic signals.

Refer to FDM 11-26 for guidance on roundabouts. Refer to FDM 11-50-50 for guidance on traffic signals or the "Traffic Signal Design Manual" (TSDM). The Region traffic personnel typically use the TSDM.

3.6 Level of Service Evaluation for Environmental Documentation

The design year LOS and supporting information shall be completed for highway improvement projects that involve the following environmental documents:

- Environmental Report (ER)
- Environmental Assessment (EA)
- Environmental Impact Statement (EIS).

A traffic summary matrix (refer to Basic Sheet 4, Traffic Summary Matrix found at https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/environment/formsandtools.aspx) is required for projects that require a ER or an EA.

The environmental evaluation should be coordinated with the region environmental staff as outlined in FDM 20-10.

The Meta-Manager model output can be used to determine the LOS under existing conditions and proposed conditions for environmental documents, when no substantial geometric or operational changes are proposed. For example, the Meta-Manager output should not be used to determine the project's LOS when adding or reducing the number of thru lanes, adding or eliminating medians or two-way left turn lanes (TWLTLs), adding or eliminating left or right turn lanes, adding or removing parking lanes, installing or retiming traffic signals, improving signal coordination, and significantly adding or eliminating the number of access points. (See the previous Level of Service Analysis section of this FDM chapter for the location of the Meta-Manager LOS data).

Projects that include significant geometric or operational changes should have a project specific traffic analysis completed to determine the LOS. The following section on Traffic Analysis Software provides guidance on the appropriate analysis software that could be used for those evaluations.

3.7 Traffic Analysis Tool Selection

The following provides a general overview of the available traffic analysis tools. Guidance on selecting the

specific traffic analysis tool software is available in the Traffic Engineering, Operations, and Safety Manual, Chapter 16, Section 10 (TEOpS 16-10).

3.7.1 Overview of Available Analysis Tools

Several traffic analysis tools are available to assist transportation professionals in evaluating traffic operations on WisDOT facilities. Most studies, including traffic impact analysis, intersection control evaluations, traffic signal timing, design reports, turn lane warrant assessment, work zone delay analysis, corridor studies, and system level analyses include an evaluation of operational conditions.

There is no "one size fits all" traffic analysis tool. The tools used for each analysis vary in their data requirements, capabilities, methodology, and output. Tools that are more powerful require greater time and effort, so it is important to match the analysis methods with the scale, complexity, and technical requirements of the project. A project may require the use of a combination of multiple traffic analysis tools. Document the rationale for choosing the selected traffic analysis tool(s) in the Traffic Analysis Tool Selection memoranda and submit to the WisDOT regional traffic staff for approval.

3.7.2 Capacity Analysis

WisDOT accepts the use of HCM6, methods in order to meet the planning, operational, and design analysis needs of most traffic studies. For project analysis initiated prior to November 2017, it may be acceptable to continue to follow the HCM 2010 methodologies for the duration of the project. Coordinate with the regional traffic engineer or BTO-TASU to verify whether to continue using the HCM 2010 methodologies or whether to update to the HCM6 methodologies.

The methodologies of the HCM should be the primary way of determining the performance measures required for a variety of traffic study projects reviewed or commissioned by WisDOT. Refer to TEOpS 16-15 for additional guidance on the specific methodological components for the core facility types addressed by the HCM.

Analysts should recognize and account for the limitations of the HCM methodology. When the analysis falls outside the confines of the HCM methodology, the project manager should specify the use of an alternative tool, such as microsimulation. Refer to TEOpS 16-20 for additional guidance on the use of microsimulation.

3.7.3 Model Calibration and Validation

All traffic analysis tools require some degree of calibration and validation to assure that their outputs match actual field conditions. For both deterministic and simulation tools, WisDOT supports changes to default and input parameters to best replicate observed conditions. For example, TEOpS 16-15 provides guidance on adjustments to saturation flow rate and right-turn on red parameters for HCM-based deterministic analysis of traffic signals. Calibration is particularly important in microsimulation models, where there are many assumptions and parameters that can affect the simulation. Provide clear documentation of the model development and calibration process to identify the model input parameters and any adjustments made to default values to reflect field measured or otherwise expected conditions.

Calibration and validation is essential for the validity of the analysis process and the project manager should assure that the project schedule and budget devote sufficient time and resources to this crucial step. Additional guidance on the calibration and validation of microsimulation models is available in TEOpS 16-20.

To ensure the integrity of the calibration process and model results, the region shall conduct a peer review of all traffic models (microsimulation and deterministic models) as outlined in the TEOpS 16-25.

FDM 11-5-5 Access Control

May 15, 2019

5.1 Introduction

According to the TRB Access Management Manual[6], "Access management is the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway. It also involves roadway design applications, such as median treatments and auxiliary lanes, and the appropriate spacing of traffic signals. The purpose of access management is to provide vehicular access to land development in a manner that preserves the safety and efficiency of the transportation system."

Both the AASHTO GDHS and the TRB Access Management Manual describe Access Management Principles:

[6] See p.3 in (*1)* Introduction and Concepts. In *Access Management Manual* Transportation Research Board, 2003, ch. 1, pp.3-11.

***Table 5.1* Access Management Principles**

AASHTO[7]	TRB[8]
Classify the road system by the primary function of each roadway Limit direct access to roads with higher functional classifications Locate traffic signals to emphasize through traffic movements Locate driveways and major entrances to minimize interference with traffic operations Use curbed medians and locate median openings to manage access movements and minimize conflicts	Provide a specialized roadway system Limit direct access to major roadways Promote intersection hierarchy Locate signals to favor through movements Preserve the functional area of intersections and interchanges Limit the number of conflict points Separate conflict areas Remove turning vehicles from through-traffic lanes Use nontraversable medians to manage left-turn movements Provide a supporting street and circulation system

See FDM Chapter 7 for additional guidance on Access management and control.

5.2 State Access Management Plan (SAMP)

Chapter 9 of WisDOT's Connections 2030 Statewide Long-Range Transportation Plan revised the State Access Management Plan (SAMP) and increased the number of tiers from two to five. All STH routes are assigned to one of the tiers.

- Tier 1 maximizes Interstate/Statewide traffic movement
- Tier 2A maximizes Interregional traffic movement
- Tier 2B maximizes Interregional traffic movement
- Tier 3 maximizes Regional/Intra-urban traffic movement
- Tier 4 balances traffic movement and property access

See FDM 7-5-1 for additional guidance.

5.3 Spacing

These guidelines are intended as a tool in relating access to facility type, functional type, and traffic volume of both the route under study and intersecting routes. Attachment 5.1 shows rural arterial access spacing. The access spacing determined from Attachment 5.1 is the minimum distance between that intersecting facility and adjacent similar type or higher type access points (private, public, at-grade, or interchange) without regard to functional classification of the adjacent access points.

Refer to FDM 11-30-1 regarding ramp terminal spacing

Urban charts are not part of this guide. Since urban areas are unique, other controls such as existing development and street spacing usually require varying degrees of access. See FDM 11-25-2 for guidance on corner clearance to driveways. See FDM 11-25-2, FDM 11-25-5 and FDM 11-25-20 for guidance on median openings.

Also, no recommendation is given for "Routes Under Study" functionally classified lower than arterial. Lower classified routes vary considerably.

Consider the possibility of changes in the degree of access control of a highway whenever modernization is contemplated. The investigation should consider both the immediate effects of changes and the impact of future

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[7] See p.90 in (*2) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[8] See pp.7-10 in (*1)* Introduction and Concepts. In *Access Management Manual* Transportation Research Board, 2003, ch. 1, pp.3-11.

development. Changes in land use patterns and intensity that occur during the ultimate life of the right-of-way will have a great effect upon the traffic patterns and highway obsolescence. It is desirable to control access according to conditions expected to exist during the latter part of the road's life expectancy.

By 2010 Wisconsin communities, including counties, should have adopted comprehensive plans which are required in order to make valid local zoning and land division decisions. Public utilities base their plans for future expansion of services on predicted population growth and movement. All of these are good sources of information about the future land uses that could affect state highways.

The proximity of adjacent intersections to locations that are or may be signalized should be maintained at a minimum of 1200-ft, unless a greater distance is shown in Attachment 5.2. See Traffic Signal Design Manual (TSDM) at:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/tsdm/tsdm.aspx

5.4 Intersecting Roadways

Determine the extent of access control to apply around intersecting roads. The degree and length of this control depends, for the most part, on the design of the intersection (stop or free-flow design), traffic volumes using the intersecting highway, and traffic generated by the adjacent property. Factors generally considered are the number and speed of vehicles approaching an intersection and the conditions of entrance to the major highway (i.e., stop, yield, unmarked). Other considerations may include intersection sight distance and vision corners addressed in FDM 11-10-5; or functional area and corner clearance addressed in FDM 11-25-2. Further extension or expansion of access control along intersecting roadways must be evaluated on a project-by-project basis.

5.5 Interchange Areas

Interchanges are expensive to build and to upgrade. Therefore, it is essential that they be designed and operated as efficiently as practical. To preserve their intended function, adequate geometry at ramp termini and appropriate access control along the crossroads are essential.

Many older interchanges have been designed with only limited access control on the intersecting crossroad. As a result, considerable development may occur near the intersection of the ramp terminus and the crossroad. Over time, such ramp termini, as well as several nearby access connections, may require signalization or roundabouts, thereby causing increased delay on the crossroad.

In urbanized areas, high turning volumes and close spacing between adjacent ramp termini and access connections can create operational problems on the crossroad that can cause; extensive queuing, delay, heavy weaving volumes, and poor traffic progression. Ultimately, these types of problems at the ramp termini can affect traffic on the ramp and may cause spill back onto the mainline freeway. These problems consist of queue spillback, stop-and-go travel, heavy weaving volumes, and poor traffic progression.

To ensure efficient operations along the crossroad at an interchange, adequate lengths of access control need to be a part of the overall design of an interchange. This minimizes potential for queue spill back on the ramp and cross road approaches to the ramp terminus. Increased spacing between access points will also provide adequate distances for weaving on the crossroad, provides space for merging maneuvers, and provides space for storage of turning vehicles at access connections on the crossroad.

Access control at interchanges should be coordinated with local zoning authorities.

For additional guidance, see pp. 749-752 of the AASHTO GDHS[9], “Access Separations and Controls on the Crossroad at Interchanges.”

5.5.1 Access Control on Interchange Crossroad

Access control at an interchange along the crossroad shall comply with Table 1 of Attachment 5.2, but not be less than intersection corner clearance as defined in FDM 11-25-2.

- Do not allow new access between the interchange ramp and the public road.
- If private access already exists on the crossroad between the ramp and the public road, evaluate the potential cost of either removing that access or restricting it to right-in, right-out only. It may be justifiable to allow interim access until the access use changes or until the traffic volume from the access point justifies a higher level of intersection control than a stop condition. The access is then re-evaluated for removal. Consider what costs and impacts there may be if it is necessary to go back at

[9] (*2) A Policy on Geometric Design of Highways and Streets 2004,* 5th edition. AASHTO, 2004.

some time in the future and acquire or close access due to serious operational problems. Do not allow a median opening between the interchange ramp and the Public Road.

- Do not allow access on the cross road in the transition area (merge or diverge condition) from 4-lanes down to 2-lanes.

Refer to the Transportation Research Board, Access Management Manual 2003, pages 158-162, for additional guidance on interchange area management.

5.5.2 Access Control Along an Expressway at an Interchange

Access control at an interchange along an expressway shall extend from the merge/diverge point of entrance/exit ramps as shown in Attachment 5.2 and shall comply with the distances shown in Table 2 of Attachment 5.2.

5.6 Traffic Impact Analysis

On both expressways and their cross roads, an approved traffic impact analysis is required to justify a less-than-upper range distance of access control. This analysis shall be included in the project file. Consider the following factors when evaluating access control distance:

1. Mainline, ramp and side road projected design year AADTs, including turning movements to and from the side road.
2. Intersection geometry, including turn lane lengths
3. Weaving and deceleration distances.
4. Posted speeds
5. Sight distance (horizontal and vertical)
6. Intersection sight distance
7. Zoning
8. Estimated cost of real estate acquisition to achieve access control,
9. Estimated cost of roadway improvements to achieve access control

5.7 References

1. TRB Committee on Access Management (ed.). Introduction and Concepts. In *Access Management Manual*. Transportation Research Board, Washington, DC, 2003, ch. 1, pp. 3-11.

2. *A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, Washington, DC, 2004.

LIST OF ATTACHMENTS

Attachment 5.1 Access Spacing Guidelines

Attachment 5.2 Access Control for Typical Interchange

FDM 11-5-10 Earthwork

August 17, 2020

Careful consideration of the design elements affecting earthwork quantities and distribution is necessary for both economic and environmental reasons. (See FDM 19-7-1 for guidance on rock excavation.)

10.1 Preliminary Design

During the preliminary design phase several alternative grade lines and alignments should be evaluated. Earthwork quantities, including the required distribution of earthwork, should be developed for each alternative. It is desirable that the final alternative chosen result in balanced earthwork quantities, but this is not always feasible because of other controlling factors.

For urban projects the primary consideration is to minimize property damage by designing the street or highway to match, as nearly as possible, the elevations of the adjacent development. Because of this requirement earthwork may have to be wasted or borrowed.

For rural projects an alignment and grade line can often be developed that will satisfy the principal controlling features (e.g., clearance under structures, meeting crossroad elevations, adequate fill height over marsh, adequate drainage ditches, etc.) and yet provide balanced earthwork quantities. Design of the grade line should

include a detailed analysis of earthwork distribution considering haul lengths, haul direction, and the capabilities of typical earthmoving equipment. Distances to potential borrow or waste sites should also be considered.

10.2 General Considerations

In general, long cuts and fills should be avoided, as larger and more expensive grading equipment becomes necessary for efficient earthmoving operations. Track or wheel type bulldozers are most efficient when material is moved less than 200 feet or steeply downhill. For longer hauls scrapers become necessary. Very long hauls or hauls on public highways require the use of dump trucks loaded by front-end loaders, power shovels, or belt conveyors.

Analysis of earthwork distribution, including the locating of earthwork divisions and the plotting of a mass diagram, can be accomplished by computer methods. The mass diagram can be a valuable tool in the planning or understanding of a grading operation, as it provides a convenient graphic display of cumulative volume over an entire project. It is not necessary to include the mass diagram in the plans, but the earthwork divisions and mass ordinates should be shown.

Design of grading projects must include provisions for the removal of undesirable or loosely compacted materials. Undercutting the mouths of cuts should be specified to remove the topsoil and humus material, which if left could result in settlement or frost heave in the transition from cut to fill.

Similarly, other sections of the grade may contain material that should be removed to assure adequate compaction can be achieved. Excessively wet or supersaturated soil should be removed and placed where it can be drained. The material itself may be adequate once it is dry.

The shaping and rounding of cut slopes should always be specified, especially in the transition to fill, as this significantly improves the highway's appearance and is less susceptible to erosion.

10.3 Project Scheduling

Earthwork issues must be analyzed carefully whenever a grading project is built in stages. There are times when the earthwork quantities for an overall project will either be in balance or be a waste project. In either case the overall project does not require borrow material. If, however, the project is built in stages, there may not be enough cut material available to meet the fill needs of a particular stage. Designers must evaluate the cut-versus-fill situation for each stage of the overall project.

10.4 Total Volume Concept for Project Earthwork.

The Department employs the “Total Volume Concept” for project earthwork. For earthwork purposes, the project is considered a single entity unless physical barriers (such as river crossings, railroads, highways and etc) or staging needs require separation into two or more divisions. Within each division, the total excavation volume is compared to the total embankment volume to determine borrow volume or waste volume for that division. Payment for all excavation and for all borrow within a division is at the established unit cost with no adjustments for haul distances. This concept involves:

1. A running total of earthwork volume showing excess or deficiencies is included in the plan. This is done on the earthwork data sheets immediately preceding the cross sections on a plan. (an EXCEL spreadsheet: FDM 11-5 File 1)
2. No balance points or references to these are shown in the plan. If a project has two or more divisions, each division is identified in the earthwork data sheets and the earthwork summary sheet.
3. Borrow or waste volumes are determined by a summary of all earthwork demands within each specific division. Each determined division of the project is considered a separate entity. If a contractor elects to use the “waste” identified in one division as “borrow excavation” in another division, the contractor will be paid, both, “common excavation” in one division and “borrow” in the other division. **Note to the designer: the designer must specify in the special provisions if the contractor is prohibited from using the waste from one division as borrow in another division.**
4. The item of overhaul has been eliminated. If there are significant changes in conditions or character of work, the contractor may be justified in seeking payment for additional hauling cost under standard spec 104.2.2 (Issuing Contract Change Orders).
5. Grading operations are conducted in the manner that best fits the operational needs of the contractor while fulfilling contract requirements. This may include wasting common excavation in one portion of the project division and replacing it with borrow in another portion of that division. However, this does not change the contract borrow volume and the Department only pays for borrow needed in excess of suitable available excavation.

6. The engineer may authorize the contractor to obtain material for embankment construction from areas within the right of way, but outside of the grading limits. The Department will pay for borrow material obtained from within the project right-of-way limits but outside project excavation limits at a price determined under standard spec 109.4 (Price Adjustments for Contract Revisions).
7. Common excavation materials determined by the engineer to be unsuitable for the embankment construction will be wasted and replaced by borrow paid at the established unit price. If no item for borrow is included in the contract, payment will be as extra work.

10.5 Borrow

The designer should strive to eliminate or at least minimize the use of borrow because of its cost and potential to delay project completion. Contractors are required to pay increasingly higher prices for borrow material, especially in areas of the state where acceptable sites are difficult to find. Environmental, archaeological, and historical considerations can prevent the use of otherwise acceptable sites. Even with apparently acceptable borrow sites, there is the potential for delay of the excavation if significant archaeological or historical materials are uncovered. WisDOT has a cooperative agreement with the Wisconsin State Historical Society to advise them of any such finds. (See Chapter 20 for details of this agreement.)

Earthwork designs that result in small borrow quantities, say, less than several thousand cubic yards, should be avoided. Small borrow quantities often result in high unit bid prices; then if actual borrow quantities greatly exceed the estimates, the cost of the item becomes excessive.

10.6 Earthwork Quantities

Earthwork quantities should be included on each cross-section sheet unless a separate “Earthwork data” sheet, identified in FDM 15-1-40, is included in the plan.

10.7 Earthwork Computations

The end areas and volumes used in earthwork computations should be the end areas and volumes with all adjustment applied. The expansion and reduction factor for all earth materials should be obtained from the soils report for the project or from the regional soils engineer.

During the process of grading, rock excavation is normally the only excavation item that expands and occupies a greater volume in the fill than it did in its original location. Cut and borrow excavation shrinks and occupies less volume in the fill than it did in its original location.

The marsh expansion factor indicates the percent that the marsh excavation quantity should be increased to determine the amount of marsh backfill required. This factor accounts for; the shrinkage of the backfill material placed in the marsh, the displacement of the marsh during the excavation and backfilling process and one (1) foot of granular backfill or select borrow material placed above the marsh (if granular backfill or select borrow is specified).

If the marsh or EBS will be used as part of the embankment, the earthwork summary sheet should indicate the volume of marsh or EBS and the estimated reduction factor for the embankment. When marsh or EBS is used as part of the embankment, outside of the 1:1 slopes, the designer must include a construction detail identifying the area where the material is designated to be used. The soils engineer should be consulted to confirm that the marsh or EBS is suitable for use in the embankment and to provide the estimated reduction factor.

The following are some of the volume correction factors that are used in earthwork computations:

1. Fill Expansion (>1): applied to the true fill volume to account for only the shrinkage of the cut and borrow material placed in the embankment.
2. Rock Expansion (>1): applied to the rock excavation volume to account for the volume of rock material after it is excavated and placed in the embankment. Rock excavation expands as it is excavated to be used in the embankment. This may also be referred to as “rock swell”.
3. Marsh Backfill Expansion (Typically >1): applied to the volume of marsh that is excavated to account for; the shrinkage of the backfill material, the displacement of the marsh during the excavation and backfilling process, and one (1) foot of granular backfill or select borrow placed above the marsh (if granular backfill or select borrow is specified). This factor is used to determine the volume of marsh backfill that is required. This volume is used in the mass ordinate computations only if cut or borrow is used as backfill material. If select borrow or granular backfill is specified, then this volume is not used in the mass ordinate.
4. Marsh Reduction (<1): applied to the volume of marsh excavation to account for the true volume of marsh material after it is excavated and placed in the embankment. Marsh excavation shrinks

considerably as it goes from its natural state to its compacted state in the embankment. If marsh excavation is utilized in the construction of the embankment, it is typically used outside of the 1:1 slope and may be restricted in height of fill. The designer may elect to waste the marsh excavation, in which case this factor is not used in the earthwork computations.

5. EBS Backfill Expansion (>1): applied to the true volume of EBS to account for the shrinkage of the backfill material used to backfill the EBS. This factor is usually close to, or the same as, the fill expansion factor on a given project, depending on the backfill material specified. Frequently, this is assumed to be the same as the fill expansion factor and the EBS backfill volume may be computed separately or as part of the fill in the mass haul computations. If select borrow or granular backfill is specified for EBS backfill, then this volume is not part of the mass ordinate.
6. EBS Reduction (<1): applied to the true volume of EBS excavation to account for the reduced volume of EBS as it is placed in the embankment. EBS typically shrinks as it goes from its natural state to its compacted state in the embankment. The appropriate factor can vary widely depending on what type of EBS material is encountered on a project. If the material is utilized in the construction of the embankments, it is typically placed outside the 1:1 slopes and may be restricted in height of fill. The designer may wish to waste the EBS material, in which case this factor is not used in the earthwork computations.

There are two methods that are used to determine the volume of earthwork quantities. These two methods are referred to as the “shrink the cut” and the “expand the fill” method.

The “expand the fill” method of earthwork computations requires the user to visualize the fill as expanding in order to account for the actual shrinkage of the cut or borrow material placed in the fill. The fill does not actually expand. The expansion factor applied to the fill is an estimated value that accounts for the percent increase in the volume of cut or borrow excavation, as measured in its original location that is needed in the fill.

The earthwork calculations shall use the “expand the fill” method. The “expand the fill” method involves the following process:

Step 1

Determine the usable volumes of all excavation and fill materials as well as the expansion/reduction factors for each material.

Step 2

If rock excavation is present, expand the rock volume and deduct this from the unexpanded fill.

Step 3

If marsh excavation is present, <u>and</u> the excavated marsh will be used in constructing the embankment slopes, reduce the marsh excavation volume and deduct this from the remaining unexpanded fill.

Step 4

If EBS is present, <u>and</u> the EBS material will be used in constructing the embankment slopes, reduce the EBS excavation volume and deduct this from the remaining unexpanded fill.

Step 5

Expand the fill volume that remains after completing steps 2 -4.

Step 6

If marsh is present, expand the marsh excavation volume to determine the required volume of marsh backfill. If common or borrow is used to backfill the marsh, it is part of the mass ordinate. (Note: if select borrow or granular backfill is specified for marsh backfill, this volume is expanded to determine the volume of select borrow or granular backfill but is not used as part of the mass ordinate.)

Step 7

If EBS is identified, expand the EBS excavation volume to determine the volume of EBS backfill. If common or borrow is used to backfill the EBS, it is part of the mass ordinate. (Note: If select borrow or granular backfill is specified for EBS backfill, this volume is expanded to determine the volume of select borrow or granular backfill but is not used as part of the mass ordinate).

Step 8

Determine the remaining volume of cut, after the marsh or EBS is backfilled, by deducting the marsh or EBS backfill determined in steps 6 and 7 from the cut. (Note: if select borrow or granular backfill is specified for

marsh or EBS backfill, the marsh or EBS backfill does not affect the cut volume and would have a value of zero (0) in this equation).

Step 9

Determine the required borrow (minus value) or waste (plus value) by subtracting the expanded fill, determined in step 5 from the remaining volume of cut, determined in step 8.

Earthwork will normally be designed and computed using the Civil 3D earthwork process. However, it is recommended that, as a minimum, the designer perform manual computation checks at each segment and each earthwork division identified in the earthwork summary table in the miscellaneous quantities section of the plan.

Two examples of earthwork calculations are included in Attachment 10.1.

10.8 Excess Incidental Excavation

Excess excavation material from the construction of storm sewer, bridges, retaining walls, etc. should be placed in embankments if the material is suitable for that purpose. On projects where the quantity of unclassified excavation or borrow is small and excess incidental excavation is large, the designer should investigate the adequacy of the incidentally excavated soil for use as fill. If it is acceptable, show such quantities in the plan in the earthwork balance tables or earthwork summaries. If this material is not suitable for embankment construction, it shall be incorporated into the project or disposed of in accordance with standard spec 205.3.11.

10.9 Soil Compaction

Attachment 10.2 is a set of guidelines concerning soil compaction. It explains some of the factors which should be considered when choosing between standard compaction, special compaction, and QMP Earthwork for individual projects.

The Region Soils Section is responsible for analyzing soils and recommending the proper soil compaction inspection method for region designed projects. Region designers should confer with their soils unit to determine which method should be applied to individual projects. Consultants are responsible for analyzing the soils for the projects they are designing and for recommending the proper soil compaction inspection method to use.

10.10 Bridge Approach Embankments

Bridge approaches represent a special earthwork situation. They should be constructed using one of the techniques shown in Attachment 10.3. The recommended procedure is shown in Attachment 10.3, Detail A. The 10:1 slope will permit concrete trucks to approach the bridge site while the 20-foot section provides contractors with adequate room to use standard compaction equipment.

Attachment 10.3, Detail B is an alternative embankment construction procedure. It is best suited for sites having non-cohesive, uniform particle size granular materials. It calls for overfilling the abutment back slope, then cutting it back only that distance necessary to construct the abutment. If possible, this surcharge embankment material should be left in place for at least six months prior to bridge construction if the foundation material is compressible. Sheet piling may be needed to retain granular embankment material.

Designers should seek the advice of their region soils section concerning which method of approach embankment construction to use. Designers should provide their soils staff with tentative grades and foundation site information. Site soils reports should also be reviewed before making a decision.

10.11 Geosynthetics

10.11.1 General

Different types of geosynthetics, geotextiles and geogrids, are used in transportation projects for the following applications:

Table 10.1 Applications for Geosynthetics

GEOTEXTILES (type)		GEOGRID (type)
Subgrade Aggregate Separation (SAS)	Modified SAS(C)	Subgrade Reinforcement (SR)
Subgrade Reinforcement (SR)	Embankment Stabilization (ES)	Marsh Reinforcement (MR)
Riprap (R)	Heavy Riprap (HR)	Slope Stability Reinforcement (SSR)
Drainage Filtration (DF)	Marsh Stabilization (MS)	

Standard spec 645 includes bid items for various applications. Most of these bid items have complete specifications for typical applications, but several require project specific customization and are specifically designed to require associated special provisions.

10.11.2 Items Requiring Project Specific Customization

Designers need to consult the Regional Soils Engineer or Bureau of Technical Services Geotechnical Engineering Unit for assistance with the design of type MS, SR, and ES geotextiles; and for type MR and SSR geogrids. Modify the standard bid items for individual projects; do not develop SPV bid items.

Geotextile types MS, SR, and ES require a project specific special provision modifying the standard spec bid items to specify required material properties. In addition, other materials and construction provisions may be required to fit the individual project requirements.

Geogrid types MR and SSR require an STSP modifying the standard spec bid items to specify both materials and construction requirements. These STSPs contain the framework for additional contract requirements, but the designer must come up with the actual requirements.

- For Geogrid Type MR use STSP 645-024 "Geogrid Type MR"
- For Geogrid Type SSR use STSP 645-026 "Geogrid Type SSR"

LIST OF ATTACHMENTS

Attachment 10.1	Earthwork Calculation Examples
Attachment 10.2	Compaction of Soils
Attachment 10.3	Bridge Approach Construction Techniques

FDM 11-5-15 Select Materials in Subgrades

December 5, 2017

The following policy will be in effect for rural state trunk highway projects and urban freeway projects constructed after 2006. In the interim, designers are encouraged to use this policy on a selective basis on applicable projects. However, funding for such applications of select materials must come from established project allocations or from other region program allocations. This policy will not affect the common practice of ordering the use of select materials during construction to correct site-specific problems.

15.1 Policy

WisDOT policy will require using select materials in the upper portions of subgrades developed from soils that are difficult for subgrade construction. These include:

- All silty soils,
- Most silty clay soils,
- Soft clay soils,
- Mineral soils with a high organic content, and
- Any other soil with a history of problems relating to subgrade construction.

The shaded portion of Attachment 15.1 is designated the Standard Inclusion Area. It shows those areas in the state where these soils predominate.

Select materials will be used in subgrades for projects located in the Standard Inclusion Area shown in Attachment 15.1 unless the project soils report recommends against such application and provides suitable justification for this recommendation.

The non-shaded portion of Attachment 15.1 is the Standard Non-Inclusion Area. Here better soils predominate and select materials are normally not needed for subgrade construction. Select materials may, however, be used on specific projects in the Non-Inclusion Areas if the soils report identifies significant areas of difficult soils and recommends such treatment.

15.2 Application

This requirement will apply to all projects with significant earthwork volumes. Select materials may be used in subgrades on safety improvement projects or other projects with minor volumes of earthwork if such use is warranted by project requirements, time constraints, or other considerations. The soils report should provide a recommendation for use on projects of this type. **The requirement for select materials will not apply to resurfacing projects, pavement replacement projects, or projects with incidental amounts of earthwork.**

Select materials may be applied to discreet segments of a project based on changes in soil conditions. Such selective use must be based on recommendations for specific areas contained in the soils report.

Select materials will be required in both cuts and fills unless otherwise recommended in the soils report. Cut areas may be excluded if the material at and below subgrade elevation is identified as stable material such as rock, gravel, sand, or dense till. Fill areas in which the top four feet of the subgrade is constructed from rock excavation may also be considered for exclusion.

15.3 Design

Attachment 15.2 shows specific materials and depths for ten different systems of select materials. These ten systems are considered to have equivalent performance and shall be used to provide the select materials for subgrades. The soils report should recommend which system or systems may be suitable for the specific project. This recommendation should be based on the materials available in the project area, the estimated cost of those materials, and past experience or performance. The designer shall review these recommendations and select the system best suited to the project.

For preliminary planning purposes, Table 15.1 provides estimated costs per mile for each of the ten select materials systems. The final cost to any project will depend on many factors that could result in significant variation from these estimated cost figures. These factors include local material costs and availability, transportation costs, earthwork adjustments, project staging, and project quantities.

Table 15.1 Estimated Cost of Select Material Systems

Select Material System	Estimated Cost per Mile
No.1 – Breaker Run Stone	$125,000
No. 2 – Breaker Run Stone with Geogrid	$130,000
No. 3 – Grade 1 Granular Backfill	$105,000
No. 4 – Grade 2 Granular Backfill or Select Borrow	$100,000
No. 5 – Pit Run Sand and Gravel	$100,000
No 6 – Pit Run Sand and Gravel with Geogrid	$115,000
No. 7 – Flyash, Lime, Cement Stabilization	$ 95,000
No. 8 – Salvaged Materials or Industrial By-Products	*
No. 9 – Select Crushed Material	$140,000
No. 10 – Select Crushed Material with Geogrid	$140,000
* = Highly variable depending on material and location.	

When included in project plans, show the chosen select materials system on the appropriate typical section(s). Determine quantities of each of the required materials and include them as separate contract bid items. Adjust other earthwork quantities as necessary to compensate for the inclusion of a select materials system.

When select materials are used as stated in this procedure, they will be considered as part of the subgrade and will be included in the contract for subgrade construction. Soil parameters for pavement design will continue to be those of the project soils as determined in the soils report.

To preserve the integrity of the select materials systems and to facilitate movement of local traffic, it is strongly recommended that the Base Aggregate Dense should be included as part of the same contract.

Breaker Run is quarried rock or concrete material processed through a primary crusher, is not further screened or crushed, and will meet the gradation requirements shown in Table 15.2.

Table 15.2 Recommended Breaker Run Gradation

Sieve	Percent Passing
6-inch **	100
** In at least one dimension.	

Select Crushed material is crushed and screened aggregate with particles predominately larger than 1 1/2 inches, free of unconsolidated overburden materials, topsoil, organic materials, steel, and other deleterious materials, and will meet the gradation requirements shown in Table 15.3.

Table 15.3 Recommended Select Crushed Material Gradation

Sieve	Percent Passing
5-inch	90 - 100
1 1/2-inch	20 - 50
No. 10	0 - 10

Pit Run is an unprocessed aggregate material obtained from a gravel pit and will meet the gradation requirements shown in Table 15.4.

Table 15.4 Recommended Pit Run Gradation

Sieve	Percent Passing
1 1/2 inch	0 - 50

Attachment 15.3 through Attachment 15.7 are schematic drawings showing how the select material is to be placed in various situations. The select materials form the uppermost portion of the subgrade. Drainage of the select material is accomplished with relief trenches at all sag points and at 250 ft intervals between sag points. The flow lines of ditches should be at or below the bottom of the select materials. This may require a special ditch. If this is not possible then Attachment 15.6 shows how a special trench and pipe underdrain system can be built to help drain the select material.

15.4 Other Design Considerations

The use of select materials could have a significant impact on excavation, waste, or borrow quantities. Consider carefully the distribution of any excess material and the impacts to the mass diagram resulting from the use of select materials.

LIST OF ATTACHMENTS

Attachment 15.1 Areas for Inclusion of Select Materials

Attachment 15.2 Standard Select Materials Systems

Attachment 15.3 Typical Half Section with Select Materials

Attachment 15.4 Typical Half Section with Select Materials, 4-Lane Divided Highway, 50 ft Median

Attachment 15.5 Typical Half Section with Select Materials, 4-Lane Divided Highway, 60 ft Median

Attachment 15.6 Median Drain Detail for Select Materials Layer Greater Than cmax

Attachment 15.7 Typical Section for 1-Lane Ramp with Select Materials

ACCESS SPACING GUIDELINES

INTERSECTING HIGHWAY		RURAL ARTERIAL UNDER STUDY					
Type	Design Year-ADT	Freeway	Expressway	Principal Arterial	Minor Arterial		
					>5000	1000-5000	<1000
Freeway		A	B	B	B	B	B
Expressway		B	B	B	B	C	C
Principal Arterial	>3000	B	B	B	B	C	C
	<3000	B	B	C	C	D	D
Minor Arterial	>5000	B	B	B	B	C	C
	3000-5000	B	B	C	C	C	D
	<3000	B	C	C	D	D	D
Major Collector		B	C	C	D	D	D
Minor Collector		B	D	D	D	D	E
Local		N/A	D	D	D	D	E
Private	>100	N/A	D	E	E	E	E
	<100	N/A	E	E	E	F	F

Recommended Spacing Between Access Points:

A = 5 miles

B = 2 miles

C = 1 mile

D = 2000 feet

E = 1000 feet

F = 500 feet

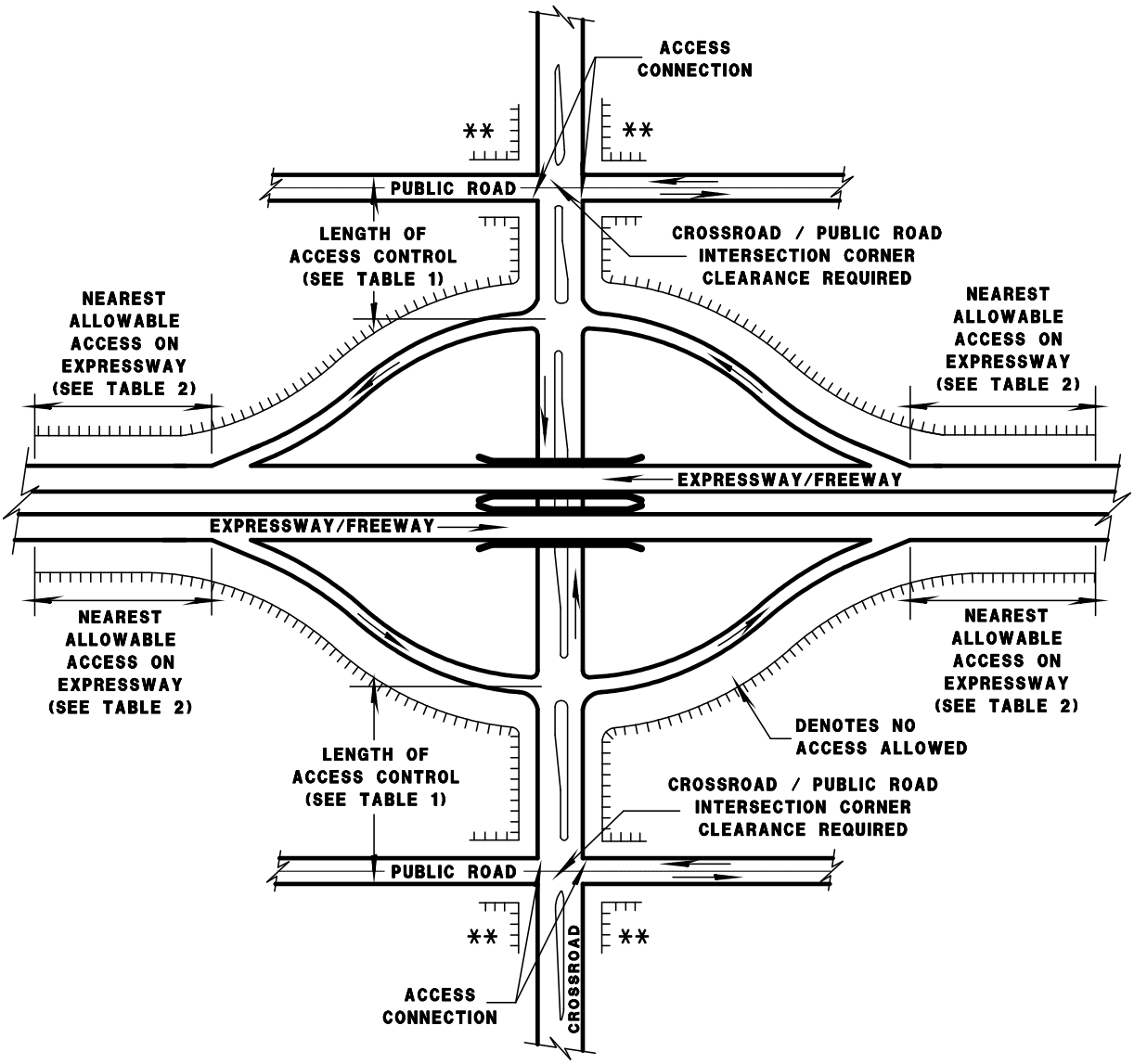


TABLE 1 - Distance of Access Control on Crossroad

Area Type	Upper Minimum	*Lower Minimum
Rural or Urban	1,320 ft	1,000 ft (1200-ft if location is or is likely to be signalized)

TABLE 2 - Distance of Access Control on Expressways

Area Type	Median opening at at-grade intersection	Upper Minimum	* Lower Minimum
Rural or Urban	**None** (intersection is right-in or right-out or both)	2,640 ft	1,500 ft
	Full or restricted (allows left-in, left-out, thru movements, or any combination of the three	2,640 ft	2,640 ft

* An approved traffic impact analysis is required to justify a less than upper minimum distance of access control. See text.

**Access control here is based on the functional area of the intersection. See FDM 11-25-1.

The following are two examples of earthwork calculations:

Example 1

Given:	Cut	= 3,250 CY
	Fill	= 33,992 CY
	Fill expansion	= 1.25
	Rock excavation	= 1,395 CY
	Rock expansion	= 1.1
	Marsh excavation	= 343 CY
	Marsh expansion	= 1.5

Common excavation is clean sand and will be used to backfill marsh.

Marsh will be wasted and will not be included in the fill.

Step 1

Identify all excavation and fill volumes as well as the expansion/reduction

Factors for each material.

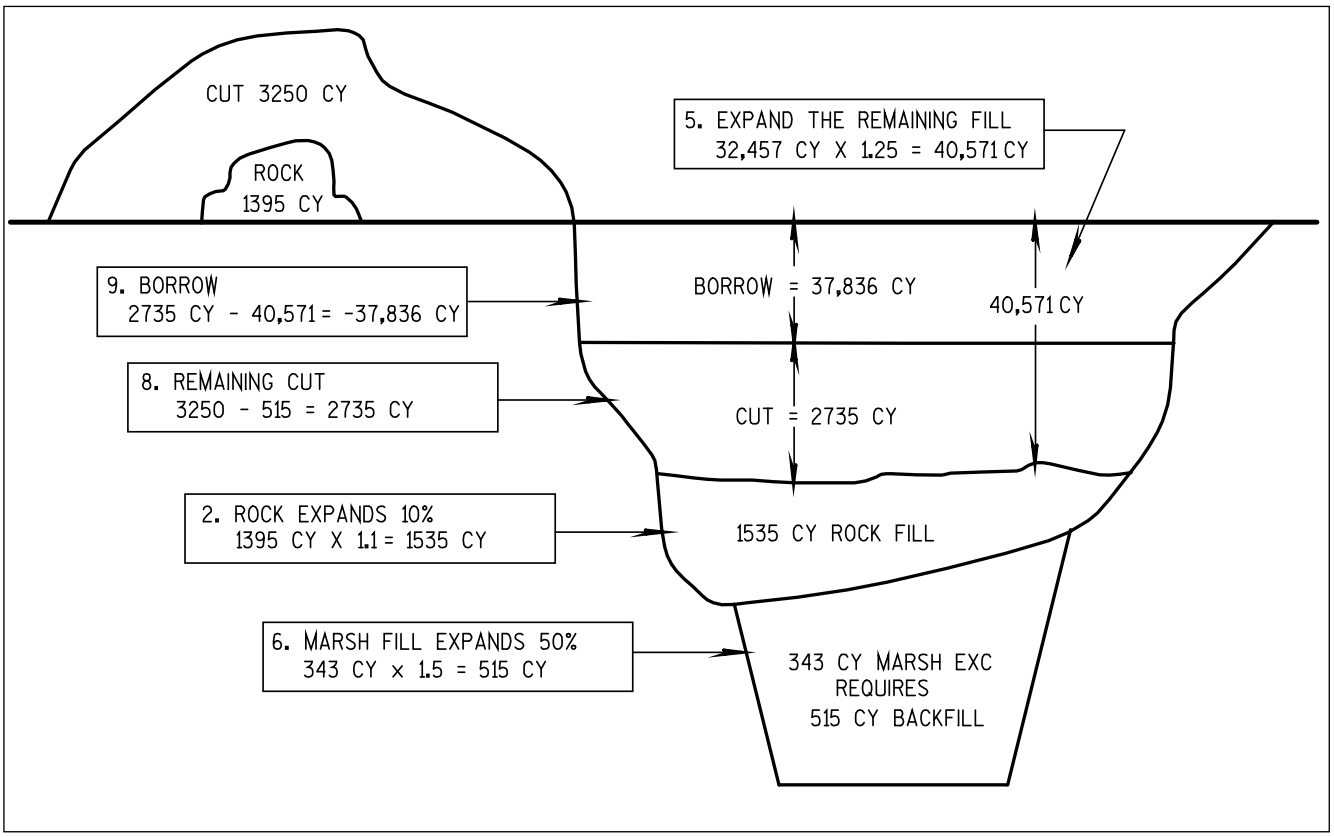


Figure 1. Schematic Earthwork Volume Sketch

Step 2

Expand the rock and deduct this from the unexpanded fill.

(Note: The 1.1 expansion factor means that the excavated rock will expand to fill a volume of 110 % in the new fill.)

1,395 CY x 1.1 = 1,535 CY

This means that the rock will expand to fill a volume of 1,535 CY in the fill.

Deduct the rock fill from the unexpanded fill.

(Note: The rock fill volume is the true volume of rock after it is excavated and placed in the fill. This rock fill must be deducted prior to expanding the fill. Remember that fill expansion does not actually occur and is only a

visualization to account for the shrinkage of the cut and borrow excavation. If the rock fill would be deducted from the expanded fill, a significant error would occur because the fill expansion factor is intended to account for only the shrinkage of the cut and borrow).

33,992 CY – 1,535 CY = 32,457 CY

This indicates that, after the rock excavation is placed in the fill, there is still 32,457 more CY of material needed, in place, to complete the fill. This is the true volume of fill, in place, and does not account for the shrinkage of the cut and borrow excavation.

Step 3

Not applicable, marsh will not be used in the embankment.

Step 4

Not applicable, EBS will not be used in the embankment.

Step 5

Expand the remaining fill.

(Note: The 1.25 expansion factor means that the fill is visualized to expand to 125 % of its true volume in order to account for the shrinkage of the cut and borrow excavation).

32,457 CY x 1.25 = 40,571 CY

This indicates that 40,571 CY of cut and borrow excavation, measured in its original location, will be needed to complete the fill.

Step 6

Determine the volume of marsh backfill.

(Note: The 1.50 expansion factor means that the marsh excavation is visualized to expand to 150 % in order to account for both the displacement of the marsh and the shrinkage of the material placed as marsh backfill. If granular backfill or select borrow would be specified as backfill, this would also include the one foot of granular backfill or select borrow placed above the marsh).

343 CY x 1.5 = 515 CY

This indicates that 515 CY of cut, borrow, select borrow or granular backfill, measured in its original location, will be needed to backfill the marsh excavation.

Step 7

Not applicable, no EBS is identified.

Step 8

Determine the volume of cut remaining after the marsh is backfilled.

In this example, cut will be used to backfill the marsh, so this reduces the amount of cut available in the remaining fill. If granular backfill would be specified as marsh backfill, the material to backfill the marsh would be paid for under the item of granular backfill and would not affect the volume of cut that is available for the fill.

3,250 CY - 515 CY = 2,735 CY

This indicates that 2,735 CY of cut will be available as fill after the marsh is backfilled.

Step 9

Determine the required borrow (minus value) or waste (plus value) by subtracting the expanded fill from the remaining cut.

2,735 CY - 40,571 CY = -37,836 CY

Note: The value is "- 37,836 CY", so 37,836 CY of borrow is required.

In the following example, the marsh and EBS are backfilled with granular backfill and the marsh and EBS are used in the fill outside of the 1:1 slope.

Example 2

Given:	Cut	= 250,001 CY
	Salvaged asphalt pavement in cut	= 1,111 CY
	Fill	= 150,001 CY
	Fill expansion	= 1.25
	Rock excavation	= 25,000 CY
	Rock expansion	= 1.1
	Marsh excavation	= 15,001 CY
	Marsh backfill expansion	= 1.5
	Marsh fill Reduction	= 0.6
	EBS	= 7,500 CY
	EBS backfill expansion	= 1.3
	EBS fill reduction	= 0.8

Step 1

Determine the usable volumes of all excavation and fill materials as well as the expansion/reduction factors for each material.

Determine the usable volume of cut.

250,001 CY – 1,111 CY. = 248,890 CY

Step 2

Expand the rock and deduct the rock fill from the unexpanded fill

Rock fill = 25,000 CY. x 1.1 = 27,500 CY

Remaining fill = 150,001 CY. – 27,500 CY. = 122,501 CY

Step 3

Deduct the marsh fill from the remaining fill

Marsh fill = 15,001 CY. x 0.60 = 9,000 CY.

Remaining fill = 122,501 CY. – 9,000 CY. = 113,501 CY

Step 4

Deduct EBS fill from the remaining fill

EBS fill = 7,500 CY. x 0.8 CY = 6,000 CY

Remaining fill = 113,501 CY – 6,000 CY = 107,501 CY

Step 5

Expand the remaining fill.

107,501 CY. x 1.25 = 134,375 CY

Step 6

Determine the volume of material needed to backfill the marsh.

15,001 CY x 1.5 = 22,501 CY

Note: This is the volume of granular backfill required to backfill the marsh. This does not affect the cut or fill and is not used in the mass ordinate computations.

Step 7

Determine the volume of material needed to backfill the EBS.

7,500 CY x 1.3 = 9,750 CY

Note: This is the volume of granular backfill required to backfill the EBS. This does not affect the cut or fill and is not used in the mass ordinate computations.

Step 8

Not applicable, granular backfill is specified to backfill the marsh and EBS, so this does not affect the volume of cut that is available.

Step 9

Determine the volume of borrow (minus value) or waste (plus value) by deducting the remaining expanded fill from the usable volume of cut.

248,890 CY – 134,375 CY = + 114,515 CY

There is 114,515 CY of waste.

COMPACTION OF SOILS

One of the essential functions of geotechnical engineering is to ensure that adequate density of the soil or rock exists to provide satisfactory performance. If this required density does not exist in the soil, either in place or after reworking by excavation and placement, compactive effort (applied energy) is necessary to increase the density. Regardless of any terminology applied, compaction means applying energy to secure a given unit weight, usually in our usage pounds per cubic foot or kilograms per cubic meter. A moisture content of the material may also be specified. For most Wisconsin soils, any concern for moisture is largely for a means to attain required density with minimum energy.

There are numerous properties of soils that affect its performance as a construction material. Fortunately, soil density has been found to be a good indicator of the properties that yield desirable results. Therefore, an effort should be made to achieve proper soil density.

In the past, density measurements were made in both old and new fills. Data from these investigations indicated a reasonable balance of desired performance properties with densities. This work found the densities achieved were in a range of what is now known as 90 to 100% of the AASHTO T-99 maximum density. Continuing studies since Proctor's work in 1923 have determined that density in the range of 90 to 95% AASHTO T-99 is desirable and adequate for most work. Later studies have recognized that special problems may require greater density. AASHTO T-180 may be required for air fields, high embankments, or heavy footing loads. Of course, there are also a few isolated special cases, which may warrant lower densities. These include expansive soils being compacted to lower density and higher moisture contents or silts being compacted at lower moistures.

Moisture content is usually more of a means to achieve density than a desired property within itself. For example, a heavy clay compacted considerably dry of optimum will be compacted only with tremendous compaction energy, say four to five times normal compactive effort. A 2% increase in moisture content would allow the clay to be compacted with normal effort. Silts compacted at or above optimum moisture usually cannot be brought up to the desirable density.

Other properties of soils are also affected to a degree by moisture content. For example, a clay compacted fairly wet will have slightly less consolidation but slightly greater strength than it would exhibit if compacted rather dry. These changes for Wisconsin soils are usually less than the effects from different rollers or differences in laboratory compaction versus field methods. One check should always be made where moisture is of concern, either in drying a wet soil or wetting a dry material. Soil does not supersaturate, so the relation of density-moisture to the zero air voids line should be checked.

If a certain density is needed, it should make no difference to a contractor what compaction inspection method is called for if he is achieving the density specified. If a contractor objects to a specific specification, one might assume he feels he can achieve and have accepted a lesser density with another method.

These preliminary remarks lead to the fact that the soil engineer should recommend the method used to determine that the needed density is achieved. Ordinarily in Wisconsin this means a recommendation of either Standard Compaction or Special Compaction. The use of QMP Earthwork generally calls for the contractor to perform the density/moisture testing on a project. In Wisconsin, the terms Special Compaction and Standard Compaction have absolutely nothing to do with the desired density. These terms are merely methods set out for checks or observations to ensure the desired density is being achieved. Having nothing to do with these terms at all, some special cases may make modification in density or additional controls necessary. The advantages and disadvantages of each method are outlined below:

Special Compaction:

Advantages	Disadvantages
Specific data at specific site.	Difficult to select standard lab density.
Enforceable in specific language.	Impossible or largely judgmental in highly variable soils.
Allows more control on problem soils such as; fat clay, silts, organics, etc.	Largely unneeded on granular soils.
Easily documented.	Requires more equipment to be effective.
Better confidence in design for high fills, plastic soils in subgrade or similar critical uses.	Process often too slow to effectively control lifts: i.e., additional lifts go on before testing is complete.

Standard Compaction:

Advantages	Disadvantages
Less testing equipment.	Experienced personnel needed.
Allows broader enforcement in highly visible soils.	Judgmental.
Adequate for many soils, particularly granular.	Poorer coverage and lift thickness control.
Simplified record keeping.	Misleading in dry cohesive soils.
	Ambiguous specification.
	Less confidence in design.
	Misleading in clod-type soils.

A study by the Region Soils Engineer of the soils encountered, along with design, construction, and service needs, should weigh these advantages and disadvantages. From this study, a recommendation on appropriate compaction control should be given to the designer as a part of the project Soils Survey Report.

The advantages and disadvantages noted above must be considered and applied to the combination of local soil conditions, the design parameters, and performance requirements. As these factors vary in significantly, no exact criteria can be specified. However, the guidelines can be applied that should set up the recommendations made in the Soil Survey Report.

While no exact criteria may exist, some broad guides are possible.

For plastic soils with liquid limits (LL) greater than or equal to 45, special compaction should be recommended. For soils with LL less than or equal to 25, standard compaction should give satisfactory performance. On some very bony soils, density tests of any type are virtually impossible. On these soils, no density requirements are expected and fortunately rarely needed.

Fill height should also be criterion. Fills with heights exceeding 35 feet should have a controlled compaction specification and fills in excess of 50 feet should mandate both density and moisture controls. Silts in higher fills should have moisture controls and always be compacted 2 to 5% below optimum moisture. Fills with heights exceeding 50 feet, if built of silts or clay, should have analyses based on tests to give design parameters. Also, low height fills of material having a liquid limit greater than 45 should have controlled compaction.

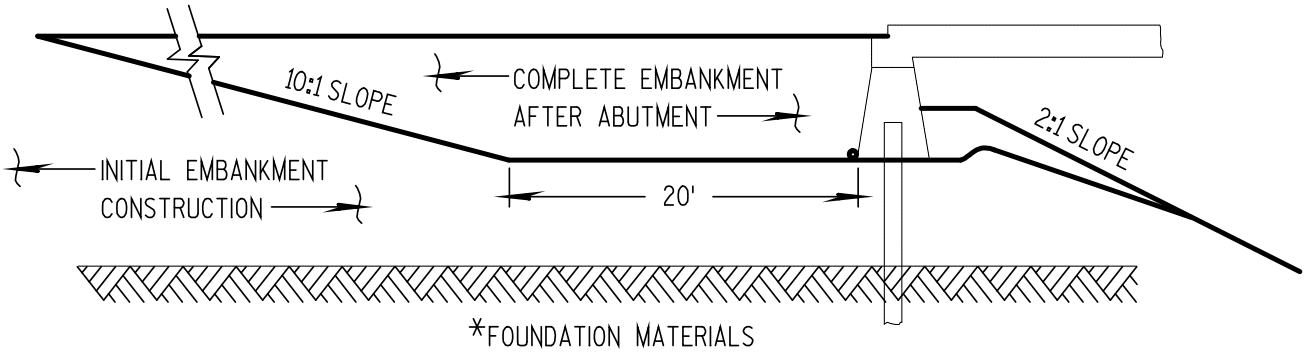
With considerable amount of current construction being on short fills that are inherently difficult to compact, the soil engineer should give special attention to these situations.

It is intended that a check density test be made on each 25,000 yards of soil in all embankments regardless of the acceptance method. On projects of smaller quantities, one or more density tests should be made.

The consequences of future settlements should be weighed. A higher fill will settle more than a shallow fill. For example, often a 25-foot fill will cause foundation settlement much more than 2-1/2 times that of a 10-foot fill. Also, the soil engineer should relate anticipated future settlement in the foundation to design. If there is to be a future settlement of, say, 1 foot in the foundation soil than 3 inches of settlement in the fill due to lack of compaction may not be of primary concern.

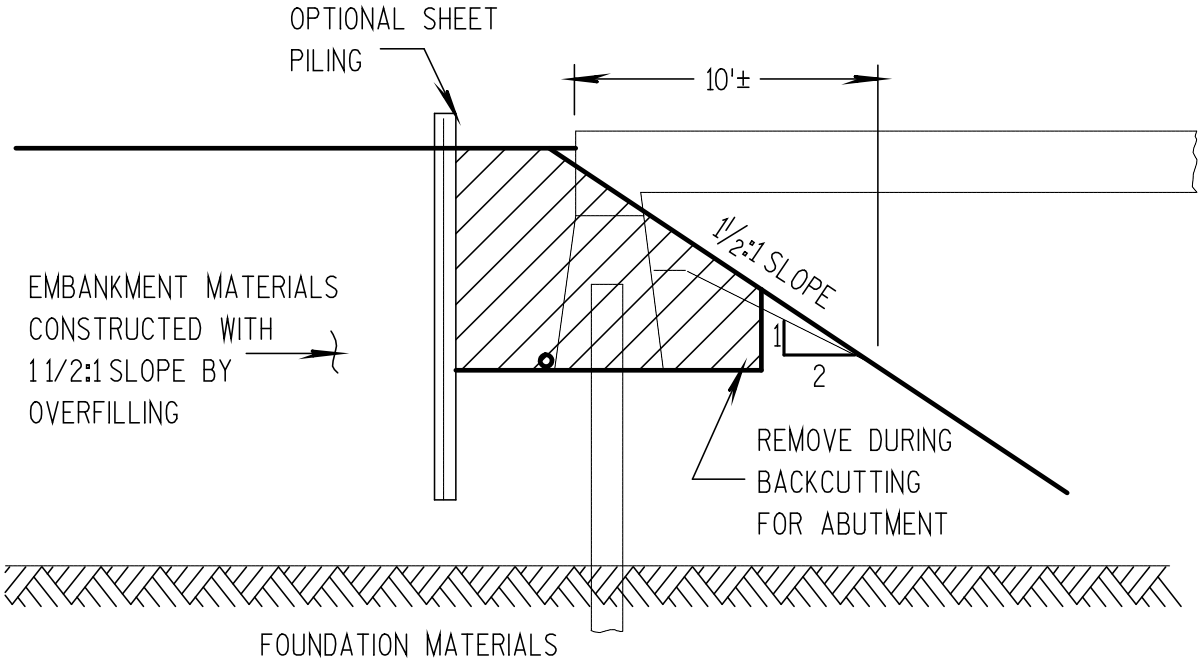
Admittedly this leaves non-specific areas in soil properties, fill height, side slope, and pavement performance where controls are still judgmental. As long as there are two compaction acceptance procedures that should achieve the same result, there must be judgments in preparing a Soil Survey Report that considers fill height, bridge end bumps, resilient modulus of subgrades, and placement conditions.

For optimum field results, it should be emphasized that standard compaction without adequate overall control can be difficult. For example, a clay soil compacted 5 or 6 percent dry of optimum will not show evidence of low density. However, when it attains the normal 90-95 percent saturation under a pavement in 3 to 5 years, severe problems develop. Similarly, grade inspections using controlled methods should never depend on tests alone to control compaction. The tests are to verify and assist in verifying desired density, but observation for and enforcement of coverage, lift thickness, and uniformity is always essential.



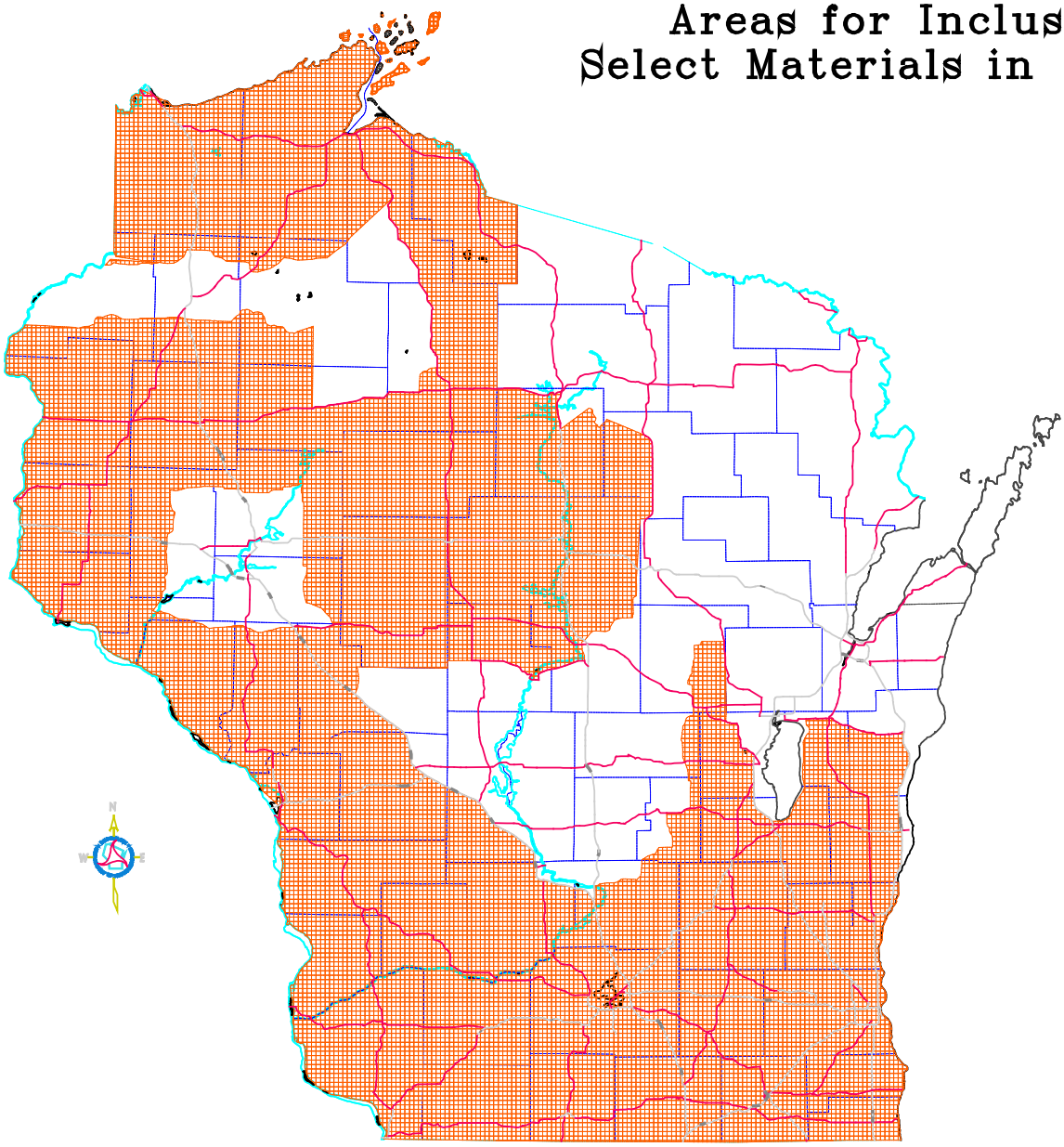
* When designing an embankment, the designer should consider the effect that the embankments weight will have on the foundation materials. This matter should be discussed with the region soils engineer.

Detail A: Recommended Embankment Construction Method



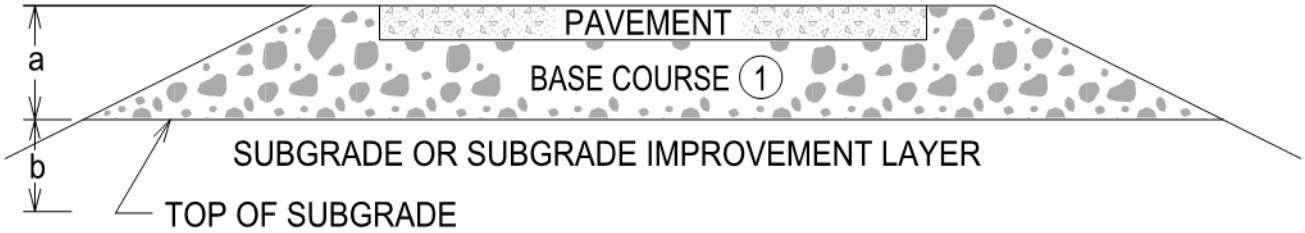
Detail B: Alternate Embankment Construction Method

Areas for Inclusion of Select Materials in Subgrades



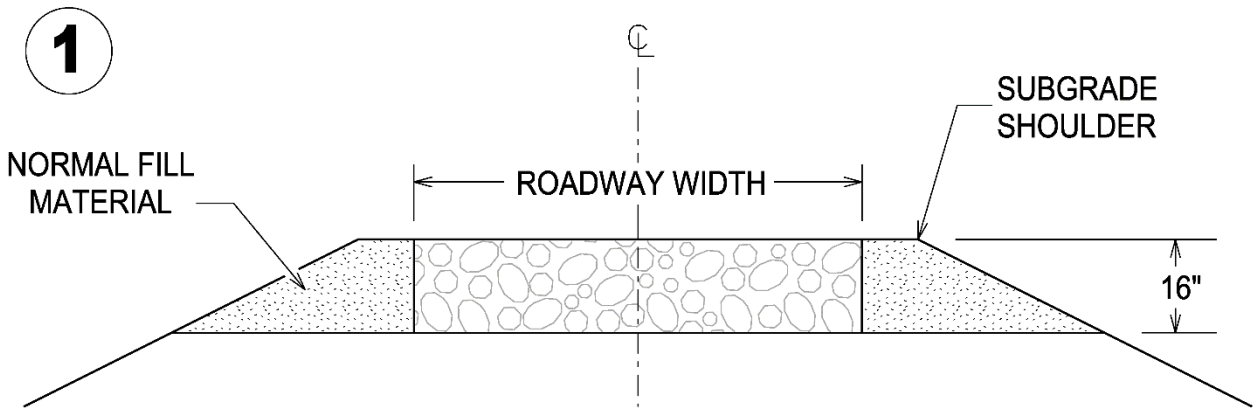
Standard Non-inclusion Areas

Standard Inclusion Areas

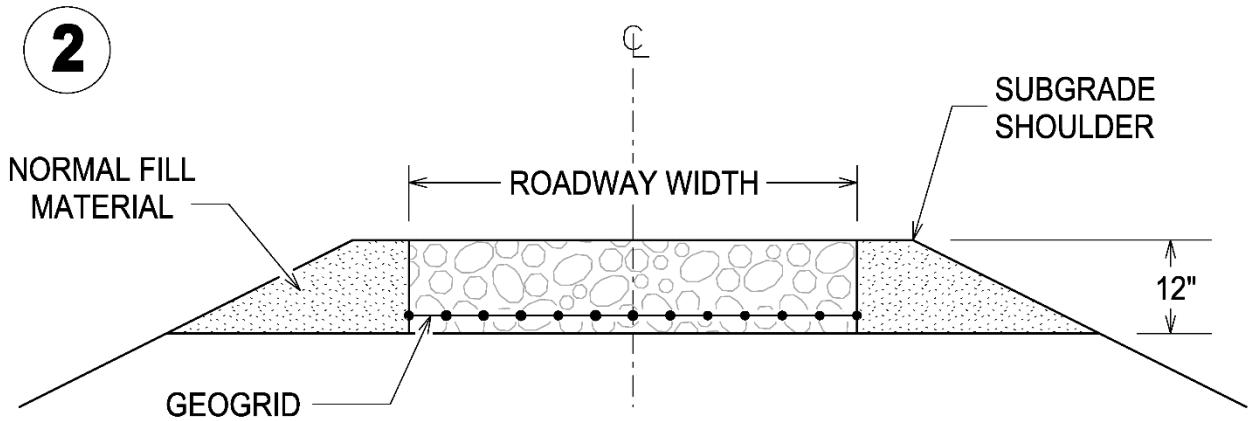


a = Pavement Structure
b = Subgrade

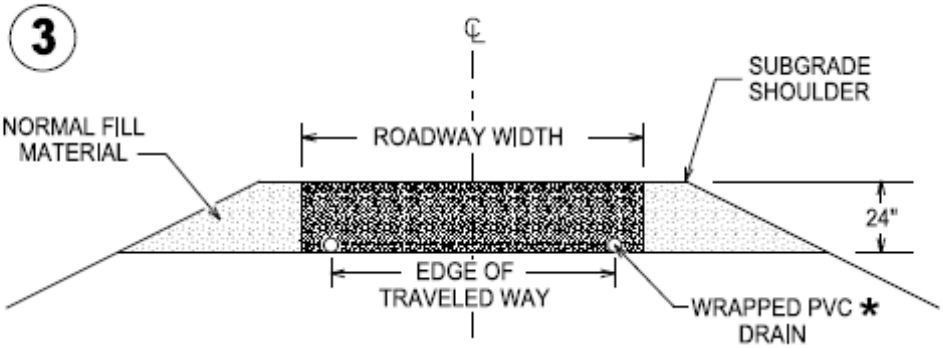
1 BASE COURSE MATERIALS INCLUDE ¾ INCH / 1¼ INCH / 3 INCH DENSE GRADED BASE AS DEFINED IN WI STANDARD SPEC SECTION 301 AND 305



BREAKER RUN STONE

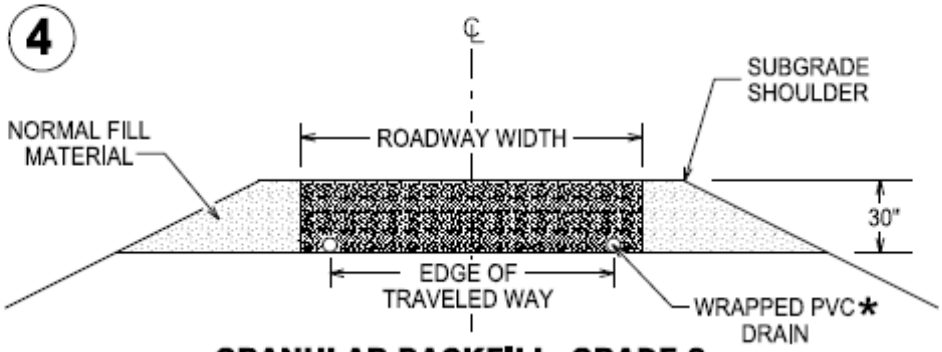


BREAKER RUN STONE WITH GEOGRID



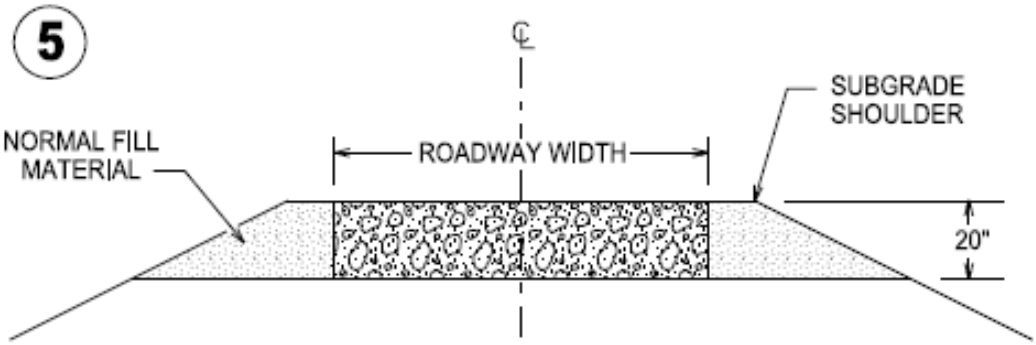
GRANULAR BACKFILL, GRADE 1

* MAY BE ELIMINATED IF GRANULAR BACKFILL SLOPES ARE COVERED WITH 3"- 4" OF BASE AGGREGATE DENSE

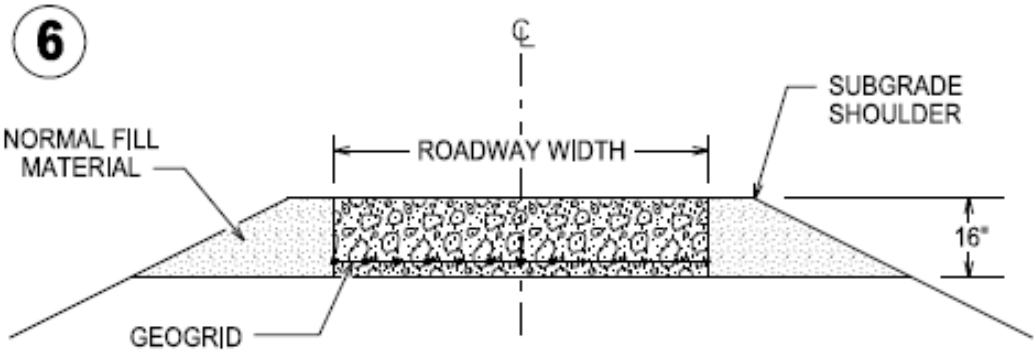


GRANULAR BACKFILL, GRADE 2 OR SELECT BORROW

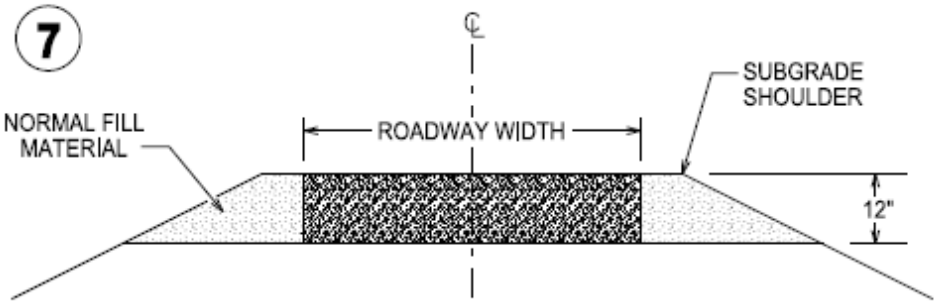
* MAY BE ELIMINATED IF GRANULAR BACKFILL SLOPES ARE COVERED WITH 3"- 4" OF BASE AGGREGATE DENSE



PIT RUN SAND & GRAVEL

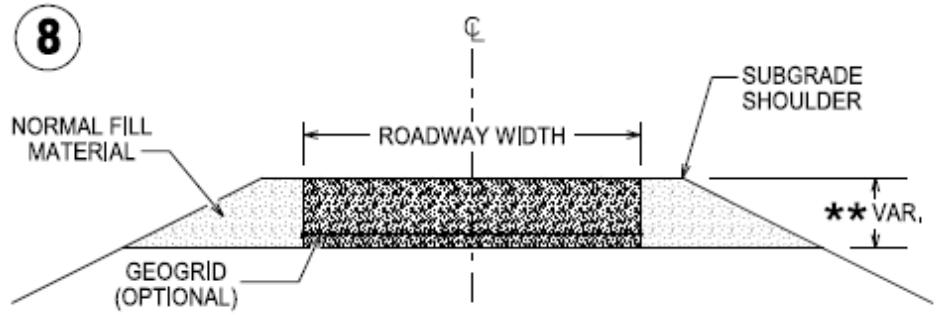


PIT RUN SAND & GRAVEL WITH GEOGRID



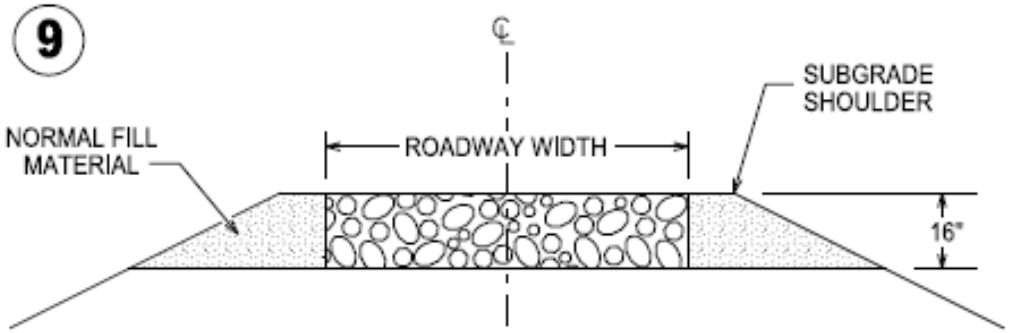
LIME, FLYASH, OR CEMENT STABALIZED SOIL

(APPLIES ONLY TO SUBGRADE SOILS CLASSIFIED AS CLAY SOILS)

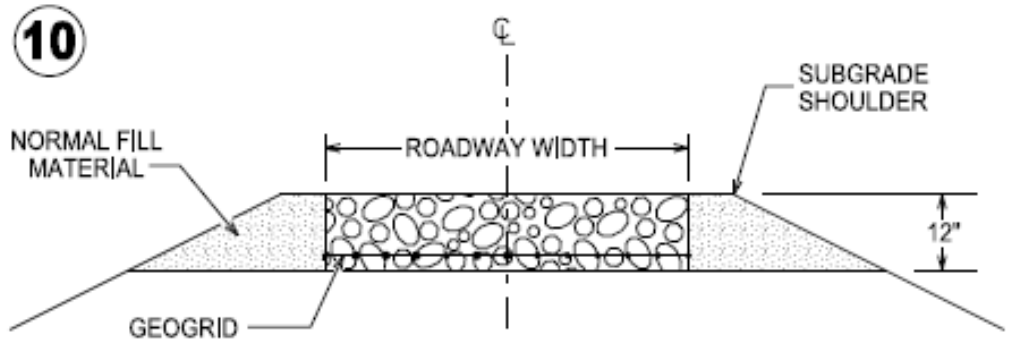


RECYCLED CONCRETE, STEEL SLAG, FOUNDRY SLAG, BOTTOM ASH, RECYCLED ASPHALTIC PAVEMENT WITH GEOGRID

** SEE RECOMMENDATION IN SOILS REPORT



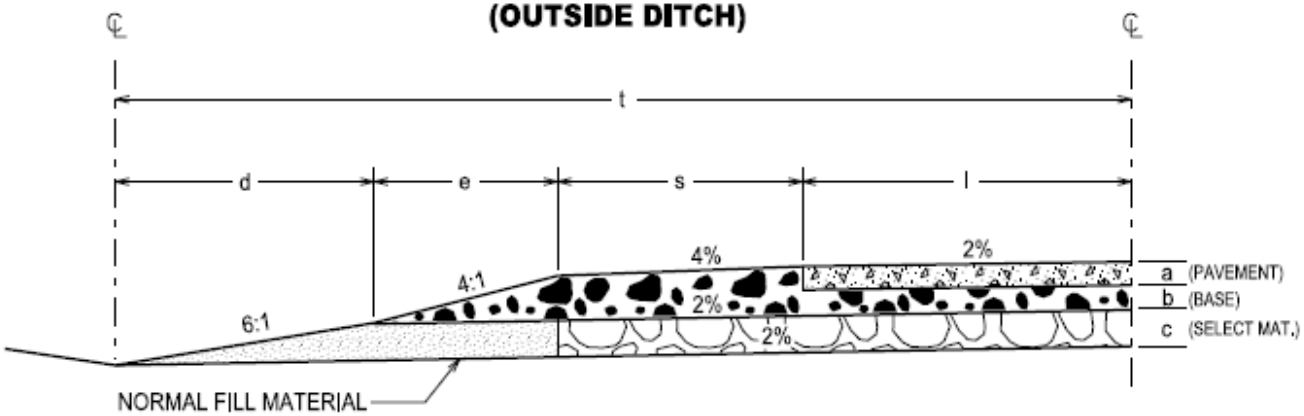
SELECT CRUSHED MATERIAL



SELECT CRUSHED MATERIAL WITH GEOGRID

THE RELIEF TRENCH DETAIL SHOWN IN FDM 11-5 ATTACHMENT 15.3 SHALL BE USED IN CONJUNCTION WITH ALL THE SELECT MATERIAL SYSTEMS EXCEPT #7.

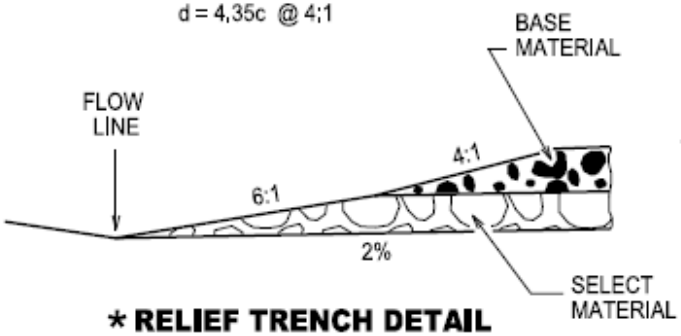
TYPICAL HALF SECTION WITH SELECT MATERIALS (OUTSIDE DITCH)



e = 4.35 (a + b - .02s)

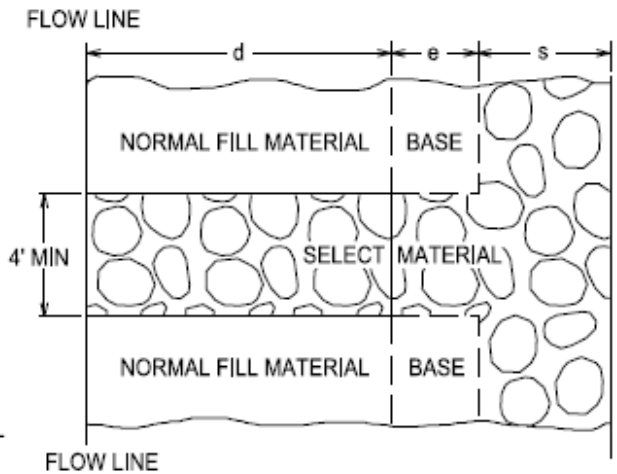
d = 6.82c @ 6:1

d = 4.35c @ 4:1



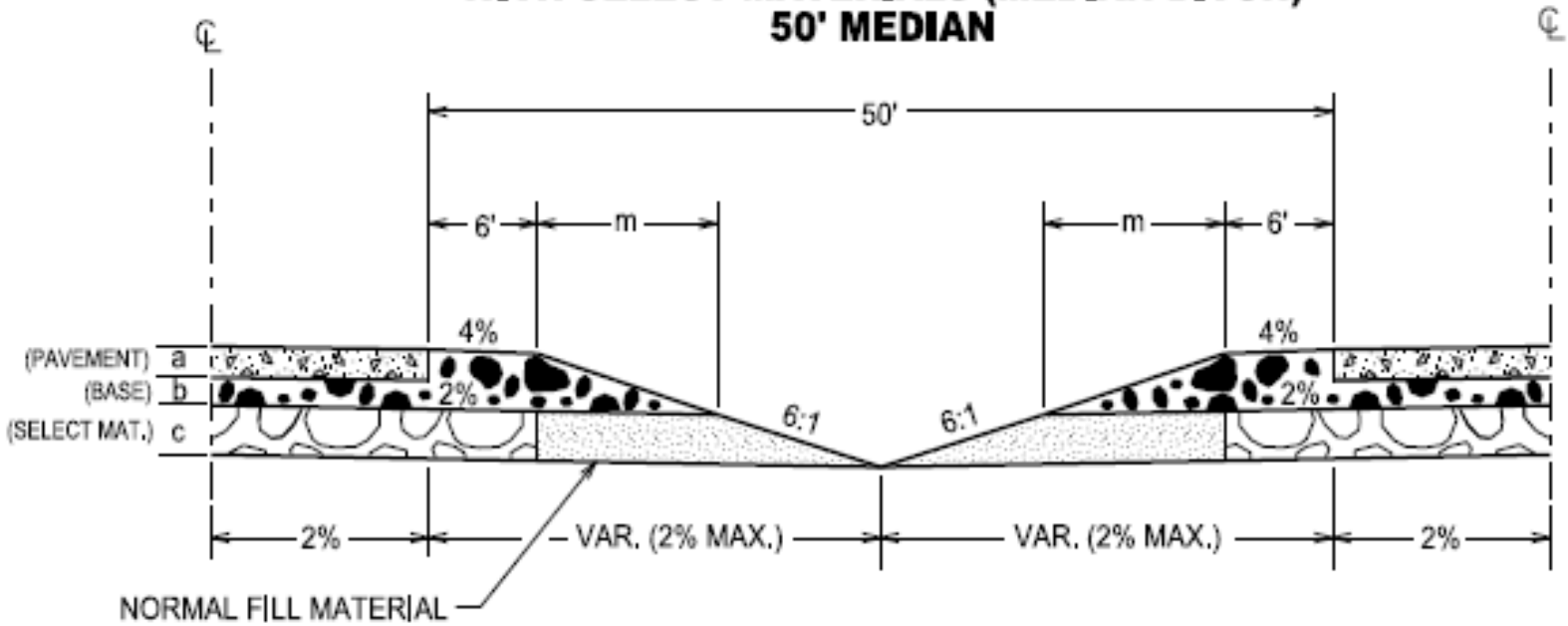
*** RELIEF TRENCH DETAIL PROFILE VIEW**

* Construct relief trench at sag points or every 250 feet



RELIEF TRENCH DETAIL PLAN VIEW THROUGH SELECT MATERIAL

TYPICAL HALF SECTION FOR FOUR LANE DIVIDED HIGHWAYS WITH SELECT MATERIALS (MEDIAN DITCH) 50' MEDIAN



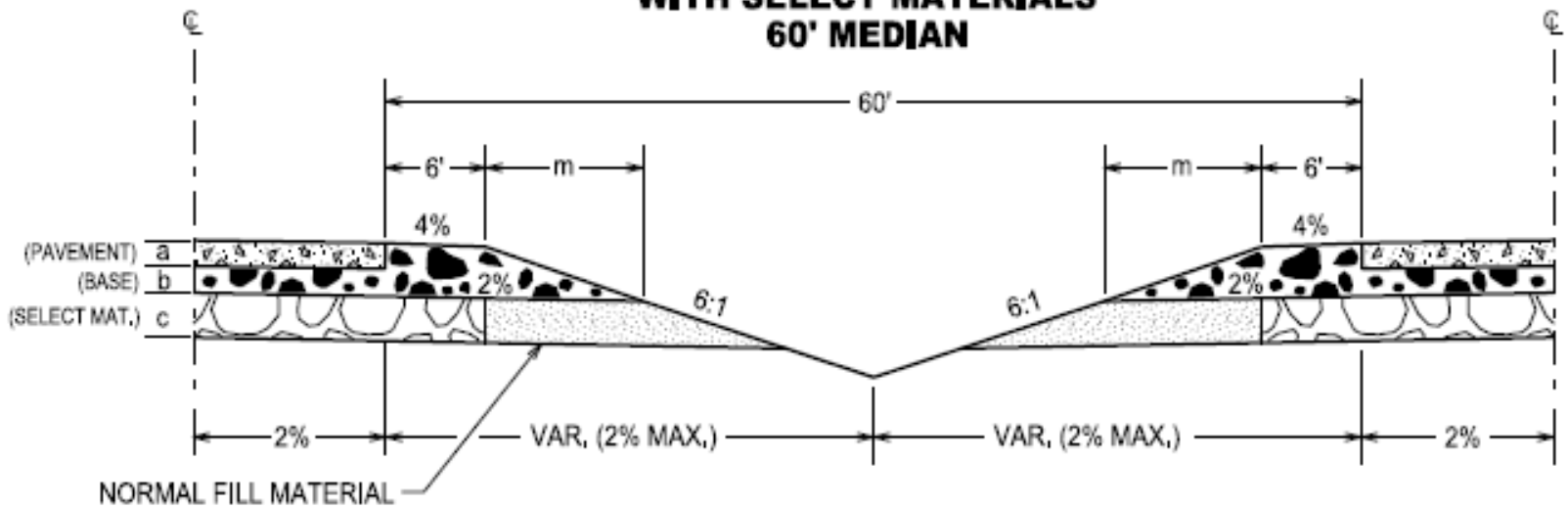
NOTE: Construct relief trenches as shown in FDM 11-5 Attachment 15.3 at ditch sag points or every 250 feet

$m = 6.82\ (a + b - 0.12)$

WITH 2% SLOPE: $C_{max} = 2.91 - (a + b)$

WITH FLAT SLOPE: $C_{max} = 3.41 - (a + b)$

TYPICAL HALF SECTION FOR FOUR LANE DIVIDED HIGHWAYS WITH SELECT MATERIALS 60' MEDIAN



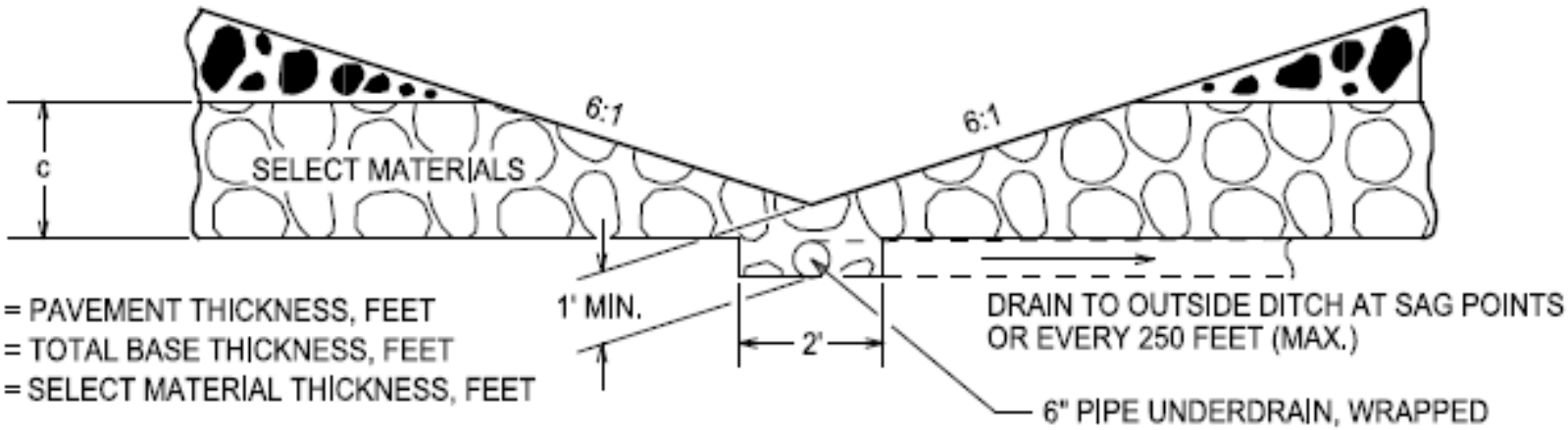
NOTE: Construct relief trenches as shown in FDM 11-5 Attachment 15.3 at ditch sag points or every 250 feet

$m = 6.82\ (a + b - 0.12)$

WITH 2% SLOPE: $C_{max} = 3.64 - (a + b)$

WITH FLAT SLOPE: $C_{max} = 4.24 - (a + b)$

MEDIAN DRAIN DETAIL FOR SELECT MATERIALS LAYERS GREATER THAN C_{max}

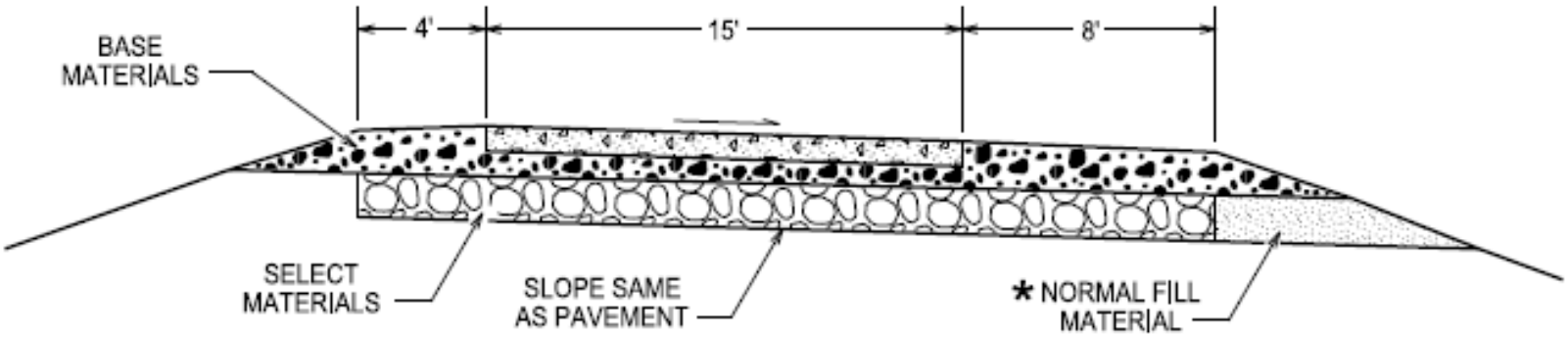


a = PAVEMENT THICKNESS, FEET
b = TOTAL BASE THICKNESS, FEET
c = SELECT MATERIAL THICKNESS, FEET

FOR A 50' MEDIAN: $C_{max} = 3.41 - (a + b)$

FOR A 60' MEDIAN: $C_{max} = 4.24 - (a + b)$

TYPICAL SECTION FOR ONE LANE RAMP WITH SELECT MATERIALS



* NOTE: Construct relief trenches as shown in FDM 11-5 Attachment 15.3 every 250 feet

FDM 11-10-1 Basic Criteria

May 15, 2019

1.1 Design Year

The design years for projects are normally 20 years from the date projects are proposed to be opened to traffic. Shorter design periods may be used when highways are to be constructed in stages or designed for shorter pavement improvement life-spans.

1.2 Traffic

Cooperate with the region's planning staff to develop design traffic data. Traffic data includes current and design year average daily traffic, design hourly volumes, directional distributions, and the percentages of heavy vehicles expected in the design year. Normally trucks and buses are the heavy vehicles considered as influencing highway capacities. Also, consider heavy recreational vehicles on certain routes. Include bicycle and pedestrian counts when requesting intersection traffic counts.

1.3 Highway Capacity

Capacity is an important factor in highway design and operation. Through capacity analyses, proposed highways can be designed to operate at predicted traffic volumes without exceeding pre-selected levels of service. Early programming and scoping processes will be the first evaluations to determine if capacity issues will be addressed or not and to what levels of scope. Generally,

- Perpetuation projects will generally not explore capacity improvements,
- Rehabilitation projects will explore limited capacity improvements in the form of incremental improvements or safety mitigation measures as defined in the projects purpose and need,
- Reconstruction-Type Modernization projects will explore more project segments/locations for incremental improvements, as defined in the projects purpose and need, and
- New Construction-Type Modernization projects will fully explore capacity expansion improvements as defined in the projects purpose and need.

Refer to FDM 11-5-3 for highway capacity procedures.

1.4 Functional Classification

Functional classification is the process by which streets and highways are grouped into classes or systems according to the character of service they are intended to provide. The basic functional systems used in highway planning are arterials, collectors, and locals. Using national classification terminology, these systems are sub-classified based on the trips served, the areas served, and the operational characteristics of the streets or highways. These systems are detailed on Wisconsin's current Functional Classification Systems Maps:

https://wisconsindot.gov/Pages/projects/data-plan/plan-res/function.aspx

1.5 Design Speeds

According to AASHTO[1], "Design speed is a selected speed used to determine the various geometric design features of the roadway. Selected design speeds should be logical ones with respect to the topography, anticipated operating speeds, the adjacent land uses, and the functional classifications of the highways."

Selections of design speeds are very important because these choices set limits for curvatures, sight distances, clear zones, and other geometric and cross-sectional features. The types and functional classifications of highways, topographies, adjacent land uses, driver expectations, and economics are all factors influencing these selections.

Speed measurements on highways of different design speeds and various traffic volumes typically show wide ranges of actual vehicle running speeds. In order to satisfy the desired travel speeds of most drivers, consideration should be given to selecting design speeds that are high-percentile values in the speed distribution ranges. Average running speeds will then normally be lower than the design speeds, because of the

[1] (*1) A Policy on Geometric Design of Highways and Streets 2004,* 5th edition. AASHTO, 2004., p.67

influences of traffic volumes, physical limitations of the highways, and speed limits.

Speed measurements on rural arterial highways in Wisconsin show the average running speeds to be in excess of the posted speeds. These studies support upper range design speeds for rural arterials on the state trunk highway system that are 5 mph greater than posted speeds. Table 1.1 provides corresponding English and metric design speeds with typical posted speeds.

Table 1.1 Design Speeds vs. Typical Posted Speeds

Posted Speed (mph)	Design Speed (mph)
25	25-30
30	30-35
35	35-40
40	40-45
45	45-50
50	50-55
55	55-60
60	60-65
65	65-70
70	70-75

Use of Design Speeds equal to Posted Speeds are acceptable if the Safety Certification Document (SCD) (See FDM 11-38) or other safety analyses show acceptable safety performance on the existing roadways.

Existing two-lane roadways being expanded to four lanes are good candidates for these 70-75 MPH design speeds also where the following conditions exist:

1. The cross sections of the roadways will be divided, i.e. opposing traffic will be separated by medians or traffic barriers.
2. The planned highways meet the requirements for freeways or expressways as defined in Section 346.57 (1) of the Wisconsin Statutes.
3. If when checked with the regional traffic unit, it is confirmed that the highway segments are long enough to allow the practical use of the higher design speeds.
4. There are no signals or stop conditions on the highway segments.
5. The median widths on expressways equal or exceed the clear zone widths required for 70 mph design speeds. Note: It is generally not practical to use median barriers on non-access-controlled highways because the barriers can obstruct the vision of drivers at intersections and safety treating the ends of interrupted barriers can be difficult. However, the use of a median barriers would be appropriate for freeways with narrow medians.

A 70 mph (110 km/h) design speed is also used under the following conditions:

1. Posted speeds of 70-75 mph exists on multilane divided highways where existing acceptable safety performance exists, which will be improved or extended.
2. Highways that qualify for expansion projects (2-lanes to 4-lanes divided) and have crash rates that are less than 25 percent above the statewide average rates for similar types of highways, and have 85th percentile speeds of at least 70-75 mph.

Lower design speeds may be considered on “Special” corridors that serve more of access, tourist or aesthetic related functions than mobility functions. These “Special” corridors might be “Rustic” Roads, “Scenic Byways,”

sections of urban corridors with high pedestrian activity or in the vicinities of schools, or other roadways located in unique environmentally or socially sensitive areas. Using lower design speeds can help to provide additional flexibility in the design of horizontal, vertical and cross-sectional elements.

Identify these lower design speed corridors in the Scoping Phase of the project development process. Selections of design speeds need to be mutually agreed on between the planning, traffic and project development sections.

On redesigned or newly designed roadways, design alignments with purposeful, curvilinear features to promote operating speeds that are compatible with the chosen design speeds. Also, give special consideration to corridor consistency and functional class, when selecting appropriate design speeds. See the design criteria tables in FDM 11-15-1 and FDM 11-20-1.

Regardless of the design speeds provided in FDM 11-15-1 and FDM 11-20-1, the basis for selections of design speeds should be fully documented in the SCD or Design Study Report (DSR) Design Justifications (DJs) if required based on the improvement types. If the selected design speeds equal or exceed the legal speed limits, statements to that effect will suffice. Otherwise this documentation shall include discussions of the road characteristics that relate to operating speeds plus characteristics of the abutting segments of roads, and statements about any advisory or regulatory speed signing in place, and discussions about practical operating speeds on the affected and abutting segments of roads; or other logic that explains the basis for the selections.

Design Justifications (DJs) to the design speed policy are not required on spot improvement projects. In these contexts, spot improvements are defined as projects less than 0.5-mile long (e.g., a bridge replacements). Instead, choose design speeds that are consistent with both existing conditions and the planned developments of the adjacent sections of highways. If these result in project design speeds that are less than the posted or statutory speeds, then mitigate these to the extent possible by appropriate advisory signing, or other means.

Project Type (Perpetuation, Rehabilitation and Modernization) should not affect selection of design speeds unless they happen to be one of the “Special” design speed projects defined above. Most projects should incorporate project wide design speeds compatible with the posted speed limits but may retain existing features having lower than design speed ratings if justified through the SCD or by acceptance of DJs as needed. “Special” design speed projects should base project design speeds on previously established corridor design speeds. For further information about design speeds, see the section titled "Speed" in the 2004 “Speed” in the 2004 GDHS[2].

1.6 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

FDM 11-10-5 Geometric Elements

August 15, 2019

5.1 Sight Distances

A primary feature of highway design is the arrangement of the geometric elements so that there is adequate sight distance for safe and comfortable vehicle operation. Sight distances are considered in terms of stopping sight distances, decision sight distances, passing sight distances, and intersection sight distances.

For the purposes of driveway permitting, driveway sight distances should equal intersection sight distances (it is also recommended that driveway sight distances be evaluated on Modernization projects).

Consistent quality designs require that sight distances be evaluated for the entire projects as wholes, rather than looking at isolated lengths of roadways. Adjustments in alignments and profiles should be evaluated to produce improvements in the availability, distribution, and balance of sight distances along the routes.

Use upper minimum design sight distance criteria categories and values on Modernization projects in most cases. Lower minimum design sight distances are available to use in appropriate situations in which they can be justified, documented and approved through the SCDs or in DJs. Below minimum sight distance criteria categories and values can be retained on Perpetuation, Rehabilitation and some Reconstruction-Type Modernization projects if the SCD results show no safety issues related to them. Otherwise, use of sight distance criteria categories and values below minimum need to be justified, documented and approved through DJs. See FDM 11-3-5 for guidance on design criteria.

[2] (*1) A Policy on Geometric Design of Highways and Streets 2004,* 5th edition. AASHTO, 2004., pp.66-72

5.1.1 Stopping Sight Distances (SSDs); Decision Sight Distances (DSDs)

5.1.1.1 Stopping Sight Distances (SSDs)

Stopping Sight Distance (SSD)[3] is the length of roadway ahead that is visible to drivers that is sufficiently long to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path. It is the sum of two distances:

1. Brake reaction distance - the distance traversed by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied
2. Braking distance - the distance needed to stop the vehicle from the instant brake applications begin. Stopping distance is calculated using the 90th percentile reaction time of 2.5 seconds and the 90th percentile deceleration rate of 11.2 feet/s^2 on wet pavement.

Prior to 2001, the AASHTO GDHS[4] provided ranges of values for SSDs. Since 2001, the AASHTO GDHS[5] has provided single SSD values per given design speeds. Attachment 5.1 shows the required stopping sight distances for design speeds from 25-70 mph. Consider adjustments to SSDs for downgrades and using values exceeding those shown in Attachment 5.1 (See Exhibit 3-2 in the 2004 AASHTO GDHS[6]).

Stopping sight distances are used when vehicles are traveling at design speeds on wet pavements when individual clearly discernable objects or obstacles are presented in the roadways. Use the same SSDs for trucks and cars because recent data shows that the braking distances of trucks and passenger cars on wet pavements are nearly equal[7].

5.1.1.2 Decision Sight Distances (DSDs)

Decision Sight Distance(DSD) is the distance needed for drivers to detect an unexpected or otherwise difficult-to-perceive information source or condition in a roadway environment that may be visually cluttered, recognize the condition or its potential threat, select an appropriate speed and path, and initiate and complete the maneuver safely and efficiently. There are 5 categories of avoidance maneuvers identified in AASHTO (*1*):

A: Stop on rural road

B: Stop on urban road

C: Speed/path/direction change on rural road

D: Speed/path/direction change on suburban road

E: Speed/path/direction change on urban road

Design values for DSDs are shown in Attachment 5.1.

Decision sight distances are to be considered when conditions are complex, driver expectancies are different for the situations, or visibility to traffic controls or design features are impaired. Complex situations create unsafe or inefficient operations because there is more information for drivers to process. Because of this, drivers need increased perception reaction times to make the proper decisions. These increased times can be especially beneficial for older drivers, because they are involved in disproportionate numbers of crashes where there are higher than average demands imposed on driving skills.

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[3] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., ch. 3, pp.109-131, "Elements of Design / Sight Distance"

[4] (*2) A Policy on Geometric Design of Highways and Streets 1990*. AASHTO, 1990. www.transportation.org, ch. III, pp.117-140, "Elements of Design / Sight Distance"

[5] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., ch. 3, pp.109-131, "Elements of Design / Sight Distance"

(*3) A Policy on Geometric Design of Highways and Streets 2001*, (2nd printing) 4th edition. AASHTO, 2001. www.transportation.org., ch. 3, pp.109-131, "Elements of Design / Sight Distance"

[6] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[7] (*4) Commercial Truck and Bus Safety Synthesis Program Synthesis 3*: *Highway / Heavy Vehicle Interaction*. Transportation Research Board, 2003. http://onlinepubs.trb.org/Onlinepubs/ctbssp/ctbssp_syn_3.pdf, p.22

5.1.1.3 Applications of Stopping Sight Distances (SSDs) and Decision Sight Distances (DSDs)

In computing and measuring sight distances along roadways, the heights of the driver's eyes are 3.5 feet above the pavement surfaces, and the heights of the objects to be seen by the drivers are, as shown below, either 6-inches or 24-inches. A 6-inch object is representative of the lowest object that can create a hazardous condition and be perceived as a hazard by a driver in time to stop before reaching it [8]. A 24-inch object is equivalent to the taillight height of a passenger car because stopping is generally in response to another vehicle or large hazard in the roadway[9].

There are 3 criteria categories for sight distances along roadways [10]:

- *Category 1* - Upper Minimum = SSD to 6-inch objects / Minimum = SSD to 24-inch objects;
- *Category 2* - Upper Minimum = DSD for avoidance maneuvers C to 24-inch objects *and* SSD to 6-inch objects* / Minimum = SSD to 24-inch objects;
- *Category 3* - Upper Minimum = DSD for avoidance maneuvers C to 24-inch objects *and* SSD to 6-inch objects* / Minimum = SSD to 6-inch objects.

  * Both conditions are important considerations because providing Decision Sight Distances to 24-inch objects does not guarantee Stopping Sight Distances to 6-inch objects at all locations. Examples include roads with “roller-coaster” type vertical alignments and roads with line-of-sight obstructions on the insides of horizontal curves.

The conditions for applying these design criteria are shown in Attachment 5.2. Application of particular design criteria are based on the complexity of the driving conditions that can be expected at particular locations. Category 1 applies to the least complex locations and is the default requirement for locations where the other categories don’t apply. Category 3 applies to the most complex locations.

Designers may use Decision Sight Distances at other locations that are not listed in Attachment 5.2 if they judge them to be necessary. These need to be evaluated in the SCDs. Some examples of locations where Decision Sight Distances may be appropriate are where:

- Complex operations or design features exist, including abrupt or unusual alignment changes;
- Detour Approaches;
- High-speed high-volume urban arterials with considerable roadside friction.

For Perpetuation, Rehabilitation and Reconstruction-Type Modernization projects the SCDs will determine the safety performance of existing sight distances and if no safety problems exist will not require any further evaluations of sight distances. Otherwise, evaluate sight distances on both horizontal alignments and vertical alignments for physical obstructions along the sight distance lines-of-sight (e.g., roadside structures, crest vertical curves, overpasses). Sag vertical curves are not considered physical obstructions (see FDM 11-10-5.4.2 for a discussion of sag vertical curves). Evaluate sight distance design criteria in both directions of travel on roadways because the sight distance categories might not be the same for both directions of travel.

When sight distances require evaluation, these criteria pertain to all roads. It is encouraged to provide sight distances that equal or exceed Upper Minimum values, particularly on two-lane bi-directional roads where passing sight distances are provided if they are economically obtainable. Providing less than minimum values requires approved SCDs or DJs per FDM 11-38, FDM 11-1-20 or FDM 11-4-10 depending on the improvement types and situations.

5.1.1.4 Sight Distances on Stop Sign Controlled Approaches

The minimum sight distance design criteria along roadways approaching stop signs is stopping sight distance (SSD) based on the design speeds of the roadways to either 24-inch or 6-inch objects, depending on the sight distance category (see FDM 11-10-5.1.1.3 and Attachments 5.1 and 5.2). The horizontal and vertical sight distance criteria are as described for the sight distance category.

Another consideration, in addition to stopping sight distances, is stop sign visibility. Road users need to perceive

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[8] (*2) A Policy on Geometric Design of Highways and Streets 1990*. AASHTO, 1990. www.transportation.org, pp.136-137

[9] (*5) NCHRP Report 400*: *Determination of Stopping Sight Distance*. TRB, National Research Council, 1997., pp. 44-45; 74-76

[10] *(6) SSD and DSD Guidance. (in-house report).* Wisconsin DOT, 2006. *(7) FDM 11-10-05_20060000_SSD-DSD-computations.xls.* Wisconsin DOT, 2009.

stop signs for sufficient distances to respond to them. Drivers approaching stop signs typically decelerate over greater distances than SSDs [11]. This allows more gradual decelerations than are used for SSDs. To achieve these, make sure that the stop signs are perceptible from the upstream functional lengths of intersections (see FDM 11-25-1). Although it is preferable that the stop signs be visible, it may be necessary to provide other traffic control devices, such as "Stop Ahead" signs, if there are none.

Also, see FDM 11-10-5.2.2 "Horizontal Curves on Stop Sign Controlled Approaches".

5.1.2 Sight Distances for Undercrossings

While not frequently problems, structure fascias may cut the lines of sight on roads passing under bridges and limit the sight distances to less than what are otherwise attainable. It is generally practical to provide the minimum lengths of sag vertical curves at grade separation structures. Even where the recommended grades are exceeded, the sight distances should not be reduced below the minimum recommended values for sight distances. See pages 277-279 of GDHS 2004[12] for more information.

5.1.3 Passing Sight Distances

Passing sight distance is the minimum sight distance that must be available to enable the driver of one vehicle to pass another vehicle safely and comfortably, without interfering with the speed of an oncoming vehicle traveling at the design speed should it come into view after the overtaking maneuver is started. The sight distances available for passing at any locations are the longest distances at which drivers, whose eyes are 3.5 feet above the pavement surfaces, can see objects 3.5 feet high on the roads (see Attachment 5.8). See GDHS 2004[13], pages 118-126 and 270 for additional information.

Minimum passing sight distances are sufficient for single or isolated passing only, and often opposing vehicles will cancel their passing opportunities. It is important to consider adequate passing sight distances over as much of the highway lengths as feasible. The greater the volumes of traffic on the roadways the more important it is to maximize well distributed passing opportunities.

When Modernizing existing facilities, it is important to consider trying to achieve passing opportunities of 60 percent or greater, if possible. It may be more advantageous to flatten smaller vertical curves rather than flattening single large vertical curves.

Guidance on establishing, marking and signing no-passing zones can be found in the Traffic Engineering Operations and Safety Manual (TEOpS) [14] and is specified in the Wisconsin Standard Specifications for Highway and Structure Construction. The sight distance values shown are not to be used directly in design but should be reviewed so that locations requiring no-passing zone markings can be recognized during design. Review proposed alignments with the region traffic section staff to assure that the passing sight distances provided will not require no-passing markings.

Passing sight design distances (AASHTO criteria) and no-passing zone criteria (TGM criteria) are based on different formulas and serve different purposes. The FHWA has determined that there is no significant need to make the two distances agree. The current no-passing zone marking practice provides a balance between passing opportunities and motorist violations.

Any highways (including bypasses and expressways) that are designed as future 4-lane divided highways, but designed to open initially as 2-lane highways, should be designed considering passing sight distance criteria for 2-lane highways. The designs should provide adequate passing sight distances as 2-lane highways for their full

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[11] See Wang et al in Transportation Research Record 1937 (*8)* Normal Deceleration Behavior of Passenger Vehicles at Stop Sign-Controlled Intersections Evaluated with In-Vehicle Global Positioning System Data. In No. *1937: Transportation Research Board of the National Academies*, 2005, pp.120-127. http://trb.metapress.com/content/u787613013238870/fulltext.pdf

see also AASHTO GDHS 2004 (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., Exh. 2-25, p. 45)

[12] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[13] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[14] (*9)* Applications / No Passing Zone Standards. In TEOpS 3-2-2, *ch. 3: Markings* 2009, sect. 3-2-2, pp.1-5.

performance life spans[15].

5.1.4 Intersection Sight Distances (ISDs), Vision Triangles, and Vision Corners

Intersection Sight Distance is the distance for which there must be unobstructed sight along both roads of an intersection, and across their included corners that is sufficient to allow the operators of vehicles approaching the intersection or stopped at the intersection, to safely carry out whatever maneuvers may be required to negotiate the intersection. Intersection Sight Distances are important to evaluate at all at-grade intersections on all projects for both passenger cars and for the design vehicles shown in Table 5.1. Intersection sight distances are ensured by establishing clear sight windows (see Figure 5.1) across each of the included corners of intersections. Design guidance on intersection sight distances for non-roundabout intersections can be found later in this section and is based on pages 650-677 of the 2004 AASHTO GDHS[16], but modified as noted. Guidance on intersection sight distances for roundabouts can be found in FDM 11-26-30. Guidance for intersection sight distances on Perpetuation and Rehabilitation projects can be found in FDM 11-40-1. See FDM 11-46-20 for guidance on sight distances for trail crossings.

Table 5.1 Design Vehicles for Intersection Sight Distances [A]

Type of Intersecting Highway	Design Vehicle for Purposes of ISD [B]
Interchange ramp terminals	Combination Truck (WB-vehicle, e.g. WB-50, WB-65)
Arterials	Combination Truck (WB-vehicle, e.g. WB-50, WB-65)
Collectors	Single Unit Truck (SU-vehicle) [C]
Local Roads / Residential Streets	Single Unit Truck (SU-vehicle) [C]

A See FDM 11-25-2.1 for guidance on Intersection Design Vehicles and Intersections. Check Vehicles for turning movements at intersections

B Only the Passenger vehicles need be considered in areas where truck traffic is minimal (<2.5% of AADTs), and right-of-way restrictions prohibit adequate sight window clearing

C If there is significant Combination Truck traffic then use those as the design vehicles instead of the Single Unit Trucks.

A vision triangle is an additional clear sight window, for intersections with stop sign control on the side road and for signal-controlled intersections. Their purpose is to provide opportunities for speed adjustments or evasive maneuvers by vehicles on the major highways if vehicles on the minor roads violate the traffic control. In other words, Vision Triangles are supplements to, and not substitutes for intersection sight distances. ISDs should be provided at all intersections whether or not vision triangles are provided. Guidance on vision triangles and where to use them can be found later in this section. Guide dimensions for vision triangles can be found in Attachment 5.13.

A "vision corner" is defined as either

- The clear sight window for intersection sight distance, if no vision triangle is used, or
- The combination of the clear sight window for ISD and the clear sight window for vision triangle, as shown in Figure 5.1.

[15] *(10) Review of Wisconsin Bypass Road Design Practices February 13-14, 2006. (Final).* Federal Highway Administration Resource Center, 2006. http://www.dot.wisconsin.gov/library/publications/docs/wis-bypass-report.pdf

[16] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

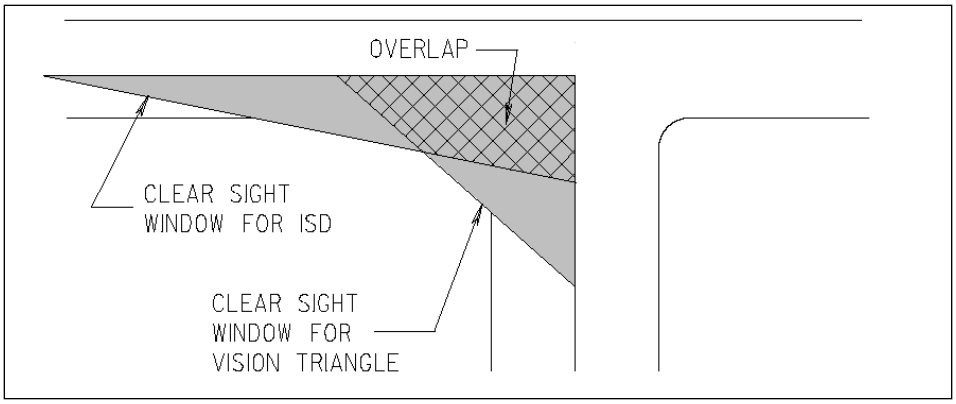

***Figure 5.1* Example of Vision Corner**

5.1.4.1 Clear Sight Windows

A clear sight window and its horizontal and vertical boundaries are shown in Figure 5.2. The dimensions of clear sight windows vary depending on the types of vehicles and the types of intersection controls (see Table 5.1 above and Design Guidance for Intersection Sight Distances below).

In establishing sight lines through clear sight windows, use eye heights above the roadway surfaces of 3.5 feet for passenger cars and 7.6 feet for trucks. Use object heights above the roadway surfaces of 3.5 feet.

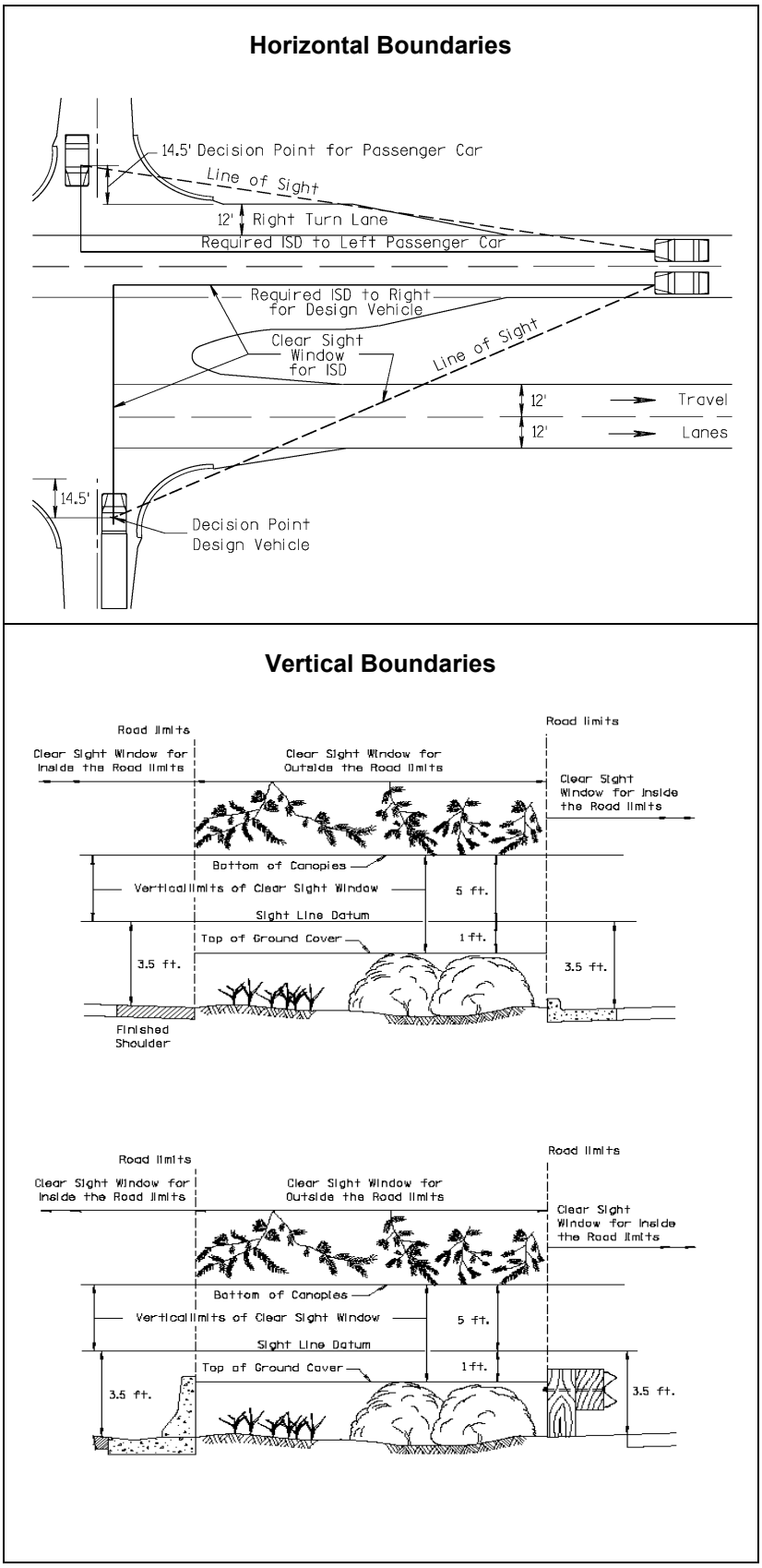

***Figure 5.2** Clear Sight Window (adapted from Florida DOT[17])*

5.1.4.1.1 Horizontal Boundaries of Clear Sight Windows

The horizontal boundaries of clear sight windows on the mainlines are the centers of the approach travel lanes, beginning at the intersections and ending at points known as the decision points for the mainlines, established

by applying the intersection sight distance requirements for the intersection control cases (see FDM 11-10-5.1.4.2 "Design Guidance for Intersection Sight Distances" below).

The horizontal boundaries of clear sight windows on the side roads is the centers of the approach travel lanes, beginning at the intersections and ending at points known as the decision points for the side roads established by applying the intersection sight distances for the intersection control cases (see FDM 11-10-5.1.4.2 "Design Guidance for Intersection Sight Distances" below).

The horizontal boundary of clear sight windows across the included corners of intersections are the lines connecting the end points, or decision points, of the first two sides.

5.1.4.1.2 Vertical Boundaries of Clear Sight Windows

The bottom boundaries of clear sight windows are the sight line datums inside the road limits, and 1-foot below the sight line datums outside the road limits. A sight line datum is defined as a line of sight which is 3.5-feet above the pavement surface on each end. The road limit is defined as the edge of finished shoulder or the back of curb, whichever is applicable, unless there is a barrier or bridge parapet. In those cases, the road limits are defined as the back edges of roadside barriers or bridge parapets.

The top boundaries of clear sight windows are 5-foot above the sight line datums.

5.1.4.1.3 Obstructions Within Clear Sight Windows

Make sure that clear sight windows are clear of obstructions that might block drivers' views of potentially conflicting vehicles. These include, but are not limited to:

- The roadways themselves - check the vertical alignments and super elevations of the highways to see if the pavements obscure the lines of sight,
- Roadside and median barriers - including beam guard,
- Bridge parapets and railings,
- Cut slopes and embankments,
- On-street parked vehicles - See Figure 5.3. Consider prohibiting on-street parking as follows, unless greater restrictions are required by statute, the Wisconsin MUTCD, or to provide adequate lines of sight for pedestrians:
    - **Upper Minimum:** within the Intersection Sight Distance clear sight windows[18].
    - **Minimum**: so that vehicles entering from the side-roads do not have to encroach on the mainline travel lanes or bicycle lanes in order for the drivers to see vehicles approaching on the mainlines at a distance equal to ISD.
    - **NOTE**: assume parked vehicles are 12 inches from the curb faces.
- Off-street parked vehicles - Consider prohibiting off-street parking within the ISD clear sight windows,
- Signal control cabinets,
- Landscaping,
- Signs - offset signs to prevent sight distance obstructions,
- Structures, including, but not limited to, buildings, fences, retaining walls, screenings,
- Vegetation, including bushes, hedges, natural growths, plantings, tall crops, tree branches, and tree trunks.

There must be sufficient right-of-way to ensure that line-of-sight obstructions can be removed.

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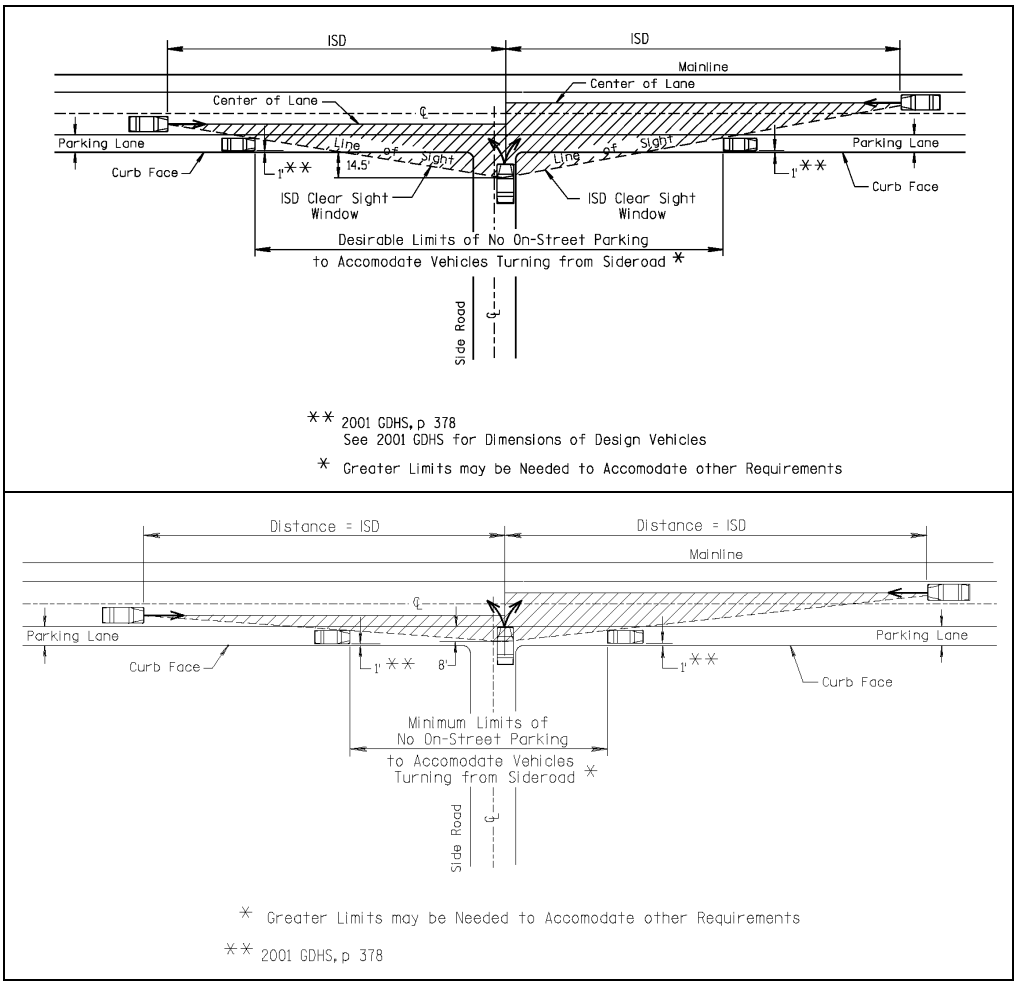
[17] *Adapted from (11) Sight Distance at Intersections. In FLDOT Road Design Detail Florida DOT, 1989, Index No. 546.*

[18](*12)Access Management Manual*. Transportation Research Board, 2003., Figure 5.8-5.9



***Note: This is not an alternative method for establishing ISD. Parked cars are not permanent sight obstructions. ISD from 14.50 feet behind the near face of mainline curb is still important to evaluate per FDM 11-10-5.1.4.2.2.

Figure 5.3* Determining On-Street Parking Limits**

Street markers, traffic signs, and other traffic controls are allowed within the Clear Sight windows, provided their numbers and arrangements do not significantly block vision across the areas. Likewise, utility pedestals and poles are allowed within the Clear Sight windows, provided their numbers and arrangements do not significantly block vision across the areas. Consider offsetting right turn lanes at intersections where there are significant numbers of right turns that impede clear sight lines.

Urban Intersections can be particularly concerning because of the abundance of street furniture and developments in the vicinities of intersections. Pay particular attention to the potential for line of sight obstructions in the placement of signs, light poles, signal controllers, tree plantings, newspaper and advertising boxes, etc.

Pedestrian Considerations: Features such as landscaping, parked cars, utility poles, traffic control devices, and street furniture can create sight obstructions for pedestrians. Consider installing curb extensions or instituting parking restrictions to ensure that pedestrian sight lines are not blocked.

5.1.4.2 Design Guidance for Intersection Sight Distances

As mentioned above, intersection sight distances are important to evaluate at all at-grade intersections on all projects for both passenger cars and for the design vehicles shown in Table 5.1. Guidance is provided below for the following intersection control cases.

- Case A - Intersections with no control
- Case B - Intersections with stop control on the minor road
    - B1 - Left turn from the minor road
    - B2 - Right turn from the minor road

    - B3 - Crossing maneuver from the minor road
- Case C - Intersections with yield control on the minor road
    - C1 - Crossing maneuver from the minor road
    - C2 - Left or right turn from the minor road
- Case D - Intersections with traffic signal control
- Case E - Intersections with all-way stop control
- Case F - Left turns from major roads

5.1.4.2.1 Case A - Intersections with No Controls

Do not allow uncontrolled at-grade intersections on STHs. For non-STH locations, use guidance from GDHS 2004[19], pages 654-657.

5.1.4.2.2 Case B - Intersections with Stop Control on Minor Roads

Gap Acceptance, as described on page 659, GDHS 2004[20] and modified herein, is the basis for computing Case B Intersection Sight Distances.

Decision point locations for side road vehicles are the positions of the side road driver's eyes in relation to the mainlines. For rural intersections, these distances approximate the locations of passenger cars at standard stop bar installations. They are equal to14.50 feet from the farthest outside edges of non-shoulder mainline pavements. In most situations, these would be either the edges of the mainline right turn lanes, the mainline right-turn tapers, the mainline downstream acceleration tapers, or the mainline travel lanes. However, if there are separate channelized right-turn lanes on the mainlines, these distances would be to either the mainline downstream acceleration tapers, or the edges of the near mainline travel lanes.

For urban intersections, these distances are 14.50 feet from the near faces of mainline curbs.

Decision Point Locations for crossing vehicles stopped in medians are the positions of the driver's eyes in relation to the far side traffic lanes. For medians without stop bars, assume the vehicles stop with their front ends 3 feet from the median edges of travel lanes. The drivers' eyes are 8 feet behind these, or 11 feet from the median edges of travel lanes. For medians with stop bars this distance is about 8.0 feet behind the stop bars.

Median widths need to be at least 6 feet greater than vehicle lengths for vehicles to complete crossings in two (2) steps.[21].

Decision point locations for mainline vehicles vary by design speeds and design vehicles. Table 5.2 shows the Intersection Sight Distance requirements for AASHTO Intersection Control Cases B1, B2, and B3. See Attachment 5.14 for an example computation.

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[19] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[20] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[21] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004, pp 456-457;

(*13) NCHRP Report 375*: *Median Intersection Design*. TRB, National Research Council, 1995. pp 67-68;

(*14)* Sight Distance / Stop Control on Cross Street. In *NJDOT Roadway Design Manual-2008 ch. 6: At-Grade Intersections* New Jersey DOT, 2008, section 6.3.3. https://www.nj.gov/nj/trans/

***Table 5.2** Intersection Sight Distance [A] Criteria for Intersection Control Cases B1, B2, and B3 - Stop on Minor Road*[22]

	Case B1 - Left turn from the minor road [B]			Case B2 - Right turn from the minor road [C]			Case B3 - Crossing maneuver from the minor road [D]		
Design vehicle	**P**	**SU**	**WB**	**P**	**SU**	**WB**	**P**	**SU**	**WB**
Eye height (feet)	3.5	7.6	7.6	3.5	7.6	7.6	3.5	7.6	7.6
Time gap (sec) **UPPER MINIMUM** (MINIMUM)	**10.0** (7.5)	**12.0** (9.5)	**13.0** (11.5)	**8.0** (6.5)	**10.0** (8.5)	**12.0** (10.5)	**7.0** (6.5)	**10.0** (8.5)	**13.0** (10.5)
Mainline Design Speed (mph)	**ISD (feet) UPPER MIN** (MIN)	**ISD (feet) UPPER MIN** (MIN)	**ISD (feet) UPPER MIN** (MIN)	**ISD (feet) UPPER MIN** (MIN)	**ISD (feet) UPPER MIN** (MIN)	**ISD (feet) UPPER MIN** (MIN)	**ISD (feet) UPPER MIN** (MIN)	**ISD (feet) UPPER MIN** (MIN)	**ISD (feet) UPPER MIN** (MIN)
25	**370** (280)	**445** (350)	**480** (425)	**295** (240)	**370** (315)	**445** (390)	**260** (240)	**370** (315)	**480** (390)
30	**445** (335)	**530** (420)	**575** (510)	**355** (290)	**445** (375)	**530** (465)	**310** (290)	**445** (375)	**575** (465)
35	**515** (390)	**620** (490)	**670** (595)	**415** (335)	**515** (440)	**620** (545)	**365** (335)	**515** (440)	**670** (545)
40	**590** (445)	**710** (560)	**765** (680)	**475** (385)	**590** (500)	**710** (620)	**415** (385)	**590** (500)	**765** (620)
45	**665** (500)	**795** (630)	**860** (765)	**530** (430)	**665** (565)	**795** (695)	**465** (430)	**665** (565)	**860** (695)
50	**735** (555)	**885** (700)	**960** (850)	**590** (480)	**735** (625)	**885** (775)	**515** (480)	**735** (625)	**960** (775)
55	**810** (610)	**975** (770)	**1055** (930)	**650** (530)	**810** (690)	**975** (850)	**570** (530)	**810** (690)	**1055** (850)
60	**885** (665)	**1060** (840)	**1150** (1015)	**710** (575)	**885** (750)	**1060** (930)	**620** (575)	**885** (750)	**1150** (930)
65	**960** (720)	**1150** (910)	**1245** (1100)	**765** (625)	**960** (815)	**1150** (1005)	**670** (625)	**960** (815)	**1245** (1005)
70	**1030** (775)	**1235** (980)	**1340** (1185)	**825** (670)	**1030** (875)	**1235** (1085)	**725** (670)	**1030** (875)	**1340** (1085)

[22] (*15) NCHRP Report 383*: *Intersection Sight Distance*. TRB, National Research Council, 1996.
(*16)* Intersections at Grade. In *FHWA-RD-01-051: Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians* Federal Highway Administration Turner-Fairbank Research Center, 2001, Section I. https://www.federallabs.org/labs/federal-highway-administration-fhwa-turner-fairbank-highway-research-center-tfhrc *(17) ISD and vision triangle recomm vs 1990 GDHS.xls.* Wisconsin DOT, 2004.

A Intersection Sight Distance = time gap x design speed in feet/s. feet/s = mph x (5280 feet per mi divided by 3600 seconds per hour). Table values have been rounded.

B Case B1 Time gaps and intersection sight distances are for stopped vehicles to turn left onto two-lane highways with no medians and grades 3 percent or less. The table values require adjustment as follows:

- For multilane highways. For left turns onto two-way highways with more than two lanes, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane, from the left in excess of one, to be crossed by the turning vehicles. Medians are computed as equivalent lane widths if they are too narrow for vehicles to stop in, e.g. a 30-foot median would be equivalent to 2.5 lanes. Mainline right turn lanes and tapers are also treated as equivalent lane widths.
- For minor road approach grades. If the approach grades are upgrades that exceed 3 percent, then add 0.2 seconds for each percent grade for left turns.
- For skews, use guidance from page 677, GDHS 2004[23].

C Case B2 Time gaps and intersection sight distances are for stopped vehicles to turn right onto two-lane highways with grades 3 percent or less. The table values require adjustment as follows:

- Add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane, from the left in excess of zero, to be crossed by the turning vehicles. Mainline right turn lanes and tapers are treated as equivalent lane widths.
- For minor road approach grades. If the approach grades are upgrades that exceeds 3 percent then add 0.1 seconds for each percent grade.
- For skews, use guidance from page 677, GDHS 2004

D Case B3 Time gaps and intersection sight distances are for stopped vehicles to cross two-lane highways with no medians and grades 3 percent or less. The table values require adjustment as follows:

- For multilane highways. For crossing major roads with more than two lanes, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane to be crossed and for narrow medians that cannot store the design vehicles. Medians are computed as equivalent lane widths if they are too narrow for vehicles to stop in, e.g. 30-foot medians would be equivalent to 2.5 lanes. Mainline right turn lanes and tapers are also treated as equivalent lane widths.
- For minor road approach grades. If the approach grades are upgrades that exceed 3 percent, then add 0.1 seconds for each percent grade.
- For skews, use guidance from page 677, GDHS 2004

5.1.4.2.3 Case C - Intersections with Yield Control on the Minor Roads

Except for roundabouts, do not allow yield-controlled at-grade intersections on STHs. Use the guidance from pages 666-673, GDHS 2004 for non-roundabout yield-controlled intersections on non-STH roads - except use Case B1 and B2 values, per Table 5.2, for mainline ISD distances for Case C2 - Left or right turns from the minor roads.

Refer to the WisDOT Roundabout Guide for guidance on Intersection Sight Distances for roundabouts.

5.1.4.2.4 Case D - Intersections with Traffic Signal Controls

Use the guidance from pages 671, 673, GDHS 2004, except use the values from Table 5.2 where Case B is called for, e.g. where right turns on red are allowed.

5.1.4.2.5 Case E - Intersections with All-Way Stop Control (AWSC)

At intersections with all-way stop controls, the first stopped vehicles on one approach should be visible to the drivers of the first stopped vehicles on each of the other approaches. There are no other sight distance criteria applicable to intersections with all-way stop controls. See page 674, GDHS 2004[24].

5.1.4.2.6 Case F - Left Turns from the Major Roads

Use the guidance from pages 674-676, GDHS 2004, except use the time gaps and Intersection Sight Distances shown in Table 5.3.

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[23] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[24] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

Provide positive offsets for opposing left turn lanes, if possible. Positive left-turn lane offsets, as shown in Figure 5.4, can be helpful in allowing drivers in opposing left-turn bays to see past each other to detect oncoming traffic. They can also improve the operations of signalized intersections by allowing more efficient use of permissive left-turn phasing. See FDM 11-25-5, "Slotted Left-turn Lanes" for additional guidance.

Table 5.3 Intersection Sight Distance (ISD) Criteria for Case F - Left Turn from Major Road[25]

Design vehicle	P	SU	WB
Eye height (ft)	3.5	7.6	7.6
Time gap [A] (sec) UPPER MINIMUM (MINIMUM)	**8.0** (5.5)	**8.0** (6.5)	**8.0** (7.5)
Mainline Design Speed (mph)	**ISD (feet) UPPER MIN** (MIN)	**ISD (feet) UPPER MIN** (MIN)	**ISD (feet) UPPER MIN** (MIN)
25	295 (205)	**295** (240)	**295** (280)
30	**355** (245)	**355** (290)	**355** (335)
35	**415** (285)	**415** (335)	**415** (390)
40	**475** (325)	**475** (385)	**475** (445)
45	**530** (365)	**530** (430)	**530** (500)
50	**590** (405)	**590** (480)	**590** (555)
55	**650** (445)	**650** (530)	**650** (610)
60	**710** (490)	**710** (575)	**710** (665)
65	**765** (530)	**765** (625)	**765** (720)
70	**825** (570)	**825** (670)	**825** (775)

[A] Time gaps and intersection sight distances are for vehicles making turns left from undivided 2-lane highways (1 lane in each direction). The table values require adjustment as follows: For left-turning vehicles that cross more than one opposing lane, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane to be crossed. Median widths crossed are computed as equivalent lane widths and are measured from the inside edges of left turn lanes to the median edges of the opposing travel lanes.

[25] *(16)* Intersections at Grade. In *FHWA-RD-01-051: Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians* Federal Highway Administration Turner-Fairbank Research Center, 2001, Section I. https://www.federallabs.org/labs/federal-highway-administration-fhwa-turner-fairbank-highway-research-center-tfhrc

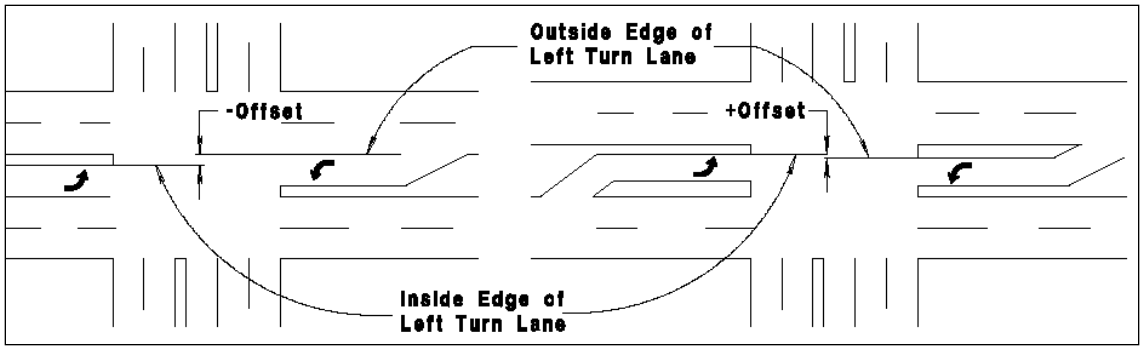

***Figure 5.4** Negative (-) Offset and Positive (+) Offset of Opposing Left Turn Lanes*[26]

5.1.4.2.7 Interchange Ramp Terminals at Crossroads

Treat ramp terminals at crossroads like any other at-grade intersections. Provide intersection sight distances based on the applicable intersection control case as described above. However, be very conscious of potential sight obstructions such as bridge railings, piers, and abutments that are likely to be found near ramp terminals. Design the crossroad profiles, and also provide enough separation between the ramp terminal intersections and the structures, so that intersection sight distances are not obstructed.

If the crossroads are under-crossings, check the sight distances under the structures graphically using the appropriate eye heights for the vehicles at the intersections, and object heights of at least 2.0 feet.

Traffic controls such as signals, all-way stop signs, or roundabouts may be possible solutions for ramp terminal locations where there are inadequate sight distances because less intersection sight distances are needed.

5.1.4.3 Design Guidance for Vision Triangles[27]

Where there are stop signs or traffic signal controls on the side roads, the clear sight windows for intersection sight distances extend only short distances along the side roads because it is assumed that the drivers of vehicles approaching on the side roads will see and obey the traffic controls. However, there are several hundred thousand crossing path crashes every year in this country caused by drivers running stop signs and red lights[28]. Adding vision triangles enhances the safety of intersections by providing opportunities for speed adjustments or evasive maneuvers by vehicles on the major highways in the events vehicles on the minor roads violate the traffic controls. These safety enhancements can be particularly important at higher volume intersections on high-speed roads.

As mentioned above, vision triangles are additional clear sight windows for intersections with stop sign controls on the side roads and for signal-controlled intersections. In other words, vision triangles are supplements to, and not substitutes for, Intersection Sight Distances (ISDs). ISD is important to evaluate at all intersections whether vision triangles are provided or not.

Guide dimensions for vision triangles are shown on Attachment 5.13. The dimensions are based on providing two seconds of travel time at the posted speeds+5 mph for both the mainlines and the side roads, i.e. they are reciprocal with respect to the time both drivers can see and react to each other. Greater dimensions may be used if desired - e.g. if local zoning ordinances show greater distances. On the other hand, if site conditions, such as building takings or unacceptable environmental impacts, preclude obtaining the recommended triangles, partial vision triangles can still be beneficial.

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[26] (*18) Median Handbook*. Florida DOT, 2001, Ch 3, p8

[27] *(17) ISD and vision triangle recomm vs 1990 GDHS.xls.* Wisconsin DOT, 2004.

[28] References: *(19) Intersection Collision Avoidance Using ITS Countermeasures.* NHTSA, 2000. http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13341.pdf, p6.10; *(20) Intersection Decision Support Project: Taxonomy of Crossing-Path Crashes at Intersections Using GES 2000 Data.* University of California Traffic Safety Center, 2003. http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1006&context=its/tsc, pp 4-6, 11 *(21) Reducing Crashes at Rural Thru-Stop Controlled Intersections.* CH2M Hill, 2002. http://www.ctre.iastate.edu/

Do not rely on vision triangles as the sole protection against run-the-stop-sign crashes. Measures such as increasing visibility of traffic control devices and providing streetlights can aid approaching drivers in detecting intersections and their controls.

Modernization projects should evaluate providing vision triangles per the criteria shown below. If it is not possible to provide vision triangles, justifications are required in the Design Study Reports (DSRs). Vision triangles are not used at roundabouts because research has shown that excessive intersection sight distances at roundabouts result in higher frequencies of crashes.

5.1.4.3.1 Criteria for Providing Vision Triangles

For Modernization Projects:

- DO NOT provide vision triangles at roundabouts
- Evaluate at at-grade intersections on expressways.
- Evaluate at other intersections and at driveways which meet either of the following warrants:
  - the posted speeds of the STHs ≥45 mph, and current or construction year traffic volumes on the STHs >750 AADT, and current or construction year traffic volumes on the side roads (or driveways) >400 AADT, and the sum of both >1250 AADT.
  - the posted speeds of the STHs ≥45 mph, and design year traffic volumes on the STHs >2500 AADT and design year traffic volumes on the side roads (or driveways) >1000 AADT.
- Provide at intersections where there has been a history of run-the-stop sign or run the red-light crashes.
- Perpetuate at intersections where they have been previously provided.
- Vision triangles are optional at other intersections and driveways.

For Rehabilitation Projects:

- DO NOT provide vision triangles at roundabouts
- Evaluate at intersections which are being upgraded, and which meet either of the following warrants:
  - the posted speeds of the STHs ≥45 mph, and current or construction year traffic volumes on the STHs >750 AADT, and current or construction year traffic volumes on the side roads (or driveways) >400 AADT, and the sum of both >1250 AADT.
  - the posted speeds of the STHs ≥45 mph, and design year traffic volumes on the STHs >2500 AADT, and design year traffic volumes on the side roads >1000 AADT.
- Provide at intersections where there has been a history of run-the-stop sign or run-the red-light crashes.
- Perpetuate at intersections where they have been previously provided.
- Vision triangles are optional at other intersections and driveways.

For Perpetuation Projects:

- DO NOT provide vision triangles at roundabouts
- Vision triangles are optional at other intersections and driveways.

5.1.4.3.2 Land Rights and Interests for Vision Triangles

See FDM 12-1-15 for definitions of the various types of land rights and interests acquired by the Department. In order of preference, land rights or interests for vision triangles can be:

1. Fee Titles,
2. Restricted Development Easements - when fee title interests will have significant adverse impacts on the parcels.
3. None -This only applies to vision triangles that are established by local zoning ordinances, since these are not necessarily dedicated as road right-of-way. In these cases, enforcement is through the local zoning authorities.

5.1.4.4 Mitigation Measures for Sight Distance Deficiencies at Intersections

Some intersections may have either inadequate intersection sight distances or inadequate roadway sight distances approaching the intersections that are causing safety and operational problems. Ideally, the deficiencies would be corrected in timely and cost-effective manners. However, this is not always possible. Consult with the Region Traffic Section on possible mitigation measures. Some mitigation measures that might be considered-either alone or in combination-are:

- Restrict or prohibit some turning movements.
- Reduce the regulatory speeds. Use appropriate signing and warning lights.
- All-way stop sign controls, traffic signals, or roundabouts - these require that there be adequate sight distances on the roadways approaching the intersections.
- Provide travel lane rumble strips (typically for approaching stop signs). Be aware of noise and proximity to houses.
- Provide advance signing, and possibly warning lights.
- Adjust signing at intersections so that they are visible from farther away. Do this by making the signs larger, brighter, or providing additional signs and marking, or a combination of any of the three.
- Provide pork chop islands on side-road approaches to allow for more effective placement of supplemental STOP signs or traffic signals, and to encourage better positioning of stopped vehicles for enhanced visibility of approaching mainline traffic.
- Provide street lighting at the intersections. Light poles also provide daytime recognition of the presence of intersections.
- Use "CROSS TRAFFIC DOES NOT STOP" signs at intersections that drivers could misinterpret as all-way stops (for example, two roads of equal status intersect and only one of them has a stop sign).

See the following references for additional safety measures and mitigation[29]:

- NCHRP Report 500, vol. 5 and vol. 12,
- FHWA bypass report,
- FHWA-SA-09-020, "Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections"

5.1.4.4 Sight Distances for Railroad-Highway Grade Crossings

See FDM Chapter 17 Railroad Coordination.

5.2 Horizontal Alignments[30]

Horizontal alignments should typically be as straight as possible and consistent with environmental, physical, and economic constraints. Whenever feasible, avoid using maximum curvatures. Flatter curvatures with shorter tangents are generally preferable to sharp curves connected by long tangents. Alignments must be consistent. Sudden changes from flat to sharp curves and long tangents followed by sharp curves can create safety hazards. Likewise, avoid using reverse curves unless sufficient lengths of tangents are included between the curves to provide for superelevation transitions. Also, avoid using very long curves because they inhibit some drivers from making passing maneuvers even when adequate sight distances exist.

The horizontal alignment development process can possibly introduce trial alignments that have curvatures, superelevations, or superelevation transitions carried onto or through structures. Such alignments should be avoided, except when there are definite needs, or specific purposes. These situations almost always result in unsightly appearances of bridges or bridge railings and create needless complications in design and construction. Safety considerations are paramount however and shall not be sacrificed to meet the foregoing

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[29] (*22) NCHRP Report 500*: *A Guide for Addressing Unsignalized Intersection Collisions*, vol 5 of Guidance for Implementation of the AASHTO Strategic Highway Safety Plan. Transportation Research Board of the National Academies, 2003. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_500v5.pdf

(*23) NCHRP Report 500*: *A Guide for Reducing Collisions at Signalized Intersections*, vol 12 of Guidance for Implementation of the AASHTO Strategic Highway Safety Plan. Transportation Research Board of the National Academies, 2004. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_500v12.pdf

(10) Review of Wisconsin Bypass Road Design Practices February 13-14, 2006. (Final). Federal Highway Administration Resource Center, 2006. http://www.dot.wisconsin.gov/library/publications/docs/wis-bypass-report.pdf

(24) Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections. FHWA-SA-09-020*.* Federal Highway Administration, 2009. http://safety.fhwa.dot.gov/intersection/resources/fhwasa09020/fhwasa09020.pdf

[30] ((*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., ch. 3, pp.131-231, "Elements of Design / Horizontal Alignment"

criteria. If the designer feels a bridge must be built on superelevation or transition, the reasons for this should be explained in the Structure Survey Report.

Horizontal curves should not be introduced near the crests of vertical curves. The combination of horizontal and vertical curves can greatly reduce sight distances creating hazardous conditions. These conditions hide the horizontal curves from the approaching drivers, especially at night. These hazards can be avoided by having the horizontal curvatures lead the vertical curvatures; i.e., the horizontal curves are made longer than the vertical curves. Although the designers must attempt to optimize the horizontal alignments with respect to other factors and avoid the appearances of inconsistencies and distortions in the alignments, the horizontal alignments should be coordinated with the vertical and cross-sectional features of the highways.

Adequate sight distances are important to provide on horizontal curves. If objects off the pavements such as bridge piers, cut slopes, or natural growth restricts sight distances then the minimum radii of curvature should be designed considering the sight distances and the lateral clearances to the objects. Attachment 5.9 shows the relationships between obstructions, degrees of curve, design speeds, and sight distances. If horizontal sight distances are not achieved then documentation and approval is needed in the SCDs or DJs in accordance with FDM 11-38, FDM 11-1-20 and FDM 11-1-4.10.

Although the use of P.I.'s without accompanying horizontal curves is discouraged, there may be situations where they are necessary. These are to be discussed and justified in the DSR. Table 5.4 shows maximum deflections without horizontal curves.

Table 5.5 shows the maximum deflections through low-speed urban intersections - both for lane shifts and for centerline deflections. Short curves may be desirable at each end of lane shifts, especially if pavement markings are used through the intersections to provide positive guidance to motorists.

If possible, avoid lane shifts at signalized intersections - particularly where mounting signal heads over each lane. They complicate the designs and may confuse drivers. Also, avoid deflections thru signalized intersections if possible. Also, avoid where lane designation signs are used.

Table 5.4 Maximum Deflections Without Horizontal Curves[31]

Posted Speed (S) mph		Deflection Δ* Lower Maximum	Deflection Δ* Maximum
Low Speed	25	3º 45'	5º 30'
	30	2º 45'	3º 45'
	35	2º 15'	2º 45'
	40	1º 45'	2º 15'
High Speed	45	1º 15'	1º 15'
	50	1º 00'	1º 15'
	55	1º 00'	1º 00'
	60	0º 45'	1º 00'
	65	0º 45'	0º 45'

* Rounded to nearest 15'

[31]Adapted from (*25)* Horizontal Alignment - Maximum Centerline Deflection without Horizontal Curve. In *OHDOT Location & Design Manual, Vol.1, Roadway Design ch. 200: Horizontal and Vertical Design* Ohio DOT, 2006, sect. 202.2, pp.5, Fig. 202-1E. http://www.dot.state.oh.us/divisions/Engineering/roadway/Pages/default.aspx and from

Use the Lower Maximum deflection values when appropriate and the Maximum deflection values to MATCH existing conditions or when justified. Providing greater than the Maximum Deflection Values requires approved SCDs or DJs.

Based on the following formulas:

Lower Maximum Deflection Values:

- Low Speed: $TAN\ \Delta = 60 / (S+5)^2$
- High Speed: $TAN\ \Delta = 1.0 / (S+5)$

Maximum

- Low Speed: $TAN\ \Delta = 60 / S^2$
- High Speed: $TAN\ \Delta = 1.0 / S$

Where:

S = Posted Speed

Δ = Deflection Angle

Minimum distances between consecutive horizontal deflections (i.e., P.I.'s) are:

- Low Speed: 100'
- High Speed: 200'

Table 5.5 Maximum Deflections for Through Lanes Through Urban Intersections

Posted Speed	25	30	35	40
Maximum Deflection	7° 30’	5° 30’	4° 15’	3° 15’

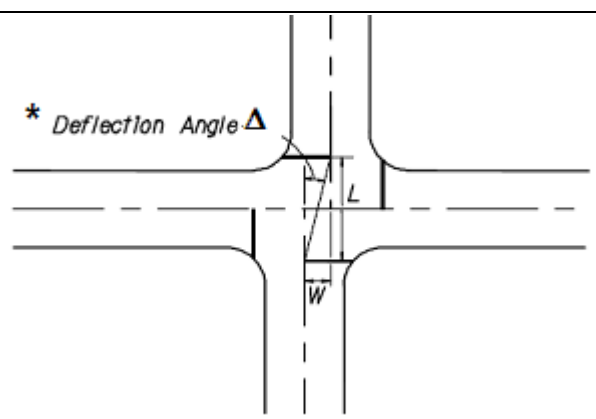
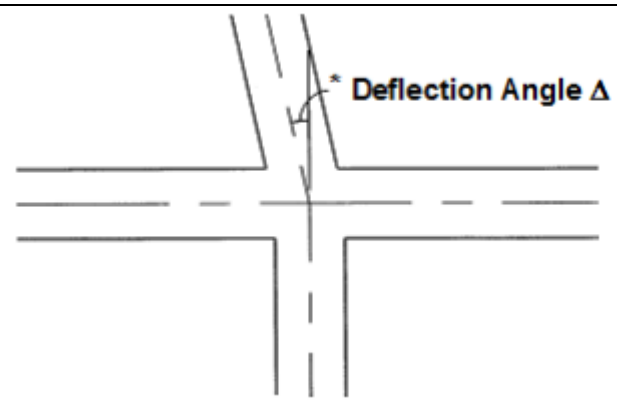
Lane Shift	Deflection Thru Intersection
	
* $TAN\ \Delta = 120 /(S+5)^2$	

Figure 5.5 Deflection Angle[32]

(*26)* Temporary Traffic Control Elements - Tapers. In *Manual on Uniform Traffic Control Devices ch. 6: Temporary Traffic Control* Federal Highway Administration, 2003, sect. 6C.08, pp.6C-5-6C-8. http://mutcd.fhwa.dot.gov/pdfs/2003/pdf-index.htm

[32] (*26)* Temporary Traffic Control Elements - Tapers. In *Manual on Uniform Traffic Control Devices ch. 6: Temporary Traffic Control* Federal Highway Administration, 2003, sect. 6C.08, pp.6C-5-6C-8. http://mutcd.fhwa.dot.gov/pdfs/2003/pdf-index.htm

(*27)* Curves - Horizontal Curves. In *FLDOT Plans Preparation Manual, Volume I - English ch. 2: Design Geometrics and Criteria* Florida DOT, 2007, sect. 2.8.1, pp.2-39-2-44. http://www.dot.state.fl.us/rddesign/PPMManual/2007/Volume1/zChap02.pdf

5.2.1 Reference Lines

Basic highway reference lines should be the centerlines of normal two-way roadways. Basic reference lines of divided highways may be located either along the centerlines of the medians or along the median edges of the right-hand through pavements in the directions of stationing. All stationing and profiles of finished grades and original ground should be referred to the basic highway reference lines. Auxiliary reference lines along the median edges of left-hand pavements may be desirable when roadways are not parallel or concentric or are widely separated.

Stationing of projects (main lines and side roads) should be from west to east or south to north based on the cardinal directions of the overall highway routes, not just the portion(s) of the highways within the projects under design.

5.2.2 Horizontal Curves on Stop Sign Controlled Approaches

Horizontal curves close to intersections on stop-sign controlled approaches, as shown in Figure 5.6, need to accommodate reasonable operating speeds, while minimizing the potential for adverse operations on super-elevated pavements during snow and ice conditions. Use the following guidelines[33]:

- Make sure that the stop signs are perceptible to the drivers for sufficient distances from the intersections to allow deceleration before reaching the curves (see FDM 11-10-5.1.1.4, “Sight Distance on Stop Sign Controlled Approaches”).
- Assume design speeds for horizontal curves of 20 mph less than the side-road design speeds, but not less than 30 mph if the side-road design speeds are less than or equal to 50 mph.
- Limit the superelevation rates on the approach curves to intersections to 5% or less. The objective is to use as flat alignments as practical with lower superelevations. The preferred designs are to maintain normal crown sections through the curves.
- Provide tangent sections prior to the intersections so that the superelevation runoffs occur outside of the intersection radius returns.

(*28)* Horizontal Alignment - Tapers. In *Florida Intersection Design Guide ch. 3: Geometric Design* Florida DOT, 2007, sect. 3.7.2, pp.3-10-3-12. http://www.dot.state.fl.us/rddesign/FIDG-Manual/FIDG2007.pdf

[33] Adapted from Illinois DOT Bureau of Design and Environment Manual ch. 36 (*29) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf

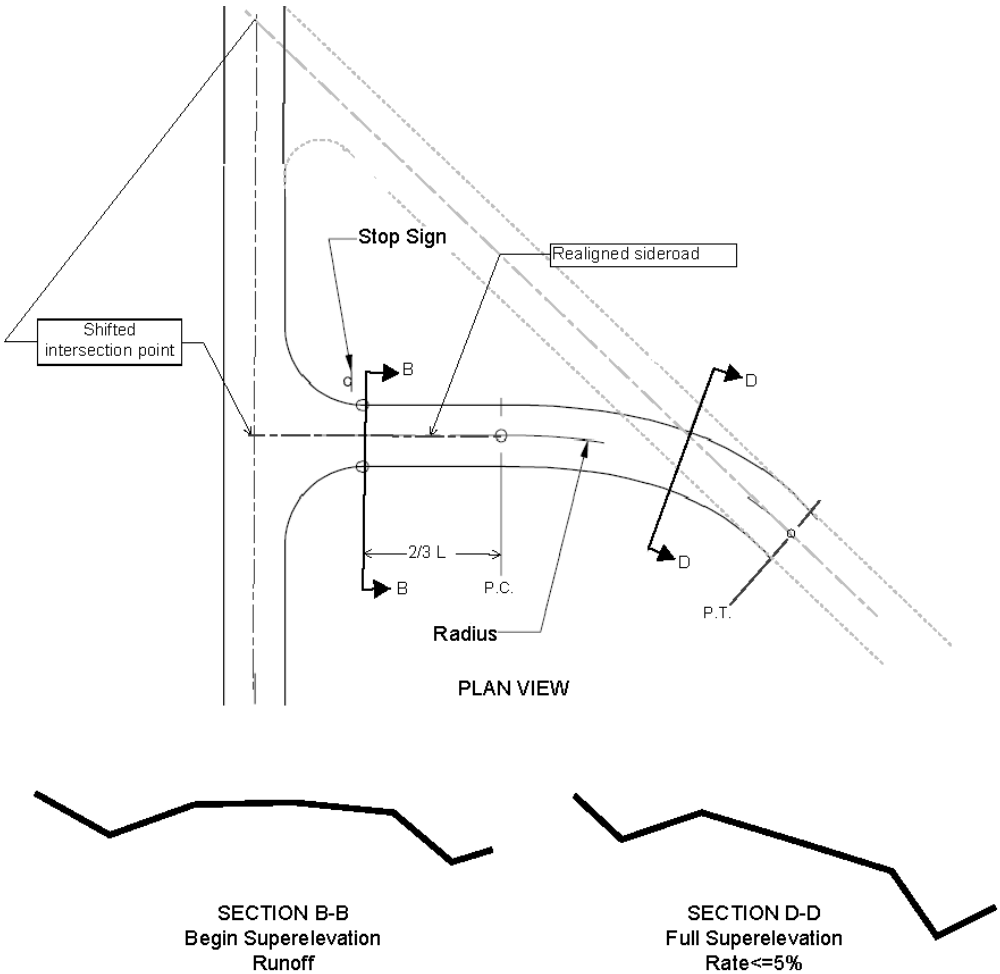


***Figure 5.6* Horizontal Curves on Stop Sign Controlled Approaches**

5.3 Superelevations

To maintain the desired design speeds, highway and ramp curves are generally super-elevated.

Superelevation may be defined as the rotation of the roadway cross section to overcome part of the centrifugal force that acts on a vehicle traveling around a curve.

Lack of adequate superelevations, where needed, can result in undesirable conditions including: loss of safety factor between the side frictions available versus side frictions used; driver failures to maintain appropriate lateral positioning within the lanes and increased occupant discomfort.

5.3.1 AASHTO Revisions

There were several significant changes made to the superelevation guidance in the 2001 AASHTO GDHS and 2004 AASHTO GDHS34 that affected side-friction factors. Some of these changes have affected curvatures ”R”, runoff lengths “L”, and transition lengths “T” for given superelevation rates.

5.3.2 Superelevation Rates

These rates of rise in cross sections of finished surfaces of the traveled ways of roadways measured from the lowest or inside edges to the highest or outside edges. Superelevation rate determinations are based on:

- Design speeds

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[34] (*3) A Policy on Geometric Design of Highways and Streets 2001*, (2nd printing) 4th edition. AASHTO, 2001. www.transportation.org, ch. 3, pp.131-235, “Elements of Design / Horizontal Alignment”

(*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., ch. 3, pp.131-231, “Elements of Design / Horizontal Alignment”

- Curve radii
- Side friction factors (see Table 5.6 below for Maximum side frictions (f). Also, see pages 148-152, GDHS 2004)
- The method used to distribute superelevation rates (e) and side friction factors (f) - AASHTO has established five (5) alternative methods of distributing superelevation and side friction for curve radii that are larger than minimum (see pages 140-142, GDHS 2004[35]).
- Allowed maximum superelevation rate (emax).

Table 5.6 Maximum Side Friction (f) Factors (per Exhibits 3-12 and 3-15, GDHS 2004)

Design Speed (mph)	Max. (f)	Design Speed (mph)	Max. (f)
10	0.38	45	0.15
15	0.32	50	0.14
20	0.27	55	0.13
25	0.23	60	0.12
30	0.20	65	0.11
35	0.18	70	0.10
40	0.16	75	0.09

AASHTO provides superelevation tables for design speed-radius combinations based on emax = 4%, 6%, 8%, 10% and 12%, which are computed based on Method 5 for distributing superelevation and side friction factors (see Exhibit 3-25 to 3-29 on pages 167-174, GDHS 2004). These apply to rural highways and high-speed urban streets. Exhibit 5.1 contains superelevation tables for e_{max} = 4% and e_{max} = 6%, which are derived from the AASHTO tables.

AASHTO also provides superelevation rates for low-speed urban streets computed based on Method 2 for distributing superelevation and side friction factors (see Exhibit 3-16 and 3-17 on pages 150-152, GDHS 2004). This is the basis for the chart in Attachment 5.12.

Table 5.7 shows WisDOT policy on maximum superelevation rates (e_{max}). Do not use e_{max} = 8% except as shown in Table 5.7 (Note: Exhibit 5.1 does not contain superelevation tables for e_{max} = 8% - use Exhibit 3-27 on page 170, GDHS 2004). Superelevation rates greater than 8 percent are not recommended for highways in areas with ice and snow - pages 144-145, GDHS 2004).

Do not use superelevation rates greater than 8 percent or less than 2 percent except as noted in Table 5.7.

The definitions of the various highway types are as follows:

Rural highway - A highway with a rural cross section and having a posted speed of 50 mph or higher.

High-speed urban highway - Generally, a highway with curb and gutter and having a posted speed of 50 mph or higher.

Transition highway - Generally, a highway with a posted speed of 45 mph that is in a developing area between a rural highway (or high-speed urban highway) and a low-speed urban street.

Low-speed urban street - Generally, a street with curb & gutter (but some low-speed urban streets do not have curb and gutter) and having a posted speed of 40 mph or lower.

[35] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

Table 5.7 WisDOT Policy on the Use of Superelevation Rate

Areas of Application		e_{max}		
Highway Type	**Work Type**	**Existing** [A]	**Design UPPER**[B]	**Design LOWER**[B]
Interstate freeways	Modernization and bridge replacements (including approaches)	any	6%	6%
Non-interstate freeways	Rehabilitation[C]	>8%	8%	6%
Expressways	Rehabilitation[C]	<=8%	6%	6%
Rural two-lane highways	Perpetuation[F]	any	Existing	Existing
High-speed urban highways	Modernization and bridge replacements (including approaches) [D]	any	6%	4%
	Rehabilitation[C, D]	>6%	6%	4%
	Rehabilitation[C, D]	<=6%	4%	4%
	Perpetuation[F]	any	existing	existing
Transition highways	Modernization and bridge replacements (including approaches)	any	4%	4%
	Rehabilitation[C]	any	4%	2%
	Perpetuation[F]	any	existing	existing
Low-speed urban streets	Modernization and bridge replacements (including approaches) [E]	any	4%	4%
	Rehabilitation[C, E]	any	4%	2%
	Perpetuation[F]	any	existing	existing

Notes for Superscript:

A. Determine existing e_{max} by inspecting superelevation information on as-built plans

B. For design consistency, use uniform design e_{max} for sections of roadways with the same highway types and work types - i.e., use either UPPER e_{max} or LOWER e_{max}.
Approved SCD's or DJs are required if design e_{max} for a project is greater than UPPER e_{max} or less than LOWER e_{max}.
Use superelevation tables in Exhibit 5.1 for Rural Highways (except, use Exhibit 3-27, p. 170, GDHS 2004 for e_{max} = 8%), High-Speed Urban Highways and Transition Highways.
Use Attachment 5.12 for Low-Speed Urban Streets (consider using Exhibit 5.1 if practical).

C. Perform safety evaluations to determine if modifying the curve radii or superelevation rates are needed to address crash problems which are occurring, and that the improvements are warranted based on acceptable benefit/costs per FDM 11-38.

D. Superelevation rates on high-speed urban roadways are preferably based on e_{max} = 4%. Consider adverse effects caused by factors such as, cross street profile site conditions that include driveways, sidewalks, or other intersections. An e_{max} = 6% may be used if minimal adverse effects are caused as a result and there are no traffic stops or signals present or anticipated in the future.

E. Superelevation rates for low-speed urban streets should not exceed 4 percent. At lower non-uniform running speeds, which are typical in urban areas, drivers are more tolerant of discomfort, thus permitting employment of increased amounts of side friction (Method 2, pages 140-142, GDHS, 2004) for use in design of horizontal curves.

[Note: The results from the nomograph in Attachment 5.12, which is based on the 2004 GDHS[36] (Exhibit 3-17 on p.152), differ considerably from the nomograph in the 2001 GDHS[37] (Exhibit 3-40 on p. 196). Low-speed urban streets with existing superelevation that meets the requirements of the 2001 GDHS may retain those superelevations that are impractical to upgrade to the superelevations obtained from the nomograph in Attachment 5.12, unless there is an unacceptable history of curve related crashes. Document this in the Design Study Report.]

F. Superelevation rates for Perpetuation projects with crash histories in which it has been determined that safety mitigation measures are appropriate, should first determine if the roadway pavement cross sections can be milled or wedged to improve the superelevations within the outside edges of the shoulder points, and if not, if other safety mitigation measures; such as surface friction treatments, shoulder pavement widening, or signing and marking, etc., are appropriate.

Consider modifying cross street approach grade(s) at signalized intersections if superelevations on the mainlines result in unacceptable break-over angles between the mainline edges of pavements and the cross-street approach profiles.

Very flat horizontal curves on rural or high-speed urban highways require no superelevations. Traffic entering curves to the right have some superelevations in the normal crown slopes. Traffic entering curves to the left have adverse or negative superelevations. Lack of adequate superelevations, where needed, can result in undesirable conditions including: loss of safety factor between the side frictions available versus side frictions used; driver failure to maintain appropriate lateral position within the lanes and increased occupant discomfort. The minimum curve radii for “Normal Crown” which can be designed without superelevation for open road conditions are shown in Exhibit 5.1 for various design speeds.

5.3.3 Superelevation Transitions

Superelevation transition is the length required to rotate the cross slope of a highway from a normal crowned slope to a fully super-elevated cross slope. See the illustration on Attachment 5.10 and Attachment 5.11. This transition includes a "tangent runout" length needed to remove or add adverse crown. The rotation of the planes of highways to achieve super-elevated roadways through horizontal curves begins on the tangent approaches to the curves. WisDOT practice is to place the tangent runouts and approximately two-thirds of the lengths of runoffs on the tangent approaches and one-third of the lengths of runoffs on the curves. For undivided highways, the axis of rotation is the centerlines of the pavements (see Attachment 5.10). On divided highways, the axis of rotation is normally the median edges of the pavements (see Attachment 5.11). Provide Vertical curves of sufficient lengths to ensure smooth pavement edges and centerline profiles within the superelevation transitions (The 2004 GDHS suggests minimum lengths in feet equal to the design speeds in mph). These curves may be either computed or determined graphically.

When using the superelevation rates from the tables in Exhibit 5.1, use the corresponding values for “L” and “T” from these tables to design the curves. Small increases in runoffs may be appropriate on high-type facilities (freeways, expressways, or other divided highways) in order to facilitate drainage or to smooth out the traveled way edge profiles. Any superelevation transition locations that are computed using something other than the superelevation tables and runoff tables provided, must be hand entered into the superelevation spreadsheet for consideration by Civil-3D. For the above example, the designer was assumed to choose a superelevation rate of 2 percent. Compute the theoretical point of normal crown and the theoretical point of full superelevation.

[36] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[37] (*3) A Policy on Geometric Design of Highways and Streets 2001*, (2nd printing) 4th edition. AASHTO, 2001. www.transportation.org.

Given:

PC = Station 870+00.00

L = $(wn_1)e_d(b_w) / \Delta$, where
w = lane width (feet) = 12-feet (use for consistency and practicality even if lane width used does not equal 12-feet);
n_1 = number of lanes rotated = 1;
e_d = design superelevation rate (%) = 2.0%;
b_w = adjustment factor for number of lanes rotated (see Table on page 9 of Exhibit 5.1) = 1.0;
Δ = maximum relative gradient (%) (see Exh 3-30 in 2004 AASHTO GDHS) = 0.58% for 40 mph
therefore, L=12*1*2.0%*1.0 / .0.58% = 41.4 ft (round to 41 ft)

X = $e_{NC}L / e_d$ = 41 * 0.02/0.02 = 41 ft

Theoretical point of normal crown (see Figure 7 and 8):

PC - 2/3L - X = 870+00.00 - 27.33 - 41 =

Station 869+31.67

Theoretical point of full superelevation (see Figure 7 and 8):

PC + 1/3L = 870+00.00 + 13.67 =

Station 870+13.67

Where:

PC = Point of Curvature

L = Length of Runoff

X = Length of Tangent Runout

e_{NC} = Normal Crown of 2%

e_d = superelevation rate

Avoid superelevation transitions on bridges because they complicate bridge designs and construction. When superelevation must be partially developed on bridges, there should be clear understanding between the bridge designers and the roadway designers as to the method used for transition development and the resulting grades.

Auxiliary lane pavements (or right turn lanes) on the high sides of super-elevated curves should be maintained at the same slopes as the adjacent traffic lanes until the superelevation reaches 4 percent. When super-elevation on the traffic lane pavements are greater than 4 percent the auxiliary lane slopes will remain constant at 4 percent. In some isolated situations where the increasing elevations of the intersecting side roads approaches the main line roads, it may be desirable to flatten the super-elevated auxiliary lanes to form gradual transitions between the super-elevated sections and the side roads. Do not exceed rollover rates greater than 5 percent between adjacent travel lanes or auxiliary lanes.

Do not exceed rollover rates greater than 8 percent between shoulders and travel lanes or auxiliary lanes.

On super-elevated divided highways where “narrow” medians are present, it may be desirable to rollover the high side shoulders and bring up the median shoulders to reduce the elevation differences between the divided highways. These special situations may be desirable in urban conditions when the highways are divided by barrier walls.

5.4 Vertical Alignments

Highway vertical alignments consists of tangents or grades and vertical curves. Vertical curves are based on sight distance considerations. Headlight sight distances are the primary factors used to determine the lengths of sag vertical curves (see Attachment 5.6 and Attachment 5.7).

Although grade changes without vertical curves are discouraged, there may be situations where they are necessary. These must be explained and justified in the SCDs or DSRs. Table 5.8 shows the maximum changes in grades without vertical curves. Some rounding of the deflection points is anticipated during construction.

***Table 5.8* Maximum Changes in Grade Without Vertical Curves**

Design Speed mph	20	30	40	45	50	60	65	70
Maximum Change in Grade in Percent	1.20	1.00	0.80	0.70	0.60	0.40	0.30	0.20

5.4.1 Grades

Maximum grades (see Attachment 5.3 of this procedure and FDM 11-15 Attachment 1.4) vary with terrains, design speeds and functional classifications.

The minimum grades on roadways with rural cross sections is 0.0 percent, i.e., flat, except in areas of super-elevation transitions and other areas with pavement rotations. Do not use flat grades in areas of superelevation transitions and other areas with pavement rotations because the combinations of flat longitudinal grades with flat cross-slopes may result in pavement surface drainage problems. Provide minimum grades in these areas based on AASHTO guidance for "Minimum Transition Grades"[38]. This applies to both rural and urban roadways.

If grades of less than 0.5 percent are used, then side ditches should be specially designed to provide sufficient longitudinal gradients for drainage. On divided highways, grade lines of opposing roadways should be treated independently except where topographic or other conditions require them to be identical. The minimum gradients on structures is 0.5 percent to ensure positive drainage.

Compatibility of curb and gutter grades with existing developments is essential in reducing damage to abutting properties and the amount of right-of-way to be acquired. To ensure drainage the minimum gradients of curb and gutters are desirably 0.50 percent but at least 0.30 percent. Special attention may be required to assure proper drainage of curbed pavements at the apex of crest vertical curves where level points occur. Drainage should be adequate for vertical curves having "k" values of 167 or less (see Attachment 5.4, Attachment 5.5 and pages 270, & 274, GDHS 2004).

SCD or DJ documentation is required for grades that are either greater than maximum or less than minimum.

5.4.1.1 Climbing Lanes

See FDM 11-15-10 for guidance on climbing lanes.

5.4.2 Vertical Curves

Design vertical curves to provide adequate sight distances, safety, comfortable driving, good drainage, and pleasing appearances. They are normally symmetrical parabolas. Notable exceptions would be the use of asymmetrical parabolic curves to provide better drainage of structures located on crest vertical curves.

Vertical curves are generally identified by their "K" values. K is the rate of curvature and is defined as the length of the vertical curve (L) divided by the algebraic difference in grade (A); i.e. the horizontal distance in feet required for a 1 percent change in gradient. K is affected by sight distances, comfort, drainage, and aesthetic quality. Sight distances and vertical curve k-values are shown in Attachment 5.4 through Attachment 5.7 for each of the sight distance categories discussed earlier in FDM 11-10-5.1.1.1 "Application of Stopping Sight Distances (SSDs) and Decision Sight Distances (DSDs)". Crest vertical curve values are shown in Attachment 5.4 and Attachment 5.5. Sag vertical curve values are shown in Attachment 5.6 and Attachment 5.7.

Compute sight distances (S) on vertical curves by re-arranging the equations on Attachment 5.4 and Attachment 5.6 to solve for (S). Note that as vehicles traverse vertical curves, the distances to the ends of the vertical curves (i.e., the L-dimension in the equation) get shorter. The A-dimensions also decrease because A=L/K and K is constant. The sight distances on the vertical curves begin to increase when the vehicles reach points where S>L. Consider this when determining if the requirements for sight distance categories are met.

SCD or DJ documentation for stopping sight distances are required if crest vertical curves do not provide minimum sight distances for the sight distance categories.

SCD or DJ documentation is required for sag vertical curves if:

- They do not provide the minimum headlight sight distances and adequate street lighting is not provided, or
- They do not meet the comfort criteria for sag vertical curves

[38] See(*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

On vertical curves with K > 167, there will be sections of roadways at least 100 feet in length near the crests or sags with grades of less than 0.30%. These conditions may create drainage problems, especially on curbed highways. It is not intended that K of 167 feet per percent grade be considered a design maximum, but merely a value beyond which drainage should be more carefully designed.

5.4.3 Vertical Clearances

See FDM 11-35-1.5, FDM 11-35 Attachment 1.8 and FDM 11-35 Attachment 1.9 for vertical clearance design criteria for different combinations of overpass and underpass facilities.

Vertical clearances for overhead utility facilities shall comply with all applicable state and national electrical codes. See WisDOT Highway Maintenance Manual chapter 9-15-25 section 2.2 (HMM 9-15-25) and WisDOT Bridge Manual Chapter 3 requirements for vertical clearance for overhead utilities.

The Department has adopted OSOW High Clearance Routes with the objective of minimizing overhead constraints for OSOW vehicles along these routes (including to sign structures, traffic signal monotube arms, overhead utilities, and other overhead appurtenances). Minimum 20'-0" vertical clearances are needed along these high clearance routes for these overhead constraints. In addition, the Department's goal is to provide minimum vertical clearances of 20'-0" for bridges and at railroad crossings along these routes. See the OSOW maps for routes designated as High Clearance routes.

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/planning-maps.aspx

See the following for additional guidance and requirements for OSOW High Clearance Routes:

- FDM 11-20-1.9 - Clearances for Urban Roadways
- FDM 11-20-1.9.5 - Traffic Signal Supports (urban)
- FDM 11-20-1.9.6 - Railroad Warning Signs and Signals (urban)
- FDM 11-25-1.4.1 - OSOW High Clearance Routes
- FDM 11-25-40.1 - Railroad Crossings (coordination)
- FDM 11-35-1.5.1 - OSOW High Clearance Routes
- FDM 11-35 Attachment 1.8 - Minimum Vertical Clearance for New Bridges and Replacement Bridges
- FDM 11-35 Attachment 1.9 - Minimum Vertical Clearance for Bridges to Remain

5.5 References

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LIST OF ATTACHMENTS

Attachment 5.1	Sight Distance Values
Attachment 5.2	Sight Distance Categories and Applications
Attachment 5.3	Maximum Grades by Functional Classification
Attachment 5.4	Sight Distance for Crest Vertical Curves
Attachment 5.5	Sight Distance for Crest Vertical Curves - Graphs
Attachment 5.6	Sight Distance for Sag Vertical Curves
Attachment 5.7	Sight Distance for Sag Vertical Curves - Graphs
Attachment 5.8	Passing Sight Distance for Crest Vertical Curves

Attachment 5.9 Sight Distance on Horizontal Curves
Attachment 5.10 Superelevation Transition of Two-Lane Highway to the Right
Attachment 5.11 Superelevation Transition of Divided Highway Curve to Right
Attachment 5.12 Superelevation Chart for Low Speed Urban Street
Attachment 5.13 Guide Dimensions for Vision Triangles, Stop Control on Minor Road
Attachment 5.14 Sample Problem - Intersection Sight Distance

LIST OF EXHIBITS

Exhibit 5.1 Superelevation Tables (emax = 4% and 6%)

***Sight Distance Values*[5]**

DESIGN SPEED MPH	SIGHT DISTANCE - FEET							
	STOPPING SIGHT DISTANCE [1]	DECISION SIGHT DISTANCE [1]					PASSING SIGHT DISTANCE [1, 3, 4]	
		AVOIDANCE MANEUVER [2]						
		A	B	C	D	E		
25	155	---	---	---	---	---	900	
30	200	220	490	450	535	620	1090	
35	250	275	590	525	625	720	1280	
40	305	330	690	600	715	825	1470	
45	360	395	800	675	800	930	1625	
50	425	465	910	750	890	1030	1835	
55	495	535	1030	865	980	1135	1985	
60	570	610	1150	990	1125	1280	2135	
65	645	695	1275	1050	1220	1365	2285	
70	730	780	1410	1105	1275	1445	2480	

Notes

1 From Chapter 3, GDHS 2001 and GDHS 2004 (values are identical in both editions).

2 Avoidance maneuver A: Stop on rural road - t = 3.0 s

Avoidance maneuver B: Stop on urban road - t = 9.1s

Avoidance maneuver C: Speed/path/direction change on rural road - t varies between 10.2 and 11.2 s

Avoidance maneuver D: Speed/path/direction change on suburban road - t varies between 12.1 and 12.9 s

Avoidance maneuver E: Speed/path/direction change on urban road - t varies between 14.0 and 14.5 s

3 See Chapter 3 of the Wisconsin Traffic Engineering, Operations and Safety Manual (TEOpS) for No passing zone standards.

4 See Attachment 5.8 for vertical curve design for Passing Sight Distance.

5 See Attachment 5.2 for Sight Distance Categories and Application

Sight Distance Categories – Sight Distance Criteria [1]

Category	Sight Distance Criteria	
	Upper Minimum	**Minimum**
1	Stopping Sight Distance (SSD) to a 6-inch object	SSD to a 24-inch object
2	*[BOTH]* Decision Sight Distance Avoidance Maneuver C (DSD-C) to a 24-inch object <*AND*> SSD to a 6-inch object. [Note: SSD to a 6-inch object is the only Upper Minimum Sight Distance Criteria for points within a Category 2 roadway segment that are closer than SSD from the End Sight Distance Boundary (SDB) of that segment (see table starting on the next page of this attachment for SDB definitions).]	SSD to a 24-inch object
3	*[BOTH]* Decision Sight Distance Avoidance Maneuver C (DSD-C) to a 24-inch object <*AND*> SSD to a 6-inch object [Note: SSD to a 6-inch object is the only Upper Minimum Sight Distance Criteria for points within a Category 3 roadway segment that are closer than SSD from the End Sight Distance Boundary (SDB) of that segment (see table starting on the next page of this attachment for SDB definitions).]	SSD to a 6-inch object

Notes:

1 The available sight distance along a roadway should meet or exceed the required sight distance at every point along the roadway. The **Sight Distance Category** for a segment of roadway determines the required sight distance.

See Attachment 5.1 for Sight Distance Values
See Table "Sight Distance Categories - Application and Sight Distance Boundaries" in this Attachment;
See Attachment 5.4, Attachment 5.5, Attachment 5.6 and Attachment 5.7 for vertical curve design for Sight Distance; and
See Attachment 5.9 for horizontal curve design for Sight Distance.

Sight Distance Categories - Application and Sight Distance Boundaries

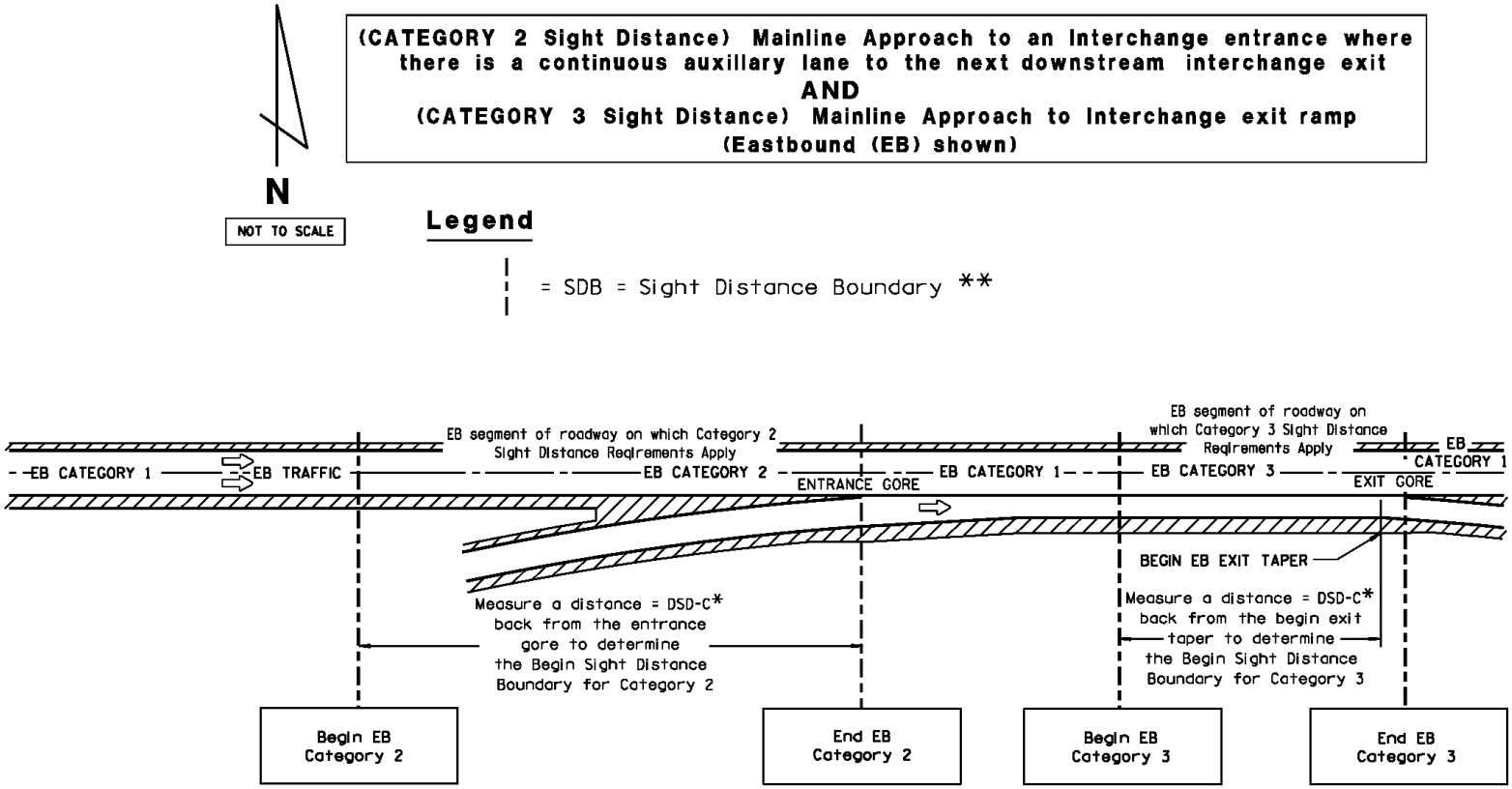
Category	Locations to Apply	Sight Distance Boundaries (SDB)	
		Begin	End
1	Default - All locations not in Category 2 or Category 3	End limit of Category 2 or Category 3	Begin limit of Category 2 or Category 3
2	Mainline approach to an Interchange entrance ramp where there is a continuous auxiliary lane to the next downstream interchange exit (See Example 1)	At a distance = DSD-C [1] from the entrance ramp gore of the upstream interchange [2]	At the entrance ramp gore of the upstream interchange [2]
	Crossroad approach to an Interchange ramp terminal where the posted speed is 40 mph or less	At a distance = DSD-C [1] from the CL of the ramp terminal intersection	At the CL of the ramp terminal intersection
	Lane drop on a non-freeway or non-expressway	At a distance = DSD-C [1] from the start of the lane drop	At the end of the lane drop
	Railroad / highway at-grade crossings (See Example 2)	At a distance = DSD-C [1] from the stop bar upstream from the RR tracks	At the stop bar upstream from the RR tracks
	High speed multilane highway approach to an intersection with a right turn but no left turn in the direction of travel (See Example 3)	At a distance = DSD-C [1] from the back of the design queue [3]	At the CL of the intersection
	Approach to an intersection where a thru lane becomes a "turn only" lane		
	Two-lane highway or non-high speed multi-lane road approach to an Intersection with an unusual configuration, including multiple right-turn lanes or multiple left-turn lanes		
	Side road approach to an at-grade intersection with a bypass roadway or expressway		
	High-speed 2-lane rural highway approach to an isolated stop sign, traffic signal, or roundabout where such control is unexpected because it is not typical		

3	Mainline thru lane that becomes an "exit only" lane at an interchange (See Example 4)	At a distance = DSD-C [1] from the begin taper to exit ramp	At the exit ramp gore [2]
	Mainline approach to an interchange exit ramp (See Example 1)	At a distance = DSD-C [1] from the begin taper to exit ramp	At the exit ramp gore [2]
	Mainline approach to an interchange entrance ramp, except an entrance ramp where there is a continuous auxiliary lane to the next downstream interchange exit (see Category 2 for this location). (See Example 5 for Category 3 entrance ramp)	At a distance = DSD-C [1] from the entrance ramp gore [2]	At the end taper from entrance ramp
	Mainline approach to an Interchange with unusual features, e.g. multiple entrance or exit points; short weaving sections	At a distance = DSD-C [1] from the 1st upstream feature, i.e., begin taper to exit ramp, or entrance ramp gore [2]	At the last downstream feature, i.e., the exit ramp gore, or the end taper from entrance ramp [2]
	High-speed multilane highway approach to an intersection with a left turn in the direction of travel (See Example 6)	At a distance = DSD-C [1] from the back of the design queue [3]	At the CL of the intersection
	Crossroad approach to an interchange ramp terminal intersection where the posted speed is 45 mph or greater	At a distance = DSD-C [1] from the CL of the ramp terminal intersection	At the CL of the ramp terminal intersection
	Lane drop on freeways or expressways	At a distance = DSD-C [1] from the start of the lane drop	At the end of the lane drop
	Approach to a major fork on a freeway or expressway	At a distance = DSD-C [1] from the start of widening	At the point of divergence
	Approach to a branch connection on a freeway or expressway	At a distance = DSD-C [1] from the point of convergence	At the end of lane reduction [or, if there is no lane reduction, at the point of convergence]

Notes

1. DSD-C = Decision Sight Distance Avoidance Maneuver C (see table on Attachment 5.1)
2. Gore = “painted nose” as defined on p.832 and as depicted in Exhibit 10-59 on p.833 of the 2004 GDHS
3. Check queue lengths for the thru, left turn and right turn movement, and use whichever is furthest from the intersection. See FDM 11-25-1, FDM 11-25-5, and FDM 11-25-10 for guidance on queue length requirements. Also, confer with region traffic staff.

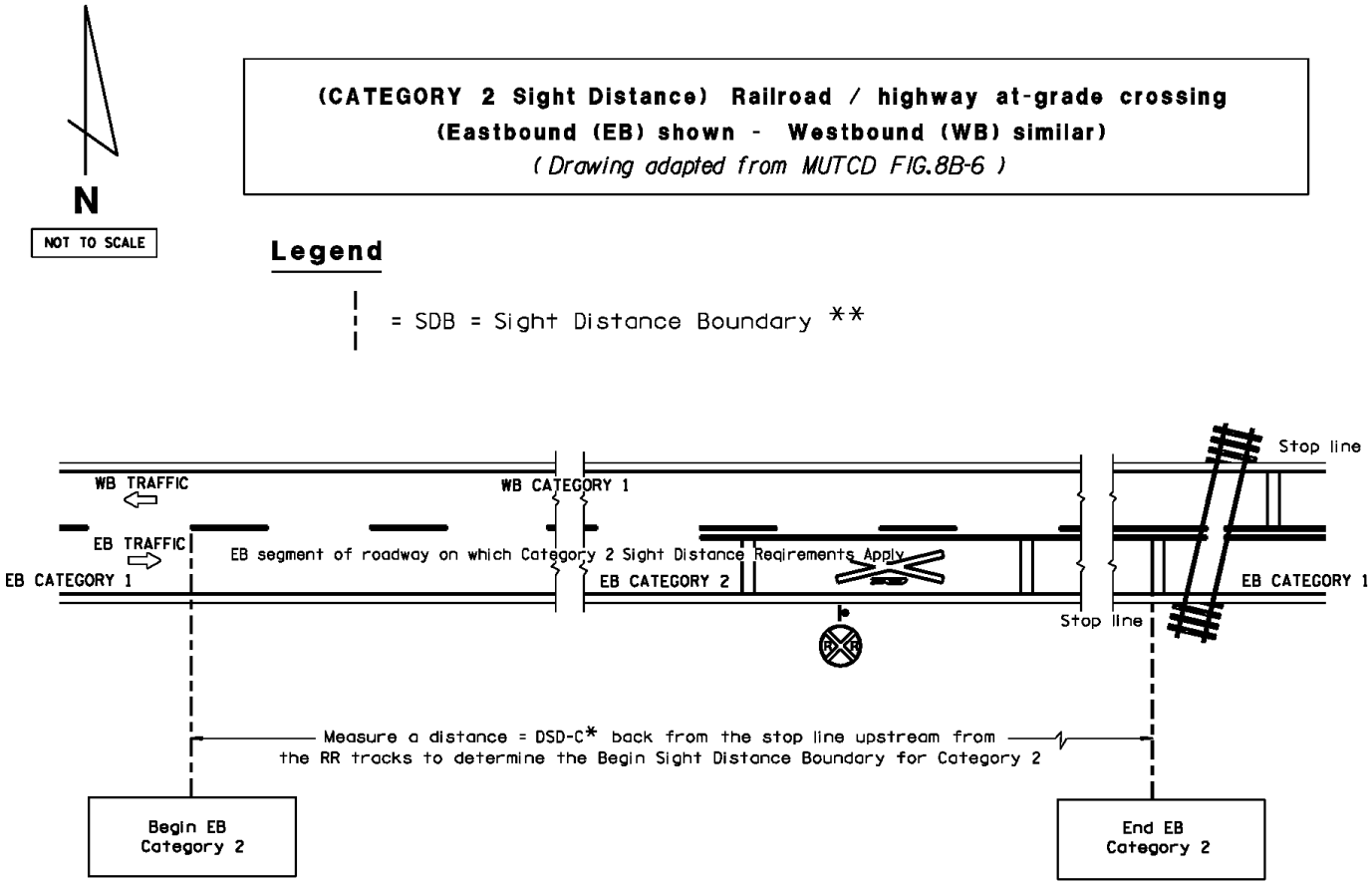
Example 1 – Sight Distance Category 2 – Mainline approach to an Interchange entrance ramp where there is a continuous auxiliary lane to the next downstream interchange exit / Sight Distance Category 3 – Mainline approach to an interchange exit ramp



* DSD-C = Decision Sight Distance Avoidance Maneuver C (see table on p. 1 of this Attachment)

** see p. 2-3 of this Attachment

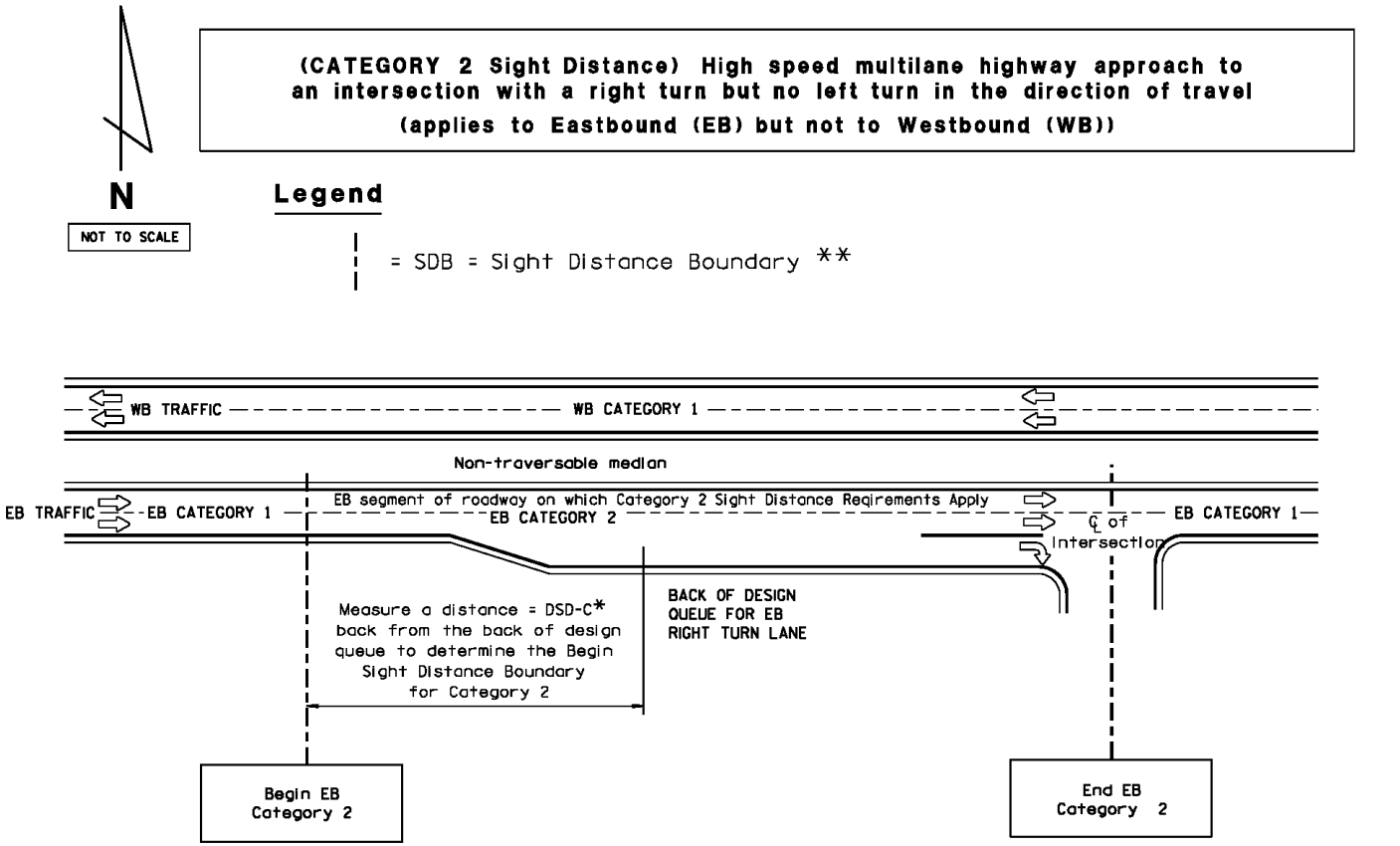
Example 2 – Sight Distance Category 2 – Railroad / highway at-grade crossings



* DSD-C = Decision Sight Distance Avoidance Maneuver C (see table on p.1 of this Attachment)

** see p.2 of this Attachment

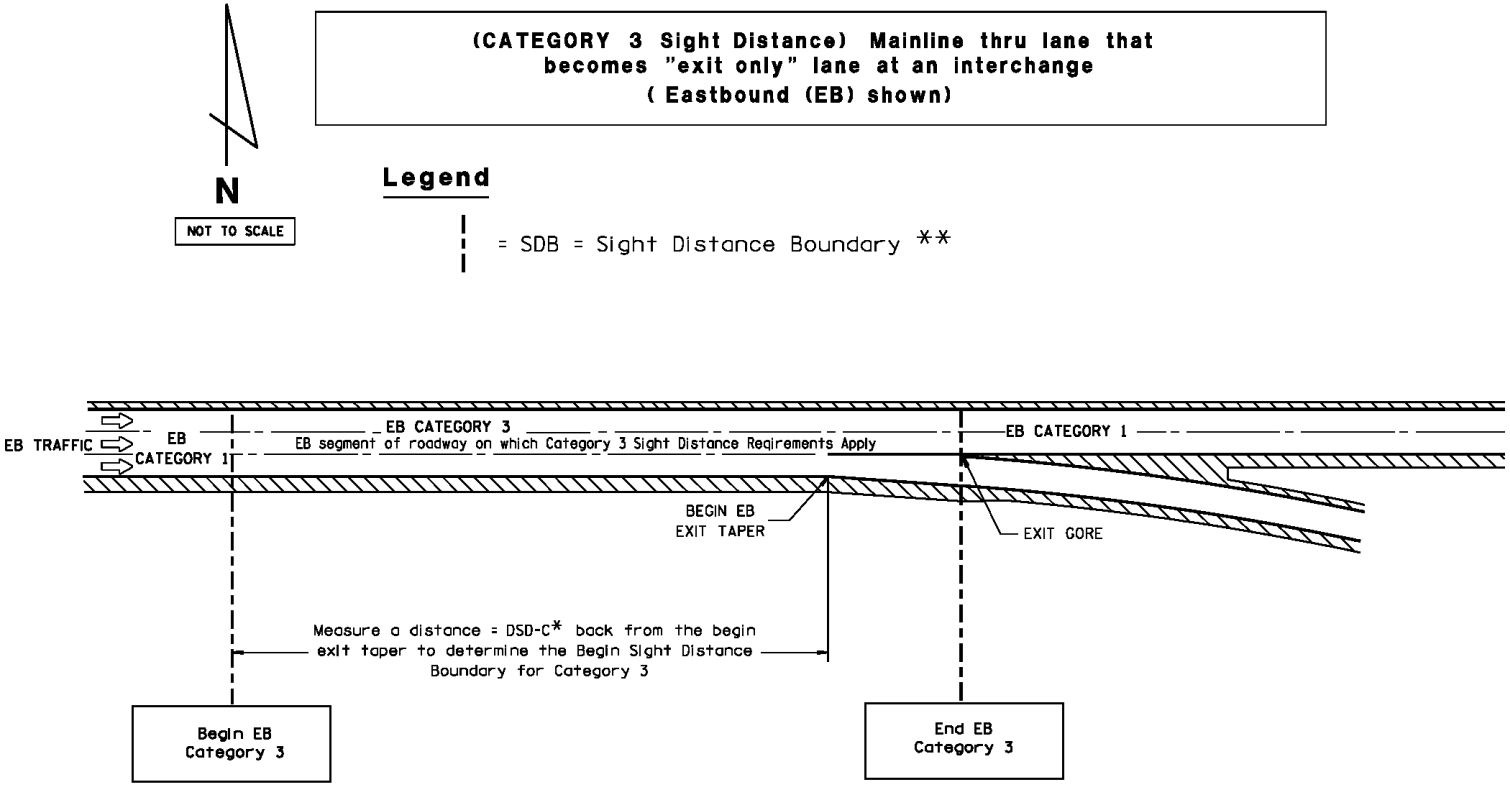
Example 3 – Sight Distance Category 2 – High speed multilane highway approach to an intersection with a right turn but no left turn in the direction of travel



* DSD-C = Decision Sight Distance Avoidance Maneuver C (see table on p. 1 of this Attachment)

** see p. 2 of this Attachment

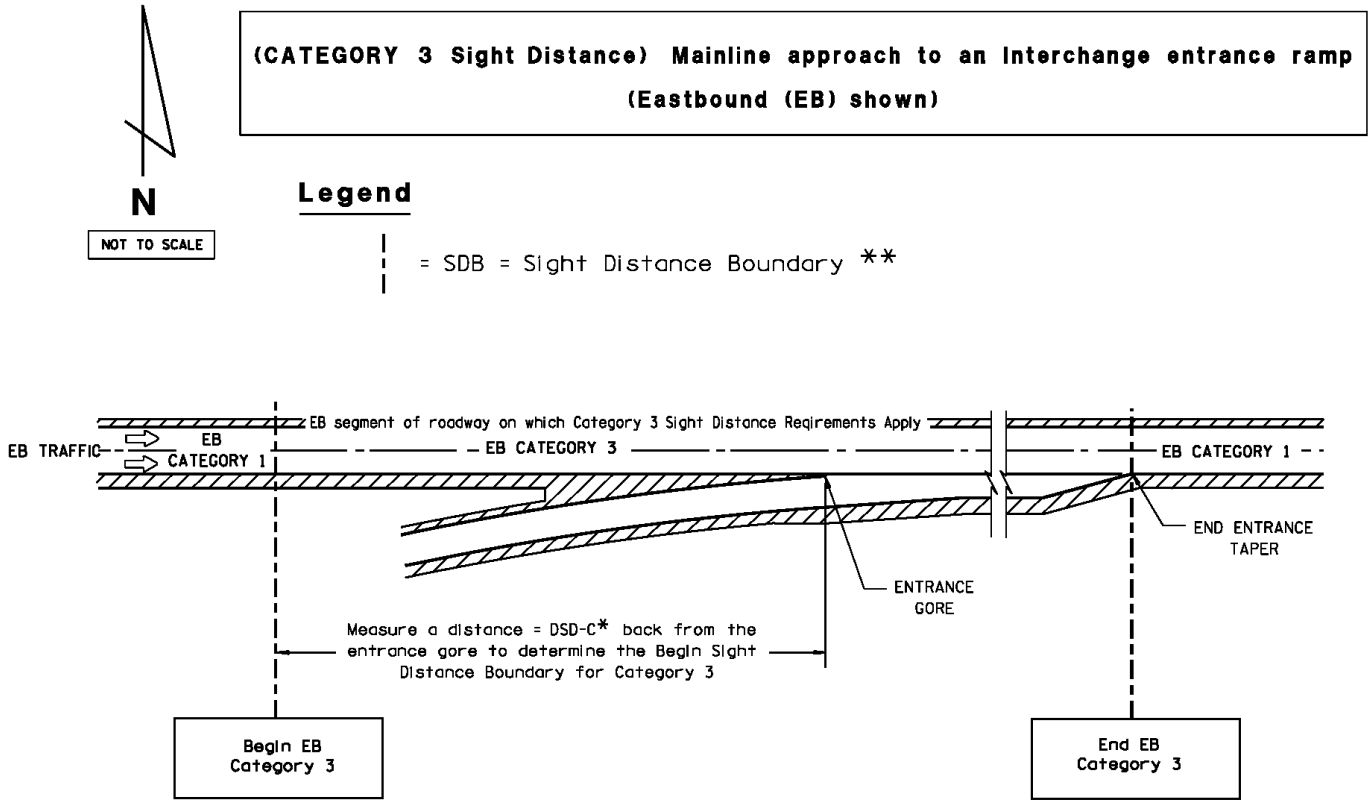
Example 4 – Sight Distance Category 3 – Mainline thru lane that becomes an "exit only" lane at an interchange



* DSD-C = Decision Sight Distance Avoidance Maneuver C (see table on p.1 of this Attachment)

** see p.3 of this Attachment

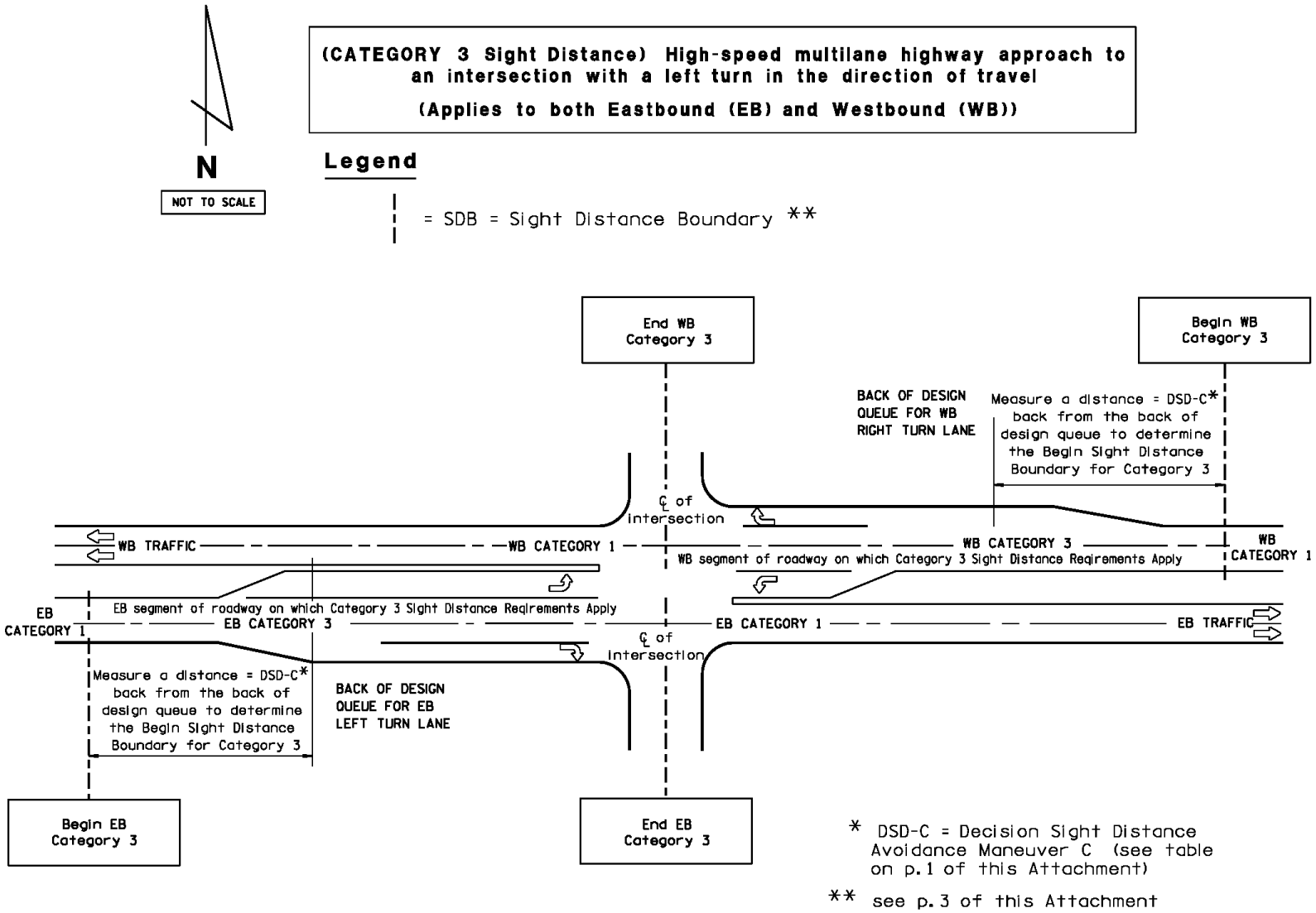
Example 5 – Sight Distance Category 3 – Mainline approach to an interchange entrance ramp



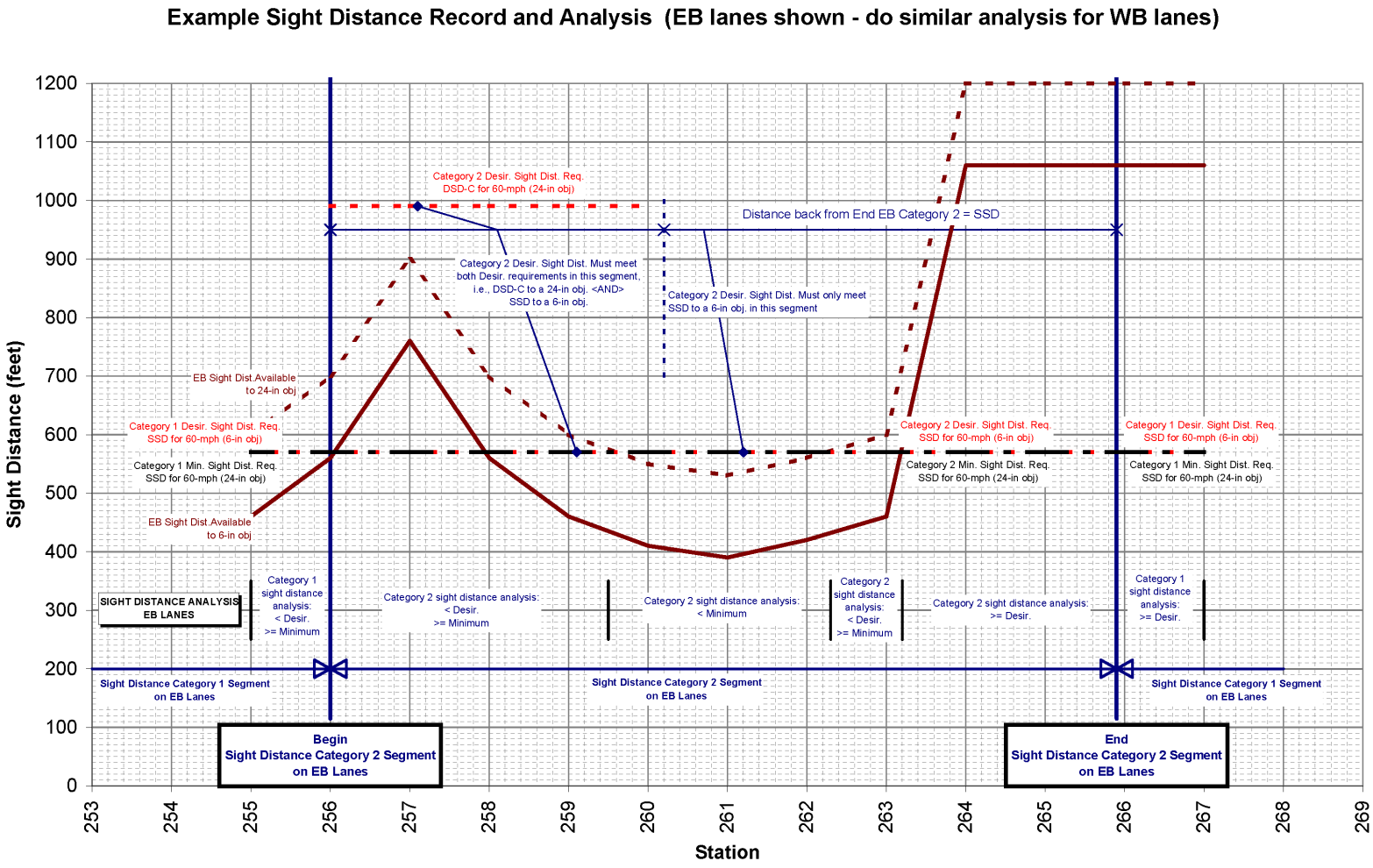
* DSD-C = Decision Sight Distance Avoidance Maneuver C (see table on p. 1 of this Attachment)

** see p. 3 of this Attachment

Example 6 – Sight Distance Category 3 – High-speed multilane highway approaches to an intersection with a left turn in the direction of travel



Example 7 – Sight Distance Record and Analysis



Plot the segment boundaries for the applicable Sight Distance Categories (Categories 1 & 2 in the above example). See the tables on pp.2-4 of this Attachment. Also, see Examples 5.1-5.6 of this Attachment.

Plot the Sight Distance for each Sight Distance Category segment – see the tables on Attachment 5.1.

Measure and record the available sight distance as described starting on p.128 of the 2004 AASHTO GDHS. The above example shows available sight distance to both a 6-inch object and to a 24-inch object. Eye height is 3.5-feet in both cases.

Compare the Sight Distance values with the measured sight distance available to determine if the Sight Distance Requirement is met.

Maximum Grades (%) for Rural Highways by Functional Classification 1

RURAL ARTERIALS [2]						
	DESIGN SPEED					
TYPE OF TERRAIN [5]	20 MPH	30 MPH	40 MPH	50 MPH	60 MPH	70 MPH
LEVEL	-	-	-	4	3	3
ROLLING	-	-	-	5	4	4

RURAL COLLECTORS [3]						
	DESIGN SPEED					
TYPE OF TERRAIN [5]	20 MPH	30 MPH	40 MPH	50 MPH	60 MPH	70 MPH
LEVEL	7	7	7	6	5	-
ROLLING	10	9	8	7	6	-

RURAL LOCAL ROADS [4]						
	DESIGN SPEED					
TYPE OF TERRAIN [5]	20 MPH	30 MPH	40 MPH	50 MPH	60 MPH	70 MPH
LEVEL	8	7	7	6	5	-
ROLLING	11	10	10	8	6	-

Notes:

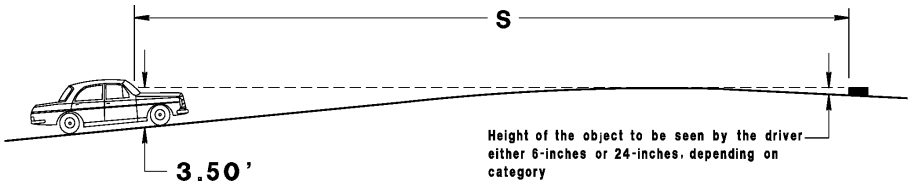
1 For Max. Grades under Urban Conditions refer to:
- Arterials: GDHS 2004, Exhibit 7-10, Page 472;
- Freeways: GDHS 2004, Exhibit 8-1, Page 506;
- Interstate: AASHTO Interstate Design Standards 2005, Page 3;
- Collectors: GDHS 2004, Exhibit 6-8, Page 432; and
- Local Streets: GDHS 2004, Page 391

2 See GDHS 2004, Exhibit 7-2, Page 446
See GDHS 2004, Exhibit 8-1, Page 506 for Freeways
See AASHTO Interstate Design Standards 2005, Page 3 for Interstates

3 See GDHS 2004, Exhibit 6-4, Page 423

4 See GDHS 2004, Exhibit 5-4, Page 382

5 See Highway Capacity Manual 2000, p.21-8 for a discussion of terrain types



Object Height	When S > L	When S < L
6-inches	$L = 2S - \frac{1329}{A}$	$L = \frac{AS^2}{1329}$
24-inches	$L = 2S - \frac{2158}{A}$	$L = \frac{AS^2}{2158}$

L= Length of Vertical Curve (feet)
S = Sight Distance (feet) (either SSD or DSD value, depending on category)
A = Algebraic Grade Difference (Percent)
K = L/A ; L= KxA

Crest Vertical Curves - Sight Distance, Object Height and Minimum Length Criteria [E]

Design Speed (V) (mph)	Category	UPPER MINIMUM				MINIMUM				Min. VC L= 3 x V (feet) [D]	Category [A]	Design Speed (V) (mph)
		Basis [B]	Sight Distance (feet) [C]	obj. hgt. (inches)	* Kcr	Basis	Sight Distance (feet) [C]	obj. hgt. (inches)	* Kcr			
25	1	SSD	155	6	19	SSD	155	24	12	75	1	25
	2	DSD	375	24	66	SSD	155	24	12	75	2	
	3	DSD	375	24	66	SSD	155	6	19	75	3	
30	1	SSD	200	6	31	SSD	200	24	19	90	1	30
	2	DSD	450	24	94	SSD	200	24	19	90	2	
	3	DSD	450	24	94	SSD	200	6	31	90	3	
35	1	SSD	250	6	48	SSD	250	24	29	105	1	35
	2	DSD	525	24	128	SSD	250	24	29	105	2	
	3	DSD	525	24	128	SSD	250	6	48	105	3	
40	1	SSD	305	6	70	SSD	305	24	44	120	1	40
	2	DSD	600	24	167	SSD	305	24	44	120	2	
	3	DSD	600	24	167	SSD	305	6	70	120	3	
45	1	SSD	360	6	98	SSD	360	24	61	135	1	45
	2	DSD	675	24	212	SSD	360	24	61	135	2	
	3	DSD	675	24	212	SSD	360	6	98	135	3	
50	1	SSD	425	6	136	SSD	425	24	84	150	1	50
	2	DSD	750	24	261	SSD	425	24	84	150	2	
	3	DSD	750	24	261	SSD	425	6	136	150	3	
55	1	SSD	495	6	185	SSD	495	24	114	165	1	55
	2	DSD	865	24	347	SSD	495	24	114	165	2	
	3	DSD	865	24	347	SSD	495	6	185	165	3	
60	1	SSD	570	6	245	SSD	570	24	151	180	1	60
	2	DSD	990	24	455	SSD	570	24	151	180	2	
	3	DSD	990	24	455	SSD	570	6	245	180	3	
65	1	SSD	645	6	314	SSD	645	24	193	195	1	65
	2	DSD	1050	24	511	SSD	645	24	193	195	2	
	3	DSD	1050	24	511	SSD	645	6	314	195	3	
70	1	SSD	730	6	401	SSD	730	24	247	210	1	70
	2	DSD	1105	24	566	SSD	730	24	247	210	2	
	3	DSD	1105	24	566	SSD	730	6	401	210	3	

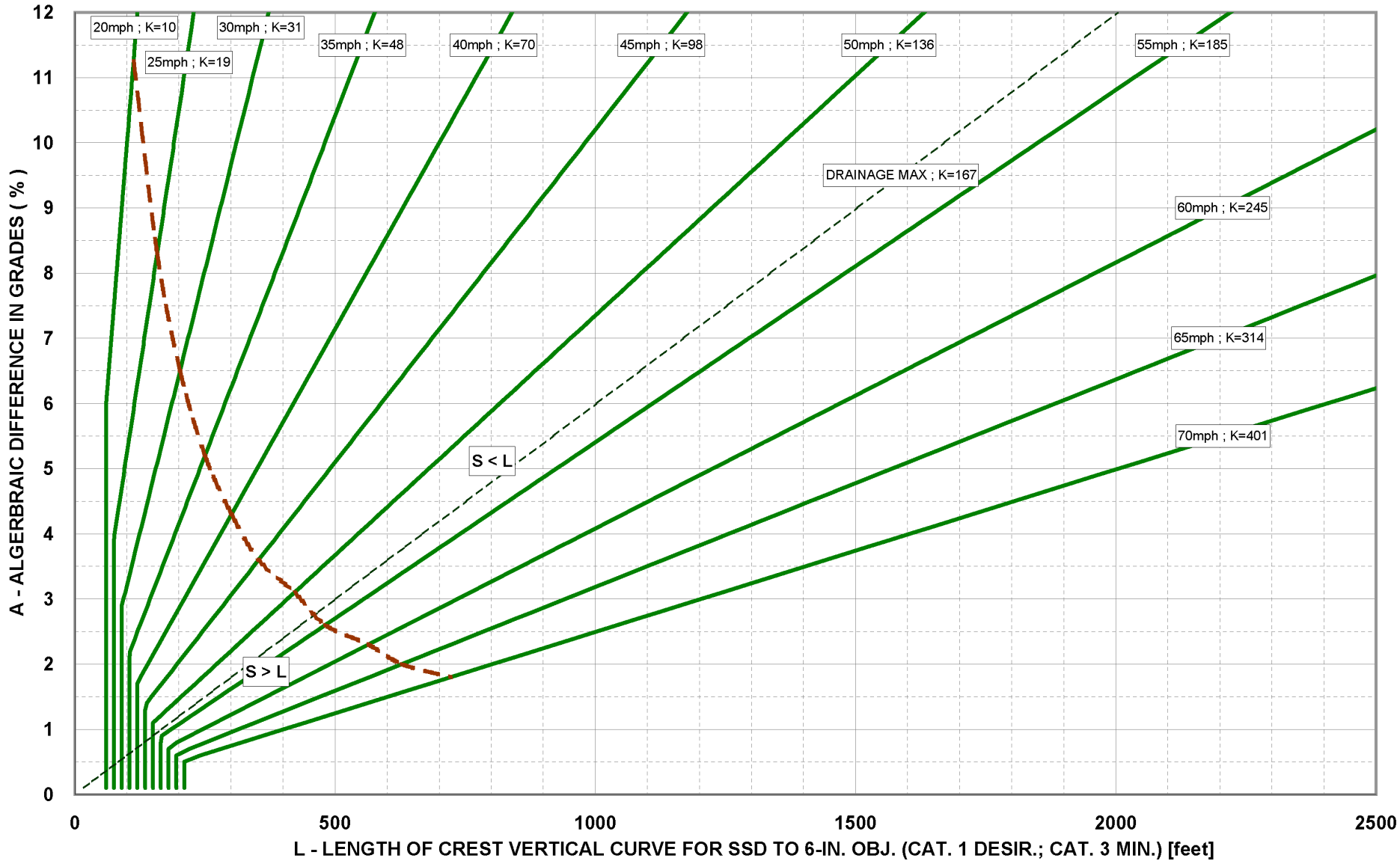
A See section "Stopping Sight Distance (SSD); Decision Sight Distance (DSD)" in text, and p.2 of Attachment 1 for definitions and criteria for Sight Distance Categories

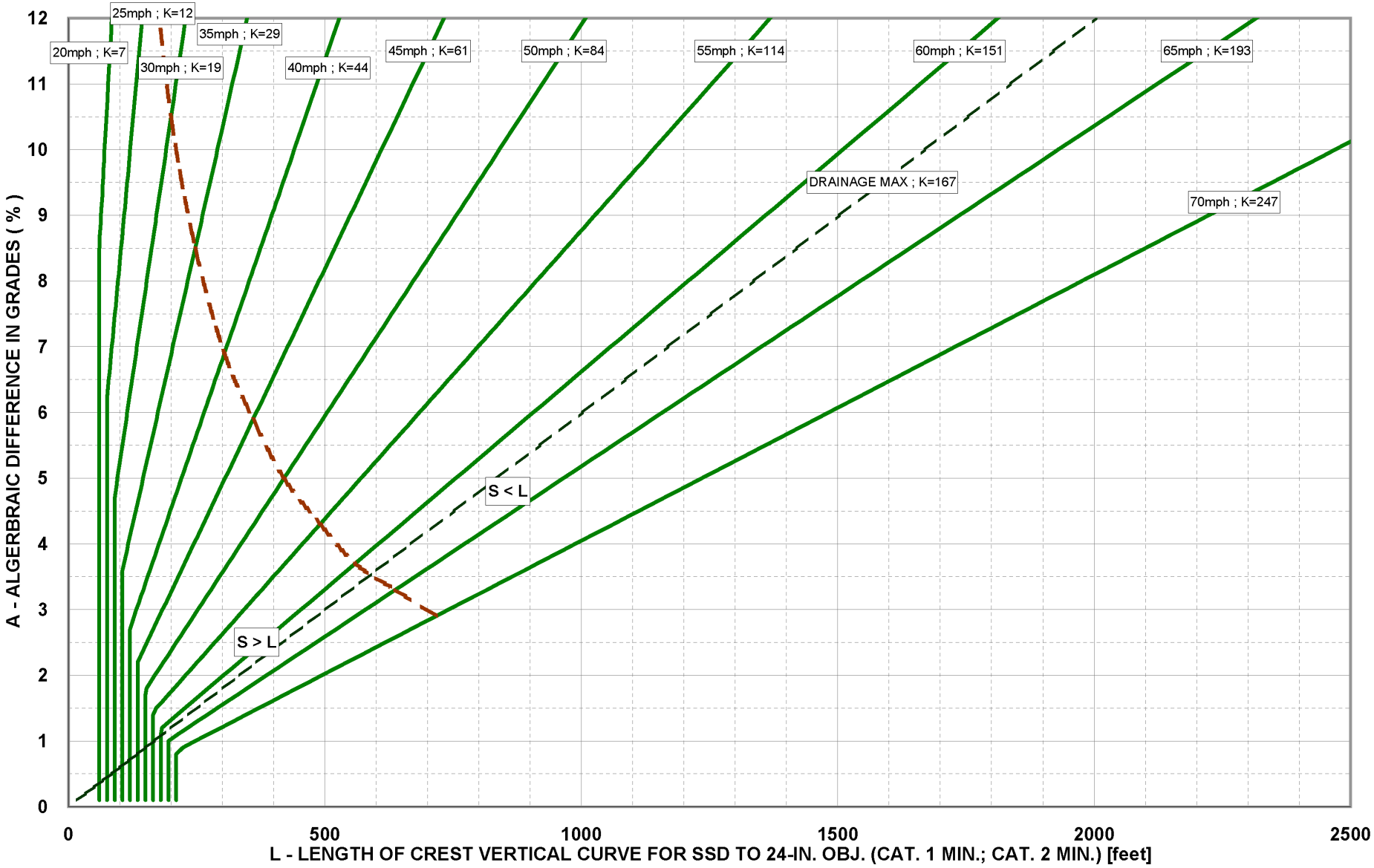
B SSD = Stopping Sight Distance
DSD = Decision Sight Distance for Avoidance Maneuver C

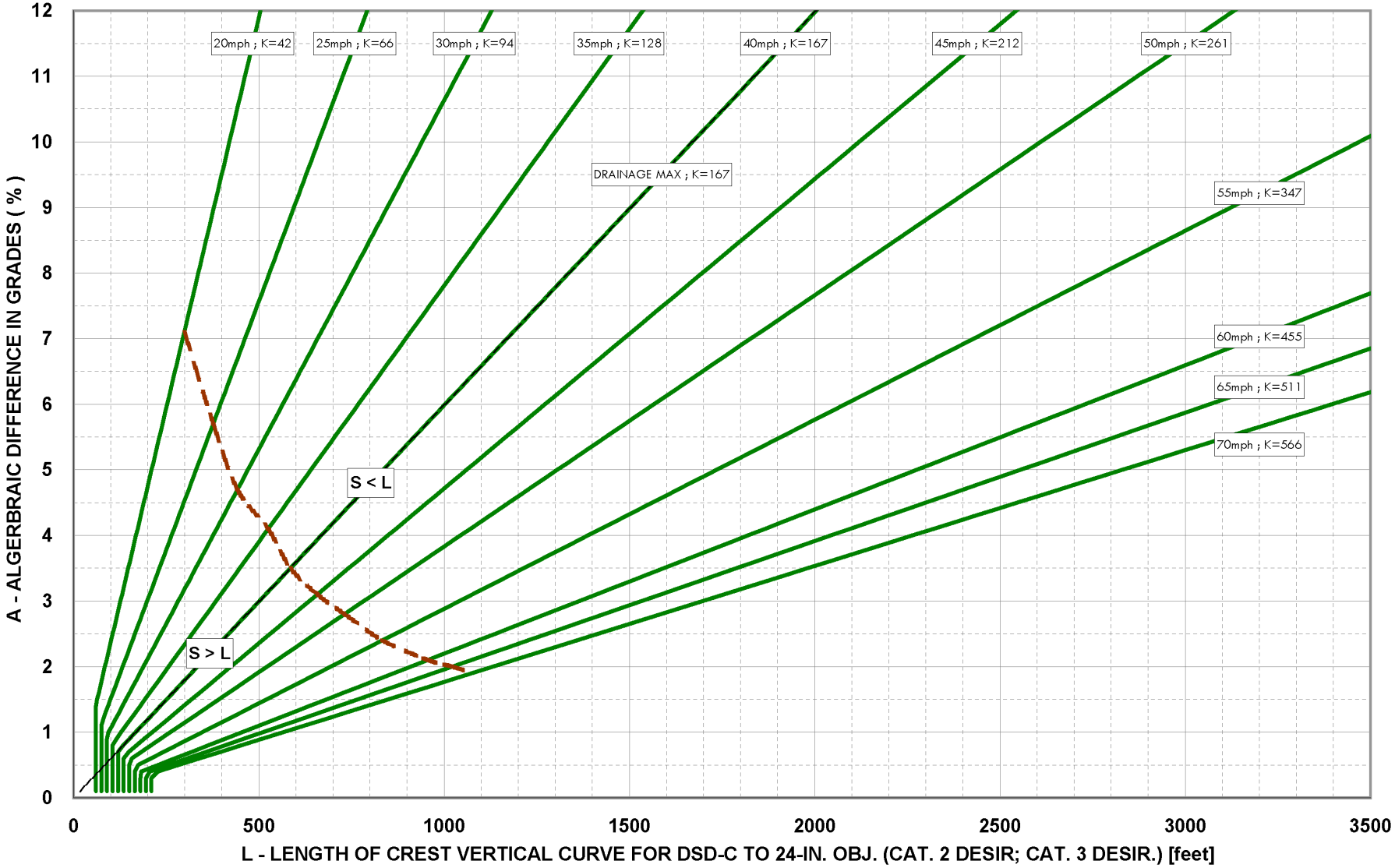
C See Attachment 5.1

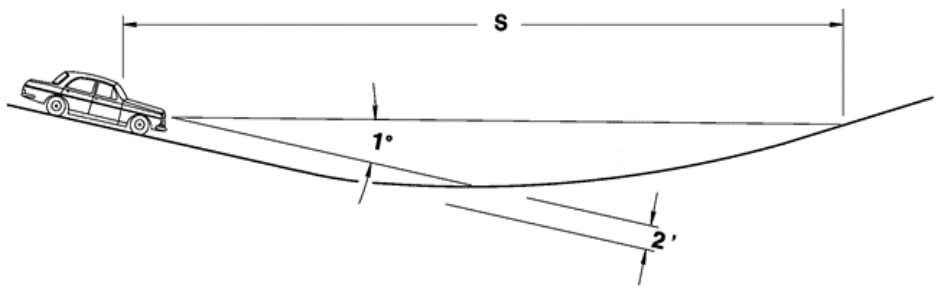
D Minimum length of crest vertical curve = the greater of either (Kcr x A), OR a distance in feet equal to 3 x the design speed in mph (3 x V)

E See Attachment 5.5 for graphs of L vs. A vs. Design Speed for crest vertical curves


20mph ; K=10
25mph ; K=19
30mph ; K=31
35mph ; K=48
40mph ; K=70
45mph ; K=98
50mph ; K=136
55mph ; K=185
60mph ; K=245
65mph ; K=314
70mph ; K=401
DRAINAGE MAX ; K=167
S < L
S > L
A - ALGERBRAIC DIFFERENCE IN GRADES (%)
L - LENGTH OF CREST VERTICAL CURVE FOR SSD TO 6-IN. OBJ. (CAT. 1 DESIR.; CAT. 3 MIN.) [feet]
0
1
2
3
4
5
6
7
8
9
10
11
12
0
500
1000
1500
2000
2500


20mph ; K=7
25mph ; K=12
30mph ; K=19
35mph ; K=29
40mph ; K=44
45mph ; K=61
50mph ; K=84
55mph ; K=114
60mph ; K=151
65mph ; K=193
70mph ; K=247
DRAINAGE MAX ; K=167
S < L
S > L
A - ALGERBRAIC DIFFERENCE IN GRADES (%)
0
1
2
3
4
5
6
7
8
9
10
11
12
0
500
1000
1500
2000
2500
L - LENGTH OF CREST VERTICAL CURVE FOR SSD TO 24-IN. OBJ. (CAT. 1 MIN.; CAT. 2 MIN.) [feet]


20mph ; K=42
25mph ; K=66
30mph ; K=94
35mph ; K=128
40mph ; K=167
45mph ; K=212
50mph ; K=261
DRAINAGE MAX ; K=167
55mph ; K=347
60mph ; K=455
65mph ; K=511
70mph ; K=566
S < L
S > L
A - ALGERBRAIC DIFFERENCE IN GRADES (%)
L - LENGTH OF CREST VERTICAL CURVE FOR DSD-C TO 24-IN. OBJ. (CAT. 2 DESIR; CAT. 3 DESIR.) [feet]
0
1
2
3
4
5
6
7
8
9
10
11
12
0
500
1000
1500
2000
2500
3000
3500



When S > L	When S < L
$L = 2S - \left[\frac{(400 + 3.5 \times S)}{A}\right]$	$L = \frac{\left(A \times S^2\right)}{\left(400 + 3.5 \times S\right)}$

L = Length of Vertical Curve (feet)

S = Sight Distance (feet) (either SSD or DSD required, depending on category)

A = Algebraic Grade Difference (Percent)

K = L/A ; L= KA

Sag Vertical Curves - Sight Distance and Minimum Length Requirements [E]

Design Speed (V) (mph)	Category [A]	UPPER MINIMUM Basis [B]	UPPER MINIMUM Sight Distance (feet) [C]	UPPER MINIMUM K_{SAG}	MINIMUM Basis	MINIMUM Sight Distance (feet) [C]	MINIMUM K_{SAG}	Min. VC L= 3 x V (feet) [D]	Category [A]	Design Speed (V) (mph)
25	1	SSD	155	26	SSD	155	26	75	1	25
	2	DSD	375	83	SSD	155	26	75	2	
	3	DSD	375	83	SSD	155	26	75	3	
30	1	SSD	200	37	SSD	200	37	90	1	30
	2	DSD	450	103	SSD	200	37	90	2	
	3	DSD	450	103	SSD	200	37	90	3	
35	1	SSD	250	49	SSD	250	49	105	1	35
	2	DSD	525	124	SSD	250	49	105	2	
	3	DSD	525	124	SSD	250	49	105	3	
40	1	SSD	305	64	SSD	305	64	120	1	40
	2	DSD	600	144	SSD	305	64	120	2	
	3	DSD	600	144	SSD	305	64	120	3	
45	1	SSD	360	79	SSD	360	79	135	1	45
	2	DSD	675	165	SSD	360	79	135	2	
	3	DSD	675	165	SSD	360	79	135	3	
50	1	SSD	425	96	SSD	425	96	150	1	50
	2	DSD	750	186	SSD	425	96	150	2	
	3	DSD	750	186	SSD	425	96	150	3	
55	1	SSD	495	115	SSD	495	115	165	1	55
	2	DSD	865	219	SSD	495	115	165	2	
	3	DSD	865	219	SSD	495	115	165	3	
60	1	SSD	570	136	SSD	570	136	180	1	60
	2	DSD	990	254	SSD	570	136	180	2	
	3	DSD	990	254	SSD	570	136	180	3	
65	1	SSD	645	157	SSD	645	157	195	1	65
	2	DSD	1050	271	SSD	645	157	195	2	
	3	DSD	1050	271	SSD	645	157	195	3	
70	1	SSD	730	181	SSD	730	181	210	1	70
	2	DSD	1105	287	SSD	730	181	210	2	
	3	DSD	1105	287	SSD	730	181	210	3	

A See section "Stopping Sight Distance (SSD); Decision Sight Distance (DSD)" in text, and Attachment 5.2 for definitions and criteria for Sight Distance Categories

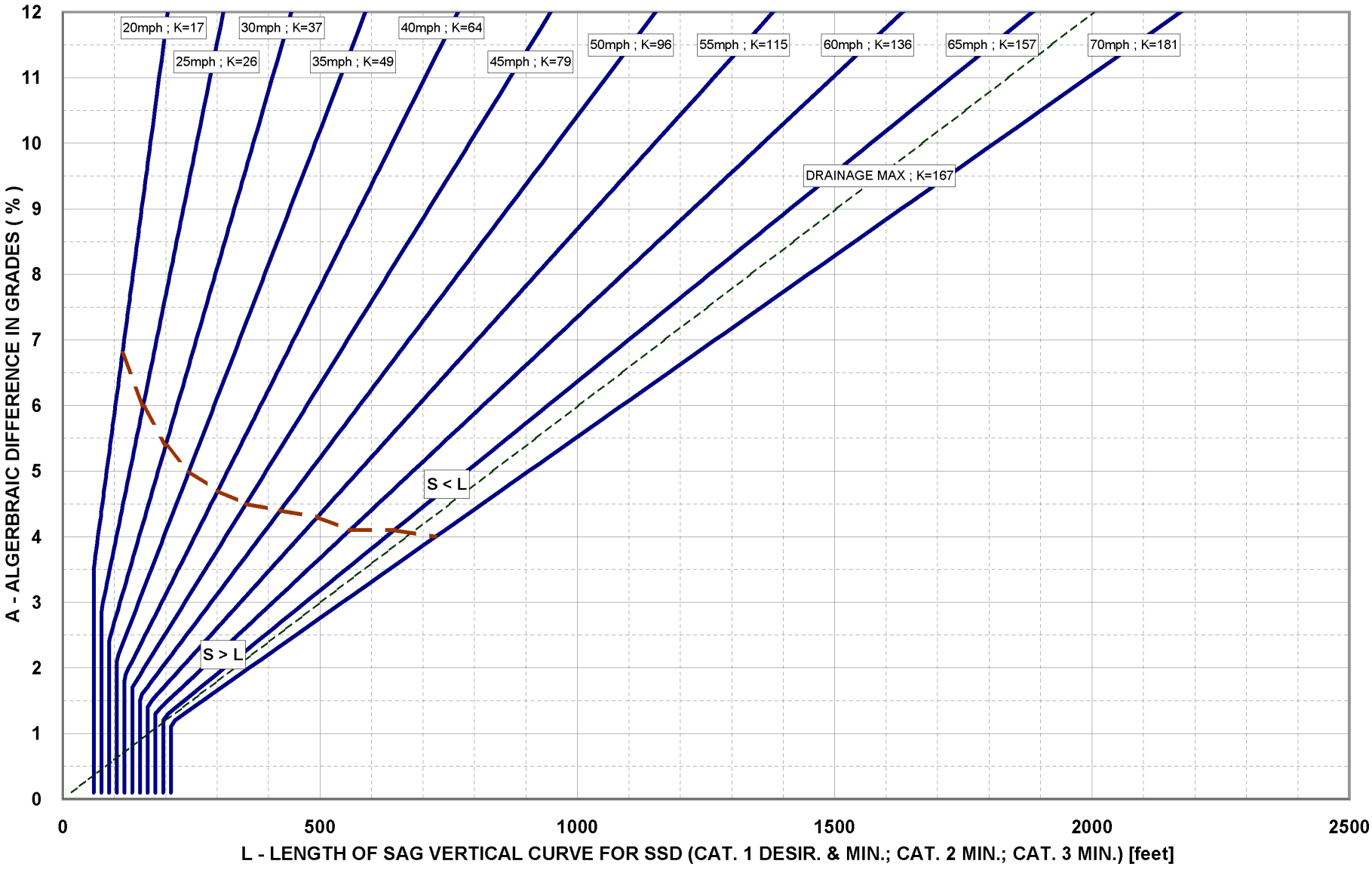
B SSD = Stopping Sight Distance

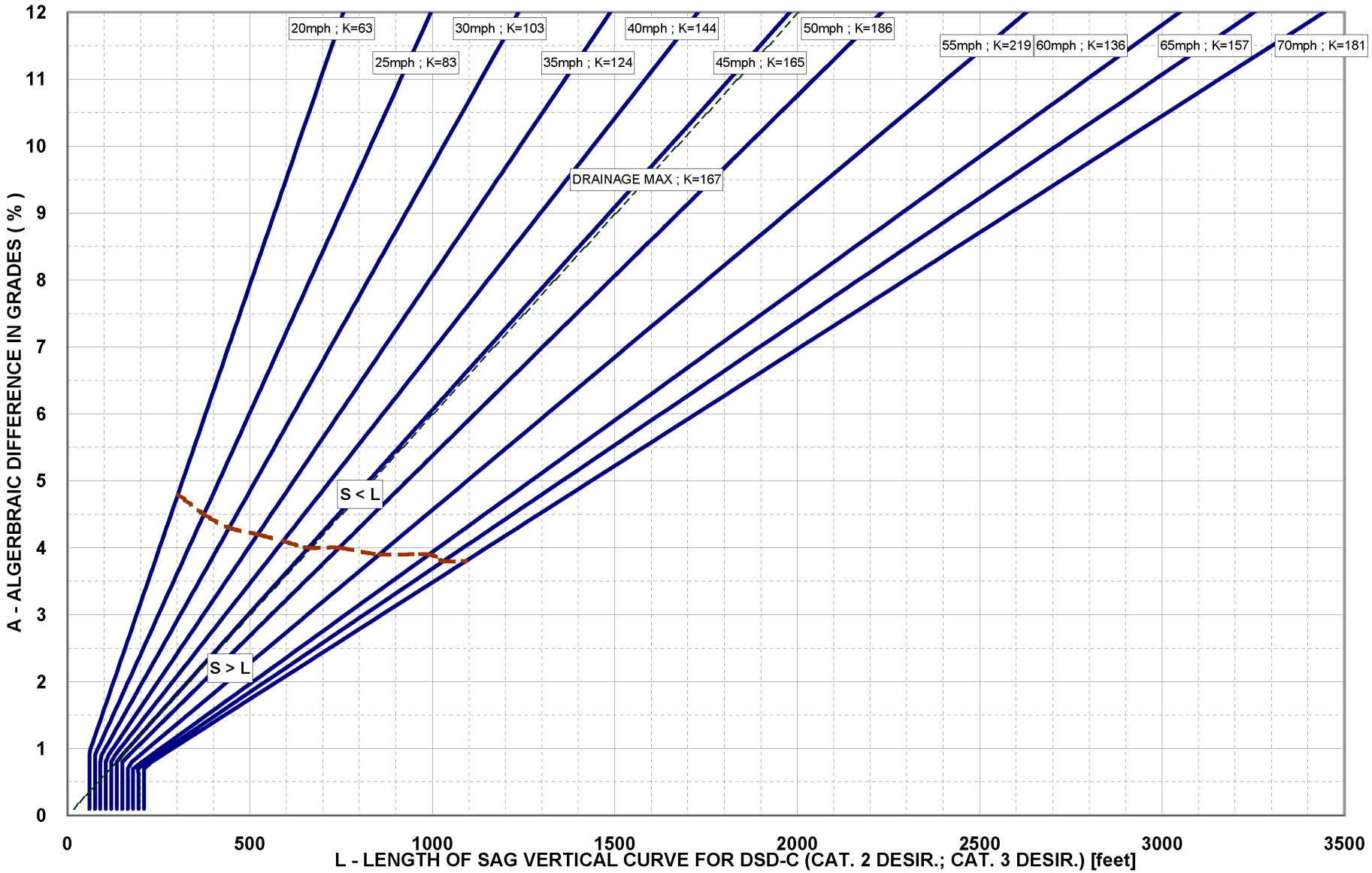
DSD = Decision Sight Distance for Avoidance Maneuver C

C See page 1 of Attachment 5.1

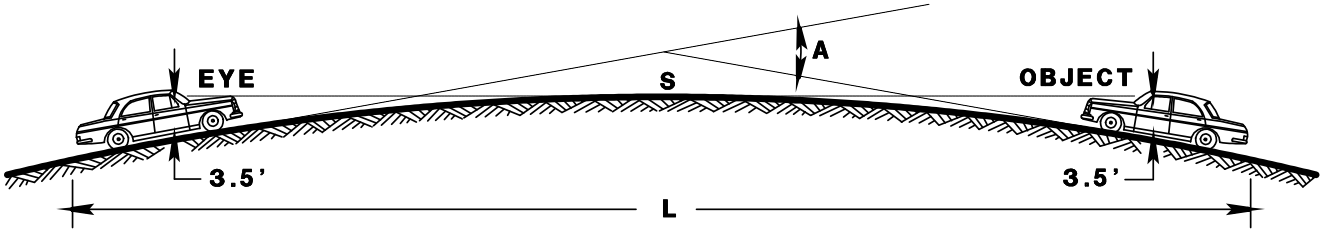
D Minimum length of sag vertical curve = the greater of either (KSAG x A), OR a distance in feet equal to 3 x the design speed in mph (3 x V)

E See Attachment 5.7 for graphs of L vs. A vs. Design Speed for sag vertical curves


20mph ; K=17
25mph ; K=26
30mph ; K=37
35mph ; K=49
40mph ; K=64
45mph ; K=79
50mph ; K=96
55mph ; K=115
60mph ; K=136
65mph ; K=157
70mph ; K=181
DRAINAGE MAX ; K=167
S < L
S > L
A - ALGERBRAIC DIFFERENCE IN GRADES (%)
0
1
2
3
4
5
6
7
8
9
10
11
12
0
500
1000
1500
2000
2500
L - LENGTH OF SAG VERTICAL CURVE FOR SSD (CAT. 1 DESIR. & MIN.; CAT. 2 MIN.; CAT. 3 MIN.) [feet]


20mph ; K=63
25mph ; K=83
30mph ; K=103
35mph ; K=124
40mph ; K=144
45mph ; K=165
50mph ; K=186
55mph ; K=219
60mph ; K=136
65mph ; K=157
70mph ; K=181
DRAINAGE MAX ; K=167
S < L
S > L
A - ALGERBRAIC DIFFERENCE IN GRADES (%)
L - LENGTH OF SAG VERTICAL CURVE FOR DSD-C (CAT. 2 DESIR.; CAT. 3 DESIR.) [feet]
0
1
2
3
4
5
6
7
8
9
10
11
12
0
500
1000
1500
2000
2500
3000
3500

Passing Sight Distance for Crest Vertical Curves

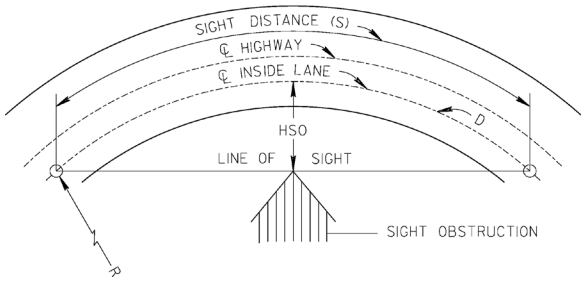


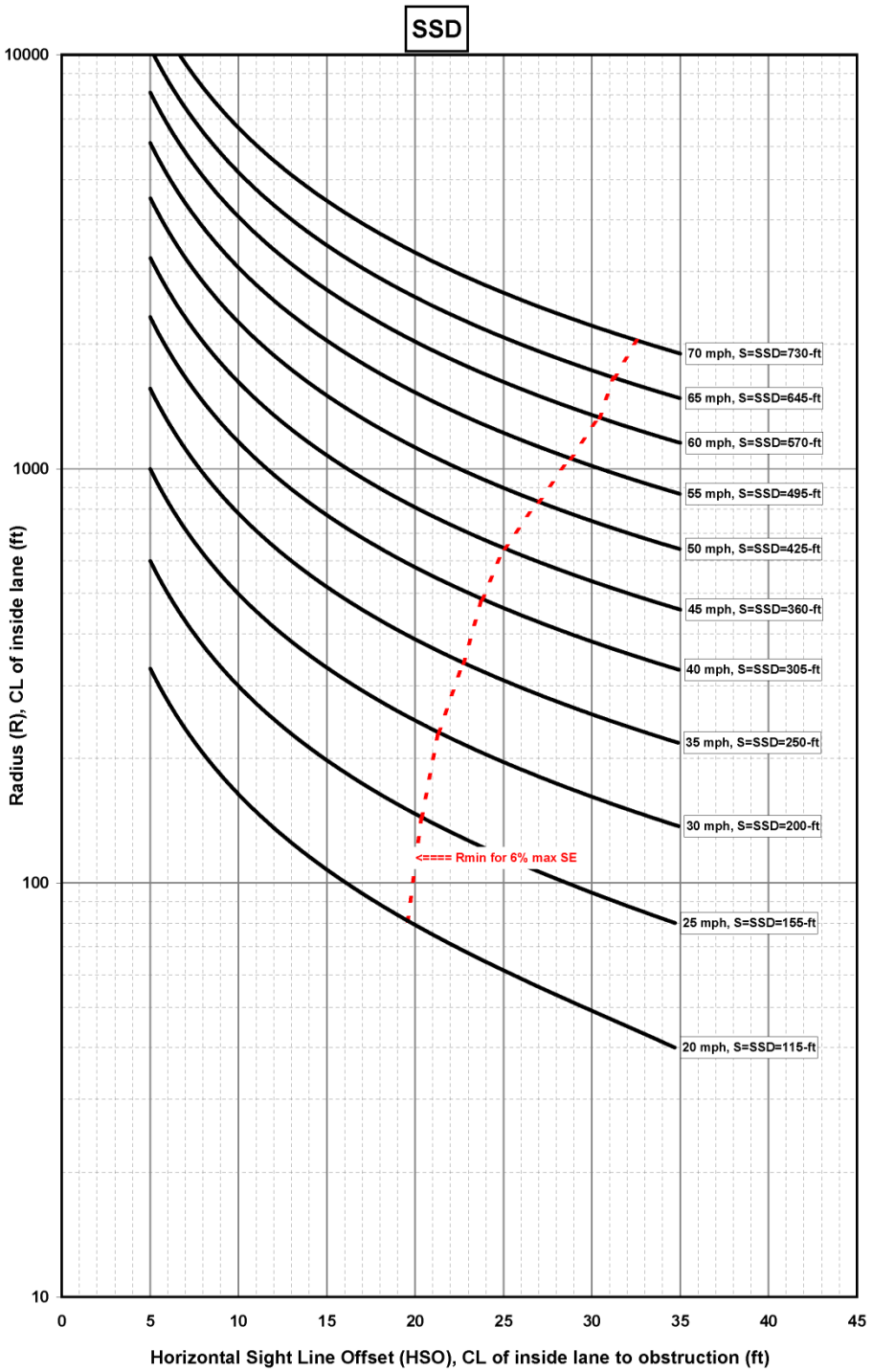
When S > L	When S < L
$L = 2S - \frac{2800}{A}$	$L = \frac{AS^2}{2800}$

L = Length of Vertical Curve (feet)
A = Algebraic Grade Difference (Percent)
S = Sight Distance (feet)

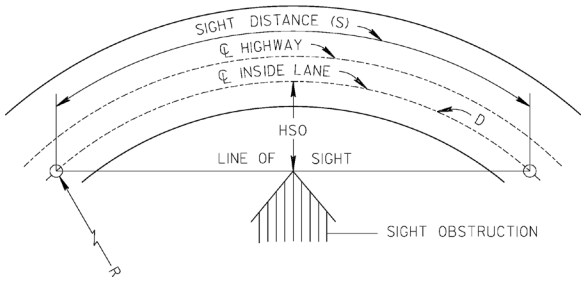
Design Speed (mph)	AASHTO Passing Sight Distance	Minimum Crest K Value to achieve PSD
25	900	289
30	1090	424
35	1280	585
40	1470	772
45	1625	943
50	1835	1203
55	1985	1407
60	2135	1628
65	2285	1865
70	2480	2197

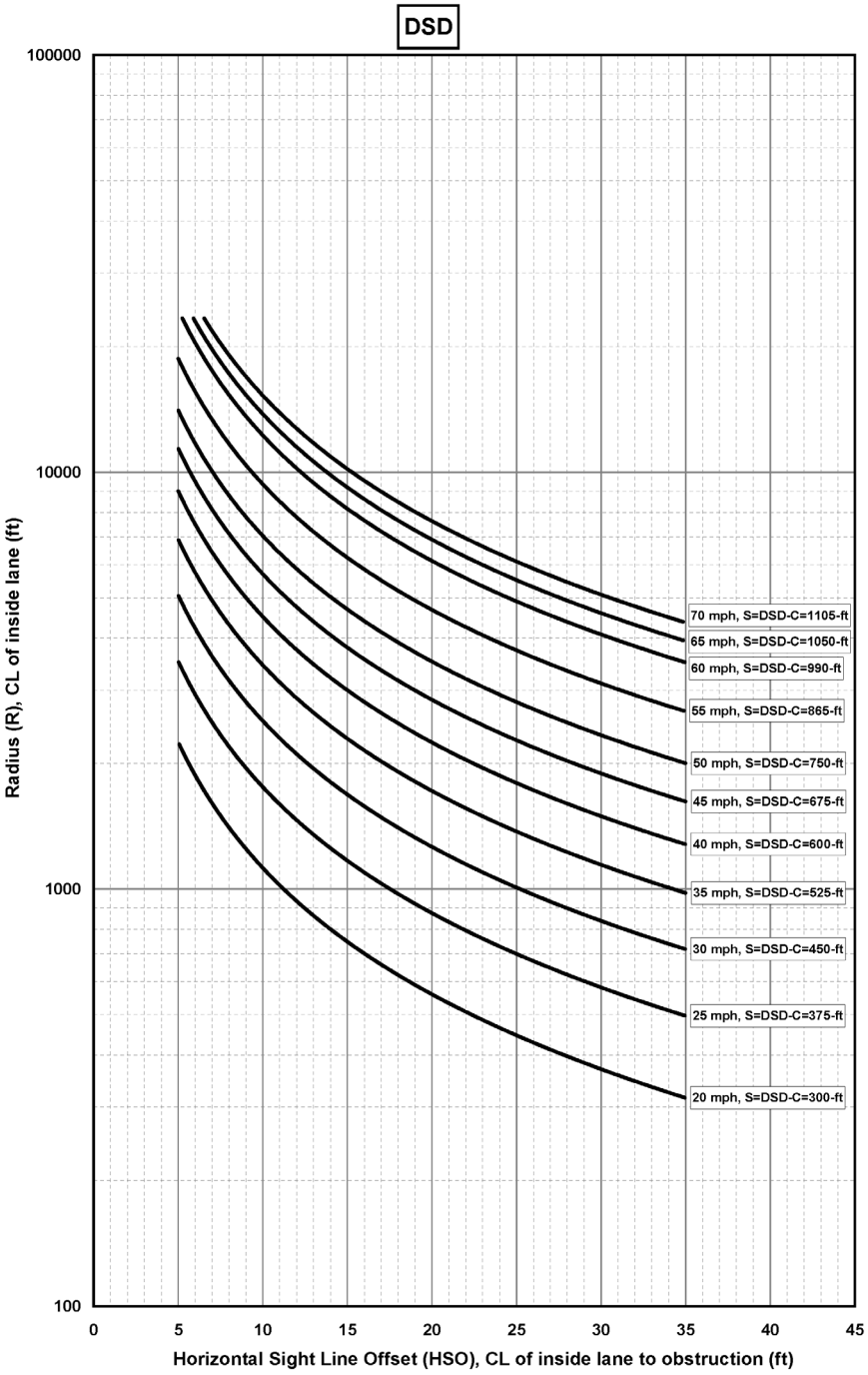
Source: A Policy on Geometric Design of Highway and Streets, AASHTO 2004





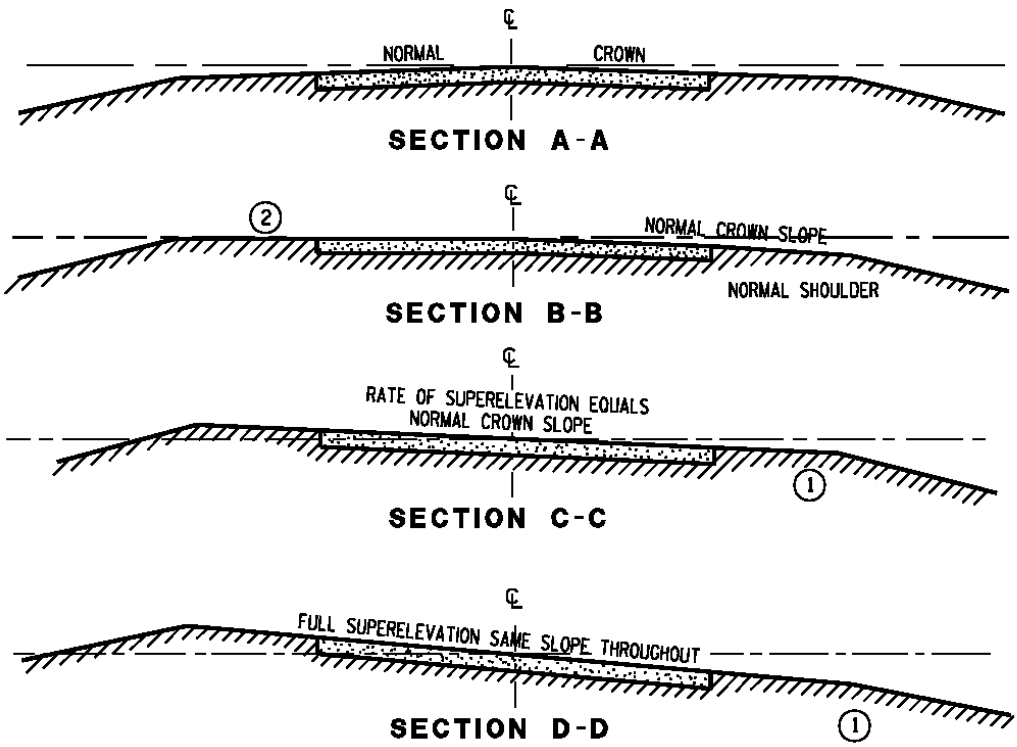
Design Controls for Stopping Sight Distance (SSD) on Horizontal Curves



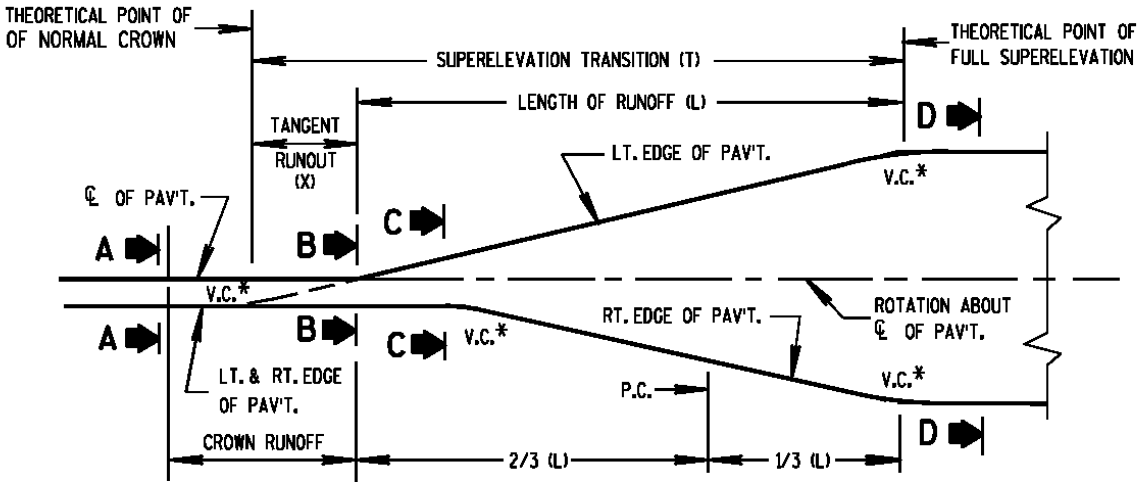


Design Controls for Decision Sight Distance for Avoidance Maneuver C (DSD-C) on Horizontal Curves

Profile and Cross Sections of Two-Lane Highway to the Right



* ANGULAR BREAKS MUST BE APPROPRIATELY ROUNDED, SUGGUESTED VERTICAL CURVE LENGTH IN FEET = DESIGN SPEED IN MPH (FOR EXAMPLE, 50-FT FOR 50 MPH) (SEE AASHTO GDHS 2004)



NOTES

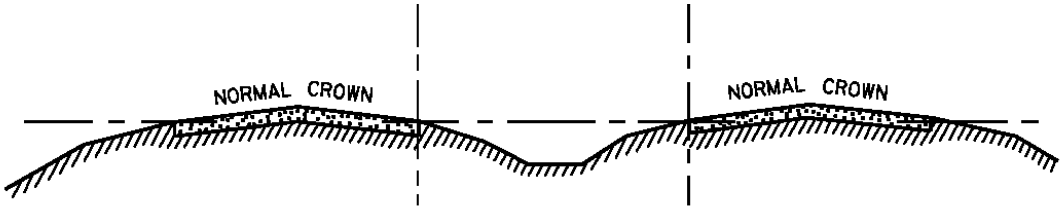
① When normal shoulder is greater than superelevation, retain normal shoulder slope

② High-side shoulder slope = FLAT at section B-B

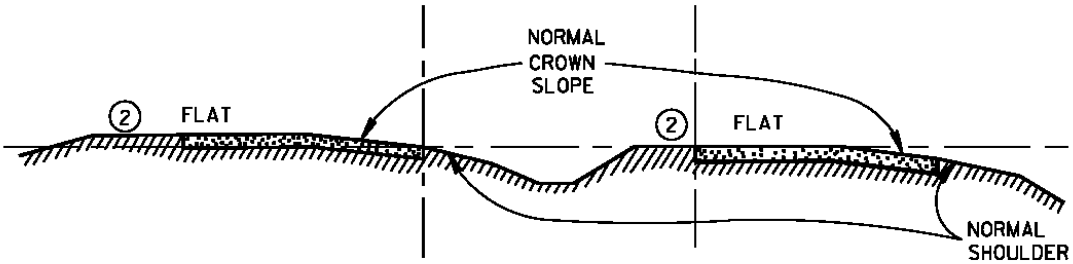
V.C.	= Vertical Curve	R.C.	= Remove adverse crown slope (section C-C)
P.C.	= Beginning of Horizontal Curve	N.C.	= Normal crown slope (%)
e	= Rate of superelevation (%)	L	= Minimum length of Runoff
X	= Tangent runout		

See FDM 11-10 Exhibit 5.1 for definitions, equations and values for L, X, and T.

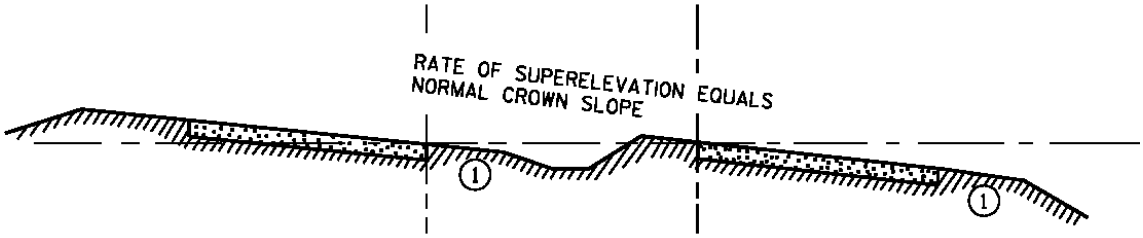
Superelevation Transition of Divided Highway Curve to the Right



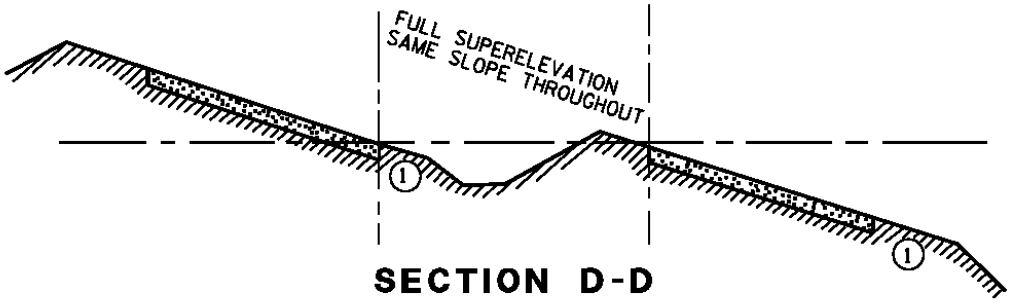
SECTION A-A



SECTION B-B



SECTION C-C

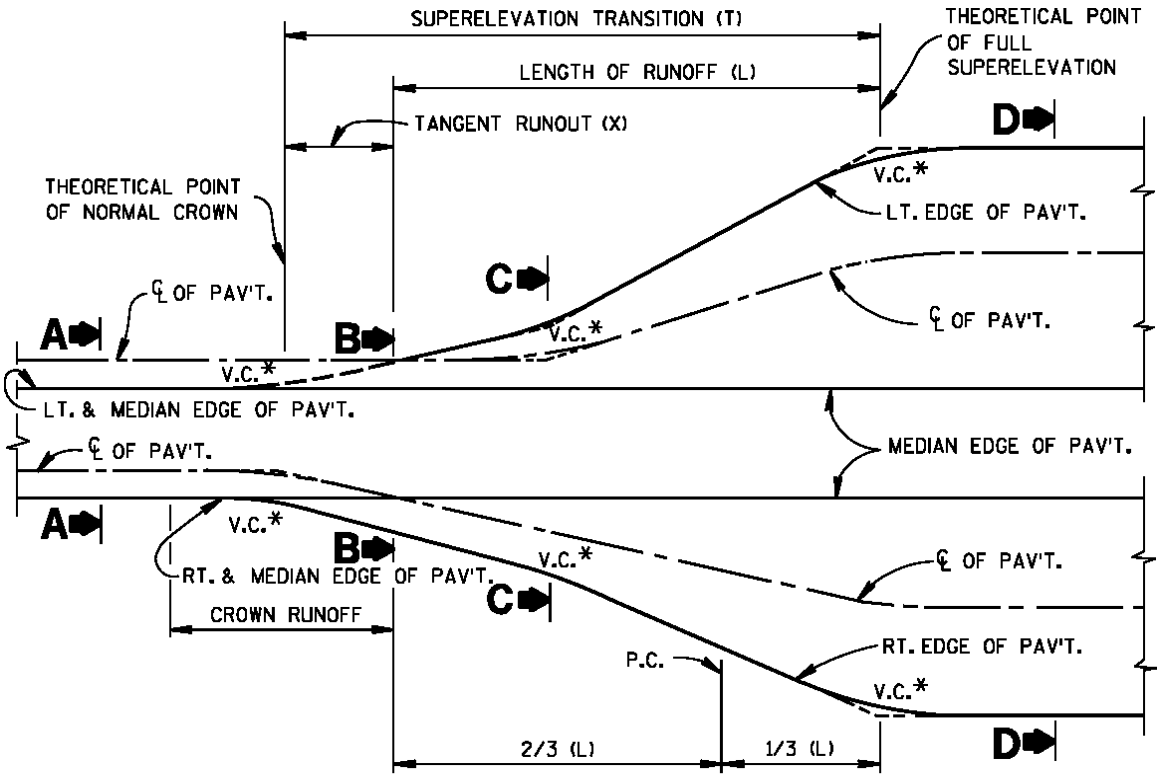


SECTION D-D

NOTES:

1. WHEN NORMAL SHOULDER SLOPE IS GREATER THAN SUPERELEVATION, RETAIN NORMAL SHOULDER SLOPE.
2. HIGH SIDE SHOULDER SLOPE = FLAT AT SECTION B-B

Profile and Cross Sections of Divided Highway Curve to Right



PROFILE

* ANGULAR BREAKS MUST BE APPROPRIATELY ROUNDED, SUGGUESTED VERTICAL CURVE LENGTH IN FEET = DESIGN SPEED IN MPH (FOR EXAMPLE, 50-FT FOR 50 MPH) (SEE AASHTO GDHS 2004, EXH. 3-40 AND P. 196 - 197 FOR ADDITIONAL GUIDANCE.)

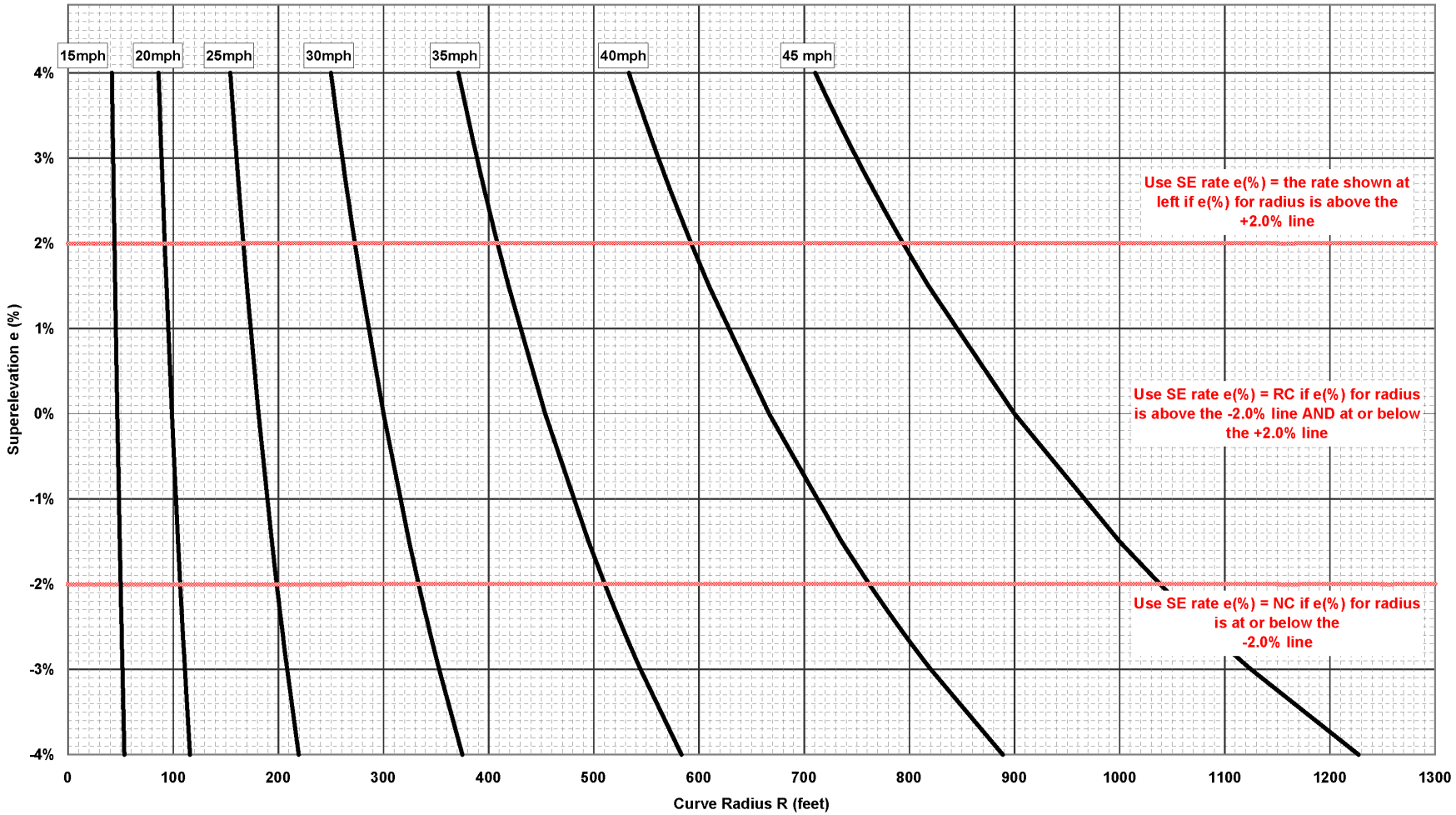
NOTES:

Superelevation rotation is about median edges of pavement.

N.C. = Normal crown slope, (%)
R.C. = Remove adverse crown slope superelevate at normal crown slope retain slope on both shoulders.
P.C. = Beginning of Horizontal Curve
V.C. = Vertical Curve
e = Rate of superelevation (%)
L = Minimum length of Runoff
X = Tangent runout

See FDM 11-10 Exhibit 5.1 for definitions, equations and values for L, X, and T.

Superelevation for Given Radius and Design Speed for Low-Speed Urban Street Design

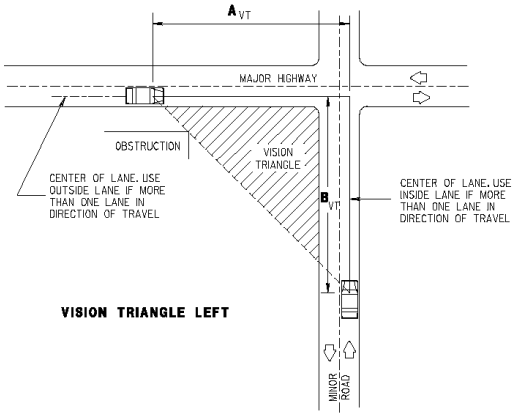


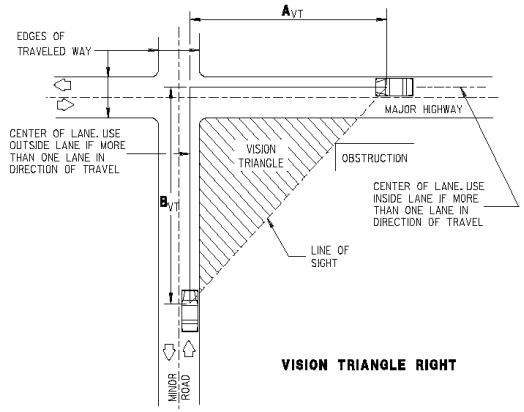
Relationship of Radius Superelevation, Cross Slope, and Design Speed for Low-Speed Urban Street Design (adapted from GDHS 2004, Exh. 3-17)

Notes

1. Compute L, X, and T for superelevation on low-speed urban streets in the same way as for other roadways [see FDM 11-10 Exhibit 5.1]
2. Low-speed urban streets with existing superelevation that meets the requirements of the 2001 GDHS (see pp.192-198) may retain that superelevation if it is impractical to upgrade to the superelevation obtained from this nomograph, unless there is an unacceptable history of curve related crashes.

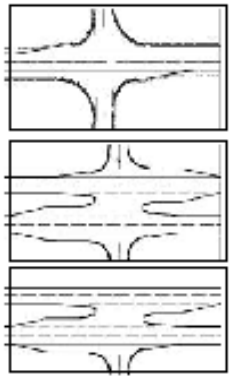
GUIDE DIMENSIONS FOR VISION TRIANGLES - STOP CONTROL ON MINOR ROAD, OR SIGNAL CONTROLLED INTERSECTION



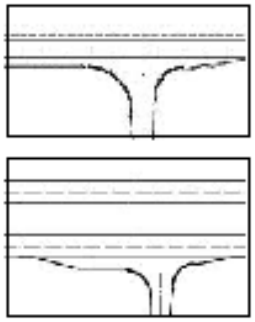


Example Intersection Layouts

THRU movement possible from sideroad



NO THRU movement possible from sideroad



Example 1	4-LEG INTERSECTION (THRU MOVEMENT POSSIBLE ON SIDEROAD)
GIVEN	POSTED SPEED IS 55 MPH ON THE MAJOR ROAD POSTED SPEED IS 45 MPH ON THE SIDEROAD
SOLUTION	READING FROM THE TABLE: DISTANCE A_{VT} ON MAJOR ROAD = 180 FT DISTANCE B_{VT} ON SIDEROAD = 150 FT
Example 2	T INTERSECTION (NO THRU MOVEMENT POSSIBLE ON SIDEROAD)
GIVEN	POSTED SPEED IS 55 MPH ON THE MAJOR ROAD POSTED SPEED IS 45 MPH ON THE SIDEROAD
SOLUTION	READING FROM THE TABLE: DISTANCE A_{VT} ON MAJOR ROAD = 180 FT DISTANCE B_{VT} ON SIDEROAD = 75 FT

* Posted Speed (mph)	** Distance "A_{VT}" (feet)	Distance "B_{VT}" (feet)	
		**THRU movement possible from sideroad	***NO THRU movement possible from sideroad (“T” intersection)
25	90	90	75
30	105	105	75
35	120	120	75
40	135	135	75
45	150	150	75
50	165	165	75
55	180	180	75
65	210	210	75

* Use the posted speed of the Major Highway to determine distance "A"
se the posted speed of the sideroad to determine distance "B".

** Based on distance traveled in 2 seconds at Posted speed + 5 mph.

*** Based on distance traveled in 2 seconds at 25 mph because vehicle approaching intersection on sideroad has to slow down to make a turn.

NO THRU Movement means either existing or proposed.

NOTES:

Distances are approximate and may be adjusted to fit site conditions.

These guidelines are for the Vision Triangle only, and are not to be interpreted as Intersection Sight Distance (ISD) or Stopping Sight Distance (SSD) requirements.

The Vision Triangle must be free of all obstructions.

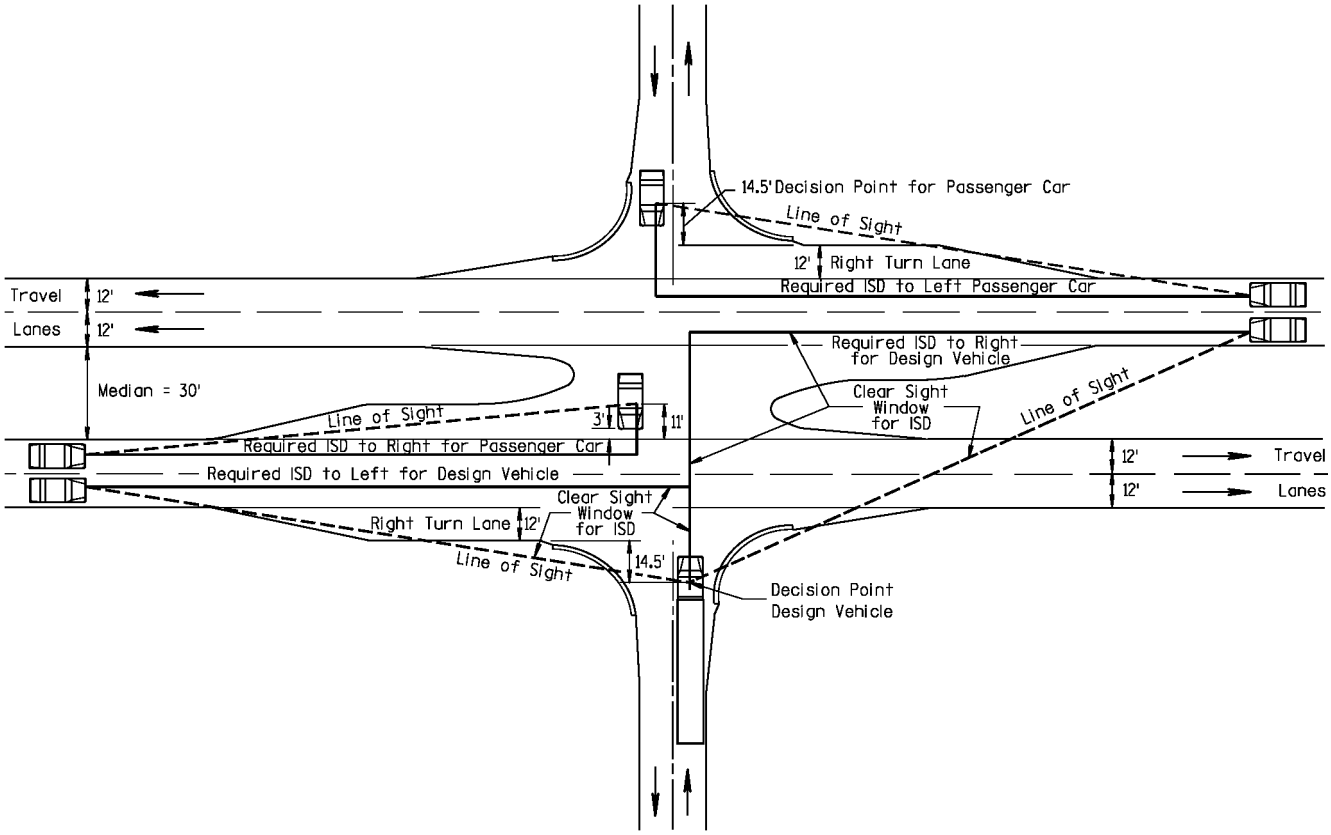
Example computation of Intersection Sight Distance for Cases B1, B2, and B3

Given

- Mainline: 4-lane divided bi-directional road (2 lanes in each direction); design speed = 50 mph; tangent alignment; lane width = 12 feet; median width = 30 feet; shoulder width = 10 ft
- Side road: arterial; grade < 3%; design speed = 40 mph
- Intersection: type B1 with 12 ft wide right turn lane

Find

- Design vehicle for intersection sight distance
- Required Intersection Sight Distances for both a passenger car and for the design vehicle



Solution

- From FDM 11-10 Table 5.1 the design vehicle for an arterial is a WB truck.
- Intersection Sight Distance to the LEFT is the greater of that required for Case B2 - Right turn from the minor road, and Case B3 - Crossing maneuver from the minor road.
- Intersection Sight Distance to the RIGHT is the greater of that required for Case B1 – Left turn from the minor road, and Case B3 - Crossing maneuver from the minor road.

Intersection Sight Distances (ISDs) to LEFT			Intersection Sight Distances (ISDs) to RIGHT	
Case B2	**Case B3**	**PASSENGER CAR**	**Case B1**	**Case B3**
8.0	7.0	UPPER MINIMUM time gap (sec) [A]	10.0	7.0
590	515	UPPER MINIMUM ISD (feet) [A]	735	515
19	19	Vehicle length (feet) [B]	19	19
NA	NA	Vehicle length+ 6'< Median width?	Yes	Yes
Cross 12-ft right turn lane	Cross 12-ft right turn lane	ADJUSTMENT description	None	None
0.5	0.5	Additional time (sec) [C]	--	--
35	35	Additional ISD (feet)	--	--
625	550	Total ISD (feet)	735	515
625		Controlling ISD (feet)	**735**	
14.5 ft from the edge of right turn lane= 26.5 ft from the edge of travel lane.		Side road decision point location	11.0 feet from the median edge of the far side travel lanes	
Case B2	**Case B3**	**WB TRUCK (DESIGN VEHICLE)**	**Case B1**	**Case B3**
12.0	13.0	UPPER MINIMUM time gap (sec) [A]	13.0	13.0
885	960	UPPER MINIMUM ISD (feet) [A]	960	960
Greater than 55 ft	Greater than 55 ft	Vehicle length (feet) [B]	Greater than 55 ft	Greater than 55 ft
NA	NA	Vehicle length+ 6'< Median width?	No	No
Cross 12-ft right turn lane	Cross 12-ft right turn lane	ADJUSTMENT description	Cross an additional 54-feet = 4.5 lanes (12' right turn lane + 12' travel lane + 30' median)	Cross an additional 66-feet = 5.5 lanes (12' right turn lane + 2x12' travel lanes + 30' median)
0.7	0.7	Additional time (sec) [C]	0.7 x 4.5 = 3.15	0.7 x 5.5 = 3.85
50	50	Additional ISD (feet)	230	285
935	1010	Total ISD (feet)	1190	1245
	1010	Controlling ISD (feet)		1245
14.5 ft from the edge of right turn lane=26.5 ft from the edge of travel lane.		Side road decision point location	14.5 ft from the edge of right turn lane= 26.5 ft from the edge of travel lane.	

A See FDM 11-10 Table 5.2.

B See Exhibit 2-3, p21 & Exhibit 2-14, p32, GDHS 2004

C See FDM 11-10 Table 5.2, Notes B & C

FDM 11-15-1 Modernization Design Guidance for Highways

August 17, 2020

1.0 Introduction

This section contains design guidance for Modernization highway projects. Modernization projects were formerly referred to as Reconstruction and New Construction projects and will continue to be sub-divided according to these Modernization type improvements. These include State Trunk Highways (STH), Non-STHs (Local Roads), Expressways and non-Interstate Freeways and Interstate Highways.

1.1 Overview and Scope of Modernization Projects

Modernization projects are intended to reconstruct or newly construct highway pavement structures and geometric and cross-sectional features to meet Modernization service life cycles. A practical minimum design analysis period for Modernization projects is 20 years with many projects meeting a project service life cycle of more than 20 years.

Design of Modernization projects shall be in accordance with the Facilities Development Process described in Chapter 3 of the Facilities Development Manual (FDM Chapter 3).

1.1.1 Definitions

The purpose and need for Modernization projects should provide pavement structures and geometric and cross-sectional features that will adequately meet the pavement, safety and operational needs for full Modernization service life cycles of 20 or more years.

FDM 3-5-1 contains definitions for Highway Improvement work types, as well as other criteria, examples and requirements, for the following Modernization improvement types:

Reconstruction-Type Modernization Projects

- Reconstruction (RECST)
- New Bridge (BRNEW)

New Construction-Type Modernization Projects

- Reconstruction with Expansion (RECSTE)
- Bridge Replacement

WI Administrative Code Trans 209, Highway and Bridge Project Selection Process", is the basis for the definitions in FDM 3-5-1.

1.2 Safety and Traffic Operations

Safety and traffic operations, in addition to pavement structure, are equally important considerations to design for within the Modernization project service life cycle time frames. Safety and traffic operations will be addressed on these projects by applying the appropriate safety and operational analyses per the WisDOT Safety Certification Process (SCP) and associated Safety Certification Document (SCD) as described in FDM 11-38 or by the application of Modernization design criteria per AASHTO and the FHWA Interstate Reconstruction and New Construction program criteria. The SCD along with Design Justifications (DJs) in the Design Study Reports (DSRs) (see FDM 11-1-20 and FDM 11-4-10.4), when needed, are the mechanisms available to justify, document and approve the retention of existing geometric and cross-sectional features or to introduce new geometric or cross-sectional features outside of existing or new design criteria values when needed for situations in which reducing environmental impacts or excessive costs. This FDM chapter will define the WisDOT policy on the proper application of these criteria and processes.

1.3 Design Criteria Application

Geometric and cross -sectional design criteria have been developed for Reconstruction and New Construction-Type Modernization improvement projects based on the following sources:

1. Interstate Highways

- A Policy on Design Standards - Interstate System, 2016, AASHTO (see FHWA web-site, "Geometric Design", http://www.fhwa.dot.gov/programadmin/standards.cfm, under "Policy")

2. Non-Interstate Highways

- New Construction and Reconstruction: A Policy on Geometric Design of Highways and Streets (GDHS), 6th edition, 2011 AASHTO (see FHWA web-site, "Geometric Design", http://www.fhwa.dot.gov/programadmin/standards.cfm, under "Information")

Modernization projects will use these nationally recognized criteria and the derived FDM 11-15 Attachments 1.1 to 1.17 as the references to base resources for design criteria values for geometric and cross-sectional feature improvements. The SCD will be used in conjunction with this guidance to allow for the evaluation and potential utilization of existing geometric and cross-sectional features. Existing features not contributing to safety issues justify improvements using the lower end of the design criteria ranges and may with the addition of other factors (environmental, public involvement, significant costs, etc.) justify the use of existing feature values outside of the range of design criteria. The applications that WisDOT will use to apply these Modernization design criteria will be the defined guidance described below as S-2 and S-3 Applications. These applications will apply to both Federal-aid and State funded projects. See FDM 11-38 for Safety Certification Process (SCP) guidance. See FDM 11-1-10 for additional information regarding S-2 and S-3 Applications.

1.3.1 S-2 Application

S-2 will be applied to Reconstruction-Type Modernization Projects in the following ways:

1. Where the SCD shows either that projects or project segments/locations have no discernible safety issues or where existing cross sectional, or geometric features are not contributing to safety issues, existing feature values within the range of design criteria may be retained and existing features outside of the range of design criteria may be considered when evaluated with other factors (such as environmental, public involvement, significant cost implications, etc.) and justified in a Design Study Report (DSR) Design Justification (DJ).
2. Where the SCD shows that existing cross sectional or geometric features are contributing to safety issues, then utilize the lowest Modernization design criteria values to acceptably meet the project purpose and need. The application of cross sectional and geometric feature improvements will begin with the use of the lower Modernization design criteria in design alternatives development. The final design criteria values chosen will be based on predictive safety benefit/cost analyses results in conjunction with the natural and societal environmental impact evaluations completed as part of the environmental process described in FDM Chapter 20.

Design Justifications (DJs) can also be used when needed to justify, document and approve the use of values outside of design criteria in which the SCP has identified existing cross sectional or geometric features as contributing to safety issues and in which environmental or other project impact evaluations have determined that existing or less than existing design criteria values are justified. See FDM 11-1-20 and FDM 11-4-10.4 for information and guidance on developing DSR DJs.

1.3.2 S-3 Application

S-3 will be applied to New Construction-Type Modernization Projects in the following ways:

1. The SCD cannot be applied to New Construction projects or project segments/locations on new alignment because no cross sectional or geometric roadway features nor crash histories exist in which to evaluate safety performance. These projects, or segments/locations of projects, will typically begin with the application of higher Modernization design criteria values in the development of design alternatives aimed at meeting the purpose and need of the project. The final design values chosen should be based on appropriate predictive safety benefit/cost analyses in conjunction with the natural and societal environmental impact evaluations completed as part of the environmental process described in FDM Chapter 20.
2. DJs can also be used to justify, document and approve the introduction of values outside of design criteria that can be justified, documented and approved based on other considerations besides just safety, such as environmental impacts, unacceptable costs, etc. See FDM 11-1-2 and FDM 11-4-10.4 for information and guidance on developing DJs.

1.4 Lanes and Shoulders

1.4.1 STH, Non-STH and Non-Interstate Expressways and Freeway Highways

Modernization design criteria for various rural highway systems are given in this procedure. Attachment 1.1, 1.2 and 1.3 are for rural state trunk highways classified as arterials, collectors and locals respectively. Attachments 1.1 to 1.3 provide separate design criteria for highways in level terrain and rolling terrain. Level terrain is the most prominent topography in Wisconsin and as such most projects will be designed using the level terrain criteria. Attachment 1.4 applies to town roads. Attachment 1.15, 1.16 and 1.17 are for rural county trunk highways classified as arterials, collectors and locals, respectively.

1.4.2 Interstate Highways

Interstate Modernization (Reconstruction and New Construction) projects are part of the 4R (Resurfacing, Restoration, Rehabilitation and Reconstruction) program which is a continuing post Interstate highway program established by Congress through a series of Federal Legislation [1] [2] [3] [4] [5]. The basic objective of this program is to preserve the integrity and operational effectiveness of the existing Interstate highway system.

This objective will be accomplished by appropriate work in three broad areas of activity. First, the useful life of various elements of the system may be substantially extended through various resurfacing, restoration and rehabilitation (or Preventative Maintenance and Perpetuation) efforts. When such efforts would not be cost effective, it would be appropriate for the elements to be completely reconstructed or newly constructed (or modernized). Finally, the program can respond to the need for improved functional effectiveness to reflect changed conditions. Consequently, where justified, these funds can be used to reconstruct (or modernize) facilities such as interchanges and overpasses and provide for safety upgrading. In addition, these funds can be used for other items of work which have been determined to be beyond that necessary "to provide a minimum level of acceptable service." Such items include rest area construction; new interchanges and added grade separations.

Interstate funds may also be used to construct new High Occupancy Vehicle (HOV) lanes but cannot be used to construct new travel lanes. Other Federal aid funds, such as National Highway System (NHS) or Surface Transportation Program (STP) funds may be used to add new travel lanes.

The definition of Interstate Reconstruction (or Modernization) is work required to effect substantial upgrading of major highway features to increase the serviceability and safety of operations for a design life of 20 years or more. This class of work may require acquisition of additional right-of-way. Examples of this type of work are the following: widening of roadways and bridge decks to add lanes; bridge work beyond replacement of decks including work to increase vertical clearance under grade separations; major grading to improve drainage and alignments; addition of ramps and through lanes on cross roads at interchanges. Note: This is a federal definition and is not meant for project programming purposes. For programming purposes use the definitions in the Program Management Manual (PMM) 5-10-5 pages 7 and 8.

See Attachment 1.18 for Interstate Freeway Design Criteria.

Interstate highway segments being constructed on new right-of-way and segments undergoing complete reconstruction along existing right-of-way shall conform to current design criteria [6] .

Requests for design justifications (DJs) (exceptions to standards) involving FHWA's controlling criteria on Reconstruction and New Construction (Modernization) Interstate Projects shall be prepared and processed in accordance with FDM 11-38 and FDM 11-1-20 for the appropriate situations. DJs (exceptions to standards), when needed, are approved by the Chief of the Design Standards and Oversight Section and, when required, by FHWA. DJs will only be acceptable if adequately supported and are not shown to lead to an identifiable loss in the safety features of highway designs.

1.5 Railroad Crossings

Avoid designing projects to start or end at railroad grade crossings. Either extend lane widths, shoulder widths, or cross section changes through the grade crossings, or stop the changes well short of the crossings. See FDM Chapter 17.

1.6 Cross Slopes

The normal cross slopes of all pavement types are 2%.

For Interstate Highways, pavement cross slopes should be 2% on tangent sections.

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[1] Federal-aid Highway Acts of 1976

[2] Federal-aid Highway Act of 1981

[3] The Highway Improvement Act of 1982

[4] The Intermodal Surface Transportation Act of 1991 (ISTEA)

[5] The Transportation Equity Act of 1998 (TEA 21)

[6] A Policy on Design Standards Interstate System, AASHTO 2005

1.7 Shoulders

Shoulders should have adequate strength and stability to support occasional vehicle tire loads under all weather conditions without rutting or other surface variations. On tangent sections and crown runoff sections, shoulders typically slope 4% downward from the adjacent pavement edges. In super-elevated sections, the shoulder slopes will typically be continuations of the pavement slopes on the high sides and 4% downward on the low sides, except when the super-elevation rates exceed 4%, in which case the low side shoulder slopes should typically equal the rates of superelevations. However, when the shoulders of two lane highways are paved as integral parts of the travel lanes and the paved portions are 6 feet or less in width, the paved shoulder cross slopes should typically match the cross slope of the travel lanes for newly constructed or reconstructed pavement, or match the existing cross slope for resurfacing, reconditioning projects, or pavement replacement projects consisting of a structural overlay. The remaining unpaved portions of the shoulders are typically sloped 4%, except as previously noted for super-elevated sections.

Non-interstate width design criteria values for paved shoulders are shown in Attachment 1.5.

1.7.1 Shoulder Paving Policy

1. On Modernization projects, the shoulder paving policies are described below.

    a. For STH's with asphalt roadways where the application of existing or design classification shoulder values show total finished shoulder widths of 6 feet or more, provide paved shoulders in accordance with Attachment 1.5 of this procedure.

    Note - STH Design Classifications C2 and L3 with current ADTs of 750 or more, 12-foot lanes, and having 6-foot or more total shoulder widths, provide 5-foot paved shoulders. Where the total shoulder widths are 3-foot or more, and less than 6-foot, provide minimum 3-foot paved shoulders.

    b. For CTH's, and other local highways with total shoulder widths of 3-foot or more and having construction year traffic volumes of 750 AADT or more, provide 3-foot paved shoulders.

    Note - Reconstruction and New Construction project types on County Trunk Highways and local roads receiving State or federal funding with construction year AADTs of 750 or more are required to include the installation of 3-foot minimum paved shoulders. See FDM 11-46-15.4 for conditions where wider than a 3-foot paved shoulders are required. For CTH's and other local highways having construction year traffic volumes less than 750 AADT, paved shoulders are at the discretion of the local officials.

    c. For Interstate highways, typical lowest width requirements for paved shoulders should be 10-foot on all right shoulders and for left shoulders 10-foot on highways with 6 or more lanes and 4-foot on 4-lane highways. Consider the use of 12-foot paved shoulders (left and right) on 6-lane freeways if truck traffic > 250 DHV or if the facility experiences a high degree of congestion and incidents. The roadway widths and clear roadway widths on bridges are increased accordingly.

    Regions may decide to pave more shoulder widths than the policy widths. There may be design justifications (DJs) for finished shoulder widths on some projects with high cuts, or fills, or adverse environmental factors. When DJs are granted that will reduce the finished shoulders to less than 6 feet, then 5-foot paved shoulders may also qualify for DJs to the design criteria.

2. When the pavement structures are PC concrete and the current AADTs are greater than 750;

    (a) two lane, two way highways should typically be constructed with 3-foot monolithic shoulders,

    (b) multi-lane divided highways should typically be constructed with 2-foot monolithic shoulders on the right.

    Total paved shoulder widths should typically be as shown in Attachment 1.5 of this procedure and as shown in the SDD for Doweled Non-Reinforced Concrete Pavements, Section A-A.

3. Shoulders may be paved full width along highways in suburban areas where closely spaced driveways and frequent turning movements cause unpaved shoulders to require excessive maintenance.

4. Continuity of shoulder paving between logical termini is desirable. Try not to leave gaps of unpaved shoulders.

5. Provide a thickness of shoulder paving based on the usual design considerations appropriate for each situation (see FDM 14-10-25).

1.8 Rumble strips

Rumble strips are an engineering treatment designed to alert drivers of a lane departure through vibration and noise created when a vehicle's tires contact the rumble strips. Rumble strips may be placed on the shoulders, between opposing travel lanes (centerline), or in the travel lanes (transverse). For additional information on rumble strips, see FHWA Technical Memorandum dated November 16, 2011:

- T 5040.39 for shoulder rumbles,

  http://safety.fhwa.dot.gov/roadway_dept/pavement/rumble_strips/t504039/

- T 5040.40 for center line rumbles,

  http://safety.fhwa.dot.gov/roadway_dept/pavement/rumble_strips/t504040/

- Also see NCHRP Report 641 - Guidance for the Design and Application of Shoulder and Centerline Rumble Strips

  http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_641.pdf

Shoulder and centerline rumbles are especially helpful during bad weather such as rain, snow or fog when visibility of the edge lines or centerlines are substantially reduced. Rumbles also help to reduce inattentive driving crashes. Driver inattention comes in many forms, including fatigue, drowsiness, daydreaming, cell phone use, texting, visual distractions, alcohol and drug impairment to mention a few.

Shoulder rumble strips help to reduce fatal and injury Run-Off-Road (ROR) crashes by 29% by alerting inattentive drivers to lane departures. Run-off-road (ROR) crashes account for over one-third of fatal and injury crashes each year, with 90% taking place on rural Wisconsin highways. Rumble strips will not eliminate all ROR crashes especially those caused by excessive speed, sudden turns to avoid on-road collisions, or high-angle encroachments.

Centerline rumble strips help to keep vehicles in their lanes and reduce head-on and sideswipe crashes by 44% on undivided highways. WisDOT installs centerline rumbles in passing and no-passing zones to address the same driver inattention forms noted above.

1.8.1 WisDOT Rumble Strips Policy and Design Criteria

WisDOT takes a systemic approach to rumble strip installation based on national evidence that rumbles strips reduce crashes and increase safety on divided and undivided roadways. WisDOT policy for each installation is described in the sections below.

WisDOT has carefully considered noise generation in the development of our rumble strips policy. The design and horizontal locations/offsets of the rumbles should minimize noise generation. WisDOT feels that the safety benefits of rumbles, described in FDM 11-15-1.8, outweigh the impacts of the noise generated a majority of the time. Therefore, it is appropriate to take a systemic approach to the implementation of rumbles. However, the regions may be aware of a few unique situations where noise generation may factor into decisions to either not install rumbles, or to provide gaps in the rumble strip installations. Unique situations may be where current high speed (50 mph posted) facilities may have posted speeds reduced in the near future because of more traffic or congestion, or future land uses allow for more adjacent developments where noise may be an issue. There may be existing isolated developments/communities or single dwellings where there is high likelihood for noise concerns, then consider providing gaps in the rumbles (no rumbles) for approximately 500 feet on each side of the potential problem sites. Policy expectations are that decisions to either not install or to gap the rumbles will be kept to a minimum. Design Justifications for these decisions are to be documented in the DSR.

WisDOT design criteria are for milled-in rumbles on concrete and asphaltic divided highway shoulders and on asphaltic undivided highways along the centerlines and shoulders. WisDOT installed rolled-in and formed rumble strips prior to the mid 1990's and some of those installations may still be in place.

Studies have shown that the milled-in designs are more effective, with less shoulder degradations, and use less shoulder widths for installations than previous designs. The designs in terms of depths, widths, lengths, spacings as well as locations on where to eliminate installations will vary between divided and undivided highways and are identified on the Standard Detail Drawings (SDD).

1.8.1.1 Divided Highways

On rural freeways and interstates, install rumble strips on both the right and left side shoulders, including parallel entrance ramp shoulders, and the last 600 feet on the right shoulders of tapered entrance ramps. Do not install rumbles on bridge approaches or bridge decks. See SDD 13A5 " Shoulder Rumble Strip, Milling" for design and location details.

On rural multi-lane divided, high speed, roadways install rumble strips on both the right and left side shoulders in

high speed (50 mph and greater) areas, except they shall not be constructed on tapers to right or left turn lanes, along turn lanes, across side road intersections, across commercial driveways, on bridge approaches or bridge decks, 100 feet in advance of railroad crossings, and private driveways. They may be constructed across field entrances, but this is not recommended. As described below for urban situations, there may be locations along rural multi-lane divided, high speed, roadways near urban areas (higher speed transition areas typically with rural cross sections) where rumbles may not be appropriate. See SDD 13A5 "Shoulder Rumble Strip, Milling" for rumble design and location details.

There may be locations on urban freeways and multi-lane divided, high speed, roadways where shoulder rumble strips may not be appropriate. These locations may include residential areas or other areas where road noise from rumble strips is undesirable. In other situations, shoulder rumble strips may not be desirable because traffic needs to use the shoulders on a recurring basis to get around mainline blockages, or the shoulders are frequently used for incident management, law enforcement or other purposes.

1.8.1.2 Undivided Highways

WisDOT will install shoulder and centerline rumble strips on asphaltic two-lane, rural, undivided, high speed (>50 mph posted) roadways on projects greater than one-half mile long. At this time, WisDOT will not install rumbles on two-lane rural, undivided concrete roadways due to potential damage from the salt deposits that may accumulate at contraction or construction joints, primarily centerlines, and may cause the concrete to spall. Rumbles should not be installed where the posted speed limits are less than 50 mph.

Consideration should be given to project types, lane widths, finished shoulder widths, paved shoulder widths, horse and buggy travel, bicyclists, roadside noises, steepness and length of downhill grades greater than 4% for more than 500 feet, and beam guard or barrier wall installations, as described below.

There may be communities within the project lengths where centerline and shoulder rumbles should not be installed. These, start and stop points should also be coordinated with posted speed limits. Obtain input from the Region bike/pedestrian coordinators.

1.8.1.2.1 Rural Centerline Rumble Strips

Install rural centerline rumbles on all asphalt highway improvement projects having 12-foot lane widths where the Region Pavement Engineer determines centerline joints will be in good, stable condition to mill-in rumbles after the work is completed.

With reference to the noise policy stated in 1.8.1 above there should be very few, if any, situations where centerline rumbles are not installed.

Do not install warning signs for the centerline rumble strips per the Traffic Engineering Operations and Safety Manual TEOpS 2-3-65.

See SDD 13A11 for more detailed design and installation location information.

1.8.1.2.2 Rural Shoulder Rumble Strips

Install rural shoulder rumbles on Modernization projects except for the following conditions:

1. Roadways with less than 12-foot travel lanes.
2. Roadways that experience recurring horse and buggy travel.
3. Segments of roadways with grades greater than 4% downgrade for more than 500 feet. Downgrades of 4% or more for 500 feet or more may allow bicyclists to achieve high speeds. Rumbles should not be installed in these conditions to allow bicyclists to maneuver carefully into the lanes to avoid debris on the shoulders or increase distances from beam guard or other roadside hazards.
4. Segments of roadways where the clear space from the outside edges of the rumbles is less than 5 feet from the faces of beam guard or barrier walls,
5. Concrete pavements.

Type 1 shoulder rumble strips are the most common type of shoulder rumbles installed. The SDD shows the installation location adjacent to the edge lines. With 5-foot or more paved shoulder widths there will be at least 4 feet of clear space outside the rumbles. This space outside the rumbles will allow wide OSOW vehicles to straddle the rumbles with the outside tires riding on the paved shoulders, and they provide the recommended 4-foot space for bicycle users. See SDD 13A10 for more detailed design and installation location information.

Type 2 rumble strips (sometimes referred to as rumble stripes) are not installed systemically like the Type 1 rumbles. Type 2 rumble strips should be installed where there are known high ROR crash problems with logical termini, not short spot locations. Type 2 rumbles may be used when the paved shoulders are at least 3 feet wide

and less than 5 feet wide. Type 2 rumbles are likely to generate more noise from nuisance hits than Type 1 rumbles because they are closer to the edges of the travel lanes. See SDD 13A10 for more detailed design and installation location information.

Contact the BTO-Safety Engineer, BPD- Standards Development Engineer, and DTIM-Bicycle and Pedestrian Coordinator to discuss installation of rumbles with less than 3-foot paved shoulders. Contact the Regional Bicycle and Pedestrian Coordinators to discuss locations of known high bike traffic, designated bike routes on local, county or state plans and installation appropriateness near recreational/resort areas with likely bike/pedestrian traffic.

1.8.1.3 Travel Lane (Transverse) Rumbles

Travel lane rumbles are typically used near intersections (not on shoulders). Travel lane rumbles must be used in combination with other traffic control such as advance-warning signs and typically under stop-controlled conditions. There are a couple scenarios where travel lane rumbles may be installed:

1. At the intersections of 2 highways that have similar functional classes or AADT volumes may be similar. This could be at the intersections of 2 STHs or the intersections of STHs and CTHs having similar traffic volumes, or at least the driver expectancies are that the facility they are driving on would not have a stop control condition.
2. There are perceived or demonstrated crash problems when drivers are unaware that they are supposed to stop for crossing traffic or where the geometrics of the roadways may prevent the drivers from seeing the approaching intersections such as at vertical crest curves or horizontal curves.

Noise generation is a primary concern with these types of rumble installations for people at residential or other properties close to the installations. It is important to communicate with and coordinate with affected property owners prior to installations. It is important to not over use these treatments as to become common place so that drivers are desensitized to the noises and vibrations generated by the rumbles.

See SDD 13A8 and SDD 13A9 for more detailed information on the rumble installations and rumble locations prior to intersections.

1.9 Auxiliary Lanes

For a definition of auxiliary lanes see FDM 11-25-35.

On PCC pavement projects, auxiliary lanes longer than 800-feet, including tapers, shall have a construction joints at the proposed pavement marking locations. See FDM 14-10-10 for more information.

1.10 Subgrade Side Slopes and Widths

Establish subgrade widths by maintaining constant side slopes between the finished shoulder points and the subgrade shoulder points on both the left and right sides of the cross sections. See Attachment 1.6 and Attachment 1.7 for typical cross sections depicting rural roadway design classes. By maintaining constant side slopes, the subgrade widths will vary throughout super-elevation transitions. The subgrade widths will be constant throughout full super-elevations but will have different subgrade shoulder point offsets (i.e. distances left and right of roadway centerlines) versus normal crowns.

Assess impacts and right-of-way needs when widening existing subgrades for roadway or shoulder improvements (e.g. adding passing lanes). Widened subgrades may also be necessary to accommodate barrier systems or other needs.

1.11 Side Slopes

Flatten and round side slopes to fit the topography consistent with site conditions, traffic safety, and cost effectiveness of design. Gradual transitions from cut to fill slopes, or within cut or fill slopes, will avoid unattractive bulges and sharp depressions. Do not vary fill slopes of adjacent full stations by more than 1:1, except under unusual conditions.

Interstate highway fore-slopes should be either recoverable (4:1 or flatter), or traversable (3:1 MAX) with adequate recovery areas to meet the clear zone criteria of FDM 11-15 Attachment 1.9. If not obtainable, install barriers as warranted in accordance with current design criteria.

Design guide values for rock slopes are shown on Attachment 1.8. Selection of rock slopes should be determined in consultation with the Region Chief Materials Engineer. (See p. 358 GDHS).

For side slope criteria in clear zones, see “Clear Zones and Side Slopes” below.

1.12 Side Ditches

Normal side ditch configurations are shown in Attachment 1.6 and Attachment 1.7. Greater ditch widths may be used in earth cuts as necessary to provide increased drainage capacity or more space for snow storage and falling rocks from unstable cut slopes. The minimum depths of ditches should be 1 foot below the sub-grade shoulder points to ensure positive drainage of the sub-grades. The flattest gradients in side ditches should be 0.5 percent. Avoid using flatter ditch gradients when excessive vegetation or debris may restrict drainage. Use the criteria in Chapter 13 when designing ditch cross sections.

All cross-drain culvert ends, and cattle passes on Modernization projects should be marked with Marker Post, Flexible, for Culvert Ends. This includes single and multiple culvert ends and cattle passes in shielded and unshielded locations either inside or outside the clear zones on the public right-of-way. Do not mark driveway culvert ends or field entrances or underdrain outfalls.

1.13 Clear Zones, Horizontal Clearances, and Clear Roadway Widths of Bridges

Clear zones, horizontal clearances, and clear roadway widths of bridges, are not the same things, and the terms cannot be used interchangeably. A quick distinction is that clear zone is for the benefit of vehicles that errantly leave the roadway; horizontal clearance is for the benefit of vehicles on the roadway, and clear roadway width of bridges applies only to structures.

The following are definitions and guidance for each of these terms.

1.13.1 Clear Zone [7]

Clear zone is defined as that roadside border area which is made available for safe use by errant vehicles. Clear zones start at the edges of the traveled ways and consist of the shoulders, auxiliary lanes, recoverable slopes, and any traversable but non-recoverable slopes with clear run-out areas at the toes of the slopes. Clear zones should not contain critical, i.e. non-traversable, slopes.

See FDM 11-45-15.1.3 for preferred roadside hazard treatment sequence.

The extent of clear zones depends on the design speeds and the probability of vehicles leaving the roadways.

Clear zone is not one of the Controlling Criteria for geometric design. However, they establish the “Zones” in which obstructions or steep slopes warrant evaluation. These “Zones” include any required clear runout areas. Therefore, the proposed clear zones and the basis for their selections should be justified in the SCDs or Design Study Reports (DSRs). If less-than-typical design criteria clear zone widths are proposed for projects, the reasons should be justified in the SCD or the DSR. Approval of the SCD or the DSR establish design variances for not meeting WisDOT’s clear zone policy.

Clear zones are key considerations when analyzing roadside hazards. There are no definitive amounts of clear zone required. The intent is to provide as much clear, traversable recovery areas as practical. Attachment 1.9 lists clear zone widths for various combinations of design speeds, AADTs and side slopes. The attachment is from the 2011 AASHTO Roadside Design Guide. The values in Attachment 1.9 are based on limited empirical data that was extrapolated to provide information for a wide range of conditions. These widths represent only the approximate center of ranges to be explored and not precise distances to be held as absolute. These widths may be modified, within reason, in consideration of site specific conditions, and are consistent with the roadway classifications, traffic volumes, roadway geometry, crash history, design speeds, available resources, available right-of-way, and good engineering judgment.

Reduced clear zone widths may be warranted to avoid extensive right of way taking, excessive property or environmental impacts or on relatively short projects to provide cross sections compatible with abutting sections of the highways.

[7] *AASHTO (2011). Roadside Design Guide. Pages 2-2, 3-3 to 3-12, 3-14 to 3-16, 4-1, 5-6, 5-9, 5-40 to 5-48, 6-12 to 6-13, 10-2 to 10-3, 10-15 to 10-18. Washington, DC.*

Consider providing wider clear zones on the outsides of horizontal curves for roadways and structures (see Attachment 1.10 for adjustment factors). Clear zone widths should be evaluated at all roadside locations where warranted because of crash history.

Clear zone widths shall be increased where necessary to include the roadside ditches. Roadside ditches shall be traversable (see Attachment 1.11 for preferred ditch sections). Utility poles or other non-breakaway hazards should not be located in or near ditch bottoms.

1.13.1.1 Clear Zones and Driveways, Side Roads and Median Crossovers

Embankment slopes created by driveways, intersection side roads, and median crossovers will be impacted at right angles by errant vehicles leaving the roadways. Flatter slopes are desirable at these locations because steeper slopes can cause vehicle bumpers to dig in, or cause vehicles to vault.

Review FDM 11-45-30 for guidance on acceptable slopes and roadside design options.

Place driveway, side road, and median crossover culvert pipes as far from the main roadways as practicable.

1.13.1.2 Clear Zones and Side Slopes [7]

Side slopes parallel to the flow of traffic can be characterized in one of three ways:

1. recoverable
2. non-recoverable, but traversable
3. critical

A recoverable slope is one on which most motorists can generally stop their vehicle on the slope or slow them enough to return to the roadway safely. Fill slopes of 4:1 or flatter and cut slopes of 3:1 or flatter are considered recoverable if they are also relatively smooth and traversable. Provide recoverable slopes within the clear zones if at all feasible.

A non-recoverable slope is one on which most motorists will be unable to stop or return to the roadway easily, but one that will not cause a vehicle to overturn. Traversable fill slopes between 3:1 and 4:1 are generally non-recoverable. On slopes between 3:1 and 4:1 many vehicles will continue to the bottom. Because of this, try to provide clear runout areas at least 10 feet wide beyond the toes of non-recoverable slopes. See Attachment 1.9 for an explanation and illustration of how recovery areas are computed.

A critical slope is one on which a vehicle is likely to overturn. Fill and cut slopes steeper than 3:1 are considered critical. If slopes steeper than 3:1 begin closer to the traveled ways than the suggested clear zone widths, then barriers may be warranted.

Clear zones with variable side slopes ranging from essentially flat to 4:1 may be averaged to produce composite clear zones. Slopes that change from negative to positive cannot be averaged and are treated as ditch sections and analyzed for traverse-ability using Attachment 1.11.

1.13.1.3 Interstate Clear Zones and Side Slopes

Attachment 1.9 and the 2011 AASHTO Roadside Design Guide should be used for guidance regarding warranted clear zone widths. Any fixed objects within clear zone limits should be removed, made breakaway, or made safe through shielding by roadside barriers or crash cushions or a combination of the two.

1. **Curbs or Curb and Gutters**
   Barrier curbs should not be used.
   Sloped curbs, when used, should be located at the outer edges of the shoulders. Also, where guardrails are used, design the faces of the curbs to be flush with the faces of guardrails or placed behind them. See FDM 11-20 for information on sloped curbs.
2. **Cross-drain Culvert End Sections and Headwalls**
   Refer to FDM 11-45-30 for the definition of hazardous cross drains or cattle passes, treatment options, and warrants for various treatment options.
3. **Median Inlets and Ditch Checks**
   Median inlets should have 6:1 or flatter traversable grates, and 10:1 or flatter ditch checks.

1.13.2 Horizontal Clearance [8] [9]

Horizontal clearance refers to:

- Minimum lateral under-clearance to structure
- Minimum lateral clearance.

1.13.2.1 Horizontal Clearance - Lateral Underclearance to Structure [8]

Lateral underclearance to Structure is defined and design criteria for roadways is shown in FDM 11-35-1. Minimum lateral underclearance to Structure for railroads is also defined in FDM 11-35-1.

1.13.2.2 Horizontal Clearance - Lateral Clearance[10]

Lateral clearance (also known as “operational offset") is defined as an obstruction free area beginning at the edge of driving lane and extending a minimum distance so as not to interfere with the operation of the roadway.

These areas should contain no fixed objects, including, but not limited to, light poles, sign posts, sign faces, beam guard, barriers, trees, shielded objects or break away objects (moving vehicles, parked vehicles, and pedestrians are not considered fixed objects). Lateral clearance design criteria apply to all urban and rural roadways.

1.13.2.3 Lateral Clearance for Rural (Shoulder) Roadways

On roadways without roadside barriers, typically provide lateral clearance from the edges of driving lanes to at least a minimum distance outside the edges of the finished shoulders. See Table 1.2 and Attachment 1.15. On roadways with narrow shoulders, offsets from the driving lanes may extend farther beyond the edges of the finished shoulders than the minimum offset outside the edges of finished shoulders.

On roadways with roadside barriers, provide the required lateral clearance between the edges of the driving lanes and the faces of the barriers. See Table 1.2 and Attachment 1.15.

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[8] *U.S. Department of Transportation Federal Highway Administration. Office of Engineering. Bridge Division. Bridge Management Branch. (1995). Recording and Coding Guide for the Structure Inventory and Appraisal of The Nation's Bridges. “Item 47 - Inventory Route, Total Horizontal Clearance; Item 51 - Bridge Roadway Width, Curb-to-Curb; Item 55 - Minimum Lateral Underclearance on Right; Item 56 - Minimum Lateral Underclearance on Left; Item 68 - Deck Geometry; Item 69 - Underclearances, Vertical and Horizontal”. (Report No. FHWA-PD-96-001). Washington, DC.*

[9] *U.S. Department of Transportation Federal Highway Administration (1996). Federal Lands Highway Project Development and Design Manual. “Chapter 9 – Highway Design, Section 9.1.B.2 – Design Standards – Design Exceptions”. (Publication No: FHWA-DF-88-003)*

[10] *AASHTO (2018). A Policy on Geometric Design of Highways and Streets. 7th edition. Pages 310, 311, 412, 504, 517, 543, 556, 570. Washington, DC.*

Table 1.2 Required Clearances from Edges of Driving Lanes for Rural Highways [1]

ROAD TYPE	WITHOUT roadside barriers[2]	WITH roadside barriers[2]
	New Construction and Re-construction	New Construction and Re-construction
All STH's Arterials non-STH Collector and Local Roads (i.e., non-arterials) with Design Year AADT ≥ 1500	**The GREATER of 6 feet** **OR** **finished shoulder width[4] + 2 feet**	**The GREATER of 6 feet** **OR** **finished shoulder width[4]** (Minimum) (The GREATER of 4 feet OR finished shoulder width[4])
non-STH Collector and Local Roads (i.e., non-arterials) with Design Year AADT < 1500	**The GREATER of 6 feet** **OR** **finished shoulder width[4] + 2 feet** (Minimum) (The GREATER of 2 feet OR finished shoulder width[4] + 2 feet)	**The GREATER of 4 feet** **OR** **finished shoulder width[4]** (Minimum) (The GREATER of 2 feet OR finished shoulder width[4])

[1] Applies to all fixed objects other than mailboxes. Clearances to mailboxes are based on the guidelines from Chapter 11 of the 2011 AASHTO Roadside Design Guide, titled "Erecting Mailboxes on Streets and Highways."

[2] Lateral Clearance extends beyond the edges of the finished shoulders. Also, additional clearances may be needed at some locations - particularly at intersections - to compensate for off-tracking.

[3] Lateral Clearance should be provided to the faces of the barriers, but do not extend behind them. Other offsets behind the barriers or beyond the edges of the finished shoulders may apply. Also, consider the potential deflections of the roadside barriers (see FDM 11-45). Also, additional clearances may be needed at some locations - particularly at intersections - to compensate for off-tracking.

[4] See Attachments 1-4 and 17-19 for guidance on finished shoulder widths for new construction and reconstruction.

1.13.2.4 Lateral Clearances vs. Other Required Offsets

In addition to lateral clearance design criteria, there may be other required minimum offsets from the edges of travel lanes, edges of shoulders or faces of curbs, e.g.

- Wisconsin Manual on Uniform Traffic Control Devices (https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/wmutcd/wmutcd.aspx) criteria for sign placement
- Traffic Engineering Operations and Safety Manual (TEOpS), Chapter 11 criteria for the placement of light poles (TEOpS 11).
- Traffic Signal Design Manual, TSDM 6-1-3 guidance on offsets for traffic signal supports.

If the lateral clearances exceed any other design criteria offsets, use the lateral clearances, otherwise use the other offsets.

1.13.2.5 Lateral Clearance and Mailboxes

Make sure that lateral clearances to mailboxes meet the guidelines contained in Chapter 11 of the 2011 AASHTO Roadside Design Guide," except that the shoulders or turnout widths at mailboxes cannot be less than the finished shoulder widths for the roadways. Mailbox installations not meeting these guidelines can be

considered hazardous (see "Hazardous Mailboxes" below). If possible, offset the roadside faces of mailboxes no closer to the driving lanes than are required for other fixed objects.

1.13.3 Clear Roadway Widths of Bridges [8]

Clear roadway width of bridges is defined as the most restrictive minimum distance between curbs or rails on a structure. This measurement is exclusive of flared areas for ramps.

Clear roadway width of bridge design criteria is shown in Attachment 1.1 - 1.4 and Attachment 1.17 - 1.19 along with FDM 11-35-1.

For interstates, widening of existing structures are high cost improvements which should be decided on a case by case basis with consideration given to site specific crash history, traffic characteristics, and the potential for crashes as traffic volumes increase. Bridges that warrant widening, except major long span structures, shall be widened to full approach roadway widths. Major long span structures shall provide for minimum offsets from the edges of the traffic lanes to the parapets of at least 4 feet. However, consideration should be given as to traffic control and snow storage needs when evaluating shoulder widths.

Bridge widths may be increased to accommodate high traffic demand during construction and to reduce user delays in work zones on rural Corridors 2030 Backbone facilities. See FDM 11-35-10 for additional information and warranting criteria.

Interstate Bridges to remain in place must have 12-foot wide traffic lanes, 10-foot wide shoulders on the right, and 3.5-foot wide shoulders on the left. On major long span bridges, minimum shoulder widths may be 3.5 feet for both left and right shoulders. However, consideration should be given as to traffic control and snow storage needs when evaluating shoulder widths.

1.14 Median

A median is the portion of the highway separating opposing directions of the traveled way. Medians may be depressed, raised, or flush. Medians on rural highways are typically depressed, i.e. ditched.

Medians perform the following functions.

- Separate opposing streams of traffic to minimize the risk of head on collisions,
- Provide recovery areas for out-of-control vehicles,
- Provide stopping areas in cases of emergencies,
- Allow space for speed changes and storage of left-turning and U-turning vehicles,
- Minimize headlight glare and gawking,
- Provide widths for future lanes,
- Provide refuge areas for wildlife, and
- Control access.

See pp 341-343, 460-470 and 513-516 GDHS 2001.

1.14.1 Median Widths for Rural Highways

Median width is expressed as the dimension between the edges of traveled ways and includes the left shoulders. The lowest median widths shall be 60 feet on Design Class A3 freeways. The lowest median widths shall be 60 feet on Design Class A3 expressways with posted speeds greater than 55 mph, and 50 feet on Design Class A3 expressways with posted speeds of 50 or 55 mph.

1.14.2 Intersections

Widen medians at median openings for un-signalized intersections on expressways if necessary to accommodate the design vehicles for those intersections. This is especially critical at locations that must handle large trucks, long school busses or combinations of farm machinery. In these situations, the median widths should typically be about 100 feet.

WisDOT crash analysis indicates that high-speed expressways with at-grade intersections on curves are problematic. See FDM 11-25-1 for more information on at-grade intersections.

1.14.3 Median Ditches

Median ditches must:

- Have sufficient depths to provide positive drainage of the adjacent sub-grades. Normally this requires median depths of at least 1-foot below the sub-grade shoulder points.

- Have ditch cross-sections within the clear zones that are within the “preferred channel cross section” area of Attachment 1.11 to prevent vehicles from “tripping.”
- Have recoverable side slopes within the clear zones, per Attachment 1.9, to facilitate the recovery of out-of-control vehicles. Typically, the ditches are based on a 6:1 maximum slope from both sub-grade shoulders. For medians between widely separated roadways, the side slopes of normal cut and fill sections are typically used.
- Have sufficient longitudinal gradients to ensure good drainage. The typical flattest longitudinal gradients of median ditches are at least 0.5 percent.
- Have sufficient hydraulic capacities to handle the expected design flows (see FDM 13-10-1).

1.14.4 Median Maintenance Crossovers for Freeways

Install median maintenance crossovers to avoid extreme adverse travel for emergency, law enforcement, and maintenance vehicles on rural freeways. They are typically provided where interchange spacings exceed 5 miles, depending on needs for snow removal equipment and other locations to facilitate maintenance operations. Median maintenance crossovers are located according to need after considering the number and spacing of interchanges and coordination with the Bureau of Highway Maintenance, State Patrol, and Emergency Management. In general, these crossovers should not be located closer than 1,500 feet from the ends of entrance or exit ramps or to any structures. Crossovers should typically be located having decision sight distances, or at least stopping sight distances.

Other factors to consider are drainage, profile differences between the divided roadways, and not to install crossovers on super-elevated sections.

In all cases, minimize the number of median crossovers, and design them to be as inconspicuous as possible. The crossover profiles are preferably sags between the opposing edges of shoulders. See SDD 11a1 titled "Maintenance Crossover for Freeways” for design details.

Median maintenance crossovers are not generally warranted on urban freeways due to the close spacings of interchange facilities. Only in rare situations would crossovers in urban areas be warranted and then only after appropriate installation of roadside design features are coordinated with the Bureau of Project Development.

For interstates, median maintenance crossovers should be eliminated if not providing a needed function or reconstructed to have 10:1 or flatter side slopes.

1.14.5 Median Construction Crossovers for Freeways

See FDM 11-50-20.4 for design information. Median construction crossovers are installed to allow traffic from one side of the divided highways to cross to the other side at high speeds (typically 50mph or greater). These are typically in work zones where two-way traffic is maintained on one roadway while the opposite direction roadway is closed.

Interstate construction crossovers should be removed after project completion unless they are planned to be used for subsequent maintenance or other traffic control operations. Construction crossovers left-in-place should have 10:1 or flatter side slopes and appropriate safety devices installed along their lengths to minimize the potential for median-crossing crashes or unauthorized U-turns. See FDM 11-50-20.4 for additional guidance.

1.14.6 Median Barriers

See FDM 11-45-30.

1.15 Transition from Divided to Two-Way Roadways

Transitions between divided and single roadways generally are made on tangent sections and never at locations with horizontal or vertical sight restrictions.

The entire transition needs to be visible to the drivers of vehicles approaching the divided sections to prevent indecision, error, or wrong-way entries. Do not change horizontal alignments of lane(s) carrying traffic onto the divided facilities from that of the approaching two-lane roadways until reaching points beyond the beginning of the median dividers. The design criteria of the superior facilities are carried through the transitions to the extent feasible rather than confront the drivers with abrupt changes in geometrics (see Attachment 1.12).

Complete lane drop transitions far enough in advance of railroad grade crossings to allow drivers to see and react to crossing warning devices. Place transitions to provide the stopping sight distances shown in FDM 17-25 Attachment 1.2. This applies to both permanent lane drops and temporary lane drops for traffic control purposes.

1.16 Marsh Section

As a rule, do not specify the use of geotextiles in lieu of marsh excavation. Many of the shallow marshes are not problems to excavate. Excavation does bring up the need for hauling and disposal, and the accompanying DNR and environmental concerns, but these considerations do not justify improper designs.

Geotextiles have many appropriate uses, in which they satisfy need and function very well. However, roadway fills placed on geotextiles over marshes will eventually settle, as the underlying marsh becomes consolidated. Geotextiles will tend to provide more uniform settlement but will not prevent consolidation.

When designers are considering the use of geotextiles in lieu of marsh excavations, the concurrence of the Central Office Soils Unit is required. The designers will continue to be responsible for the necessary project design activities, and the Central Office Soils Unit must be contacted and provided the opportunity to review and concur in both the geotextiles specified and the intended uses.

The designs for marsh removals and backfills will be influenced by several factors, including marsh, fill heights, marsh bottom slopes, marsh material qualities, backfill material qualities, and water table locations. Because of these many variables, a standard detail drawing for marsh excavation is not practical. Attachment 1.13 is a typical marsh section that may be used as a guide when designing marsh excavation details for specific projects. Consult the Region Soils Supervisor to ensure adequate treatment of marsh areas is implemented.

The following general guidelines should be considered:

1. Avoid locating earthwork balance points in marsh excavation areas. Excavations and backfills should progress across the marsh from one end to the other.
2. Marsh excavation is usually feasible to upper depths of 20 feet. With rolling surcharges and excavations, marsh removals to depths of 40 feet in peat are usually possible, but the chances of total removal decreases with depth. In organic silts, successful displacements depend on strengths of the silts, and individual studies will be necessary to evaluate these.
3. Care must be exercised when using surcharges in order that loads do not exceed the shearing strengths of the marshes and cause failures of the fills and excessive settlements.
4. Clays or silty clays ordinarily will not displace satisfactorily; therefore, other methods will be required in such soils.
5. Provide for disposal areas in the immediate vicinities of the excavations.

1.17 Local Service

Local service roads (frontage roads) are most often used adjacent to freeways, where their primary functions are to serve abutting developments and to collect and distribute traffic between local streets and roads and the freeway interchanges. Local service roads are also used to control access to arterials, including freeways.

Normally, provide two-way service roads in rural areas to avoid the inconveniences and added travel distances to local traffic often required by one-way service road systems.

Local service roads do not necessarily have to parallel, abut, or front on and along the main highways, but may be located some distance away from the highways on separate, non-contiguous right-of-way.

Local service roads normally become part of local road systems, i.e., town roads, county trunk highways, or city streets, and are typically designed in accordance with the appropriate design criteria for those road systems.

1.18 Rural Driveways and Entrances

Refer to FDM 11-20-10 for information on rural and urban driveways.

1.19 Traffic Control Devices/Signing on Interstate Highways

All traffic control devices shall be in conformance with the current Manual on Uniform Traffic Control Devices (MUTCD) and the Wisconsin Manual on Uniform Traffic Control Devices (WMUTCD).

1.20 Access Control on Interstate Highways

Right-of-way fencing, or other appropriate measures, shall be incorporated into all Interstate projects to address any access control issues within the proposed project limits.

LIST OF ATTACHMENTS

Attachment 1.1	Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Arterials

Attachment 1.2	Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Collectors
Attachment 1.3	Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Local Roads
Attachment 1.4	Modernization Design Criteria for Town Roads (New Construction Only)
Attachment 1.5	Rural State Trunk Highway Modernization Paved Shoulder Width Criteria
Attachment 1.6	Typical Modernization Cross Sections for Rural 2-Lane Highways
Attachment 1.7	Typical Modernization Cross Sections for Divided Highways and 1-Lane Ramps
Attachment 1.8	Modernization Roadway Sections in Rock Cut
Attachment 1.9	Modernization Clear Zone Distance Tables and Recovery Area Width Determination
Attachment 1.10	Modernization Horizontal Curve Correction Factors
Attachment 1.11	Modernization Ditch Traverseability Evaluation Charts
Attachment 1.12	Typical Modernization 2- to 4-Lane Transition
Attachment 1.13	Typical Modernization Marsh Sections
Attachment 1.14	Lateral Clearance on Modernization Rural Roadway
Attachment 1.15	Modernization Design Criteria for County Trunk Highways Functionally Classified as Arterials
Attachment 1.16	Modernization Design Criteria for County Trunk Highways Functionally Classified as Collectors
Attachment 1.17	Modernization Design Criteria for County Trunk Highways Functionally Classified as Local Roads
Attachment 1.18	Modernization Design Criteria for Interstate Highways

FDM 11-15-5 Design Criteria for the Great River Road

May 15, 2019

5.1 Introduction

The Great River Road (GRR) is a national scenic highway located along the Mississippi River that is routed along the existing road systems of ten states. The designated GRR route in Wisconsin is along STH 35 between Prescott and Prairie du Chien and then along STH 133 and USH 61 to the state line at E. Dubuque, Illinois. See Attachment 5.1. The GRR serves local traffic but is primarily a tourist route that provides travelers the opportunity to enjoy the scenic beauty of the Mississippi River corridor and to learn about its history.

The special character of tourist traffic using the GRR warrants the use of modified design criteria for improvement projects on this road. Because people using the road are viewing the scenery, they tend to drive slower and pull onto the shoulders more often than is the case on typical state trunk highways. Also, the traffic mix during tourist seasons include an unusually high number of recreational type vehicles and bicycles.

5.2 Design Criteria

The GRR should be designed to the extent practicable as a parkway including scenic overlooks, waysides, special signing and, where warranted, wider shoulders and shoulder pavements. The design criteria for rural highways in FDM 11-15-1 for Modernization and in FDM 11-40-1 for Perpetuation and Rehabilitation improvements should be used for GRR projects except wider shoulders may be warranted.

5.3 Shoulder Width

Determination of shoulder widths and especially paved shoulder widths on the GRR should consider shoulder use by motorists and bicyclists, traffic safety, construction and maintenance costs, aesthetics and environmental impacts. Motorists frequently stop along the shoulders of the GRR, particularly where the scenery is attractive and there are no nearby scenic overlooks or waysides. This practice can result in traffic hazards where there are large numbers of vehicles entering and leaving the shoulder areas or where the parked vehicles obstruct driver vision.

Warning signs and advisory speed signs should be evaluated for use where the excessive use of the shoulders is an identified safety concern. Regulations prohibiting parking on the shoulders are generally not practicable because they are difficult to enforce, and the signs are unsightly. Frequent use of the shoulders occurs most

often on the segments of the GRR identified on Attachment 5.1 as the closest roads to the Mississippi River. The following design criteria and guidance apply to shoulder widths and shoulder paving on those segments of the GRR:

5.3.1 Graded Width of Shoulder

The design widths of the graded shoulders may be increased to a maximum of ten feet where needs exist, and the cost of the extra widths add less than ten percent to the cost of typical-width shoulders. The use of wider shoulders should be evaluated for those sections of the GRR where there is frequent use of the shoulders by motorists and possibly bicyclists and this has caused or potentially could cause safety hazards.

5.3.2 Paved Shoulder Width

The paved shoulder widths shall be a minimum of 5-feet where the road has current traffic volumes over 1000 ADT. Full width paved shoulders should be evaluated to reduce maintenance requirements where barriers will be installed along the shoulders. Note: Bicycle traffic is not a warrant for full width paved shoulders. Refer to FDM 11-15-1.8 for rumble strips policy.

5.4 Special Design Features

To provide a parkway appearance to the road, the seeding and fertilizing of the roadway fore-slopes should be extended to the edges of the shoulder pavements.

5.5 Application of Design Criteria

This design criteria should be applied to future projects and projects now being designed for the GRR. Projects of limited scope to simply widen the shoulders of existing sections of the GRR to comply with these criteria are not intended.

LIST OF ATTACHMENTS

Attachment 5.1	Great River Road Map

FDM 11-15-10 Passing Lanes and Climbing Lanes

May 15, 2019

10.1 Passing Lanes

A passing lane is an added lane constructed alongside a two-way, two-lane rural highway to provide the desired frequency of safe passing zones. Passing lanes are particularly advantageous where passing opportunities are limited because of traffic volumes, roadway alignments or high proportions of slower vehicles. Passing lanes differ from truck climbing lanes in that passing lanes are provided regardless of topography. Truck climbing lanes are provided specifically on hills to allow faster moving traffic an opportunity to pass safely. However, newly constructed truck climbing lanes should meet the same design criteria entrance/merge taper lengths, lane widths, shoulder widths and pavement markings as newly constructed passing lanes. Refer to Truck Climbing Lanes in this procedure for guidance pertaining to truck climbing lanes.

Design criteria were selected from various published studies on the subject of passing lanes which can be used for background information and guidance. [11] [12] [13]

10.1.1 Application Criteria

Use the following criteria to determine if passing lanes are appropriate for the corridors in question.

10.1.1.1 Access Control

Passing lane areas should be access controlled early in the process to protect the corridors from potential conflicts.

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[11] *"Low-Cost Methods for Improving Traffic Operations On Two-Lane Roads" by D. W. Harwood and C. J. Hoban, January 1987;*

[12] *Transportation Research Record (TRR) 1303 "Warrants For Passing Lanes" and "Traffic Performance and Design of Passing Lanes"; TRR 1512 "Relationship Between Operational and Safety Considerations in Geometric Design Improvements"; TRR 1628 "Drivers' Attitudes, Understanding, and Acceptance of Passing Lanes in Kansas";*

[13] *Ministry of Transportation, Ontario, Canada, "Operational Safety Review of Passing Lane Sites".*

10.1.1.2 Passing Lane Corridors

Corridor lengths of 15 to 50 miles are appropriate for planning and design purposes. Designers must also consider logical termini and abutting projects, such as Corridors 2030. Some sections of the corridors may not warrant passing lanes at the same time or with the same urgency as others, however the entire corridor should be reviewed.

See Attachment 10.1 for a state-wide map illustrating potential passing lane corridors. This map is based on 20-year traffic projections or for year 2030. Each region has participated in the development of this map and has concurred in the initial locations of the passing lane corridors. This map does not identify county trunk highways, however, there may be situations where the use of passing lanes on county trunk highways would be appropriate and should be considered.

10.1.1.3 Location

The general guidelines for selecting appropriate locations for passing lane segments are given below:

1. Passing lanes should be constructed in segments of highways which have minimal numbers of entrances and preferably no side roads. For some passing lane segments, it may be necessary to include side roads. When selecting sites for passing lane facilities avoid side roads with 500 ADT and over. Driveways and field entrances should be avoided in the merge taper area on either side of the highways. The merge areas extend from the W4-2R signs (lane reduction transitions) to the ends of the tapers, or 1,200 feet. See SDD 15C35, sheets b and c. No driveways or intersections should be located closer than 500 feet from the end of the downstream taper. Designers should consider relocating field entrances and driveways in the merge areas. Commercial driveways may be more problematic than side roads, depending on peak hour usage and traffic mix.
2. Widened segments of roadways, with protected left turn lanes, may be constructed in passing lane sections to provide for left turning traffic when left turn volumes are significant. See FDM 11-25-5 and FDM 11-25-10 for more detailed information on turn lanes. In those limited areas where 4-lane undivided passing lane sections are required, crossing intersections are not permitted and tee intersections are not desirable.
3. If the comparative costs for construction of passing lanes in rolling and level terrains are nearly the same, it may be desirable to construct them in the rolling terrain at locations where passing sight distances are unavailable, leaving flat sections for normal passing during the off-peak periods. Avoid passing lanes on horizontal curves greater than 3 degrees, if possible.

10.1.1.4 Traffic Volumes

Determine current and design year (projected 20 year) Average Annual Daily Traffic (AADT) and two-way Design Hour Volumes (DHVs). Use the 100th highest hour (K100) when determining the DHVs. On most rural two-way highways, the DHVs range from 10% to 15% of the AADTs. Recreational routes, however, can have significantly higher percentages of traffic in the DHVs. Regions should consult with their Systems Planning and Operations sections to get site specific hourly counts for recreational routes (including weekends) in order to gain a more realistic understanding of the situations.

To obtain traffic projections submit TRAFFIC FORECAST REQUEST (see FDM 11-5-2).

Generally, if the 20-year traffic projections exceed 12,000 AADT or exceed 1,400 two-way DHVs it may be appropriate to consider expanding the facilities to 4-lanes. The regions will consider the priority and funding of all projects, then determine whether passing lanes or other treatments are most appropriate.

When the 20-year projected, two-way DHVs fall between 200 and 1,400 use the nomograph provided in Attachment 10.2 and the DHVs from the Traffic Forecasts to see if passing lanes should be considered further. Note, this nomograph is from the Washington State DOT design manual so “rolling” implies a high degree of elevation variation.

Higher priority highways will generally have design year AADTs > 3,500 and <12,000; two-way DHVs greater than 400 and less than 1,400; passing opportunities less than 61%; trucks and RV’s greater than 4%.

10.1.2 Design Criteria

10.1.2.1 Lane Widths and Shoulder Widths

1. Passing lane widths are normally 12 feet for Modernization (New Construction and Reconstruction) projects.
2. Shoulders should be full width, similar to the adjacent two-lane highway sections, for the classifications and ADTs of the facilities. Shoulders should be paved similar to the adjacent two-lane facilities.

Designers may consider providing less than design criteria shoulder widths in certain areas where excessive cuts and fills would substantially increase the construction costs. In such cases the designer must request DJs to design criteria as specified in FDM 11-20.

3. Minimize the occurrences of 4-lane sections of undivided highways (overlapping passing lane areas).
4. It is important, where possible, to provide advancing traffic with the experience of the passing lanes prior to seeing them in the opposing lanes.

10.1.2.2 Clear Zones

The clear zones on newly constructed passing lane sections, independent of project types, should be computed from the outer most lanes, outside edges of traveled ways.

On Modernization (New Construction and Reconstruction) projects the clear zones should meet Modernization design criteria per FDM 11-15-1. Justifications for not meeting/exceeding the Modernization design criteria shall be provided in the DSR.

10.1.2.3 Passing Lane Lengths

The optimal passing lane lengths, excluding tapers, is provided in the following table and is based on design year two-way Design Hour Volumes (DHVs).

Table 10.1 Optimal Passing Lane Length

Two-Way Total DHV	Length of Passing Lane (Miles)
Less than 600	0.50 - 1.0
600 - 1,000	0.75 - 1.50
1,000 - 1,400	1.0 - 2.0

10.1.2.4 Spacing Between Passing Lane Sections

Provide 3-8-mile spacings between passing lanes in the same direction of traffic. These spacings depend on traffic volumes and passing opportunities outside of the actual passing lane locations. The spacings must be flexible to permit selection of suitable and inexpensive passing lane locations.

10.1.2.5 Taper Lengths, Locations and Signal Locations

1. Passing lane approach and merge taper lengths should be 700 feet.
2. Passing lanes should be designed with good visibility at the ends of merge tapers. Do not end merge tapers at or near crests of hills. The ends of the tapers should be physically visible from the W4-2R signs (lane reduction transitions).
3. Access is undesirable on either side of highways in merge taper areas. Do not end merge tapers immediately prior to intersections. Provide at least 500 feet of space downstream from the ends of the tapers to the nearest access points.
4. Signals downstream from passing lanes should be at least 1 mile from the closest merging taper ends.
5. Merge taper shoulders may include rumble strips or raised pavement markers.

10.1.2.6 Signing and Pavement Marking

Drivers may not know if the extra lanes they encounter are passing lanes or truck climbing lanes. For driver expectancies and design consistency similar design criteria should apply where practical. See SDD 15C35, sheets b and c for pavement marking and signing information.

10.1.2.6.1 Pavement Marking

1. Provide diagonal skip-dash pavement markings at entrance tapers to guide traffic to the right when the shoulder widths and construction is the same as the adjacent two-lane facilities. Do not install the skip-dash pavement markings when the shoulder widths are less than design criteria for the facilities.
2. Allow passing by opposing lanes of traffic if passing sight distances are available. This is allowed in

accordance with the MUTCD[14] and Highway Capacity Manual[15]. Studies have found no adverse problems with this procedure. Regions should consider side roads, commercial driveways or other situations when it may be desirable to provide double yellows at the center lines.

10.2 Climbing Lanes

Climbing lanes should be provided to assure uniform levels of service rather than as necessities to avoid extreme congestion and disruption of traffic flows. Climbing lanes are warranted when the upgrades are so steep and long that loaded trucks experience speed reductions of ten miles per hour or more and when the DHVs exceed levels of service 'D' (5.00). Other factors to consider, on the upgrades, are the amount and location of left or right turns at intersections or driveways within the segments. Refer to GDHS[16], pages 227-262, for guidance in determining the lengths of need for climbing lanes.

10.2.1 Design Criteria

10.2.1.1 Lane Widths and Shoulder Widths

1. Climbing lane widths are normally 12 feet independent of project types.
2. Newly constructed climbing lanes should include full width shoulders for the classifications and ADTs of the facilities. These are independent of project types. Shoulders should be paved similar to adjacent two-lane facilities. When beam guard is present it may be desirable to extend the paved shoulders to the post locations.
3. Designers may consider providing less than normal shoulder widths in certain areas where excessive cuts and fills would substantially increase the construction costs. In such cases the designers must request design justifications as specified in FDM 11-1-20 and FDM 11-1-4.10.
4. For existing climbing lane shoulders on Perpetuation and Rehabilitation (formerly referred to as 3R) projects refer to FDM 11-40-1.

10.2.1.2 Clear Zones

Clear zones on new climbing lane sections, independent of project types, shall be computed from the outer most lanes, outside edges of traveled ways.

On Modernization projects, the clear zones should meet Modernization design criteria per FDM 11-15-1. Justifications for not meeting/exceeding the Modernization design criteria shall be documented in the DSR.

10.2.1.3 Taper Lengths and Locations

1. Climbing lane approach and merge taper lengths should be 700 feet.
2. Climbing lane merge tapers should be physically visible from the W4-2R sign(s) (lane reduction transitions). Climbing lanes should be carried well beyond the crests to points where trucks are able to regain speeds within 10 mph of the speeds of other vehicles.
3. Access is undesirable on either side of highways in merge taper areas. Do not end merge tapers immediately prior to intersections. Provide at least 500 feet of space downstream from the ends of the tapers to the nearest access points.

10.2.1.4 Signing and Pavement Marking

Drivers may not know if the extra lanes they encounter are passing lanes or truck climbing lanes. For driver expectancies and design consistency similar design criteria should apply where practical. See SDD 15C35, sheets b and c for pavement marking and signing information.

10.2.1.4.1 Pavement Marking

1. Provide diagonal skip-dash pavement markings at the entrance tapers to guide traffic to the right when the shoulder widths are the same as the adjacent two-lane facilities. Do not install the skip-dash pavement markings when the shoulder widths are less than the design criteria for the facilities.
2. Allow passing by opposing lanes of traffic if passing sight distances are available [6,7]. Studies have

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[14] *Manual on Uniform Traffic Control Devices, 1988 Edition*

[15] *Highway Capacity Manual, Special Report 209, 1999 Edition*

[16] *A Policy on Geometric Design of Highways and Streets*

found no adverse problems with this procedure. Regions should consider side roads, commercial driveways or other situations when it may be desirable to provide double yellows at the center lines.

LIST OF ATTACHMENTS

Attachment 10.1	Rural STH Passing Lane Corridors
Attachment 10.2	Warrant for Considering Passing Lanes

Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Arterials (Level Terrain)

Traffic Volume		Roadway Width Dimensions				Bridges	
Design Class	Design AADT	Design Speed (mph)	Traveled Way Width (feet)	Shoulder Width (feet)	Roadway Width (feet)[2]	Minimum Design Loading	Clear Roadway Width of Bridges (feet)[2, 3]
A1	Under 3500	55-60	24	6	36	[5]	36
A2[1] (2 lanes)	3,500–8,700[A] 3,500–15,000[C]	55-60	24	8-10	40-44	[5]	40-44
A3[1] (4 lane divided)	8,700[A] - 44,000[A] 8,700[B] - 53,500[B] 15,000[C] - 60,000[C]	65-70[4]	2 at 24	4-6LT 10RT[6]	2 at 38-40	[5]	2 at 40
A3[1] (6 lane divided)	44,000[A] - 69,000[A] 53,500[B] - 85,000[B] 60,000[C] - 90,000[C]	70[4]	2 at 36	10 LT and RT[7]	2 at 56	[5]	2 at 56

[A] for Non-Freeway Corridors 2030 Backbone and Connector Routes, LOS threshold is C/D or 4.0.

[B] for Freeway Corridors 2030 Backbone Route, LOS threshold is C/D or 4.0.

[C] for Other Principal and Minor Arterials, LOS threshold is D/E or 5.0.

[1] The top of the traffic volume range for design class A2 is 8,700 AADT for Corridors 2030 Routes and 15,000 AADT for Non-corridors 2030 routes. These volumes are based on the 2000 Highway Capacity Manual assuming; level terrain, 12-foot lanes, ≥ 6-foot shoulders, 80% passing, 10% trucks, K30 design factor, and 60/40 directional split. In cases where reduced levels of service are determined to be acceptable and the uses of passing lanes are found to be adequate treatment for the facilities, the 8,700 AADT value for C2030 Connector Routes may be increased to 12,000 AADT. Design class A3 assumptions: level terrain, 12-foot lanes ≥ 6-foot shoulders, 10% trucks, K30 design factor, 61/39 directional split, 2 access points per mile, except freeways. See FDM 11-5-3 for additional information on level of service thresholds for different facility types and the respective numerical values.

[2] Normally provide full widths of approach roadways across all new bridges. Justifications may be made when the bridges are considered major structures on which design dimensions are subject to individual economic studies because of high unit costs.
See FDM 11-26-30.5.13.3 for Roadway Widths, Clear Roadway Widths of Bridges, and Underpasses between Closely Spaced Roundabouts.

[3] Lateral clearance design criteria for underpass bridges are included in FDM 11-35-1.

[4] See FDM 11-10-1.

[5] See WisDOT Bridge Manual and consult with Bureau of Structures for appropriate Bridge Design Loading.

[6] Use 12-foot paved shoulders (right) on 4-lane freeways if truck traffic >250 DHV, or if the facilities experience a high degree of congestion and incidents. The roadway widths and clear roadway widths on bridges are increased accordingly.

[7] Use 12-foot paved shoulders (left & right) on 6-lane freeways if truck traffic > 250 DHV or if the facilities experience high degrees of congestion and incidents. The roadway widths and clear roadway widths on bridges are increased accordingly.

Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Arterials (Rolling Terrain)

Traffic Volume		Roadway Width Dimensions						Bridges[3,4]	
			Traveled Way Width Based On Design Speed (feet)			Roadway Width Based On Design Speed (feet)[3]			
Design Class	Design ADT	Design Speed (mph)[2]	55 mph or less	60 mph or greater	Shoulder Width (feet)	55 mph or less	60 mph or greater	Design Loading	Bridge Clear Roadway Width (feet)
A1	0-1500	50-60	22-24	24	6	34-36	36	[5]	36
	1500-3500		24	24	6	36	36	[5]	36
A2[1] (2 lanes)	3,500-8,700[A] 3,500-15,000[C]	50-60	24	24	8-10	40-44	40-44	[5]	40-44
A3 [1,B] (4 lane divided)	8,700 - 40,000[A] 15,000 - 55,000[C]	60-70[6]		2 at 24	4-6 LT 10 RT[7]		2 at 38-40	[5]	2 at 40
A3 [1,B] (6 lane divided)	40,000 – 63,000[A] 55,000 - 82,000[C]	60-70		2 at 36	10 LT & RT[8]		2 at 56	[5]	2 at 56

[A] for Non-Freeway Corridors 2030 Backbone and Connector Routes, LOS threshold is C/D or 4.0.
[B] Level terrain design criteria apply to Freeway Corridors 2030 Backbone Routes, LOS threshold is C/D or 4.0.
[C] for Other Principal and Minor Arterials, LOS threshold is D/E or 5.0.

[1] The top of the traffic volume range for design class A2 is 8,700 AADT for Corridors 2030 Routes (LOS threshold of 4.0) and 15,000 AADT for Non-corridors 2030 Routes (LOS threshold of 5.0). These volumes are based on the 2000 Highway Capacity Manual assuming; rolling terrain, 12-foot lanes, ≥ 6-foot shoulders, 80% passing, 10% trucks, K30 design factor, and 60/40 directional split. In cases where reduced levels of service are determined to be acceptable and the use of passing lanes are found to be adequate treatments for the facilities, the 8,700 AADT value for C2030 Connector Routes may be increased to12,000 AADT. Design class A3 assumptions: rolling terrain, 12-foot lanes, >6-foot shoulders, 10% trucks, K30 design factor, 61/39 directional split, 2 access points per mile, except Freeways. See FDM 11-5-3 for additional information on level of service thresholds for different facility types and the respective numerical values.
[2] Design Speeds should typically be 5 mph greater than the posted speeds. Lower design speeds equal to the posted speed limits are acceptable if justified in the SCD or DSR DJ.
[3] Normally provide full widths of approach roadways across all new bridges. Justifications may be made when the bridges are considered major structures on which design dimensions are subject to individual economic studies because of high unit costs.
See FDM 11-26-30.5.13.3 for Roadway Widths, Clear Roadway Widths of Bridges, and Underpasses between Closely Spaced Roundabouts.
[4] Lateral clearance design criteria for underpass bridges are included in FDM 11-35-1.
[5] See WisDOT Bridge Manual and consult with Bureau of Structures for appropriate Bridge Design Loadings.
[6] See FDM 11-10-1.
[7] Use 12-foot paved shoulders (right) on 4-lane freeways if truck traffic >250 DHV, or if the facilities experience high degrees of congestion and incidents. The roadway widths and clear roadway widths on bridges are increased accordingly.
[8] Use 12-foot paved shoulders (left and right) on 6-lane freeways if truck traffic > 250 DHV or if the facilities experience high degrees of congestion and incidents. The roadway widths and clear roadway widths on bridges are increased accordingly.

Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Collectors (Level Terrain)

Traffic Volume			Roadway Width Dimensions [1,6]						Bridges [3,4]	
				Traveled Way Width Based on Design Speed (feet)			Roadway Width[3] Based on Design Speed (feet)			
Design Class	Current ADT	Design ADT	Design Speed (mph)[2]	50 mph or less	55 mph or greater	Shoulder Width (feet)	50 mph or less	55 mph or greater	Min. Design Loading	Clear Roadway Width of Bridges
C1	0 - 400		40-60	20-24	22-24	2-4	24-32	26-32	[5]	26-30
C2	401 - 750	Under 1500	50-60	22-24	22-24	5-6	32-36	32-36	[5]	28-30
C3		1500-2000	50-60	22-24	24	6	34-36	36	[5]	32-34
		2000-3500	60		24	6		36	[5]	36
C4		Over 3500	60		24	8		40	[5]	40

[1] Where ranges of widths are shown, the smaller numbers are the lower range of the widths and the larger numbers are the upper range of the widths eligible for federal or state project participation.

[2] Design Speeds should typically be 5 mph greater than the posted speeds. Lower design speeds equal to the posted speed limits are acceptable if justified in the SCD or DSR DJ.

[3] Bridges in Design Classes C3 and C4 with total lengths over 100 feet may be designed with clear roadway widths of 30 feet. See FDM 11-26-30.5.13.3 for Roadway Widths, Clear Roadway Widths of Bridges, and Underpasses between Closely Spaced Roundabouts.

[4] Lateral clearance design criteria for roadways under bridges are included in FDM 11-35-1.

[5] See WisDOT Bridge Manual and consult with Bureau of Structures for appropriate Bridge Design Loadings.

[6] Lane widths shall be 12 feet on Federally Designated Long Truck Routes (i.e. the "National Network" as defined in 23 CFR Part 658).

Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Collectors (Rolling Terrain)

Traffic Volume			Roadway Width Dimensions[1,6]						Bridges[3,4]	
				Traveled Way Width Based on Design Speed (feet)			Roadway Width 3 Based on Design Speed (feet)			
Design Class	Current ADT	Design ADT	Design Speed (mph)[2]	50 mph or less	55 mph or greater	Shoulder Width (feet)	50 mph or less	55 mph or greater	Design Loading	Clear Roadway Width of Bridges
C1	0-400		30-60	20-24	22-24	2-4	24-28	26-28	[5]	26-30
C2	401-750	Under 1500	40-60	22-24	22-24	5-6	32-36	32-36	[5]	28-30
C3		1500-2000	40-60	22-24	24	6	34-36	36	[5]	32-34
		2000-3500	50-60	24	24	6	36	36	[5]	36
C4		Over 3500	50-60	24	24	8	40	40	[5]	40

[1] Where ranges of widths are shown, the smaller numbers are the lower range of the widths and the larger numbers are the upper range of the widths eligible for federal or state project participation.

[2] Design Speeds should typically be 5 mph greater than the posted speeds. Lower design speeds equal to the posted speed limits are acceptable if justified in the SCD or DSR DJ.

[3] Bridges in Design Classes C3 and C4 with total lengths over 100 feet may be designed with clear roadway widths of 30 feet. Bridges in Design Classes C3 and C4 with total lengths over 100 feet may be designed with clear roadway widths of 30 feet. See FDM 11-26-30.5.13.3 for Roadway Widths, Clear Roadway Widths of Bridges, and Underpasses between Closely Spaced Roundabouts.

[4] Lateral clearance design criteria for roadways under bridges are included in FDM 11-35-1.

[5] See WisDOT Bridge Manual and consult with Bureau of Structures for appropriate Bridge Design Loadings.

[6] Lane widths shall be 12 feet on Federally Designated Long Truck Routes (i.e. the "National Network" as defined in 23 CFR Part 658).

Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Local Roads (Level Terrain)

Traffic Volume			Roadway width Dimensions [1]								Bridges [1,3,4]		
				Traveled Way Width Based on Design Speed (feet)				Roadway Width [3], Based on Design Speed (feet)				Clear Roadway Width of Bridges Based on Design Speed (feet)	
Design Class	Current ADT	Design ADT	Design Speed (mph) [2]	40 mph or less	45-50 mph	55 mph or more	Shoulder Width (feet)	40 mph or less	45-50 mph	55 mph or more	Design Load	50 mph or less	55 mph or more
L1	0-250		30-60	18-22	20-22	22	2-4	22-26	24-26	26	[5]	24-28	26-28
L2	250-400		40-60	18-22	20-22	22	2-4	22-30	24-30	26-30	[5]	26-30	26-30
L3	400-750	Under 1500	50-60		22-24	22-24	5-6		32-36	32-36	[5]	28-30	28-30
L4		1500-2000	50-60		22-24	24	6		34-36	36	[5]	30-34	30-34
		2000-3500			24	24	6		36	36	[5]	36	36
L5		Over 3500	50-60		24	24	8			40	[5]	40	40

[1] Where ranges of widths are shown, the lower numbers are the lower range of widths and the larger are the upper range of widths eligible for federal or state project participation.

[2] Design Speeds should typically be 5 mph greater than the posted speeds. Lower design speeds equal to the posted speed limits are acceptable if justified in the SCD or DSR DJ.

[3] Bridges in Design Classes L4 and L5 with total lengths over 100 feet may be designed with clear roadway widths of 30 feet. See FDM 11-26-30.5.13.3 for Roadway Widths, Clear Roadway Widths of Bridges, and Underpasses between Closely Spaced Roundabouts.

[4] Lateral clearance design criteria for underpass bridges are included in FDM 11-35-1.

[5] See WisDOT Bridge Manual and consult with Bureau of Structures for appropriate Bridge Design Loadings.

Modernization Design Criteria for Rural State Trunk Highways Functionally Classified as Local Roads (Rolling Terrain)

Traffic Volume			Roadway width Dimensions [1]								Bridges [1,3,4]		
				Traveled Way Width Based on Design Speed (feet)				Roadway Width [3], Based On Design Speed (feet)				Clear Roadway Width of Bridges Based on Design Speed (feet)	
Design Class	Current ADT	Design ADT	Design Speed (mph) [2]	40 mph or less	45-50 mph	55 mph or more	Shoulder Width (feet)	40 mph or less	45-50 mph	55 mph or more	Design Load	50 mph or less	55 mph or more
L1	0-250		30-60	18-22	20-22	22	2-4	22-26	24-26	26	[5]	24-28	26-28
L2	250-400		40-60	18-22	20-22	22	2-4	22-26	24-26	26	[5]	26-30	26-30
L3	400-750	Under 1500	40-60	20-24	22-24	22-24	5-6	30-36	32-36	32-36	[5]	28-30	28-30
L4		1500-2000	40-60	22-24	22-24	24	6	34-36	34-36	36	[5]	30-34	30-34
		2000-3500		24	24	24	6	36	36	36	[5]	36	36
L5		Over 3500	40-60	24	24	24	8	40	40	40	[5]	40	40

[1] Where ranges of widths are shown, the lower numbers are the lower range of widths and the larger are the upper range of widths eligible for federal or state project participation.

[2] Design Speeds should typically be 5 mph greater than the posted speeds. Lower design speeds equal to the posted speed limits are acceptable if justified in the SCD or DSR DJ.

[3] Bridges in Design Classes L4 and L5 with total lengths over 100 feet may be designed with clear roadway widths of 30 feet. See FDM 11-26-30.5.13.3 for Roadway Widths, Clear Roadway Widths of Bridges, and Underpasses between Closely Spaced Roundabouts.

[4] Lateral clearance design criteria for underpass bridges are included in FDM 11-35-1.

[5] See WisDOT Bridge Manual and consult with Bureau of Structures for appropriate Bridge Design Loadings.

Modernization Design Criteria for Town Roads
(New Construction Only)

Design Class	Traffic Volume	Roadway							Structure	
	AADT Current	Roadway Width (feet)	Surfacing Width (feet)	Minimum Shoulder Width (feet)	Horizontal Curve (degrees)		% Grade		Highway Load	Clear Roadway Width for Structures (feet)**
					Desired Max	Max	Des. Max	Max		
T1	Local Service Intermittent Traffic	20, 22*	16, 18*	2					*	24
T2	Under 100	24	18	3			9	11	*	24
T3	100 - 250	26	20	3			8	11	*	24
T4	251 - 400	32	22	5	6°	12.25°	6	8	*	26
T5	401 - 1000	34	22	6	5°	12.25°	5	8	*	28
T6	1001-2400	44	24	10	4.5°	7.5°	5	7	*	30
T7	Over 2400	USE STATE TRUNK DESIGN CRITERIA								

* See WisDOT Bridge Manual and consult with Bureau of Structures for appropriate Bridge Design Loadings.

** For federal-aid funded projects with design hourly volumes greater than 400, the clear roadway widths for structures shall equal the approach roadway widths.

Source: Section 82.50(1) Wisconsin Statutes Except Maximum

Horizontal Curve Values are from Table V-6, Page 424, GDHS

Modernization Design Criteria for Reconstruction* of Town Roads[1]

TRAFFIC		DESIGN SPEED[2] (MPH)	ROADWAY WIDTH DIMENSIONS		
Design Class	Current AADT		Traveled Way Width (feet)	Shoulder Width (feet)	Roadway Width (feet)
RT1	0 - 250	40 or less	18-20	2-3	22-26
		45-50	20	2-3	24-26
		55 or greater	22	2-3	26-28
RT2	251 - 400	40 or less	18-22	2-4	22-30
		45-50	20-22	2-4	24-30
		55 or greater	22	2-4	26-30
	401 - 750	(50)	22	6	34
		55 or greater	22	6	34
RT3	Over 750	50 or less	22-24	6	34-36
		55 or greater	24	6	36

* Note: Reconstruction means total rebuilding of existing town roads to improve maintainability, safety, geometrics and traffic service. Design criteria for construction of new town roads are shown on page 1 of this attachment. To avoid confusion in the terminology used to label design classes for the two design criteria, the design classes for town road "Reconstruction" begin with the letter "R".

[1] Source: TRANS 204, Existing Town Road Criteria.

[2] Design Speeds should typically be 5 mph greater than the posted speeds. Lower design speeds equal to the posted speed limits are acceptable.

RURAL STATE TRUNK HIGHWAY MODERNIZATION PAVED SHOULDER WIDTH CRITERIA [1]

DESIGN CLASS		PAVED SHOULDER WIDTHS (reconstruction, new construction, or pavement replacement projects)
A1		3 feet on concrete roadways 5 feet on asphalt roadways
C3, L4		3 feet on concrete roadways 5 feet on asphalt roadways
A2		3 feet on concrete roadways 5 feet on asphalt roadways
C4, L5		3 feet on concrete roadways 5 feet on asphalt roadways
A3	4 - LANE DIVIDED EXPRESSWAY	R[2] - 8 feet L - 3 feet
A3	6 - LANE DIVIDED EXPRESSWAY	R - 8 feet L - 8 feet
A3	4 - LANE INTERSTATE OR FREEWAY	R[3] - 10 feet L - 4 feet
A3	6 - LANE INTERSTATE OR FREEWAY	R[4] - 10 feet L[4] - 10 feet
A3	1 - LANE RAMPS	R - 5 feet L - 3 feet

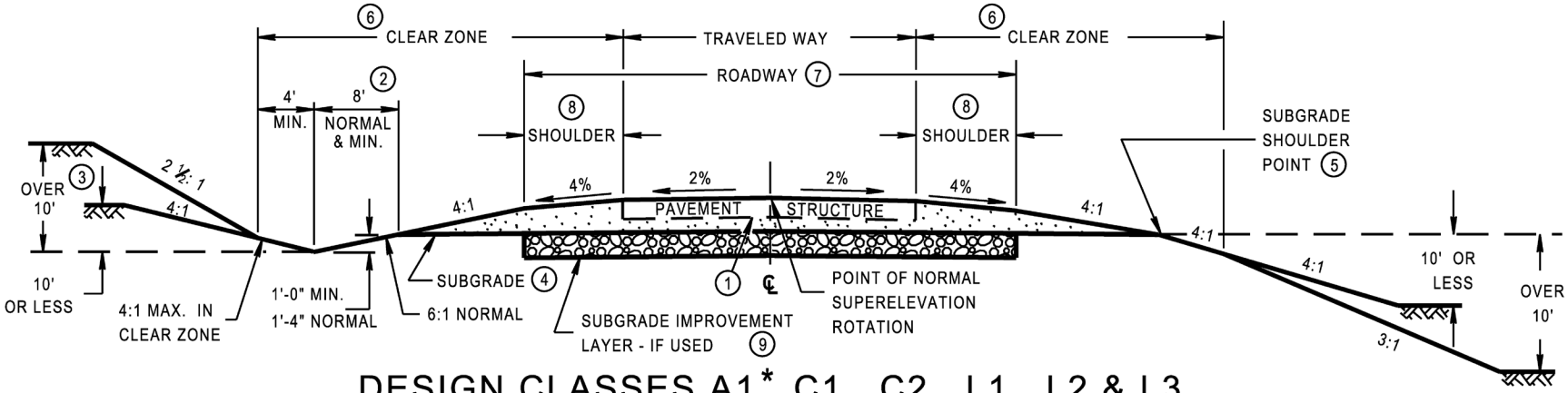
[1] See FDM 11-15-5 for shoulder width criteria for projects on the Great River Road. See FDM 11-46-15 for shoulder criteria to accommodate bicycles.

[2] These shoulder widths also apply to initial two-lane roadways of ultimate four-lane highways except when construction of the second roadways are not expected for at least six years. In these cases, initially pave only 3 feet right along concrete roadways and 5 feet right along asphaltic roadways.

[3] Use 12-foot paved shoulders (right) on 4-lane freeways if truck traffic >250 DHV, or if the facilities experience high degrees of congestion and incidents. The roadway widths and clear roadway widths on bridges are increased accordingly.

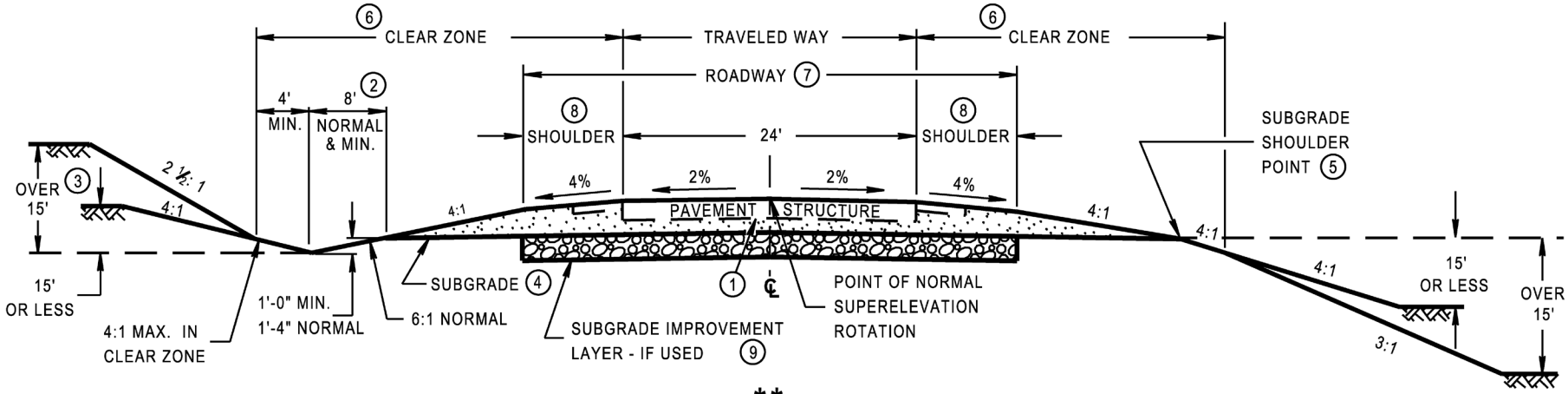
[4] Use 12-foot paved shoulders (left and right) on 6-lane freeways if truck traffic > 250 DHV or if the facilities experience high degrees of congestion and incidents. The roadway widths and clear roadway widths on bridges are increased accordingly.

TYPICAL SECTIONS FOR TWO LANE RURAL HIGHWAYS



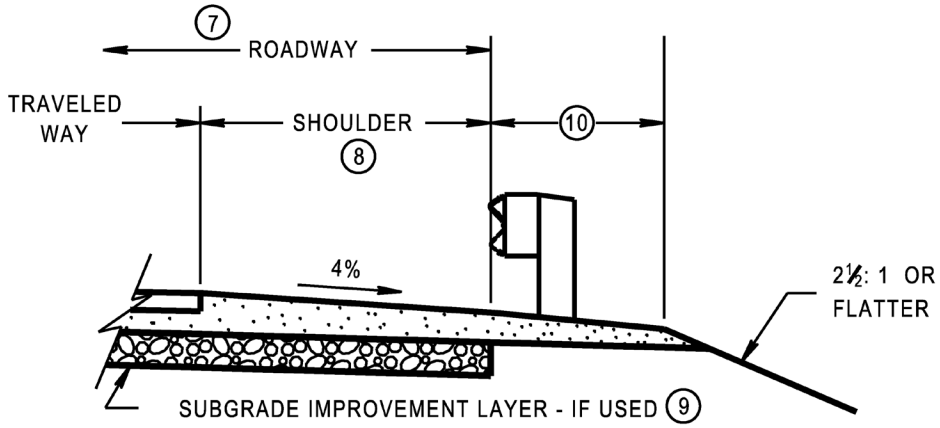
DESIGN CLASSES A1,* C1, C2, L1, L2 & L3

* DESIGN ADT UNDER 1500



DESIGN CLASSES A1,** A2, C3, C4, L4 & L5

** DESIGN ADT OVER 1500

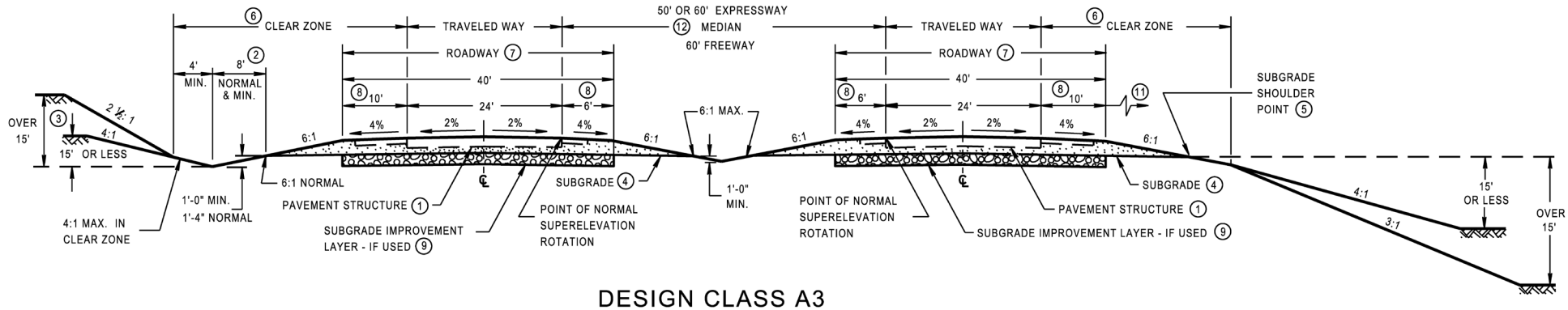


PARTIAL TYPICAL SECTION
WITH A BARRIER SYSTEM AT EDGE OF SHOULDER

NOTES:

1. Pavement structure elements vary depending on the pavement designs.
2. If special ditch grades or greater ditch capacities are necessary for longitudinal drainage then vary the widths or side slopes (not steeper than upper values) of the ditches.
3. Use combinations of flat slopes and rounding to blend earth cut back slopes into the natural topography. The designs of cut-to-fill transitions also require special attention to ensure gradually steepened slopes to produce natural and aesthetically pleasing cross sections.
4. Subgrade slopes are parallel to pavement structures.
5. See FDM 11-15-1.7 for guidance on subgrade widths and locating subgrade shoulder points.
6. See FDM 11-15 Attachments 1.9, 1.10 or 1.11 for clear zone distances.
7. See FDM 11-15 Attachments 1.1, 1.2, 1.3, 1.4, 1.15, 1.16 and 1.17 for traveled way widths and roadway width criteria.
8. See FDM 11-15-1.4 for guidance on shoulders. See FDM 11-15 Attachments 1.1, 1.2, 1.3, 1.4, 1.15, 1.16 and 1.17 for total shoulder width criteria. See FDM 11-15-1.4.2 and FDM 11-15 Attachment 1.5 for policy and criteria on paved shoulders.

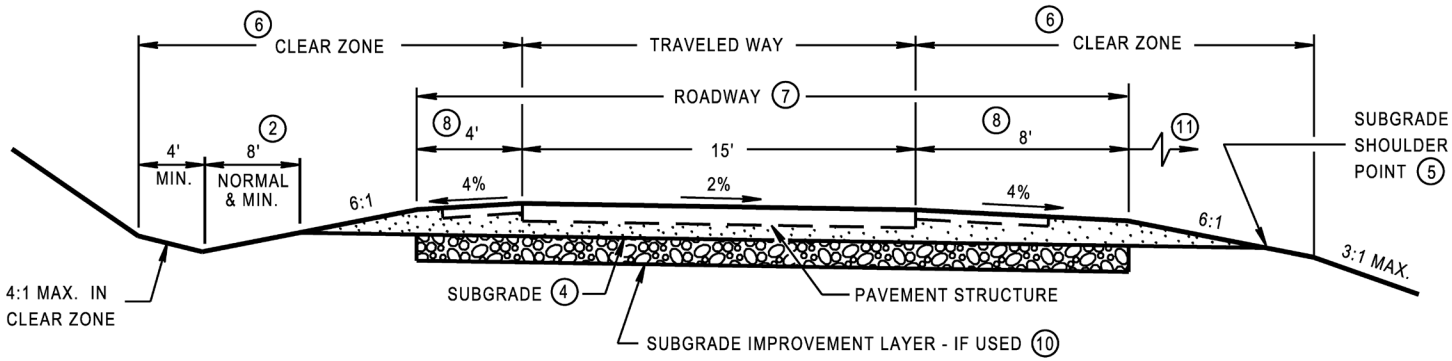
   See FDM 11-15-1.4 for guidance on shoulder cross slopes - including conditional use of 2% on asphaltic and concrete shoulders.
9. See FDM 11-5-15 for guidance on subgrade improvement layers. WisDOT policy requires using select materials in the upper portions of subgrades developed from soils that are difficult for subgrade construction. Drain these select materials with relief trenches at all sag points and at intervals between sag points.
10. Provide additional roadway widening for barrier systems. See other sections of the FDM for guidance.



DESIGN CLASS A3

(FOR UNGRADED MEDIANS, THE MEDIAN SLOPES SHOULD CONFORM TO THE NORMAL CUT OR FILL SLOPES.)

TYPICAL SECTION FOR FOUR LANE DIVIDED HIGHWAY



TYPICAL SECTION ONE-LANE RAMP

NOTES:

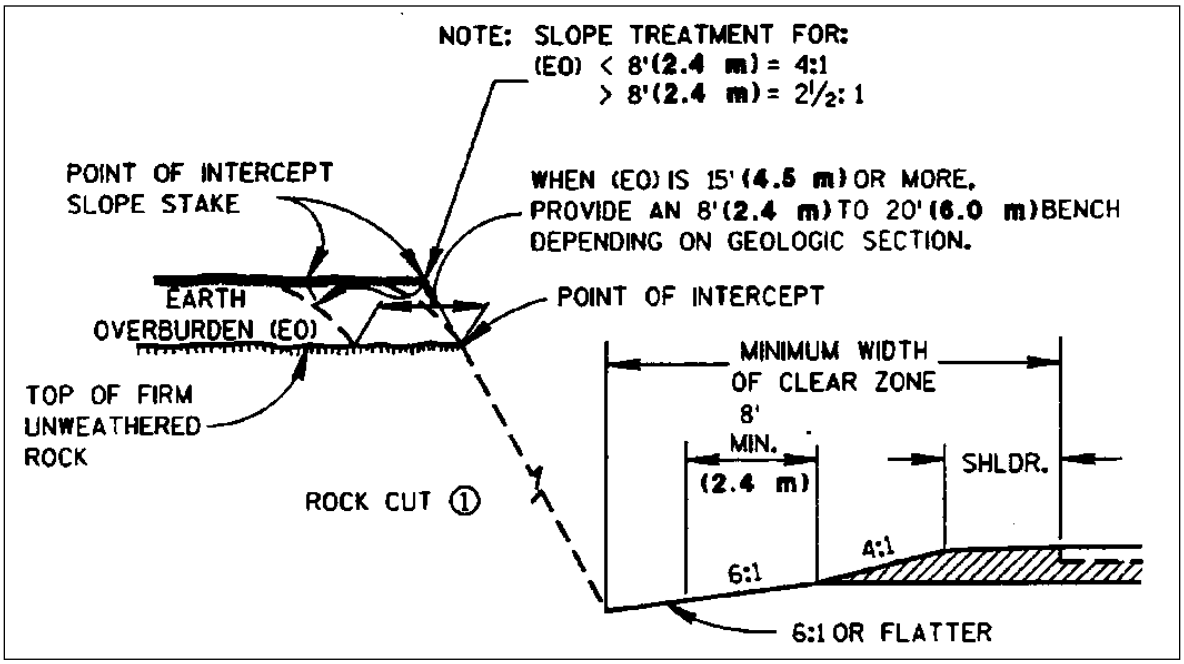
1. Pavement structure elements vary depending on the pavement designs.
2. If special ditch grades or greater ditch capacities are necessary for longitudinal drainage then vary the widths or side slopes (not steeper than upper values) of the ditches.
3. Use combinations of flat slopes and rounding to blend earth cut back slopes into the natural topography. The design of cut-to-fill transitions also requires

special attention to ensure gradually steepened slopes to produce natural and aesthetically pleasing cross sections.

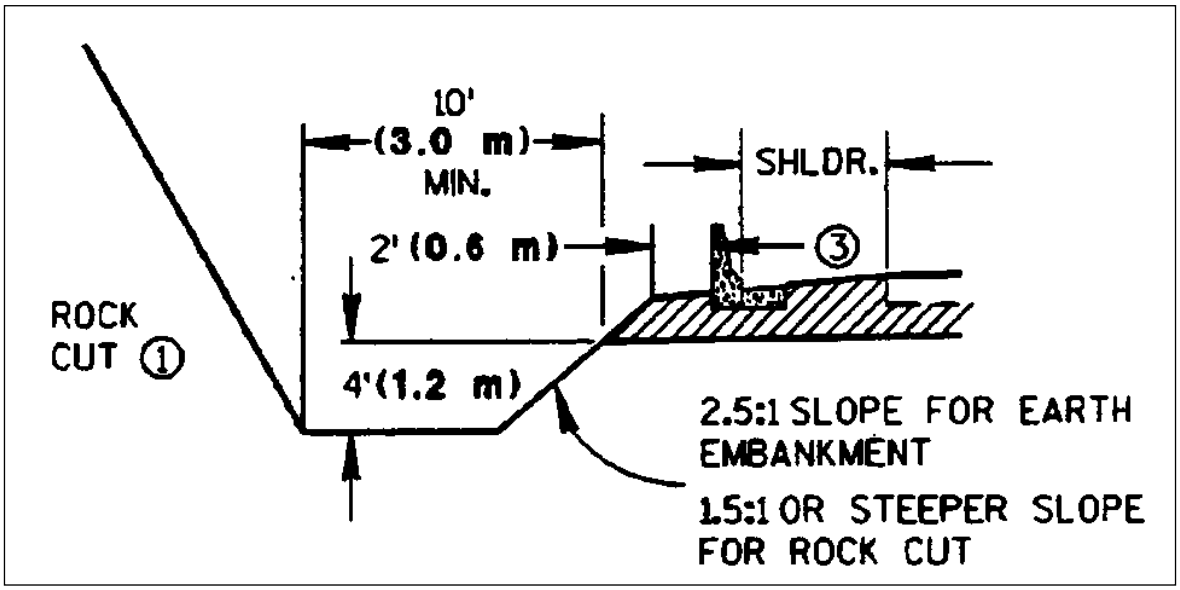
4. Subgrade slopes are parallel to pavement structures.
5. See FDM 11-15-1.7 for guidance on subgrade widths and locating subgrade shoulder points.
6. See FDM 11-15 Attachments 1.9, 1.10 or 1.11 for clear zone distances.
7. See FDM 11-15 Attachments 1.1, and 1.15, for traveled way widths and roadway width criteria for Design Class A3.
8. See FDM 11-15-1.4 for guidance on shoulders. See FDM 11-15, Attachments 1.1, and 1.15, for total shoulder width criteria for Design Class A3. See FDM 11-15-1.4.2 and FDM 11-15 Attachment 1.5 for policy and criteria on paved shoulders.

   See FDM 11-15-1.4 for guidance on shoulder cross slopes – including conditional use of 2% on asphaltic and concrete shoulders.

   If the mainline pavement structures are PC concrete then 2-foot monolithic shoulders are required on the right (i.e., outside) shoulder (excluding ramps).
9. See FDM 11-5-15 for guidance on subgrade improvement layers. WisDOT policy requires using select materials in the upper portions of subgrades developed from soils that are difficult for subgrade construction. Drain these select materials with relief trenches, special trenching with pipe underdrain systems, or a combination of both, at all sag points and at intervals between sag points.
10. See FDM 11-5-15 for guidance on subgrade improvement layers, including their lateral drainage. Use of subgrade layers are at the discretion of the designers in consultation with the region soils engineer.
11. Provide additional roadway widening for barrier systems. See other sections of the FDM for guidance.
12. The median widths shall be 60 ft. on expressways with posted speeds greater than 55 mph. Do not steepen side slopes to achieve lesser ditch depths below subgrade shoulders.



ROADWAY SECTION IN ROCK CUT



ALTERNATE DITCH SECTION IN ROCK CUT

NOTES:

1. When rock cuts are less than 15', backslopes should generally be treated the same as backslopes in earth cuts. When rock cuts are 15' or more, slopes should be as steep as practical for the particular types of rock on the projects. A commonly used design criteria slope for rock cuts is 1/2:1. Consult with the region soils engineer when determining roadway cross sections in rock cuts.
2. Alternate ditch sections may be used when warranted on the basis of cost/benefit analyses.
3. Traffic barriers should be used to shield the ditches. Steel plate beam guard may be used as alternatives to the concrete shoulder barriers. Removable barrier sections should be provided at approximately 200' intervals for maintenance access to the ditches.

Modernization Clear Zone Distance Table (in Feet from Edge of Traveled Way)

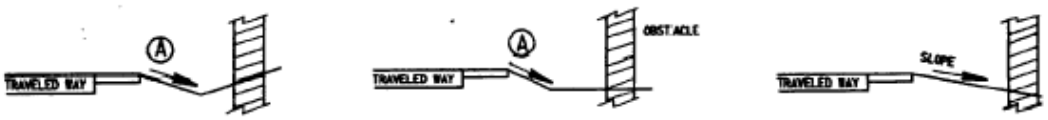
Ref. (2) Table 3.1, pages 3-6

(U.S. Customary Units)

Design Speed	Design ADT	Foreslopes			Backslopes		
		IV:6H or flatter	IV:5H To IV:4H	IV:3H	IV:3H	IV:5H To IV:4H	IV:6H or flatter
40 mph or less	Under 750	7-10	7-10	**	7-10	7-10	7-10
	750-1500	10-12	12-14	**	10-12	10-12	10-12
	1500-6000	12-14	14-16	**	12-14	12-14	12-14
	Over 6000	14-16	16-18	**	14-16	14-16	14-16
45-50 mph	Under 750	10-12	12-14	**	8-10	8-10	10-12
	750-1500	12-14	16-20	**	10-12	12-14	14-16
	1500-6000	16-18	20-26	**	12-14	14-16	16-18
	Over 6000	18-20	24-28	**	14-16	18-20	20-22
55 mph	Under 750	12-14	14-18	**	8-10	10-12	10-12
	750-1500	16-18	20-24	**	10-12	14-16	16-18
	1500-6000	20-22	24-30	**	14-16	16-18	20-22
	Over 6000	22-24	26-32*	**	16-18	20-22	22-24
60 mph	Under 750	16-18	20-24	**	10-12	12-14	14-16
	750-1500	20-24	26-32*	**	12-14	16-18	20-22
	1500-6000	26-30	32-40*	**	14-18	18-22	24-26
	Over 6000	30-32*	36-44*	**	20-22	24-26	26-28
65-70 mph	Under 750	18-20	20-26	**	10-12	14-16	14-16
	750-1500	24-26	28-36*	**	12-16	18-20	20-22
	1500-6000	28-32*	34-42*	**	16-20	22-24	26-28
	Over 6000	30-34*	38-46*	**	22-24	26-30	28-30

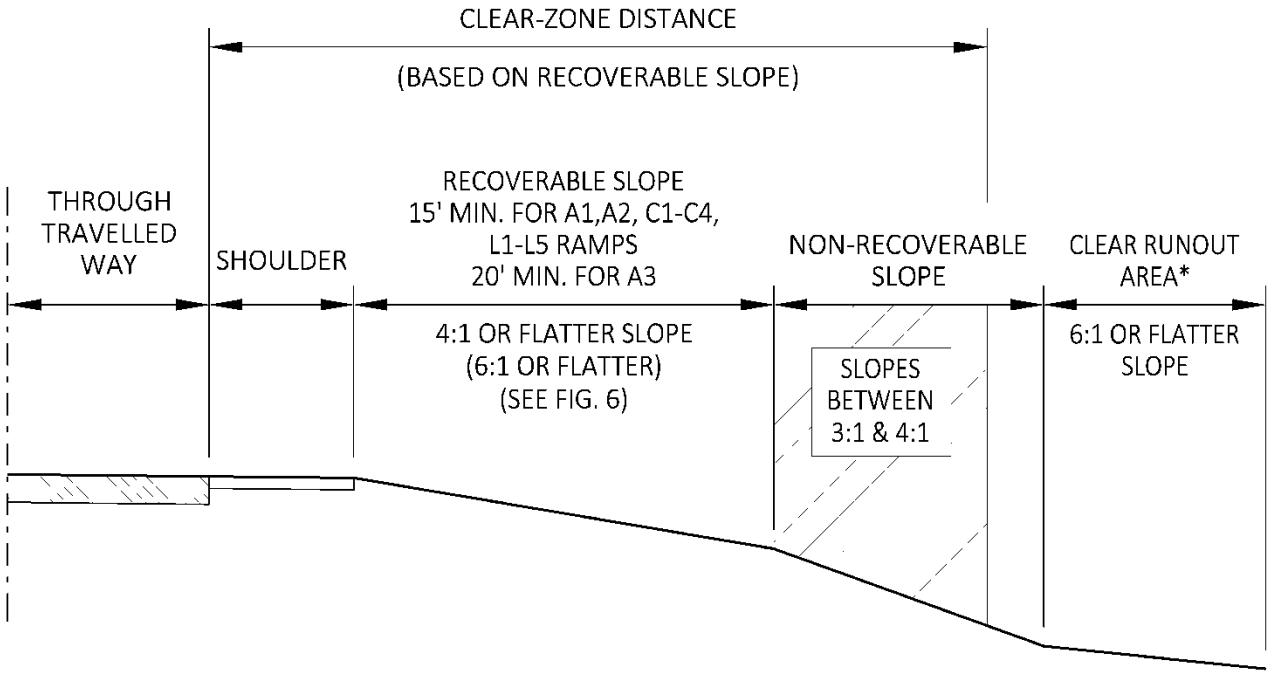
* Clear zone widths greater than 30 feet as indicated are beginning points for new construction and major reconstruction and where site-specific investigations indicates high probabilities of continuing crashes or where such occurrences are indicated by crash history. Clear zones may be limited to 30 feet for practicality and to provide consistent roadway templates if previous experiences with similar projects or designs indicates satisfactory performance and if justified by the SCDs or DSR DJs.

** Since recovery is less likely on unshielded, traversable 3:1 slopes, fixed objects should not be present in the vicinity of the toes of these slopes. Recoveries of high-speed vehicles that encroach beyond the edges of shoulders may be expected to occur beyond the toes of slopes. The method for determining the widths of recovery are described on page 2 of this Attachment.



SLOPES·SLOPING·TOWARDS·OBSTACLE··(Ⓐ··See·clear·zone·discussion·on·variable·slope·determination)¶

SLOPES·SLOPING·AWAY·FROM·OBSTACLE¶



* The clear runout area is additional clear-zone space that is needed because a portion of the clear zone (shade area) falls on a non-recoverable slope. These configurations are not the first choice because of the difficulty of maintaining the clear runout areas. Provide the entire required clear zone widths adjacent to finished shoulders, if at all possible. The widths of the clear runout areas are equal to those portions of the clear zone distances that are located in the non-recoverable slopes, or 10 feet, whichever is greater.

The clear runout areas may be reduced in width based on existing conditions or site investigations. Such variable sloped typical sections are often used as compromises between roadside safety and economics. By providing relatively flat recovery areas immediately adjacent to the roadways, most errant motorists can recover before reaching the steeper slopes beyond. Round the slope break points liberally so encroaching vehicles do not become airborne. Make the steeper slopes as smooth as practical and rounded at the bottoms.

Kcz (Curve Correction Factors)

Ref. (2) Table 3.2, Page 3-7

Radius (ft)	Design Speed (mph)						
	40	45	50	55	60	65	70
2860	1.1	1.1	1.1	1.2	1.2	1.2	1.3
2290	1.1	1.1	1.2	1.2	1.2	1.3	1.3
1910	1.1	1.2	1.2	1.2	1.3	1.3	1.4
1640	1.1	1.2	1.2	1.3	1.3	1.4	1.5
1430	1.2	1.2	1.3	1.3	1.4	1.4	---
1270	1.2	1.2	1.3	1.3	1.4	1.5	---
1150	1.2	1.2	1.3	1.4	1.5	---	---
950	1.2	1.3	1.4	1.5	1.5	---	---
820	1.3	1.3	1.4	1.5	---	---	---
720	1.3	1.4	1.5	---	---	---	---
640	1.3	1.4	1.5	---	---	---	---
570	1.4	1.5	---	---	---	---	---
380	1.5	---	---	---	---	---	---

Note:

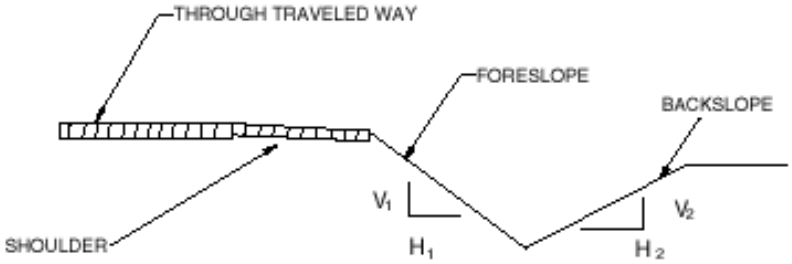
The clear zone correction factors are applied to the outsides of curves only. Curves flatter than 2860 feet do not need to provide adjusted clear zones.

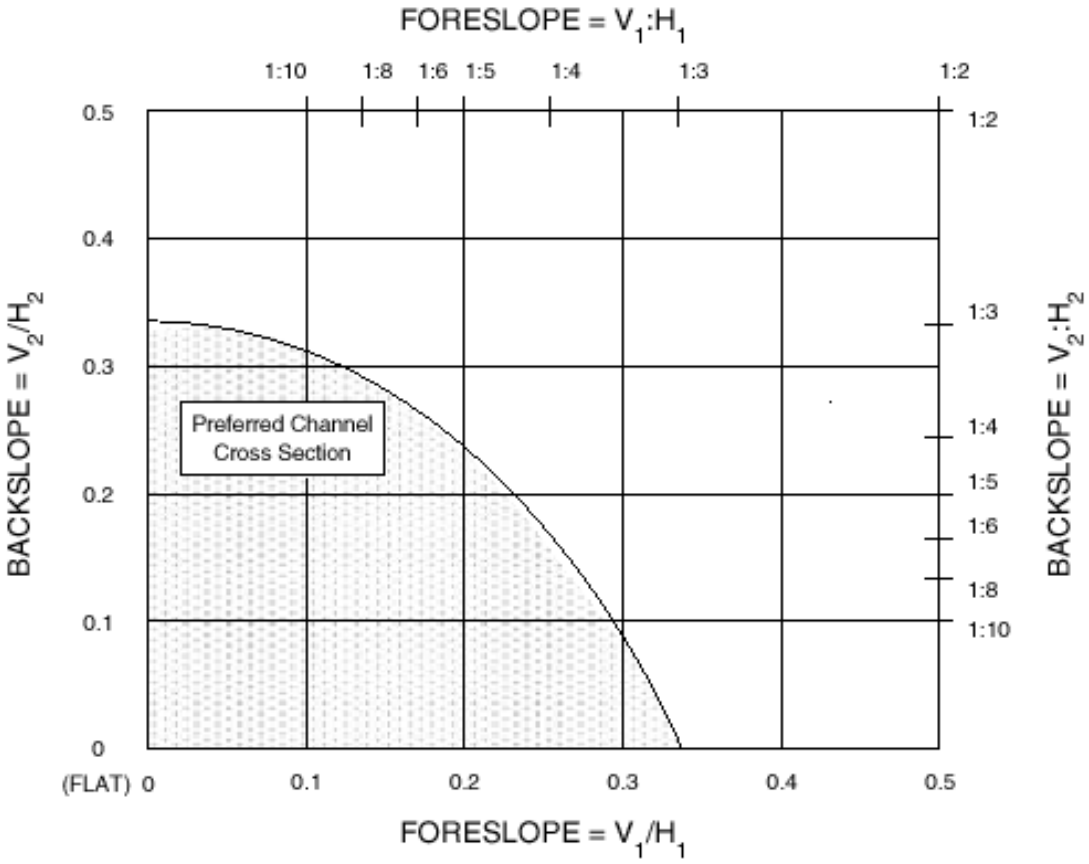
CZc = (Lc) (Kcz)

Where: CZc = clear zone on outside of curvature,

Lc = clear zone tangent section,

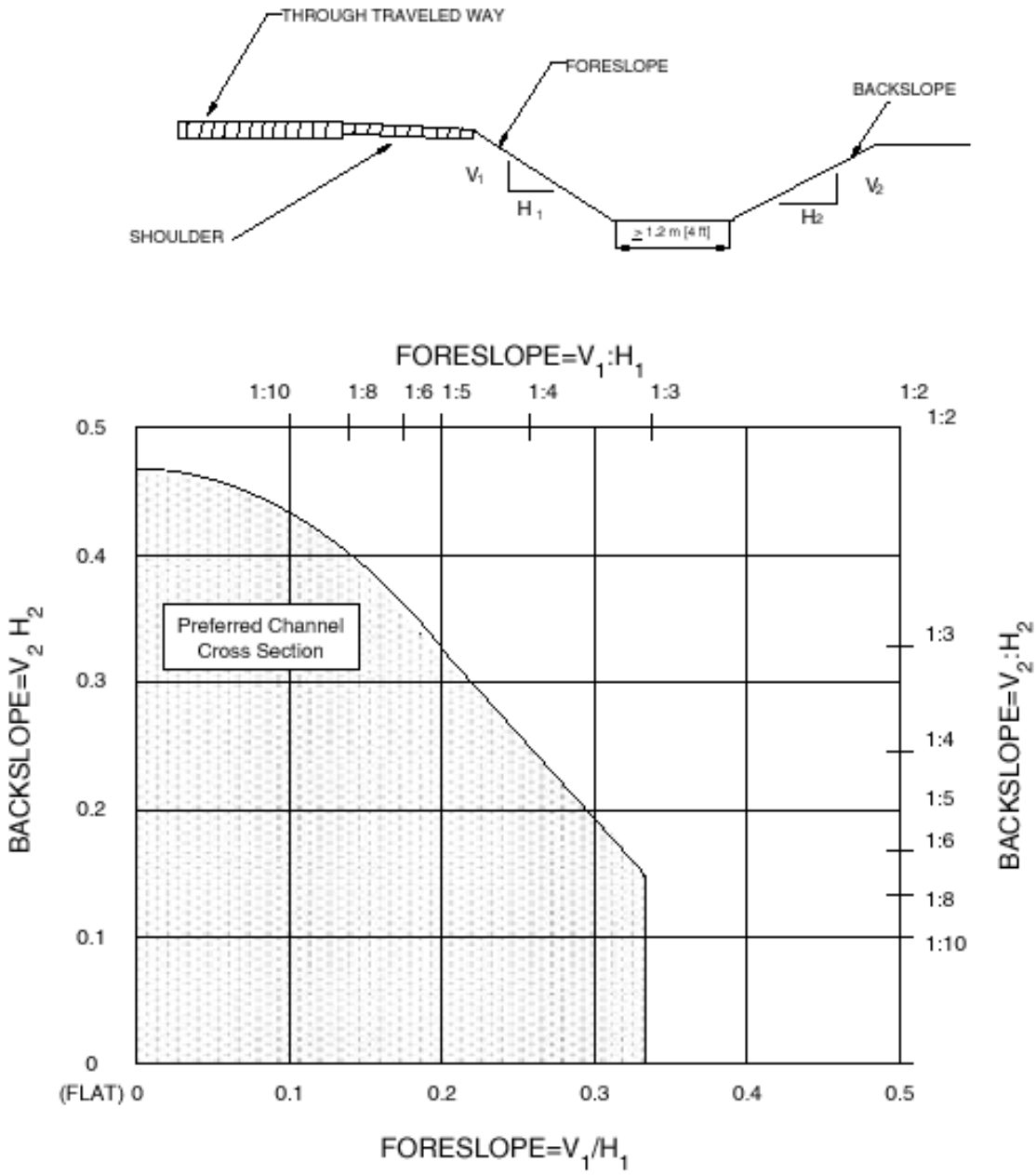
Kcz = curve correction factor





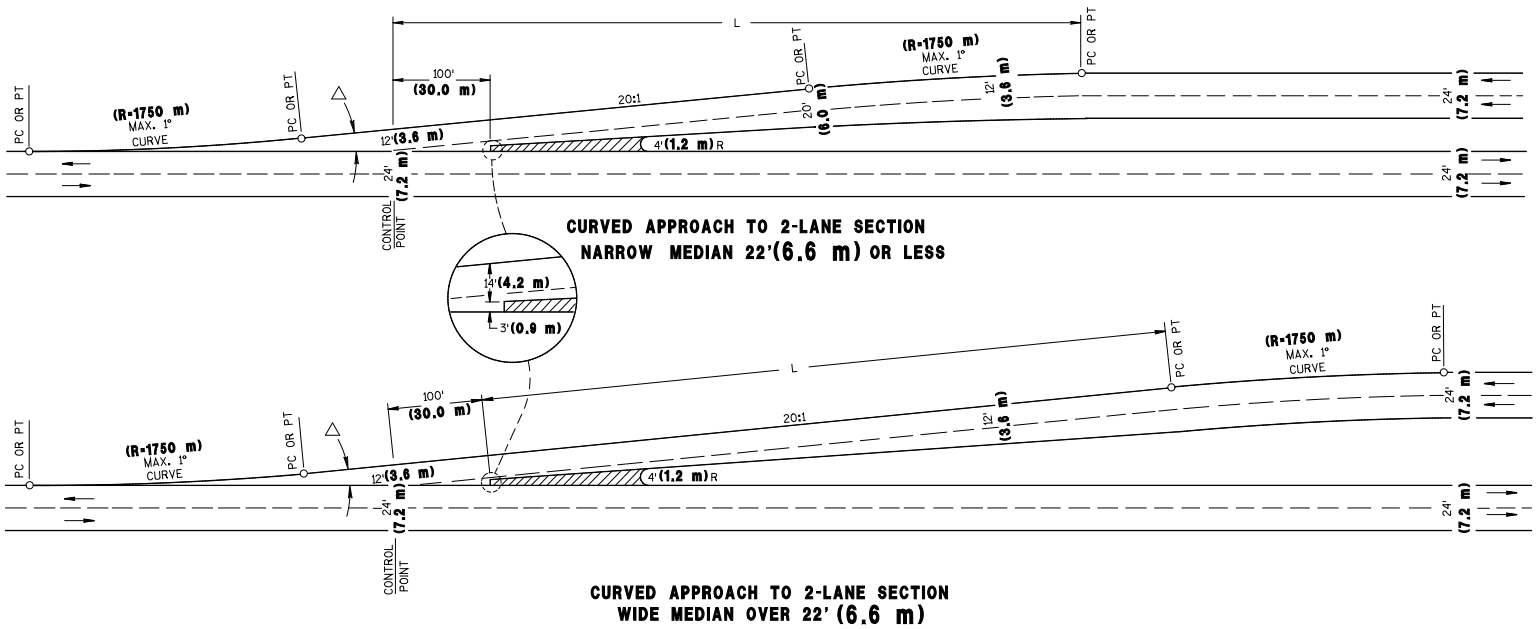
*This chart is applicable to all Vee ditches, rounded channels with a bottom width less than 2.4 m [8 ft] and trapezoidal channels with bottom widths less than 1.2 m [4 ft].

Ref. (2) Figure 3.6, Page 3-11



*This chart is applicable to rounded channels with bottom widths of 2.4 m [8 ft] or more and to trapezoidal channels with bottom widths equal to or greater than 1.2 m [4 ft].

Ref. (2) Figure 3.7, Page 3-12



NOTES

△ CAN VARY BETWEEN 3°-00' AND 5°-00', BUT NOT LESS THAN 2°-30'.

TRANSITIONS BETWEEN TWO-LANE HIGHWAYS AND FOUR-LANE HIGHWAYS SHALL BE DESIGNED TO DIRECT DRIVERS APPROACHING THE DIVIDED SECTION INTO THE INTENDED PATH TO THE RIGHT OF THE MEDIAN WITHOUT ANY APPRECIABLE CHANGE IN DIRECTION. ANY SIGNIFICANT CHANGE IN DIRECTION SHALL BE MADE BY DRIVERS LEAVING THE DIVIDED SECTION.

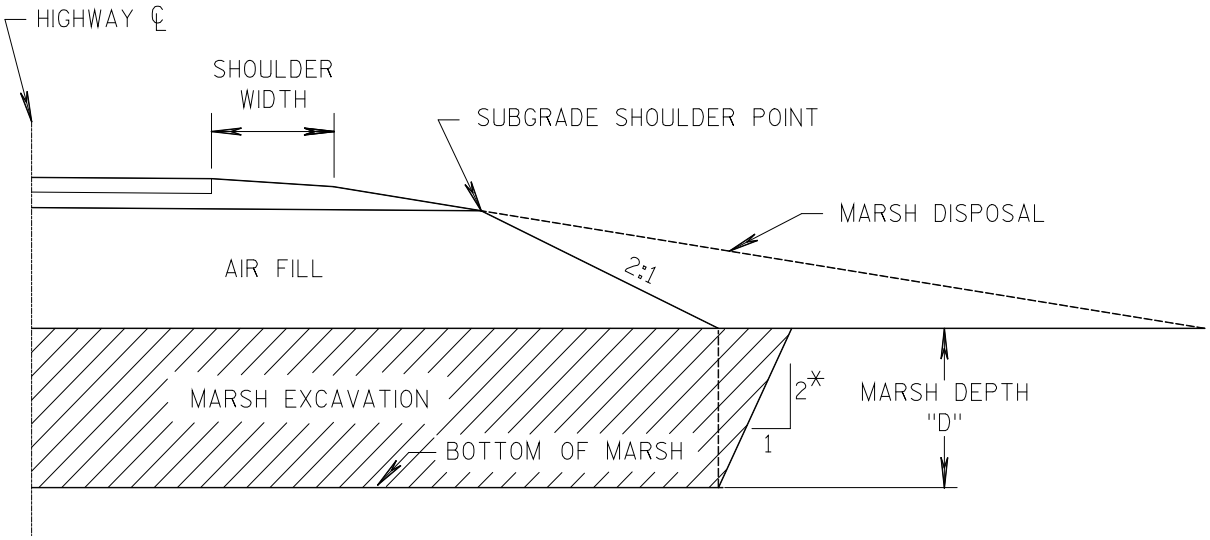
THE LANE DROP SHALL TAKE PLACE ON THE LEFT IN THE DIRECTION OF TRAFFIC. MOST DRIVERS STAY TO THE RIGHT EXCEPT WHEN PASSING AS REQUIRED BY WISCONSIN'S TRAFFIC REGULATION. IT IS ASSUMED, THEREFORE, THAT THERE WILL BE FEWER VEHICLES IN THE LEFT LANE AND DRIVERS USING THE LEFT LANE WILL PROBABLY BE IN A PASSING MANUEVER AND MORE ALERT TO THE CHANGE IN LANE WIDTH.

TRANSITIONS SHALL BE AVOIDED BEFORE INTERCHANGES AND AT LOCATIONS WITH HORIZONTAL OR VERTICAL SIGHT DISTANCE RESTRICTIONS.

SEE 11-30-1 FOR MORE DETAILED INTERCHANGE GEOMETRY.

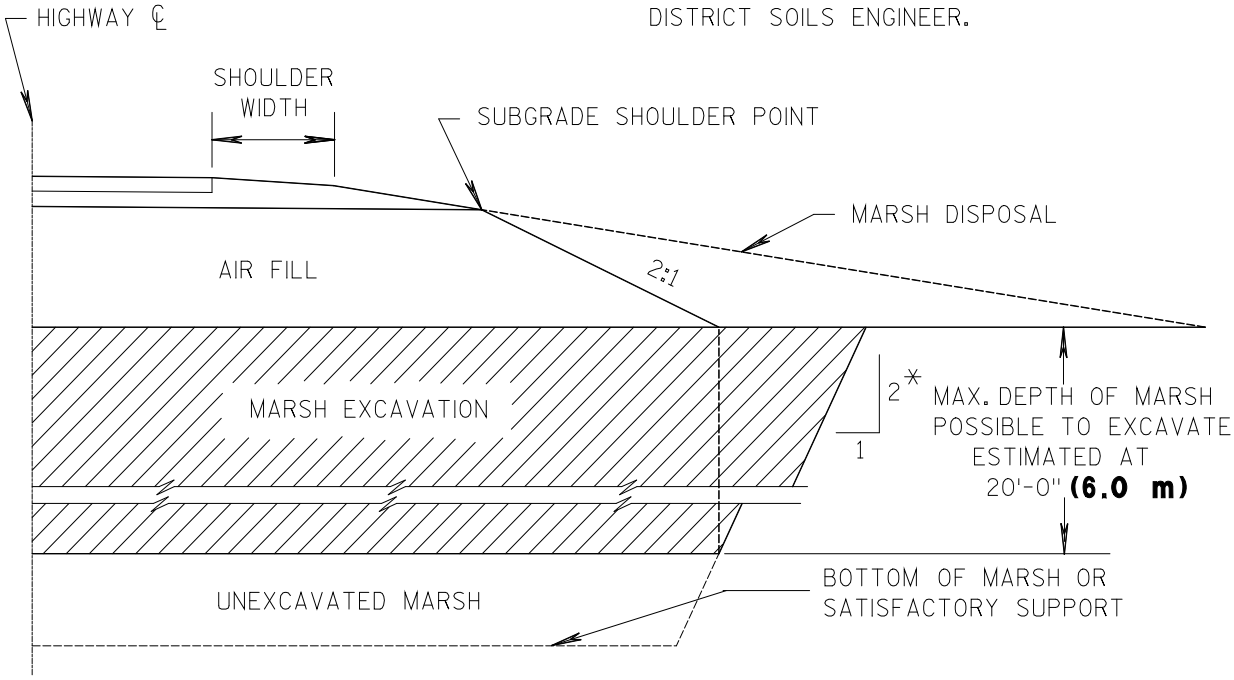
	L	V
L=12V	LENGTH OF VARIABLE WIDTH TRAVELED WAY (ft)	DESIGN SPEED (mph)
L=2.27V	LENGTH OF VARIABLE WIDTH TRAVELED WAY (m)	DESIGN SPEED (km/h)

TYPICAL TWO TO FOUR-LANE TRANSITION



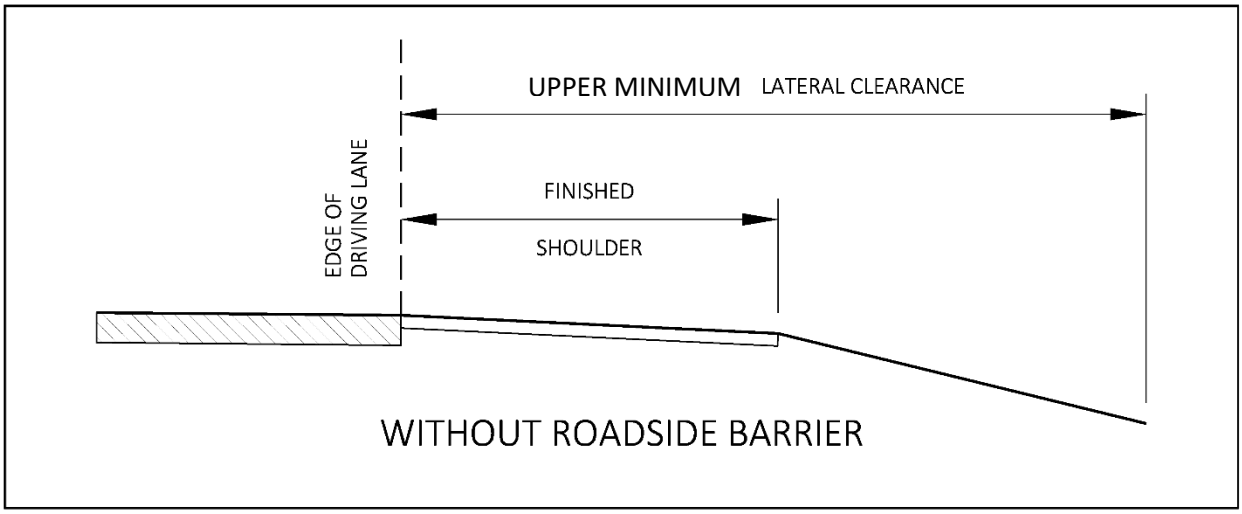
COMPLETE MARSH EXCAVATION

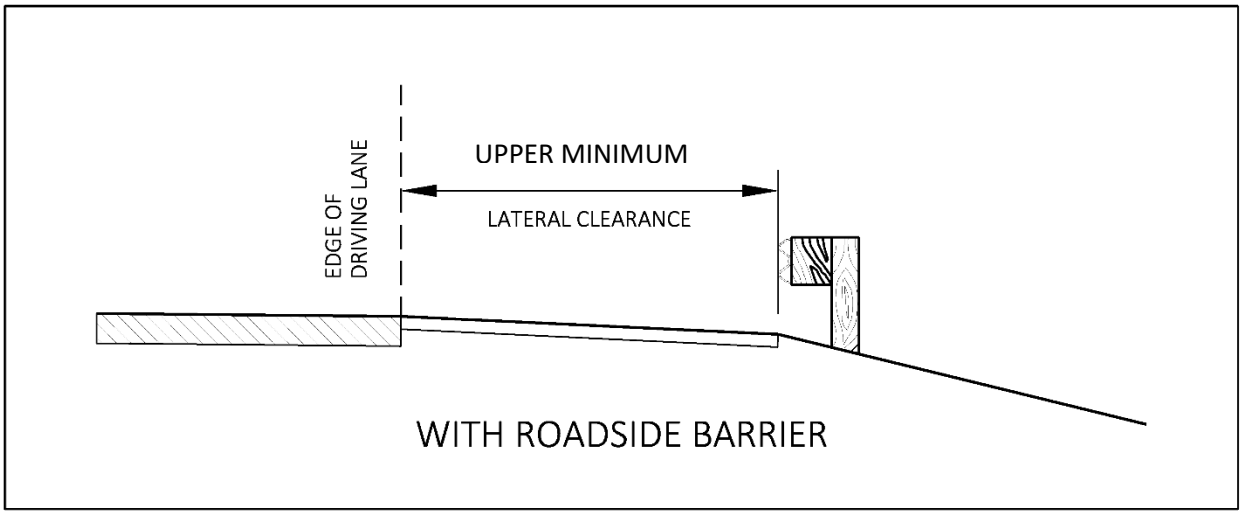
*A FLATTER SLOPE MAY BE NECESSARY FOR STABILITY IN WET MARSHES. CONSULT WITH DISTRICT SOILS ENGINEER.



PARTIAL MARSH EXCAVATION

TYPICAL MARSH SECTIONS





Lateral Clearance on Modernization Rural Roadways

Modernization Design Criteria for County Trunk Highways Functionally Classified as Arterials

TRAFFIC VOLUME		ROADWAY				BRIDGES[2]	
Design Class	Design AADT	Design Speed	Traveled Way Width	Shoulder Width	Roadway Width	Minimum Design Loading	Clear Roadway Width of Bridges[3]
A1	Under 3500	60 mph [4]	24’	6’	36’	[5]	36’
A2[1]	3500-15000	60 mph	24’	10’	44’	[5]	44’
A3	Over 15000	70 mph [6]	24’ (2)	6’ L 10’ R	40’ (2)	[5]	40’

1 The top of the traffic volume range for design class A2 is 15,000 AADT (LOS trigger of 5.0.) The volume is based on the 2000 Highway Capacity Manual assuming; level terrain, 12-foot lanes, ≥ 6-foot shoulders, 80 percent passing, 10 percent trucks, K30 design factor, and directional split of 60/40. See FDM 11-5-3 for additional information on threshold triggers, levels of service for different facility types and the respective numerical values.

2 The full widths of approach roadways should normally be provided across all new bridges. Design Justifications may be made when bridges are considered major structures on which design dimensions should be subject to individual economic studies because of the high unit costs.

3 Lateral clearance design criteria for underpass bridges are included in FDM 11-35-1.

4 For County Highways in design class A1 the design speeds should typically be 60 mph; however, lower design speeds of 55 mph are acceptable if justified by a safety analysis and documented in the DSR as a Design Justification (DJ).

5 See WisDOT Bridge Manual and consult with Bureau of Structures for appropriate Bridge Design Loadings.

6 See discussion in FDM 11-10-1.

Source: For County Trunk Highway Design Criteria see TRANS 205.

Modernization Design Criteria for County Trunk Highways Functionally Classified as Collectors

TRAFFIC VOLUME			ROADWAY[1] WIDTH DIMENSIONS					BRIDGES[1,4]
Design Class	Current ADT	Design ADT	Design Speed	Traveled Way	Shoulder	Roadway	Minimum Design Loading	Clear Roadway Width of Bridges
C1	0-400		40 MPH	22'-24'	2'-4'	26'-32'	[5]	26'-30'
C2	400-750	Under 1500	50 MPH	22'-24'	6'	34'-36'	[5]	28'-30'
C3		1500-3500	60 MPH[3]	24'	6'	36'	[5]	32'-34' [2]
C4		Over 3500	60 MPH	24'	8'	40'	[5]	40' [2]

1 Where ranges of widths are shown, the smaller numbers are the lower range of widths and the larger numbers are the upper range of widths eligible for federal or state project participation.

2 Bridges in Design Classes C3 and C4 with total lengths over 100 feet may be designed with clear roadway widths of 30 feet.

3 For County Trunk Highways in design class C3, design speeds of 55 mph are acceptable.

4 Lateral clearance design criteria for roadways under bridges are included in FDM 11-35-1.

5 See WisDOT Bridge Manual and consult with Bureau of Structures for appropriate Bridge Design Loadings.

Source: Administrative Rule Trans 205, "County Trunk Highway Standards"

Modernization Design Criteria for County Trunk Highways Functionally Classified as Local Roads

TRAFFIC VOLUME			ROADWAY[1] WIDTH DIMENSIONS					BRIDGES[1,4]
Design Class	**Current ADT**	**Design ADT**	**Design Speed**	**Traveled Way**	**Shoulder**	**Roadway**	**Minimum Design Loading**	**Clear Roadway Width of Bridges**
L1	0-250		40 MPH	20'-22'	2'-4'	24'-30'	[5]	24'-28'
L2	250-400		40 MPH	22'	2'-4'	26'-30'	[5]	26'-30'
L3	400-750	Under 1500	50 MPH	22'-24'	6'	34'-36'	[5]	28'-30'
L4		1500-3500	60[2] MPH	24'	6'	36'	[5]	30'-34' [3]
L5		Over 3500	60 MPH	24'	8'	40'	[5]	40' [3]

1 Where ranges of widths are shown, the smaller numbers are the lower range of widths and the larger numbers are the upper range of widths eligible for federal or state project participation.

2 For County Trunk Highways in design class L4, design speeds of 55 mph are acceptable.

3 Bridges in Design Classes L4 and L5 with total lengths over 100 feet may be designed with clear roadway widths of 30 feet.

4 Lateral clearance design criteria for underpass bridges are included in FDM 11-35-1.

5 See WisDOT Bridge Manual and consult with Bureau of Structures for appropriate Bridge Design Loadings.

Source: Administrative Rule Trans 205, "County Trunk Highway Standards"

Modernization Design Criteria for Interstate Highways

Number of Travel Lanes (Total Both Directions)		4-Lane	6-Lane or More
Sideslopes		4:1 or flatter (Recoverable) or 3:1 maximum (Traversable) with Recovery Area meeting FDM 11-15 Attachment 1.9	
Traffic Lanes	Widths	12 feet	12 feet
	Cross Slope	2%	2%
	Superelevation	6%maximum	6% maximum
Shoulders	Widths	10 feet Right[1] / 4 feet Left	10 feet Right and Left [2]
	Cross Slope	4%	4%
New and Replacement Bridges	Vertical Clearance	16 feet minimum. See FDM 11-35 Attachment 1.8	
	Roadway Width[3]	Full Approach Roadway Width except Major Long Span Structures shall provide 4-foot minimum from edge of traffic lanes to parapets[3]	
	Design Loading Structural Capacity[4]	HL-93 (HS-20) minimum [4]	HL-93 (HS-20) minimum[4]
Bridges to Remain in Place	Lane Widths (Feet)	12 feet	12 feet
	Shoulder Widths (Feet)	10 feet Right / 3.5 feet Left minimum except 3.5 feet Left and Right minimum for Major Long Span Structures	10 feet Right and Left minimum except 3.5 feet Left and Right minimum for Major Long Span Structures
Lateral Clearance[5]		See FDM 11-15 Table 1.2 [5]	
Roadside Design	Curb or Curb and Gutter	Barrier curbs shall not be used. Mountable curbs, when used, should be located at the outer edge of the shoulder. Also, where guardrail is used, the face of the curb should be flush with the face of guardrail or behind it.	
	Clear Zone Widths and Fixed Objects	FDM 11-15 Attachment 1.9 and the AASHTO Roadside Design Guide should be used for guidance regarding warranted clear zone widths. Fixed Objects within the clear zone should be removed, made breakaway or made safe through shielding by a roadside barrier, crash cushion, or a combination of both.	
	Median Inlets and Ditch Checks	Median inlets should have 6:1 or flatter traversable grates and 10:1 or flatter ditch checks.	
	Median and Maintenance Crossovers	Median/Maintenance Crossovers should be eliminated whenever possible or constructed to have 10:1 or flatter side slopes.	
	Construction Crossovers	Removed after project completion unless they are planned to be used for future maintenance or other traffic control operations. Construction crossovers left-in-place should 10:1 or flatter side slopes and appropriate safety devices installed along their length to minimize the potential for median-crossing crashes and unauthorized U-turns.	
Traffic Control Devices/Signing		Shall be in conformance with the current Manual on Uniform Traffic Control Devices (MUTCD) and the Wisconsin Manual on Uniform Traffic Control Devices (WMUTCD).	
Access Control		Right-of-way fencing, or other appropriate measures, shall be incorporated into all Interstate projects to address any access control issues within the proposed project limits.	

Notes:

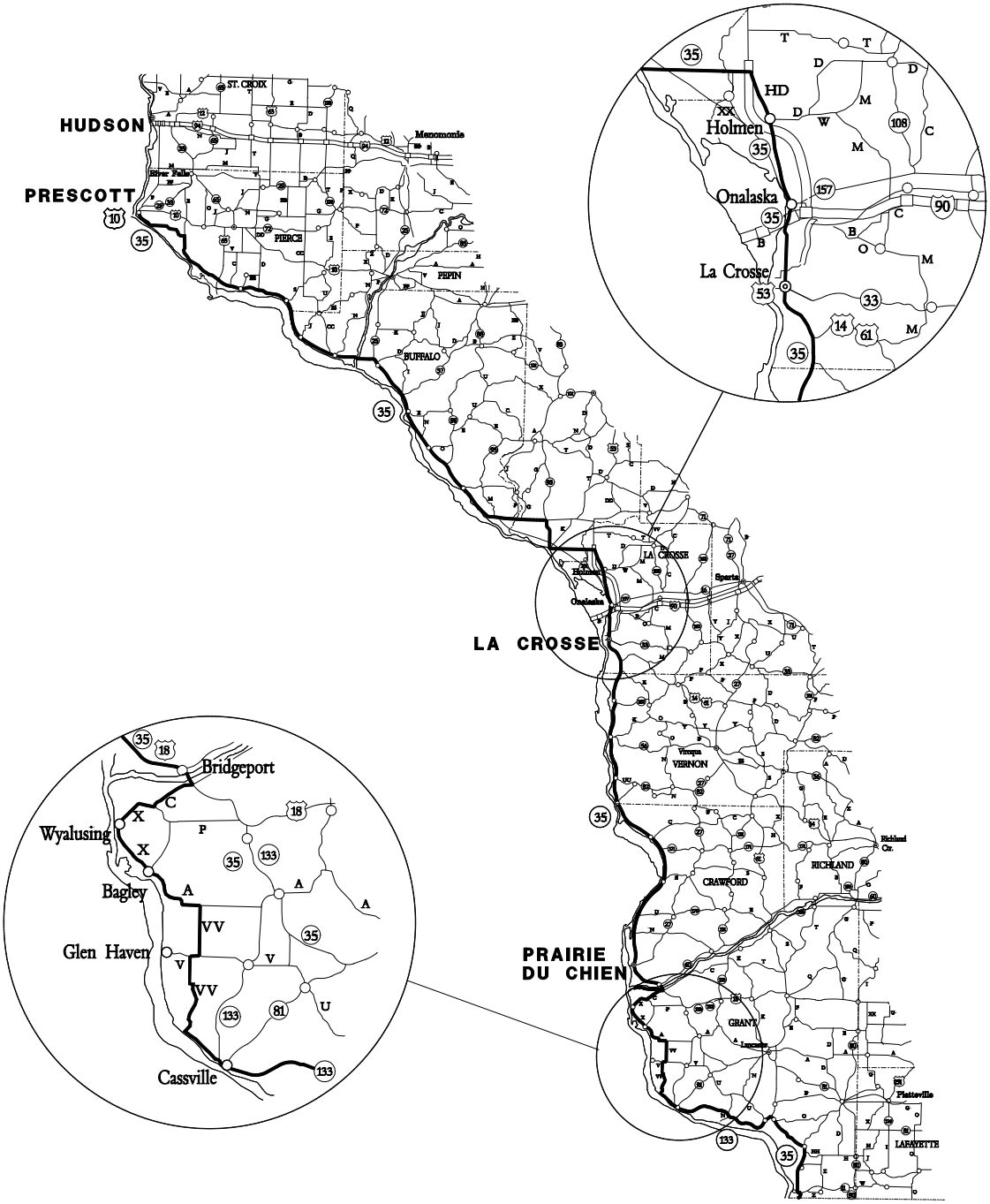
[1] Use 12-foot paved shoulders (right) on 4-lane freeways if truck traffic >250 DHV, or if the facilities experience a high degree of congestion and incidents. The roadway widths and clear roadway widths on bridges are increased accordingly.

[2] Use 12-foot paved shoulders (left and right) on 6-lane freeways if truck traffic > 250 DHV or if the facilities experience high degrees of congestion and incidents. The roadway widths and clear roadway widths on bridges are increased accordingly.

[3] Normally provide full widths of approach roadways across all new bridges. Justifications may be made when the bridges are considered major structures on which design dimensions are subject to individual economic studies because of high unit costs.

[4] See WisDOT Bridge Manual and consult with Bureau of Structures for appropriate Bridge Design Loading.

[5] Lateral clearance design criteria for underpass bridges are included in FDM 11-35-1.



LEGEND

——— - GREAT RIVER ROAD

GREAT RIVER ROAD

Great River Road – Legal Definition

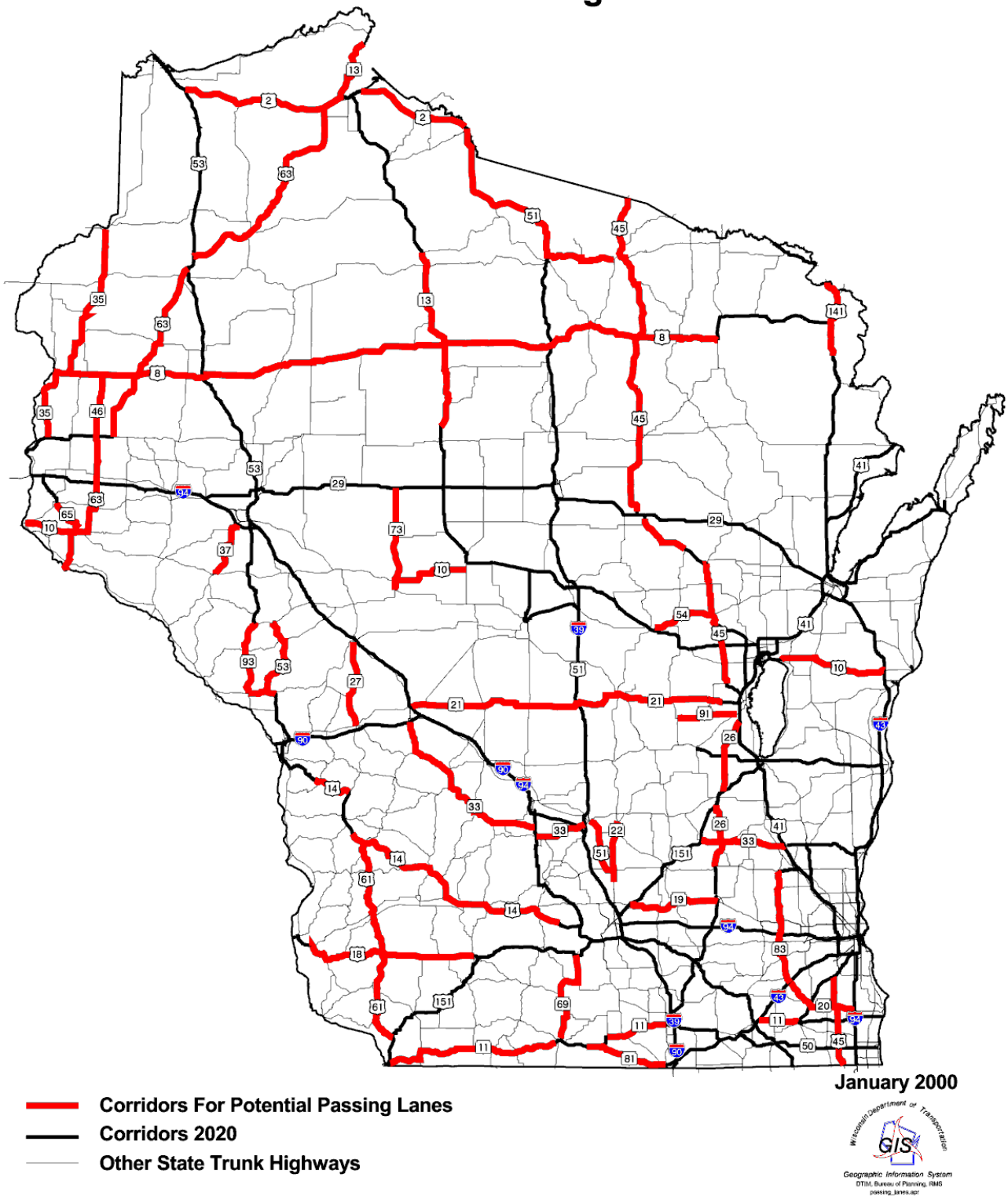
84.107 Great River Road.

(1) The department shall designate and mark as the “Great River Road” the route in Grant, Crawford, Vernon, La Crosse, Trempealeau, Buffalo, Pepin and Pierce counties commencing at the Wisconsin–Illinois border and proceeding northerly on STH 35 to its junction with STH 133; then proceeding westerly on STH 133 to its junction with CTH “VV” near Cassville; then proceeding northerly on CTH “VV” to its junction with CTH “A”; then proceeding westerly on CTH “A” to its junction with CTH “X” in Bagley; then proceeding northerly on CTH “X” to its junction with CTH “C”; then proceeding easterly on CTH “C” to its junction with STH 35, with all of the preceding highways in Grant County; then proceeding northerly on STH 35 to its junction with USH 14/61 in La Crosse County; then proceeding northerly on USH 14/61 to its junction with USH 53; then proceeding northerly on USH 53 to its junction with STH 35; then proceeding northerly on STH 35 to its junction with Business 35/CTH “HD” near Holmen; then proceeding northerly on Business 35/CTH “HD” to its junction with STH 35; then proceeding northerly on STH 35 to its junction with USH 10 in Pierce County; and then proceeding westerly on USH 10 to the Wisconsin–Minnesota border.

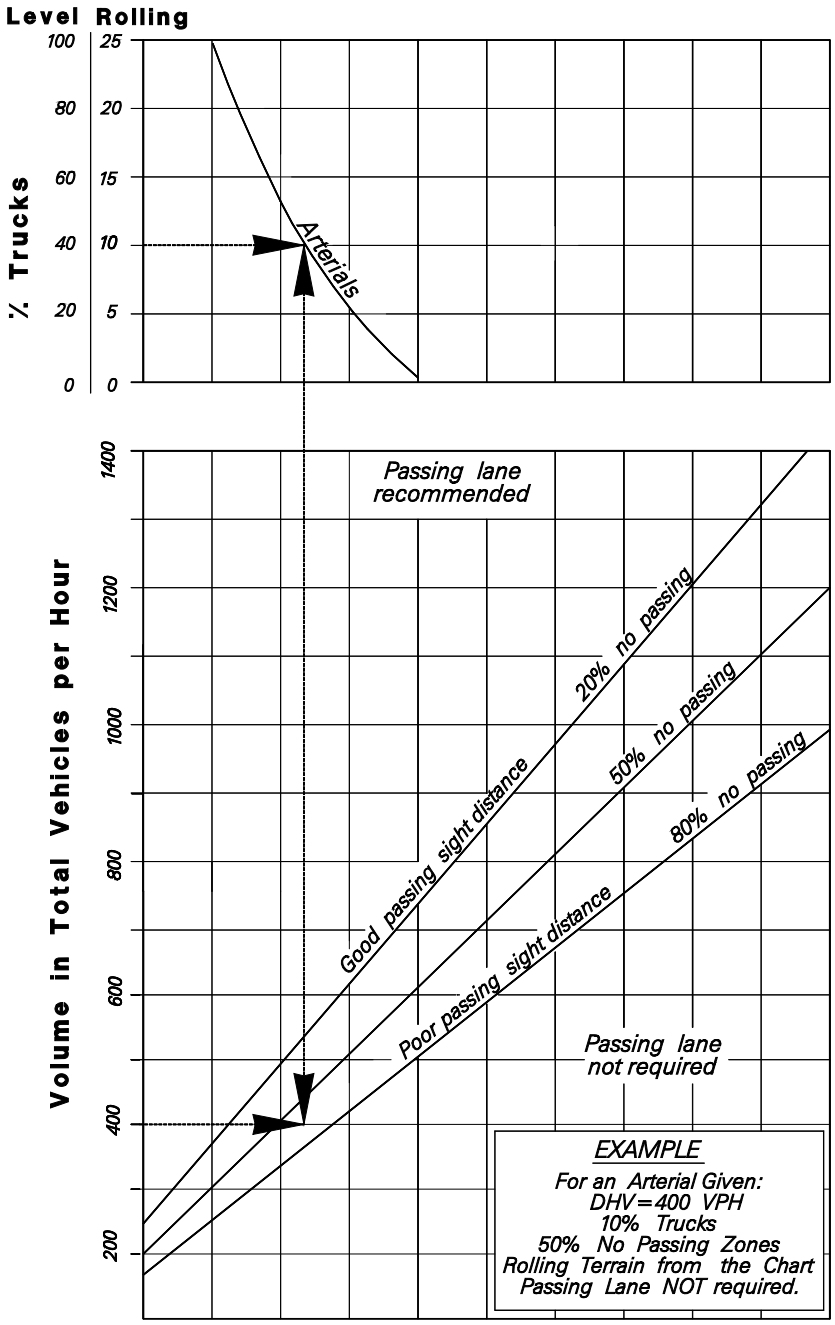
(2) If the department, after investigations and studies, finds that any proposed Great River Road development is advantageous to the state, it shall have full authority to perform, on behalf of the state, each and every duty required of the state, in order to secure and complete the proposed development project. For the purposes of such development projects, the Great River Road shall be a portion of the state trunk highway system.

History: 1993 a. 357.

Wisconsin Rural State Trunk Highway Passing Lane Corridors



Warrant for Considering Passing Lanes



Note: The Rolling Terrain criterion should be considered only for projects located in western and southwest Wisconsin. See the text of this procedure for additional warranting criteria.

Source: Washington State DOT

FDM 11-20-1 Modernization Dimensions and Design Classes

August 17, 2020

1.0 General

Modernization design criteria for various urban highway systems are given in this procedure. Attachment 1.1 and Attachment 1.5 contain modernization design criteria for urban highways. Modernization projects include what was formerly referred to as Reconstruction and New Construction projects and will still be sub-categorized by these project types in this section to clarify guidance. The biggest difference between Reconstruction and New Construction-Type Modernization projects is that Reconstruction projects will be evaluated under the WisDOT Safety Certification Process (SCP) to determine the safety performance of the existing cross sectional and geometric features. This SCP information can be used to justify the use of lower end of the range design criteria and outside of the range design criteria when evaluated in conjunction with other appropriate Design Justification (DJ) information (environmental impacts, public input, significant costs) in the DSR. Reconstruction projects will apply the S-2 Application as described in FDM 11-15-1.3.1. New Construction projects cannot use the SCP because no existing cross sectional or geometric features or crash histories exist in which to analyze safety performance, however predictive safety benefit/cost analyses in conjunction with environmental process evaluations can be used to compare alternatives. New Construction projects will use the S-3 Application as described in FDM 11-15-1.3.2. See FDM 11-15-1, FDM 11-1-20, FDM 11-4-10.4 and FDM 11-38 for further information on the S-2/S-3 Applications, Design Study Report (DSR) Design Justifications (DJs), and the SCP for use on Modernization projects. DJ approvals in the DSR are also available to use when needed to justify the preservation of existing features or the application of new cross sectional or geometric feature values outside of FDM design criteria values which are not initially recommended by the Safety Certification Process Document (SCD) or other safety analyses. See FDM 11-1-20 and FDM 11-4-10.4 for information and guidance on the use of DSR DJs.

1.1 Cross Slopes

The pavements of urban roadways typically have crowns in the middle and slope downward towards both edges. The downward cross slopes should be in planes rather than curved (parabolic) sections. Table 1.1 shows the usual Lower and Upper cross slope rates to use:

Lanes	Lower	Upper
Driving	2%	3%
Parking, Turning, etc.	2%	4%

Cross slope rates outside these ranges may be warranted in unique situations.

1.2 Curbs or Curb and Gutters

The designs of curbs are based on whether the improved roadways will be defined as “low speed urban,” “transitional,” or, “high speed urban.” Designers must therefore first determine the types of roadways, then use the guidelines for those roadway types to determine the curb designs that may be needed.

Roadways are defined as “low speed,” “transitional,” or, “high speed” based on two characteristics:

- Cross-sections
- Posted speeds (Regulatory speeds)

Generally, urban roadways are ones that control surface drainage using curbs and may have enclosed storm sewer systems that may discharge into open channels.

As Table 1.2 shows, roadways with urban cross sections and posted speeds of 40 mph or less are considered “Low Speed Urban,” whereas roadways with urban cross sections and posted speeds of 50 mph or greater are considered “High Speed Urban.” Other roadways are considered “Transitional.” Please note that the locations of roadways within the corporate limits of cities do not necessarily mean that the roadways have urban cross-sections.

Table 1.2 Matrix for Determining Roadway Types

Posted Speed	40 mph or less	45 mph	50 mph or greater
Urban Cross Section	Low Speed Urban Roadway	Transitional Roadway	High Speed Urban Roadway

Normally, the methods of handling drainage determine the cross section. Given the cross sections, designers then use the posted (regulatory) speeds or operating speeds to determine the types of roadways along with the information in the following paragraphs to select the appropriate curb designs.

When designing curbs for Modernization roadways, the expected posted speeds are used. The posted speed limits are not required to correspond to the design speeds or to individual design elements within the projects. Consult with region traffic engineers to determine the appropriate posted speeds that will be implemented following completion of improvement projects. (See Chapter 13 of the WisDOT Traffic Engineering Operation and Safety Manual[1] (TEOpS 13) for guidance relating to posted speed limits). In cases of local roadways or connecting highways, also consult with the local municipalities having jurisdiction over the roadways when determining the appropriate posted speed limits.

When determining the acceptability of given curb designs (heights and offsets), consider other characteristics of the roadway corridors. In addition to drainage and the posted speeds, consider:

- need to maximize capacity,
- degree of adjacent roadside property development,
- need for on-street parking
- need for sidewalks
- need for bicycle facility accommodations
- frequency of access points
- functional classification(s)
- availability and cost of right-of-way

Increases in any of these factors may make the character of the roadways more, low speed urban.

1.2.1 General Curb Design Information

Dimensions and details of recognized curb and gutter designs are on WisDOT's standard detail drawings web page (http://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/rdwy/sdd.aspx). Curbs can be categorized as either vertical face or sloping face. Table 1.3 lists the standard WisDOT curbs shown in Chapter 16, and categorizes them as vertical face, 4-inch sloping face, or 6-inch sloping face.

Gutter width is the distance between the gutter flange line and the curb face. Gutter widths are considered part of the offsets from the edges of the traveled ways to the faces of curbs.

[1] WisDOT Traffic Engineering Operations and Safety Manual: http://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/teops/default.aspx

***Table 1.3* Curb, Curb & Gutter, and Inlet Covers per FDM Chapter 16**

	Curb type	**Inlet Covers ***
Vertical Face	Type A curb	A, A-S, H, H-S, WM, S, V, Z
	Type A, 18-inch	Z
	Type A, 30-inch	A, A-S, H, H-S, WM, Z
	Type D curb	A, A-S, H, H-S, WM, S, V, Z
	Type D, 18-inch	Z
	Type D, 30-inch	A, A-S, H, H-S, WM, Z
	Type K, 30-inch	A, A-S, H, H-S, WM, Z
	Type L, 30-inch	A, A-S, H, H-S, WM, Z
	Milwaukee: 18-inch	
	Milwaukee: 22-inch	
	Milwaukee: 31-inch	R, W
4-inch Sloping Face	Type A, 36-inch	HM, HM-S
	Type D, 36-inch	HM, HM-S
	Type G, 30-inch	HM-GJ, HM-GJ-S
	Type J, 30-inch	HM-GJ, HM-GJ-S
	Type T, 36-inch	T
	Type R, 36-inch	T
6-inch Sloping Face	Type A, 36-inch	F, HM, HM-S
	Type D, 36-inch	F, HM, HM-S
	Type G curb	HM-GJ, HM-GJ-S, S, V
	Type G, 30-inch	HM-GJ, HM-GJ-S
	Type J curb	HM-GJ, HM-GJ-S, S, V
	Type J, 30-inch	HM-GJ, HM-GJ-S

* *Inlet covers can fit curb heights and curb and gutter widths. Some adjustments may be required. Also, check hydraulic capacities and the safety for bicycles, pedestrians, and disabled users.*

Another approach is to widen the gutters at the inlet locations. This can be done by either flaring back the curb faces or flaring in the gutter flags.

Use of non-standard curb designs is discouraged but may be necessary where site conditions dictate. Prior to inclusion in project plans, alternate designs should be discussed in the SCDs or DSR DJs.

Curb types and placements near traffic barriers (guardrails, etc.) and crash cushions is important because there is the potential for errant vehicles to vault. High speed impacts to curbs can cause vehicle damage leading to loss of vehicle control.

Evaluate whether roadway tapers or curb cuts (driveway entrance curbs) need to be provided at the approach ends of traffic barrier end treatments or crash cushions to minimize any adverse effects on traffic barrier or crash cushion performance. Base these decisions on the types of end treatments, drainage requirements, roadway cross-sections and available right-of-way.

Further guidance on curb placements around traffic barriers and crash cushions can be found in the Roadside Design Guide (AASHTO RDG, 2011[2]).

1.2.1.1 Gutter Cross Slopes

A 4% gutter cross slope is required for projects that do not have design study report (DSR) approvals yet at the date of this transmittal publication. For projects at post-DSR stages, designers are encouraged to re-evaluate their projects and adopt the new design criteria slopes but will not be required to adopt the new design criteria if unacceptable impacts or costs to project scope or schedule would be needed.

A 4% gutter cross slope is the design criteria slope and replaces the longstanding 3/4" per foot (6.25%) gutter cross slope. Consider on-road bicycle accommodations, including concrete bike lanes, in gutter slope selections. A 2% gutter slope may be appropriate for these conditions.

Refer to FDM 11-46-10.3 for gutter cross slope design guidance with curb ramp applications. Provide inlet spacings per FDM 13-25-15 for the selected gutter slope designs.

Label any non-standard (i.e. other than 4%) gutter cross slope locations within the plans. At a minimum, include gutter cross slope labels or notes within the contract typical cross sections and miscellaneous quantities. Include additional labels or notes within contract construction details and cross sections for all gutter cross slopes as needed and to provide further clarity.

1.2.2 Low Speed Urban Roadways

- Use 6-inch vertical curbs to control both surface drainage and access.
- For raised median curbs, designers may use either 1 or 2-foot offsets from the edges of the traveled ways to the faces of curbs. (1 - 2-foot gutter sections will meet design criteria).
- For outside curbs, designers may use either 1 or 2-foot offsets from the edges of the traveled ways to the faces of curbs. (1 - 2-foot gutter sections will meet design criteria)
- Give due consideration to bicycle accommodations on arterials and collectors according to FDM 11-46-1.
- Typically, match island curbs to the curb designs used on the roadway sections unless the roadway environment or maintenance activities dictate different approaches such as traffic pavement markings or alternative curb designs. Coordinate the designs with region or municipal operations and maintenance staffs. - Certain characteristics of roadway corridors may limit the ability to offset the curbs by the 1-foot minimum from the edges of the traveled ways. In these situations, the median curbs and curbs on the outside edges of the roadways may have offsets less than 1-foot. However, the reasoning for the reduced offsets are to be justified in the SCDs and DSR DJs (See FDM 11-38, FDM 11-1-20 and FDM 11-4-10.4). (To mitigate for the reduced offsets, sloping curbs may be needed)
- Further guidance on curb types and placements can be found in A Policy on Geometric Design of Highways and Streets (AASHTO GDHS, 2011[3]) and the Roadside Design Guide (AASHTO RDG, 2011[2]).

1.2.3 Transitional Roadways

- If posted speeds are greater than 40 mph, eliminate curbs when possible.
- If curbs are required to control drainage, use 6-inch sloping curbs rather than 4-inch sloping.
- In limited situations where the access points are not clearly delineated and cannot be controlled by other means, 6-inch vertical curbs may be used. Document the justifications for using the vertical curbs in the SCDs and DSR DJs (See FDM 11-38, FDM 11-1-20 and FDM 11-4-10.4).
- Curbs and Curb Offsets - Consult region planning and traffic personnel, local municipalities, regional planning organizations, or County planning departments to determine the nature and extent of existing or planned developments surrounding or impacting the proposed roadway corridors. To qualify projects as being in developing areas; written documentation is needed from either the local municipalities, regional planning organizations or county planning departments verifying current or future zoning and other long-range planning goals. In addition to reviewing the nature and extent of existing or planned developments, consider the roadway's functional classification and frequency of access points.

1.2.3.1 Undeveloped Areas:

- Use 6-inch sloping curbs.

[2] Roadside Design Guide, 4th edition. AASHTO, Washington, DC, 2011
[3] A Policy on Geometric Design of Highways and Streets 2011, 6th Edition. AASHTO, Washington, DC, 2011

- Offset both median curbs and outside curbs to the edges of normal-width shoulders. (See FDM 11-15 Attachment 1.1 - 1.4 and FDM 11-15 Attachment 1.17 - 1.19).
- Median curbs and curbs on the outside edges of the roadways with offsets less than the normal-width shoulders will require justification and approval in the SCDs and DSR DJs (See FDM 11-38, FDM 11-1-20 and FDM 11-4-10.4).

1.2.3.2 Developing Areas:

- Use 6-inch sloping curbs.
- Offset both median curbs and outside curbs to the edges of normal-width shoulders. (See FDM 11-15 Attachment 1.1 - 1.4 and FDM 11-15 Attachment 1.17 - 1.19)
- Certain characteristics of the roadway corridors may limit the ability to offset the curbs by the normal width shoulders. In those situations, the median curbs and curbs on the outside edges of the roadways may have reduced offsets, down to minimum 1.8-foot offsets, from the edges of traveled ways to faces of curbs, but reasoning shall be justified and approved in the SCDs and DSR DJs (See FDM 11-38, FDM 11-1-20 and FDM 11-4-10.4).
- Median curbs and curbs on the outside edges of the roadways with offsets less than the 1.8-foot minimum require justification in the SCDs and DSR DJs (See FDM 11-38, FDM 11-1-20 and FDM 11-4-10.4).
- Give due consideration to bicycle accommodations on all arterial and collector streets, according to FDM 11-46-1.

1.2.3.3 Developed Areas:

- Use 6-inch sloping curbs.
- Offset both median curbs and outside curbs to the edges of normal-width shoulders. (See FDM 11-15 Attachment 1.1 - 1.4 and FDM 11-15 Attachment 1.17 - 1.19).
- Certain roadway characteristics may limit the ability to offset the curbs by the normal width shoulders. Minimum offsets of 1-1.8 feet may be used but shall be justified and approved in the SCDs and DSR DJs (See FDM 11-38, FDM 11-1-20 and FDM 11-4-10.4).
- Offsets of less than 1-foot may be considered in unique circumstances but require justification in the SCDs and DSR DJs (See FDM 11-38, FDM 11-1-20 and FDM 11-4-10.4).
- Give due consideration to providing bike accommodations on all arterial and collector streets, according to FDM 11-46-1.

1.2.4 High Speed Urban Roadways

- In general, neither vertical nor sloping curbs are ideal for use on high-speed roadways. Therefore, eliminate curbs on urban high-speed roadways, where it is practical to do so.
- When curbs are used, 4-inch sloping curb designs are preferable. However, 6-inch sloping curb designs may be used when required for drainage or access control considerations.
- Shoulder width offsets from the traveled ways to the faces of median curbs and from the traveled ways to the outside edges of the roadways are required (See Attachment 1.5). However, in special cases, when justified and approved in the SCDs and DSR DJs (See FDM 11-38, FDM 11-1-20 and FDM 11-4-10.4), minimum offsets of 1.8 feet to the faces of curbs may be acceptable.
- Give due consideration to providing Bike accommodations on all arterial and collector streets, according to FDM 11-46-1.

1.3 Design Criteria Guidance

The FDM design criteria tables show ranges of design criteria values based on design speeds, lane widths, parking lane widths and roadway widths (faces of curbs to faces of curbs) including widths for providing bicycle accommodations/lanes.

- For Reconstruction projects (no capacity expansions) use existing values if the SCD identifies no safety problems or safety problems contributable to existing geometric features as long as they are above the lower design criteria range value, otherwise start with the lower ranges of FDM values equal to or above the existing values as the starting points to evaluate design alternatives to meet project purpose and need including addressing safety needs as evaluated in safety benefit/cost analyses. Existing values outside of the range of design criteria may be perpetuated if the safety performance is acceptable, and if environmental, excessive project costs, or other impacts justify them.
- For New Construction projects (new alignment or capacity expansions), since there are no existing geometric features and crash histories to evaluate, start with the upper ranges of FDM values as the starting points for evaluating alternatives in conjunction with predictive safety benefit/cost analyses

(such as HSM) as needed to meet the project purpose and need.

- For both Reconstruction and New Construction-Type Modernization projects, in addition to the safety benefit/cost analyses evaluations, appropriate environmental impact evaluations need to be completed and documented in the project environmental documents when selecting final design alternatives. Justifications for the use of design criteria outside of the values given in this chapter need to be documented and approved in the project SCDs and DSR DJs (See FDM 11-38, FDM 11-1-20 and FDM 11-4-10.4).

1.3.1 Low Speed Urban Roadways

In low-speed urban areas with restricted space or historically sensitive resources, lower range design criteria alternatives need to be evaluated during the environmental analysis processes. Evaluation of lower range design criteria on urban streets can help to reduce impacts to the surrounding developed environment, reduce pedestrian crossing distances, allow for on-street bike provisions, parking and transit stops, or enable development of left turn lanes for safety. An important factor to be aware of when considering the use of lower range design criteria is that narrower travel lanes reduce the distances separating various transportation users sharing the same roadway space. Careful review of existing or predictive crash analyses can give an indication as to how existing or proposed narrower lane widths are or may operate into the future. Selections of design vehicles are also an important consideration when evaluating the use of lower range design criteria because heavy trucks require more room to maneuver, both along the roadways and at intersections.

1.3.2 Transitional and High-Speed Urban Roadways

Careful reviews of existing and predictive crash analysis results are even more important when evaluating the use of narrower lane width alternatives on Transitional and High-Speed Urban Roadways because of their higher operating speeds. Reduced separation between transportation users, when operating speeds are higher, make the interactions between various users even more complicated with increased risk of higher severity type crashes. However, use of narrower lane widths can be evaluated when looking to better allocate roadway space for multi- transportation modes, improving operations within narrower urbanized roadway corridors or reducing the roadways impacts on natural or societal resources with or without considerations for operational improvements. Selections of design vehicles are even more important in these situations because heavy trucks operating at higher speeds require more room to maneuver, both along the roadways and at intersections.

At the same time, use of upper range design criteria values may contribute to higher vehicle operating speeds than would otherwise occur if lower range design criteria were used. In situations where it is desirable to lower vehicle operating speeds, consider using pavement markings, small plantings and other traversable features to visually narrow lanes and shoulder/curb offset widths and lateral clearances, rather than physically reducing their dimensions. Physical reductions in lanes, shoulder/curb offsets and lateral clearance widths can be accomplished by either moving curb and gutters in or allowing small, non-hazardous plantings to be placed closer to the traveled ways. However, careful evaluations are needed when considering such physical reductions. As mentioned elsewhere in this procedure, curbing has no re-directive capability at medium and high speeds (45 mph or greater) and can destabilize vehicles or cause them to vault traffic barriers.

1.4 Medians

Types of medians and their recommended designs are addressed below and on pages 7-30 – 7-34, GDHS 2011[3].

Medians for urban streets are designated as either curbed or flush.

Except at intersections, obstacles in medians that cannot be installed with breakaway supports, such as bridge piers, should be either shielded with attenuators or traffic barriers, or be removed.

For guidance on median openings and median widths where left-turn bays will be installed, refer to FDM 11-25 particularly FDM 11-25-2, "Design Criteria and Guidelines", FDM 11-25-5, "Left-Turn Lanes" and FDM 11-25-20, "Median Opening". The minimum median widths required for U-turns are shown in Table 9-30, p.9-166, GDHS 2011[3].

Indicated widths of medians referred to in this procedure are based on the definition appearing in the GDHS, which is "the dimension between through lane edges and includes the left shoulders, if any."

1.4.1 Curbed Medians

The median edges usually consist of 1 to 2-foot gutters and six-inch high vertical or sloped face curbs (see SDD for curb and gutter details).

Several choices are available as to the treatment of the median areas between the curbs. They can be raised or depressed and covered with grass, artificial turf, gravel, paved with asphaltic or P.C. concrete, etc. Selected

treatments will vary depending primarily on drainage considerations and pavement slopes, with secondary consideration of aesthetics, plantings, etc.

If the median areas are crowned, low-side median curb and gutters (gutters slope toward curbs) are generally used. These assume that the roadways are also crowned and the driving lanes adjacent to the medians drain toward the medians. Use low-side curb and gutters in super-elevated areas, also.

For projects where all roadway lanes pitch to the outsides, use depressed medians and high-side curb and gutters (gutters slope away from curbs).

Designs utilizing low-side curb and gutters are best as they tend to minimize the wet and slippery conditions caused by snow melt.

1.4.2 Flush Medians

Two types of flush medians are available:

1. The first is truly flush with the edges of driving lanes on either side. (Figure 7-4 B, page 7-20, GDHS 2011[3]). They are delineated by either painting or paving with contrasting types of pavement.
2. The second types of flush medians consist of slightly raised pavements, normally having corrugated surfaces.

On streets with numerous businesses, raised medians restrict access and force drivers to make U-turns at median openings to reach their destinations. With flush medians, the center lanes can be reserved for vehicles making left turns from both directions. For more information on two-way left-turn lanes refer to FDM 11-25-5.

1.4.3 Low Speed Urban Roadways

Medians are included on two-way streets in Design Classes 4 and 5 (see Attachment 1.2 and Attachment 1.3). Curbed medians are to be as wide as practical, with 30 feet normally being the upper width. When crossing traffic is a factor, curbed medians should not be less than 24 feet. Lesser widths down to 14 feet are appropriate when there are predominantly left-turning movements and few cross-traffic vehicles. Curbed median widths less than 14 feet are adequate to provide for separation and prevent conflicts between vehicles traveling in opposite directions.

1.4.4 Transitional and High Speed Urban Roadways

Medians are included on two-way streets in Design Classes UCL5 and UA3 (see Attachment 1.6). The narrowest median widths provided on these roadways should be 30 feet for the following reasons:

- Provides minimal clear zone in one direction for up to 60 mph design speeds
- Provides the narrowest widths needed to meet the operational requirements of cable-guard and other median roadside safety barriers that may be needed to prevent or eliminate cross over crashes.
- Provides reasonable widths for semi-trailer trucks to safely cross medians in single crossing maneuvers (includes crossing the adjacent traffic lanes, medians and either into or across the far side traffic lanes). For semi-trailer trucks to cross in multiple stages by storing in the medians, requires median storage widths of 80 feet or greater.

1.5 Travel Lanes

The number and width of travel lanes for each design class are shown in Attachment 1.1 and Attachment 1.5. For low-speed urban roadways (Attachment 1.1) threshold traffic volumes are given in the tables for LOS C, D and middle E for typical “worst case” and typical “best case” scenarios and for transitional and high speed urban roadways (Attachment 1.5) threshold traffic volumes are given based on the FDM 11-5-3 level of service triggers.

The intent of the threshold volumes is to indicate when incremental improvements or capacity improvements might need to be considered. For the low-speed urban roadways, the “worst case” and “best case” thresholds provide a range of capacities based on a range of possible geometric and operational features.

The “worst case” scenario thresholds are based on roadways that contain typically the worst, capacity-reducing features such as narrow lanes, high turnover parking stalls, no exclusive turn lanes, poor access control, poor signal timing and coordination, etc. The “best case” scenario thresholds are based on roadways containing typically the best, capacity increasing features such as wide lanes, no parking stalls, exclusive turn lanes, good access control, good signal timing and coordination, etc.

If the projected traffic volumes are below the “worst case” thresholds, then the highways will most likely operate sufficiently under their current configurations; if the projected traffic volumes are above the “best case” thresholds, then additional lanes or other major improvements are most likely needed; and if the projected traffic

volumes fall between the "worst case" and "best case" thresholds, then traffic analyses are needed to individually evaluate each project's capacity, level of service and necessary incremental improvements. See FDM 11-5-3 for use of meta-manager data or whether project specific traffic analyses need to be completed.

For transitional and high speed urban roadways, the thresholds are based on typical geometric and operational features. When the thresholds for transitional and high-speed urban roadways are exceeded, consider adding travel lanes or other improvements such as passing lanes or climbing lanes.

Consider the use of physically narrower lanes where no safety issues exist and where limitations are imposed by topography, right-of-way, social/environmental impacts or when costs significantly outweigh benefits; but only when appropriate analyses have been completed on the effects on traffic safety and capacity.

Lane widths for Federally Designated Long Truck (i.e. the "National Network" as defined in 23 CFR Part 658) routes are 12-foot (11-foot minimum), but there shall be at least one 12-foot lane in each direction. Lane widths for NHS Routes and Arterials and Collectors that are not Federally Designated truck routes are 12-foot (11-foot minimum if truck and bus volumes exceed an average of 200/lane/day for undivided roadways and 300/lane/day for divided roadways) (e.g., the threshold for urban design class 3 (4-lane undivided) is 4 x 200 = 800 trucks per day; the threshold for urban design class 4 (4-lane divided) is 4 x 300 = 1,200 trucks per day).

Wide curb lanes (aka "wide outside lanes" or "wide outside thru lanes") are outside curb lanes that are wider than 12-feet. The widths of wide curb lanes are equal to the lesser of the distances from the lane lines to the curb flange lines or from the lane lines to 1-foot inside the curb faces. The outside thru travel lanes are part of the wide curb lanes (travel lane widths do not exceed 12-feet). The use of wide curb lanes as bicycle accommodations is discussed in FDM 11-46-15.3.3 and in the Wisconsin Bicycle Facility Design Handbook[4].

If there is room for single lanes in the center of undivided two-way streets, then they may be:

1. Marked for traffic in one direction if the volumes are always heavier in that direction. These would be considered travel lanes.
2. Marked as reverse flow lanes if the heavy direction of flow changes during the day. These would be considered travel lanes.
3. Used for left-turn storage and paved with contrasting materials or conspicuously marked if there is a large percentage of turns at many intersections. These would *not* be considered travel lanes. (Note: two-way left-turn-lanes (TWLTLs) need to be 14-16 feet wide - see FDM 11-25-5).

Reverse flow lanes can generally be considered when right-of-way is restrictive, and more than two-thirds of the peak-hour traffic flows are in opposite directions daily. More than one lane may be designed to carry reverse flow traffic if needed (refer to pages 7-48 – 7-50, GDHS 2011[3]).

1.6 Auxiliary and Parking Lanes

Urban roadway widths over and above that required for traffic lanes (typically 36 feet Fc - Fc) are frequently necessary (or useful) to accomplish the following urban needs:

1. Enable two-way arterial traffic to bypass disabled vehicles.
2. Allow for safer entrances and exits from intersections and driveways.
3. Maintain greater separation between pedestrians and moving vehicles when sidewalks abut curbs.
4. Maintain greater separation between bicyclists and moving vehicles.
5. Enable turning movements to be accomplished by trucks or buses minimizing or eliminating encroachments on opposing traffic lanes.
6. Provide temporary storage areas for snow.
7. Provide storage spaces for turning vehicles.
8. Provide for parking.

When parking must be accommodated, the additional roadway widths required for this purpose more than suffice for all the other items in the preceding listing. Designs that include parking lanes are typically discouraged. It is preferable that street widths be selected such that design year traffic volumes will justify all lanes to function as live traffic lanes. Parking can then be permitted until the lanes are needed for traffic.

Parallel parking is an added benefit for adjacent businesses, but results in reductions in capacity, especially

[4] Wisconsin Bicycle Facility Design Handbook: http://wisconsindot.gov/Documents/projects/multimodal/bike/facility.pdf

during peak traffic times. Studies of street capacity have found that curb parking reduces capacity by 1/4 - 1/3 or more on typical streets. The areas occupied by parked vehicles are not available for traffic movements. The effect on capacity and service volumes is thus equivalent to reductions in effective widths of at least 8 feet. Additionally, in areas of heavy parking turnover, sporadic interruptions in the adjacent lanes will result from vehicles entering or leaving parking spaces. When capacity problems exist, consider removing all on-street parking, when possible. Parking can interfere with emergency and service vehicles such as: police, fire, ambulance, trash collection and water utilities. On-street parking can also be a major contributing factor to traffic crashes because of improperly or illegally parked vehicles and pedestrians entering streets from between parked vehicles.

In the cases of arterials, design year traffic volumes may be high enough to require the parking lanes to ultimately act as live traffic lanes on either a part-time or full-time basis. If parking lanes are used as travel lanes, then the widths of these travel lanes do not include the gutter widths. These travel lanes become the outside travel lanes and their outside edges are considered the edges of the traveled ways.

Regardless of whether the anticipated ultimate uses are for parking or driving, wider parking lanes are desirable in commercial areas. See Table 1.4 below.

Table 1.4 Parking Lane Widths to Accommodate Parallel Parking

Roadway Type	(Width Including Gutter)	
	Upper	Lower*
Arterial Street (or Collector in commercial area)	12 feet	7 feet
Collector (non-commercial area)	8-10 feet	7 feet
Local Street	8 feet	7 feet

** See FDM 11-46-15.3 for bicycle accommodations with parking.*

Consider restricting parking near intersections for the purposes of:

- increasing sight distances, both for vehicles and pedestrians (see FDM 11-10-5.1.4.1.3 and FDM 11-10 Figure 5.3)
- reducing conflicts for turning traffic,
- providing bus storage or loading zones, and
- Complying with state and local regulations.

See pages 7-47 and 9-88, GDHS 2011[3] for parking restrictions at intersections.

1.6.1 Angle Parking

Various studies have shown that angle parking is particularly unsafe and is to be replaced with parallel parking, if possible. Angle parking presents problems because of the varying lengths of vehicles and the sight distance problems associated with vans and recreational vehicles.

Angle parking requires much wider parking lanes than parallel parking. Lane widths of 15 to 20 feet are required depending on the degrees of angles used.

Do not use angle parking, except in the following situations.

1. On low-volume local streets which have adequate widths to safely accommodate this type of parking
2. The additional parking is absolutely needed for the economic stability of the local communities.

Typical situations when angle parking may become an issue is when street improvements are planned and angle parking already exists. In these cases, review crash records to assess the safety impacts of this type of parking before allowing it to continue.

When angle parking is determined to be required, treat it as a Design Justification and document it accordingly. Documentation is to include crash analyses, posted speeds, street widths, traffic volumes and discussions of why the parking is necessary to the economic stability of the communities to retain it.

1.6.2 No Parking

When provisions for parking are unnecessary, use the roadway widths for the no-parking conditions given in Attachment 1.1. However, if the roadways are two-lane STHs or Connecting Highways, and no provisions for

parking are to be made, total widths of 36 feet from faces to faces of curbs are recommended. These widths will provide all the needs previously listed under the Auxiliary and Parking Lanes section, except parking. If parking is to be permitted on one side only, consider providing total widths greater than 36 feet only when there are reasonable chances of needing additional traffic lanes within the foreseeable future.

1.7 Borders

See FDM 11-46-5.2.

1.8 Slopes and Ditches

In urban areas where roadways are designed to match the existing properties at the street right-of-way, slopes (widths) are usually kept to minimums. If the roadways do not match abutting properties, the choices are to acquire permanent right-of-way (acquire in fees or easements), or temporary construction permits, or build retaining walls when close structures do not permit the use of adequate slopes. See pages 514-515, GDHS 2004[5] and the Wisconsin LRFD Bridge Manual[6] for guidance in the use of retaining walls.

When the depths of cuts or fills are about 5 feet or above, permanent right-of-way (acquired in fees or easements) are typically required to have permanent rights to maintain the slopes. For lesser heights where it is only necessary to construct the slopes and "dress up" the adjacent lands, temporary limited easements are obtained.

Flatten and shape slopes to fit the existing topography, and to provide pleasing, natural appearances consistent with effective erosion control and adequate drainage.

Generally, ditches that are parallel to streets (roadside ditches) are not required in urban areas. However, if ponding is anticipated adjacent to fill sections, or if the natural sheet flows are interrupted because of the streets, place inlets in the ponded areas, or construct roadside ditches to drain the ponded areas (use longitudinal ditch slopes of 0.5% or steeper).

1.9 Clearances for Urban Roadways

Definitions and guidance for Lateral Clearances and Clear Zones can be found in FDM 11-15-1. As mentioned there, the distinction between lateral clearance and clear zone is that is that lateral clearance is for the benefit of vehicles on the roadway, and clear zone is for the benefit of vehicles that errantly leave the roadway.

The Department has adopted OSOW High Clearance Routes with the objective of minimizing overhead constraints for OSOW vehicles along these routes. OSOW High Clearance Routes may traverse through communities. Refer to FDM 11-10-5.4.3 for further vertical clearance guidance along the high clearance routes. See FDM 11-20-1.9.5 for guidance applying to traffic signal supports. See FDM 11-25-40.1 for guidance applying to railroad signals.

1.9.1 Lateral Clearance for Urban Roadways

Lateral clearances are important to provide on all roadways. On urban roadways without roadside barriers, lateral clearances should be provided from the edges of driving lanes to at least a small distance behind the faces of curbs. On urban roadways with roadside barriers, provide the required lateral clearances between the edges of driving lanes and the faces of the barriers. Table 1.5 and Attachment 1.7 show lateral clearance design criteria.

Street parking may be unrestricted, restricted, or prohibited. On streets with prohibited or restricted parking, the outer lanes are available to carry moving traffic.

On streets with unrestricted parking, the driving lanes will have sufficient lateral clearances because they are offset from the faces of curbs by the widths of the parking lanes. However, lateral clearance offsets must still be provided behind the faces of curbs to reduce interference with parked vehicles.

Do not place roadside barriers adjacent to parking lanes. Install roadside barriers so they meet the lateral clearance design criteria and the guidance in FDM 11-15-1.13.1.3, i.e. the curb faces are either flush with or behind the faces of beam guard railings.

[5] A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004
[6] WisDOT LRFD Bridge Manual: http://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/strct/bridge-manual.aspx

***Table 1.5* Lateral Clearance from Edge of Driving Lane for Modernization of Urban Streets [A]**

Parking Condition	Urban Roadway Type	WITHOUT roadside barrier [B]	WITH roadside barrier at curb face[C]
With Parking	ALL	**Parking lane width + 4-feet** [D] (Lower Value) (Parking lane width + 2 feet [D])	**Should not allow parking where roadside barrier is used**
Without Parking	HIGH SPEED and TRANSITIONAL	**The Larger of** **6 feet** ***OR*** **the offset from edge of driving lane** **to face of curb + 4 feet [E]** (Lower Value) (The offset from edge of driving lane to face of curb + 2 feet [E])	**The Larger of** **6 feet** ***OR*** **the offset from edge of driving lane** **to face of curb[E]** (Lower Value) (The GREATER of 1.8 feet *OR* the offset from edge of driving lane to face of curb[E])
	LOW SPEED AND TURNING LANES	**The Larger of** **4 feet** ***OR*** **the offset from edge of driving lane to face of curb + 2 feet [E]** (Lower Value) (The offset from edge of driving lane to face of curb + 2 feet [E])	**The Larger of** **4 feet** ***OR*** **the offset from edge of driving lane to face of curb[E]** (Lower Value) (The GREATER of 1.8 feet *OR* the offset from edge of driving lane to face of curb[E])

A. Applies to all fixed objects other than mailboxes. Clearances to mailboxes are based on the guidelines from Chapter 11 of the 2006 AASHTO Roadside Design Guide[7], titled "Erecting Mailboxes on Streets and Highways."

B. Lateral clearances extend behind the curb faces.

C. Lateral Clearances should be provided to the faces of barriers, but do not extend behind them. Other offsets behind barriers or curb faces may apply. Also, consider the potential deflections of the roadside barriers (see FDM 11-45).

D. Parking lane widths include gutter widths.

E. Include gutter widths - see this Procedure for guidance on offsets from edges of driving lanes to faces of curbs.

1.9.2 Clear Zones for Urban Roadways

Clear zones are important in urban and transitional roadways. Nationally in 2010, 42% of fixed object fatalities occurred in urban areas (Insurance Institute for Highway Safety). In another study, 48% of run off the road fatalities, occurred at speeds less than 50 mph.

[7] Roadside Design Guide, 3rd edition. AASHTO, Washington, DC, 2006

Because of this, clear zones on urban roadways are important. However, there may be trees, utility poles, utility cabinets, or other fixed objects within the clear zones, which are impractical to remove or shield. That, along with limited right-of-way, generally makes it more difficult to provide clear zones on urban roadways than on rural roadways.

The 2011 Green Book[3] indicates the following:

- "Where establishing a full-width clear zone in an urban area is not practical due to right-of-way constraints, consideration should be given to establishing a reduced clear zone or incorporating as many clear-zone concepts as practical, such as removing roadside objects or making them crashworthy"[3], page 4-15).
- "On curbed facilities located in transition areas between rural and urban settings there may be an opportunity to provide greater lateral offset in the location of fixed objects." [3], page 7-37).

In the past, there has been much confusion over what clear zones are required for urban or transitional roadways. The 2011 AASHTO Roadside Design Guide[2] has provided the following clarifications:

- "This minimum lateral offset was never intended to represent an acceptable safety design criteria, though sometimes it has been misinterpreted as such. In a constrained urban environment, there is still a need to position rigid objects as far away from the active traveled way as possible."

A common misconception about urban roadways is that curbs act as barriers that help prevent vehicles from leaving the roadways. Slope faced curbs have no re-directional capabilities and vertical faced curbs have only limited re-directional capabilities and only at low speeds (approximately 25 mph or lower).

***Table 1.6* Recommended Clear Zone for Modernization of Urban**

Low Speed (40 mph posted speed or less)	Transitional (45 mph posted speed) - (By Level Of Development)			**High Speed (50-55 mph posted speed)**
	Developed	Developing	Undeveloped	
Provide clear zones to the extent practical	Provide clear zones to the extent practical	Provide rural clear zones until developments occur. See FDM 11-15 Attachment 1.9 and FDM 11-15 Attachment 1.10	Provide rural clear zones. See FDM 11-15 Attachment 1.9 and FDM 11-15 Attachment 1.10	Provide rural clear zones. See FDM 11-15 Attachment 1.9 and FDM 11-15 Attachment 1.10

Practical clear zones can depend on many different variables. Review FDM 11-45-20, and FDM 11-45-30 for additional discussion.

1.9.3 Additional Guidance for Treatment of Fixed Objects - Low Speed Urban (40 mph posted speed or less), With or Without Parking

Place light poles beyond the lateral clearances. Breakaway light poles are generally the preferred light pole installation in developed areas. However, non-breakaway light poles are acceptable to install in the following situations.

- Downtown streets with commercial buildings behind sidewalks.
- Where there is a preponderance of other non-breakaway features such as trees, or street furniture.
- Where ornamental poles are used which cannot be made breakaway.
- At locations that are frequented by high concentrations of pedestrians, and where the likelihood of poles coming down on pedestrians is high, e.g. bus stops.
- Playgrounds.

1.9.4 Additional Guidance for Treatment of Fixed Objects - Transitional (45 mph posted speed) and High-Speed Urban (50 mph posted speed or greater)

Curbs are ineffective at redirecting errant vehicles at these speeds. Therefore, providing clear zones are more important in transitional and high-speed urban areas than in low-speed urban areas. Guidance for choosing the location of various fixed objects is provided below,

- Utility poles. The most desirable treatments are to bury utilities, or install on poles at, or as close as practical to the right-of-way line. Make accommodations in accordance with the WisDOT Utility

Accommodation Policy Manual, Chapter 96 of the State Highway Maintenance Manual[8].

- Utility junction boxes, pedestals, cabinets, and other above ground facilities. It is undesirable to locate these on the right-of-way. However, when above ground facilities are allowed on the right-of-way, place these at locations that are not vulnerable to errant vehicles and at, or as near to, the right-of-way line as practical.
- Trees. Generally, do not allow trees on constricted right-of-way. Plant trees beyond sidewalks or arrange for special treatments.
- Overhead sign supports, non-breakaway. Individual attention must be given to look for locations which may give adequate offsets. If the horizontal clearances must be less than the values prescribed in FDM 11-15-1 or if located on substantial curves, then shield with guardrail or crash cushions. Shielding may be unnecessary or undesirable under the following conditions:
    - Buildings, walls or drop-offs near curbs.
    - Interference with pedestrian movements, or potential driveway developments.
    - Sight obstructions may result.
    - Shielding themselves may be hazards.
- Light poles. State-owned light poles, and those under permits, shall comply with the lateral offset criteria in Section 11-10-1 of the Traffic Engineering operations and Safety Manual[1]. For convenience, a portion of that information is provided in Table 1.7 below.

Table 1.7 Light Pole Lateral Offsets for Transitional and High-Speed Urban

Posted Speed (MPH)	Traffic Volume (ADT)	Minimum Offset* For Rigid	Minimum Offset for Breakaway
45-50	0 - 1,500	20 Feet	**
	1,500 - 6,000	26 Feet	**
	over 6,000	28 Feet	**
55 and over	0 - 1,500	24 Feet	**
	1,500 - 6,000	30 Feet	**
	over 6,000	30 Feet	**

* *Offset distances are measured from the adjacent edges of traveled ways (through lanes), to the faces of the poles.*

** *Breakaway poles should be a minimum of 12-feet as measured from the adjacent edges of traveled ways (through lanes) in rural cross-sections. Breakaway poles should be at least 2-feet from faces of vertical curbs, or flow lines of sloping curbs, in urban cross-sections.*

1.9.5 Traffic Signal Supports

See section 6-1-3 of the Traffic Signal Design Manual (TSDM)[9] for guidance on offsets. Breakaway installations are not required per the 2006 AASHTO Roadside Design Guide[7]. Non-breakaway traffic signal supports are allowed within the clear zones. Shielding may be necessary at some locations. Consult with the Region Traffic Signal Design Engineer.

Along the Department's adopted OSOW High Clearance Routes, design traffic signals that provide minimum 20'-0" vertical clearances. Coordinate with the Region and State Traffic Signal Design Engineers during the design process.

[8] WisDOT Highway Maintenance Manual: http://wisconsindot.gov/Pages/doing-bus/local-gov/hwy-mnt/mntc-manual/default.aspx
[9] WisDOT Traffic Signal Design Manual: http://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/tsdm/tsdm.aspx

1.9.6 Railroad Warning Signs and Signals

See FDM 17-60-20 and Part 8 of the WisDOT MUTCD[10] for guidance. Consult with the Region Railroad Coordinator.

Refer to FDM 11-25-40.1 for guidance on railroad signal vertical clearances along OSOW High Clearance Routes.

LIST OF ATTACHMENTS

Attachment 1.1	Urban Streets Modernization Roadway Criteria for Posted Speed Limits of 40 mph or less
Attachment 1.2	Typical Modernization Street Cross Sections, Classes 1b, 2a, 2b & 3
Attachment 1.3	Typical Modernization Street Cross Sections, Class 4 and Class 5
Attachment 1.4	Factors Used for Highway Capacity Manual LOS Thresholds
Attachment 1.5	Transitional and High Speed Urban Modernization Roadway Criteria For Posted Speed Limits of 45 - 55 mph
Attachment 1.6	Typical Transitional / High-Speed Urban Modernization Street Cross Sections
Attachment 1.7	Lateral Clearance Criteria
Attachment 1.8	Run off the Road Frequency Calculator

FDM 11-20-5 One-Way Streets

May 15, 2019

5.1 Guidelines

Designs for one-way operations are recommended when geometrically feasible and economically justifiable. These should normally be applied when adjacent streets can be paired to carry traffic in both directions. One-way operations are most applicable when two-way operations would cause problems with heavy turning movements, when closely spaced signals make progressive signalization difficult on two-way facilities, or when directional distributions are well balanced throughout the entire day. Also, one-way pairs can sometimes be used to good advantage to provide the desired capacities through corridors without requiring extensive street reconstructions or property damage.

With the exceptions listed below, all guidelines pertaining to two-way street operations should also apply to one-way streets.

A table of roadway characteristics has not been prepared for one-way streets as was done for two-way streets; therefore, design classes, normal traffic volume ranges, and functional classifications have not been assigned. However, two-, three-, and four-lane facilities can be taken to be roughly equivalent to design classes 1, 2, and 3, respectively, as shown in FDM 11-20 Attachment 1.1 for two-way streets. Attainable traffic volumes should be computed using procedures shown in the Highway Capacity Manual (see FDM 11-5-3). Medians should not be used on one-way streets, and because of this, typical cross sections should not include more than four driving and two parking lanes.

One significant difference between one-way and two-way streets is that two adjacent lanes may be used as turning lanes in the same direction of travel from one-way streets. Before this is done, however, the following conditions should exist:

1. The movements should be onto other facilities with more than one lane operating in the directions of the completed turns.
2. The roadway cross sections beyond the intersections should be reduced in widths so that the outer lanes do not continue through the intersections. The streets beyond the intersections could be the same widths if the outer lanes are parking lanes. Preferably, the intersections should also mark the ends of the major streets.
3. Turning lanes should be well marked and lane lines should carry completely through the turning areas.
4. The movements should be adequately signed, signalized, or a combination of both.
5. Adequate lane widths should be provided throughout the radius areas of the turns to prevent lateral

[10] WisDOT Manual on Uniform Traffic Control Devices, Chapter 8: http://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/wmutcd/wmutcd.aspx

encroachments upon other lanes by the largest vehicle classes upon which the designs are based.

FDM 11-20-10 Driveways

February 18, 2020

10.1 Introduction

The purpose of this section is to provide guidance on the design and construction of driveways.

There are four types of driveways outlined in the Wisconsin Administrative Code TRANS 231:

- Commercial rural
- Commercial urban
- Non-commercial rural
- Non-commercial urban

TRANS 231 specifies maximum widths for urban driveways, but not minimum widths.

10.2 Driveways for Parcels

Each parcel on a highway project must be evaluated for access controls, restrictions, permits, and related items before determining the number, location, and designs of the driveways. The responsibility for this rests with the Region's Access Management (AM) Engineer or Coordinator. The project manager needs to work closely with AM staff to see that all design issues are considered during this phase of project development.

Where properties are served by single driveways that provide the only reasonable accesses to the highway system, WisDOT typically replaces the existing driveways in kind. For access management purposes, the locations of entrances may be moved or combined with neighboring property entrances. Where more than one driveway exists, or reasonable access is available from lower tier roads, the access coordinator's input should be sought regarding the possibility of closing or combining driveways to improve safety and mobility on the state highways or higher tier roads.

Additional driveways between state highways and parcels should not be added without evaluations from the Region's AM staff. Each driveway contributes to additional conflict points and may decrease mobility. TRANS 231.03(2) generally does not warrant multiple driveway entrances on state highways.

10.2.1 Access Control and Right of Way Considerations

Review existing right of way plats and real estate records to determine whether parcels are access restricted from prior acquisitions of highway access rights. It is possible that the Real Estate section may have agreed to access related matters such as driveway removals, relocations, or eliminations in the negotiations and acquisition processes.

On streets and highways with controlled access, driveways may only be located at points shown on the right of way plats, and to widths that correspond to openings in the access controls. Site topography may also influence the placements of driveways relative to horizontal and vertical criteria. Temporary limited easements (TLE) may be required to perform grading operations outside the right of way, to fit the driveway(s) to the site(s). The project manager and project engineer should perform the work and research associated with development of the right of way plats or transportation project plats.

10.2.2 Driveways at Intersections

For parcels at intersections between state highways and local roads, one driveway may be provided on each frontage of the lots, for a total of two driveways. However, if only one driveway is needed, preference should be given to locating the driveways on the side streets. The driveways provided should follow the guidance on marginal corner clearances (see FDM 11-25-2 Figure 2.10, and Table 2-7). At high traffic intersections, it may be required to limit traffic movements to right-in and right-out, by constructing raised medians. Evaluate driveways for stopping sight distances.

On corner lots, access for the properties should be obtained from the lower tier facilities. TRANS 231.03(2) limits the number of driveways serving single parcels to the minimum necessary for reasonable service to the parcels without undue impairment of safety, convenience, and utility of the highways. If reasonable service is obtained via driveways from the intersecting facilities and without driveways directly onto state highways, no driveways may be permitted or constructed on the state highways.

There are circumstances where second driveways may be appropriate, such as where the nature of traffic at the sites make it impossible to provide reasonable service with single entrances. In such cases, second entrances may be constructed, preferably onto the lower tier roads, but onto the higher tier highways, if necessary. Such occurrences may be gasoline stations.

Attention should be given to throat capacities for any proposed driveways onto state trunk highways. Any entrances should have sufficient throats to accommodate expected traffic from the state highways so that vehicles do not stop on the highways to wait for internal traffic or parking on the parcels. Consideration may also be given to limiting the direction of traffic, noted above regarding right-in, right-out driveways. Median installations and signing may also be used to restrict turns or prevent left turning maneuvers at the entrances. Turn lanes may be required or constructed where warranted by expected traffic (trips per day).

10.3 Design Criteria

Geometric elements of driveways include:

- Cross slopes
    - ADA requirements where driveways cross sidewalks
- Vertical alignments
    - Grades
    - ADA requirements where driveways cross sidewalks
    - Break-over angles
    - Vertical curves
    - Drainage considerations
- Widths
- Driveway (intersection) sight distances
- Skew angles

Urban driveways are typically relatively short with straight horizontal alignments.

10.3.1 Cross Slope and Vertical Alignment

One reference on driveways is the Guide for the Geometric Design of Driveways, NCHRP Report 659 (GGDD). This is the successor to the TRB publication Access Management Manual (AMM). Twelve (12) percent should usually be the maximum slopes of residential driveways in some references. The absolute maximum is 15 percent for residential driveways and 10 percent for commercial driveways in GGDD (Exhibit 5-67, Page 70). When the driveways have sidewalk cross slopes of 1.5 percent, the maximum slopes for the driveways beyond the sidewalks is 11.5 percent based on the 10 percent rollover / break-over criteria for crests. The range of such driveway slopes are shown in Table Z of SDD 8d19. The lower limits range from 5 to 9 percent in order to drain the adjoining terraces toward the streets.

The recommended maximum rollovers / break-overs are 9 percent for sag points (curves) in the profiles and 10 percent for crest points (curves) in profiles. These criteria are set in Exhibit 5-68 (Page 71) and Exhibit 5-75 (Page 74) of the GGDD. Rollover limits for other situations are also presented in these exhibits, depending on the types of vehicles under consideration. It should be noted that using the 9 percent criteria for sag points (curves) with gutter cross slopes of 6.25 percent, the resulting maximum upslopes are 2.75 percent for the depressed curb heads and the initial slopes of the driveway aprons (see SDD 8d18 and SDD 8d19). Correspondingly, the maximum upslopes are 5 percent with gutter cross slopes of 4 percent.

One additional slope related criterion is the use of 1.5-inch lips in the curb and gutters at points where the curbs tie into driveway aprons. This condition is constructed for drainage purposes of the design flows. These lips are generally okay for vehicles, but not where bicycles and wheel chairs use the driveways for access to buildings or sidewalks. The wheel chairs can tip over if the 1.5-inch lips are encountered. Bicycles may also have similar problems with vertical lips. The lips are also a problem for snowplows. As such, it is recommended that the lips not be vertical, but rather be transitioned at 2.75 percent over the 6-inch depressed curb heads. This is shown on SDD 8d19.

10.3.1.1 Cross Slope and Vertical Alignment - ADA

Restrictions on driveways include those related to the Americans with Disabilities Act (ADA) and the Public Right of Way Accessibility Guidelines (PROWAG). They cover the interactions of street cross slopes and sidewalk cross slopes with driveway profiles, all being along the same alignments. The maximum sidewalk cross slope according to these laws and regulations is 2 percent. For construction administration purposes, WisDOT has set the sidewalk cross slope limit to be 1.5 percent with a construction tolerance of 0.5 percent, plus or minus. This is set to avoid the situations where the constructed cross slopes do not comply with the PROWAG maximums of 2 percent.

For driveways with crossing sidewalks, the maximum sidewalk ramp slope tying into driveways (in line with the sidewalk profile alignments and perpendicular to the driveway cross slopes) is set as 8.33 percent (12 to 1). According to PROWAG, this applies for maximum distances of 15 feet. This information is shown on the Type X

and Type Y driveway details included in SDD 8d18. When applying the 15-foot criteria, the running profile slopes of the sidewalks should be as flat as feasible and not exceed the longitudinal profile grades of the streets or highways. This is to avoid chasing steep slopes indefinitely when fitting the sidewalks to the sites. The Type X detail is for driveways with sidewalks directly abutting the curb and gutters, and Type Y is for driveways with narrow terraces, of 4 to 6 feet. SDD 8d19 shows a Type Z driveway with a wider terrace, of 7 to 12 feet.

10.3.2 Width of Driveways

Provide 12-foot lower minimum widths for non-commercial, residential and field driveways and 16-foot lower minimum for commercial even if the existing driveways are narrower beyond the right of way lines. Do not provide more than 24-foot for non-commercial, residential and field driveways or 35-foot commercial driveways even if the existing driveways are wider.

Select driveway widths based on lower minimum and maximum criteria as compared to the existing driveway widths for perpetuation, rehabilitation and reconstruction-modernization projects. For new construction-modernization, select driveway widths based on lower minimum and maximum criteria.

There are exceptions. For example, it may not be practical to provide 12-foot wide driveways for narrow cemetery entrances. In addition, driveway aprons for buildings housing fire departments or combined EMS facilities may require larger widths to accommodate all of the bays.

10.3.3 Driveway Sight Distance

Sight distances should be checked using intersection sight distance (ISD) criteria found in FDM 11-10-5.1.4. The presence of parking needs to be taken into consideration as well.

10.3.4 Driveway Skew

The range of allowable skews is recommended to be the same as for intersections. This is shown in SDD 8d20. The allowable ranges are from 70 degrees to 110 degrees, with respect to the centerlines of the streets or highways.

10.4 Driveway Pavement Materials

There are three material types typically used for driveways and field entrances:

- non-reinforced Portland cement concrete,
- asphaltic surface, or
- aggregate.

Paving driveways within the right of way is done to limit the tracking of soil and loose materials onto the lanes and shoulders of the roadways.

For urban driveways, Portland cement concrete pavements (hereafter referred to as concrete pavements) are typically used for constructing the portions of driveways within the right of way. Asphaltic surfaces are acceptable, except for the portions of the driveways that are considered parts of the sidewalks, which should be concrete. Beyond the right of way lines, match the types of materials in the existing driveways.

The lower minimum thicknesses of concrete driveways are 6 inches, with 6-inch base aggregate courses. The bid items used can be dense or open graded, depending on the types of bases used on the mainlines. If the mainline pavements are 9 to 12 inches, calculate the pavement thicknesses for the driveways using WisPave and site-specific soil conditions, as well as delivery traffic information from the land owners, store owners, or developers.

The lower minimum thicknesses of asphaltic surfaces on driveways and field entrances should be 2 to 3 inches, with a lower minimum of 6 inches of base aggregate (dense or open graded). The lower minimum thicknesses of aggregate surfaces on driveways is 6 inches. For heavy trucks, these thicknesses may need to be increased per WisPave. They also may need to be increased for clay subgrades and other low strength soils. Confirm any increases with the regional pavement engineer.

10.5 Plan Preparation

Evaluate driveway profiles using the vertical concepts shown on Attachment 10.1. Driveway concepts for Type X, Type Y, and Type Z are presented in Attachment 10.2.

Label driveway profiles on the cross sections in the plan sets, showing the percent slopes and segment lengths. Also show the spot elevations at the edges of pavements, low points, break points, high points, the right of way lines, and TLEs.

In Attachment 10.1, typical driveways are shown with curb and gutter (urban typical) and without curb and gutter (rural typical). They are shown for the cases with an upgrade driveway and a downgrade driveway. The details show driveways with sidewalk directly abutting the curb and gutter, as well as with a driveway apron and terrace. The driveways may be composed of segments; however, vertical curves are recommended when the break-overs exceed 6 percent. Sidewalks at driveways are generally five feet wide, except where the sidewalks abut the curb and gutters. In that case, the lower minimum width of sidewalk is six feet. Driveways and shared use trails (typically 10 feet in width) can be designed and constructed with the same guidelines as 5-foot sidewalks. If the driveways have curb and gutter returns, detectable warning fields should be used where sidewalks cross the curb and gutters.

Plan preparation is required for all projects. One cross section is required for each driveway, except where the driveways are 24 feet or wider, where two cross sections should be shown. The driveway slopes should be labeled on the cross sections, and widths should be shown on the plan and profile sheets, and the miscellaneous quantity sheets. Stations and offsets should be labeled on the plan and profile sheets along with the abbreviations of PE, FE or CE (private entrances, field entrances, or commercial entrances).

SDD 8d20 shows driveways with concrete curb and gutter (i.e. urban driveways), as referenced in TRANS 231. SDD 8d20 shows driveways with acceptable skews between 70 degrees and 110 degrees. Also shown are driveways near an intersecting street and with two entrances close to each other.

SDD 8d21 shows details for driveways without concrete curb and gutter (i.e. rural driveways).

SDD 8d22 shows aggregate and asphaltic surfaced driveways on asphaltic concrete resurfacing projects, without curb and gutter.

Minimum island requirements between driveways on adjacent parcels are prescribed in TRANS 231.06. For urban commercial connections, when sidewalks are adjacent to the curbs, islands of intact curbs with lower minimum lengths of 6 feet, measured along the curb lines, are required between each entrance to state highways. When there are terraces between the sidewalks and the curbs, islands with lower minimum lengths of 10 feet measured along the right of way lines must be maintained between each entrance (see SDD 8d20). Where driveway entrances are near property lines, at least 3 feet of curbs must be left undisturbed adjacent to the property lines to serve as island areas should the adjoining property owners request permits for entrances. See TRANS 231.06 for minimum requirements for non-commercial and rural commercial connections.

LIST OF ATTACHMENTS

Attachment 10.1	Conceptual Driveway Profiles
Attachment 10.2	Driveway Design Concepts for Type X, Type Y, and Type Z

Urban Streets Modernization Roadway Design Criteria for Posted Speed Limits of 40 mph or Less

Functional Class	Design Year ADT Thresholds at Levels of Service C, D & E [1]				Design Basis	Roadway Criteria [9]						
						Travel Lanes			Roadway (Face of Curb to Face of Curb) Width (feet)[4]			
									No Parking[6,7]		Parking [6,7]	
	Scenarios	C[2] LOS 4.0 ADTs (DHVs)	D LOS 5.0 ADTs (DHVs)	Middle E LOS 5.5 ADTs (DHVs)	Urban Design Class [Design Speed] (mph)[3]	No.	Lane Widths (feet)[5]	Median Widths (feet)	Range of Normal Widths[8]	Range of Widths including Bike Accommodations/ Lanes	Range of Normal Widths[8]	Range of Widths including Bike Accommodations/ Lanes
Locals	N/A	Low Volume Residential (0-250 ADT)			1a **[20-25]**	1	**12**	No	**N/A**	**N/A**	**28**	**N/A**
		Volume not a consideration			1b **[25-30**(20)**]**	2	**10-12** (9)	No	**24-28** (22)	**32-36** (30)	**36-40** (32)	**46-56** (44)
Arterials and Collectors	N/A	≤ 4,500 ADT (660 DHV)			2a **[30-45]**	2	**11-12** (10)	No	**34-36** (24)	**34-36** (32)	**46-48** (34)	**48-56** (46)
	Worst Best	6,500 (1086) 20,000 (2260)	7,500 (1170) 22,500 (2475)	8,000 (1216) 25,000 (2700)	2b **[30-45]**	2	**11-12** (10)	No	**34-36** (24)	**34-36** (32)	**46-48** (34)	**48-56** (46)
	Worst Best	16,000-(1888) 41,000 (4100)	17,500 (2048) 47,000 (4610)	18,000 (2088) 50,500 (4900)	3 **[30-45]**	4	**11-12** (10)	No	**48-60** (44)	**56-60** (52)	**68-72** (54)	**70-80** (66)
	Worst Best	22,000 (2440) 41,500 (4110)	22,750 (2500) 47,000 (4610)	23,000 (2530) 51,000 (4950)	4 **[30-45]**	4	**11-12** (10)	**14-30** (6)	**2 @ 26-28** (2 @ 24)	**2 @ 30-32** (2 @ 28)	**2 @ 36-38** (2 @ 29)	**2 @ 37-42** (2 @ 35)
Arterials	Worst Best	35,500 (3660) 68,000 (6390)	37,500 (3790) 76,000 (7070)	38,500 (3850) 81,500 (7580)	5 **[30-45]**	6	**11-12** (10)	**14-30** (6)	**2 @ 36-40** (2 @34)	**2 @ 41-44** (2 @ 38)	**2 @ 47-50** (2 @ 39)	**2 @ 48-54** (2 @ 45)

Upper values are shown in **bold** and Lower values are shown in parentheses. Use of values below existing roadway dimensions are to be justified by completing environmental process, predictive safety and benefit/cost analyses.

See page 2 of this attachment for superscript notes.

Superscript Notes:

1 ADT thresholds represent typical "Worst" Case and "Best" Case scenarios for Levels of Service (LOS) C, D and middle E. These volumes are based on the 2000 Highway Capacity Manual using the assumptions shown in Attachment 1.4. See Section 1.5, "Travel Lanes" section for guidance on use of "worst" and "best" case thresholds. See FDM 11-5-3 for further guidance on acceptable LOS for Corridors 2030 Routes, Non-corridors 2020 rural roadways, roadways in small urban areas (Pop. < 50,000), and roadways in Urbanized areas (Pop. > 50,000).

2 LOS C is not obtainable if the traffic signal density is greater than 5 signals per-mile.

3 Design Speeds should be 5 mph greater than the posted speeds. Lower design speeds equal to the posted speed limits are acceptable if justified in the Project SCDs or DSR DJs.

4 Based on 2-foot gutter widths. Gutter widths of 1-foot may be used when appropriate. If 1-foot gutters are used, then the face-to-face widths might differ from values shown in the table.

5 Gutter widths are not included.
Lane widths for Federally Designated Long Truck (i.e. the "National Network" as defined in 23 CFR Part 658) Routes are 12-foot (11-foot minimum), but there shall be at least one 12-foot lane in each direction. Wide curb lanes, as discussed in Section 1.5, "Travel Lanes", meets the 12-foot truck lane criteria.
Lane widths for NHS Routes and Arterials and Collectors that are not Federally Designated Truck Routes are 12-foot (11-foot minimum) if truck and bus volumes exceed an average of 200/lane/day for undivided roadways, and 300/lane/day for divided roadways (e.g., the threshold for urban design class 3 (4-lane undivided) is 4 x 200 = 800 trucks per day; the threshold for urban design class 4 (4-lane divided) is 4 x 300 = 1,200 trucks per day).

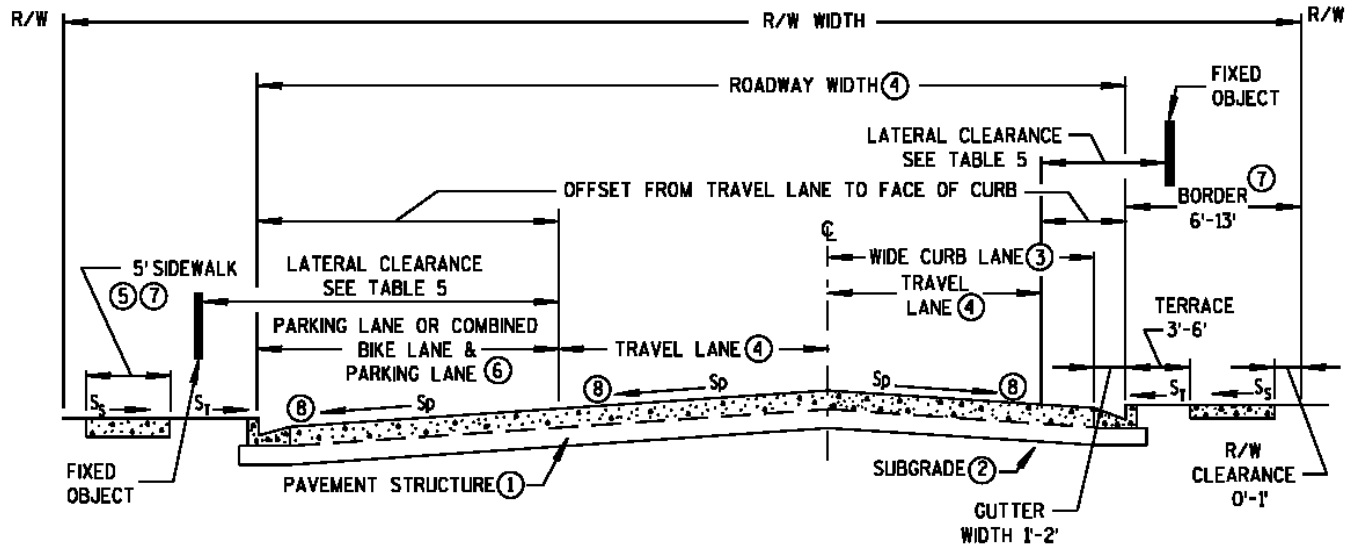
6 Two lane Connecting Highways and STHs should have curb to curb widths of 36 feet if no provisions for parking are to be made. Designs that use parking lanes are discouraged.

7 Department policy in conformance with Federal policy, Wis. Stat. Section 84.01(35) and Connections 2030 shall give due consideration to establishing bikeways and pedestrian ways on new construction and reconstruction highway projects (including pavement replacement projects) funded in whole or part from state or federal funds. FDM 11-46 provides guidance on the process and evaluation analyses. In addition, certain bicycle and pedestrian design practices are required when applicable, e.g., curb ramps and bicycle-acceptable grates.

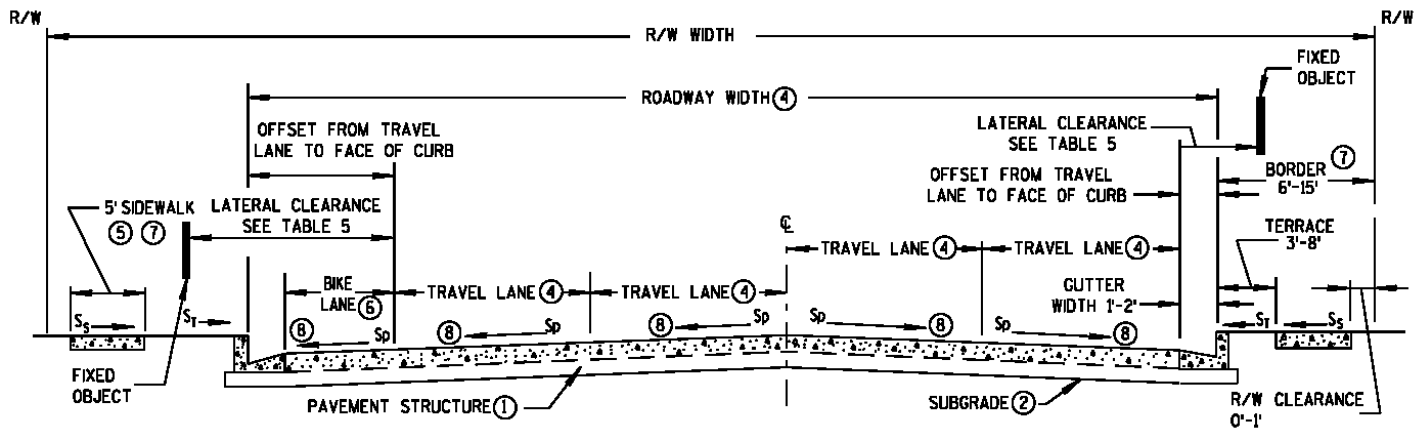
See FDM 11-46 for additional information and guidance on bicycle and pedestrian accommodations and policies.

8 The upper ranges of values include the additional roadway widths between the outside edges of the outside travel lanes and the faces of curbs to provide wide curb lanes as discussed in FDM 11-20-1.5, "Travel Lanes", or to provide for the various urban needs as listed in FDM 11-20-1.6, "Auxiliary and Parking Lanes".

9 See FDM 11-35-1.2.3 for bridge width criteria for urban roadways.



Urban Design Classes 1b, 2a & 2b



Urban Design Class 3

Notes:

① Pavement structure, materials and dimensions vary according to individual project subgrade and traffic conditions.

② Subgrade cross slopes are parallel to pavement cross slopes (S_P).

③ FDM 11-20-1.5 discusses "Wide Curb Lanes". See FDM 11-46-15.3 for limits on wide curb lane longitudinal joint placements for concrete pavement thicknesses less than 10 inches.

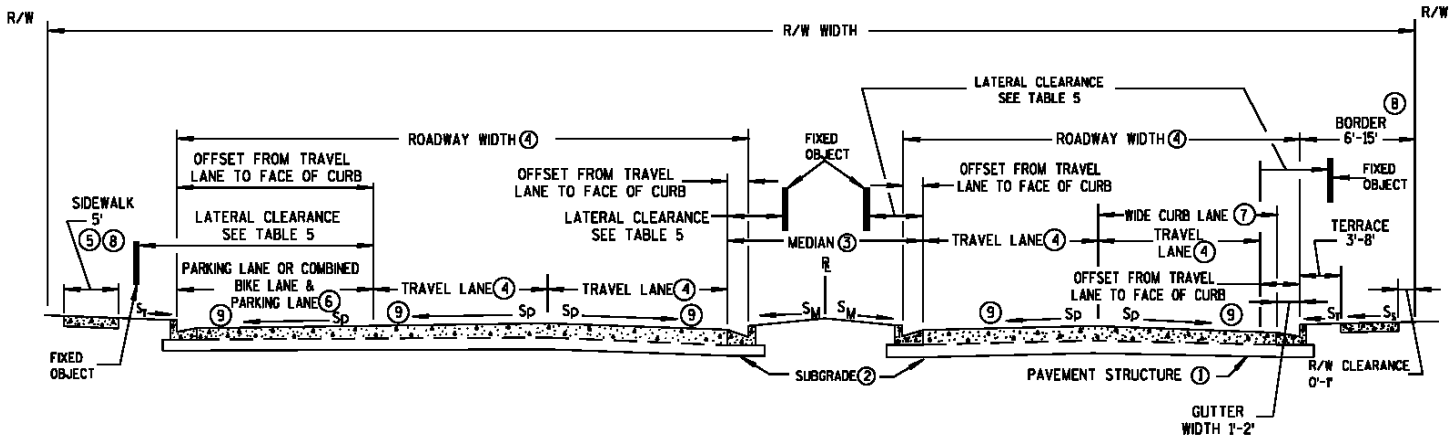
④ Attachment 1.1 shows travel lane widths and roadway widths.

⑤ The 5-foot sidewalk widths shown are for residential areas where the sidewalks are adjacent to terraces. Sidewalks are to be 6-foot wide if adjacent to the backs of curbs. Sidewalk widths are typically 6-12 feet in central business districts or in high pedestrian retail areas or where stores are directly abutting sidewalks.

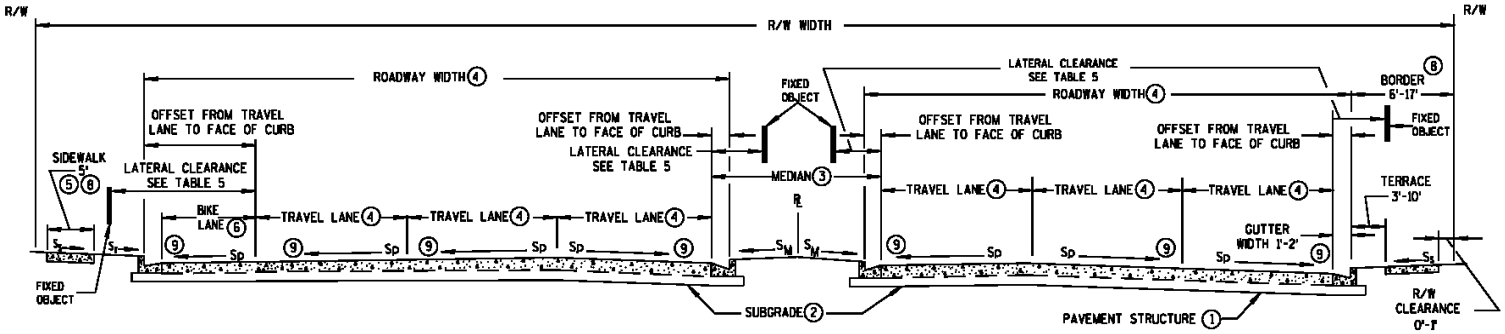
⑥ Table 1.4 shows parking lane widths; FDM 11-46-15 has guidance on bike lanes and on combined bike lanes and parking lanes; Attachment 1.1 shows roadway width design values.

⑦ FDM 11-46-5.2 (Urban Borders and Zone System) discusses borders including widths and slopes for sidewalks and terraces.
S_T = Terrace cross slopes = 4% typical. Grass = 4% lower min., Paved = 2% lower min./ 2% upper minimum when adjacent to on-street parking. See FDM 11-46-5.2.2 (Terraces).
S_S = Sidewalk cross slopes = 1.5%, $\pm$ 0.5% construction tolerance.

⑧ Table 1.1 shows pavement cross slopes.
S_P = Pavement cross slopes = 2% lower minimum.



Urban Design Class 4



Urban Design Class 5

Notes:

① Pavement structure, materials and dimensions vary according to individual project subgrade and traffic conditions.

② Subgrade cross slopes are parallel to pavement cross slopes (S_P).

③ FDM 11-20-1.4 (Medians), discusses medians for urban streets. Attachment 1 shows the range of median widths to use.
S_M = Median cross slopes = 2% (paved) / 4% (grass)

④ Attachment 1.1 shows travel lane widths and roadway widths.

⑤ The 5-foot sidewalk widths shown are for residential areas where the sidewalks are adjacent to 3 foot or wider terraces. Sidewalks are to be 6-foot wide if adjacent to terraces less than 3-foot wide. Sidewalk widths are typically 6-12 feet in central business districts or in high pedestrian retail areas or where stores are directly abutting sidewalks.

⑥ Table 1.4 shows parking lane widths; FDM 11-46-15 has guidance on bike lanes and on combined bike lanes and parking lanes.

⑦ FDM 11-20-1.5 (Travel Lanes) discusses “Wide Curb Lanes”. See FDM 11-46-15.3 for limits on wide curb lane longitudinal joint placements for concrete pavement thicknesses less than 10 inches.

⑧ Refer to FDM 11-46-5.2 (Urban Borders and Zone System).
S_T = Terrace cross slopes = 4% lower minimum for grass. 2% lower minimum for paved/ 2% upper minimum when adjacent to on-street parking.
S_S = Sidewalk cross slopes = 1.5%, $\pm$ 0.5% construction tolerance.

⑨ Table 1.1 shows pavement cross slopes.
S_P = Pavement cross slopes = 2% lower minimum.

Urban Class	Traffic Factors	Lane Width (feet)	% Trucks	Parking/Bus Stops	% Grade	Adjusted Saturation Flow Rate (pcphgpl)	% Turns from Exclusive Lanes	Number of Through Lanes One Direction	Free Flow Speed (FFS)	HCM Urban Class	Median	Left-turn Bays	Number of Signalized Intersections (Actuated)	Arrival Type	Cycle Length (C)	Effective Green Ratio (g/c)
2b																
Worst Case	K30	10	6	Yes	4	1700	10	1	35 30 30	3 4 4	No	No	1 4 7	3 4 4	80	0.45
Best Case	59/41 Directional Distribution 1.00 PHF	12+	2	No	0	1900	10	1	35 30 30	3 4 4	No	Yes	1 4 7	4 5 5	110	0.55
3																
Worst Case	K30	10	6	Yes	4	1700	10	2	40 35 30	2 3 4	No	No	1 4 7	3 4 4	90	0.40
Best Case	59/41 Directional Distribution 1.00 PHF	12	2	No	0	1900	10	2	40 35 30	2 3 4	No	Yes	1 4 7	4 5 5	110	0.50
4																
Worst Case	K30	10	6	Yes	4	1700	10	2	40 35 30	2 3 4	Yes	No	1 4 7	3 4 4	90	0.45
Best Case	59/41 Directional Distribution 1.00 PHF	12	2	No	0	1900	10	2	40 35 30	2 3 4	Yes	Yes	1 4 7	4 5 5	110	0.50
5																
Worst Case	K30	10	7.5	Yes	4	1700	10	3	40 35 30	2 3 4	Yes	No	1 4 7	3 4 4	90	0.45
Best Case	59/41 Directional Distribution 1.00 PHF	12	4	No	0	1900	10	3	40 35 30	2 3 4	Yes	Yes	1 4 7	4 5 5	110	0.50

Design Class[1]	Design ADT	No. of Lanes	Lane Widths By Posted Speed[2]		Median Width[3]	Shoulder (Curb Offset) Width Based on Posted Speed[4]					Recommended Clear Zone or Lateral Clearance Based on Posted Speed Limit			
						45 mph (By Level of Development)			50-55 mph	Bike Lanes[5]	45 mph (By Level of Development)			50-55 mph
			45-50 mph	55 mph		Undeveloped	Developing[5]	Developed[5]			Undeveloped	Developing	Developed	
Collectors & Locals											Provide Rural Clear Zone. See FDM 11-15 Attachment Att.1.9 Consult with Local Unit of Government or Maintaining Authority as to need for future sidewalk and terraces.	Provide Rural Clear Zone until development occurs. See FDM 11-15 Attachment 1.9 & FDM 11-20-1 Coordinate sidewalk and terrace widths with local unit of government or maintaining authority.	Provide lateral clearance per FDM 11-20 Table 1.5. If sidewalk is not present, discuss construction of sidewalk and terrace with the local unit of government or maintaining authority.	Use rural clear zone. See FDM 11-15 Attachment 1.9.
UCL1	0-400	2	**11-12** (10)	**11-12** (10)		**2** (1.8)	**2** (1.8)	**2** (1)	**2**	**5**				
UCL2	400-1500	2	**11-12**	**11-12**		**6** (5)	**6** (1.8)	**4-6** (1-1.8)	**6**	**5-6**				
UCL3	1500-2000	2	**11-12**	**12**		**6**	**6** (1.8)	**4-6** (1-1.8)	**6**	**5-6**				
UCL4	2000-3500	2	**12**	**12**		**6**	**6** (1.8)	**4-6** (1-1.8)	**6**	**5-6**				
UCL5	3500-20,000	2	**12**	**12**		**8**	**8** (1.8)	**4-8** (1-1.8)	**8**	**5-8**				
	20,000-42,000	4	**12**	**12**	30	**6L** (4L) **10R**	**6L** (1.8L) **10R** (1.8L)	1.8-6L 4-10R	**6L** **10R**	10				
Arterials														
UA1	Under 3500	2	**12**	**12**		**6**	**6** (1.8)	**4-6** (1-1.8)	**6**	5-6				
UA2	3500-17,000[A] 3500-19,000[B]	2	**12**	**12**		**10** (8)	**10** (1.8)	**4-10** (1-1.8)	**10 (8)**	10				
UA3	17,000-39,000[A] 19,000-42,000[B]	4	**12**	**12**	30	**6L** (4L) **10R**	**6L** (1.8L) **10R** (1.8R)	**1.8-6L** (1L) **4-10R (1-1.8R)**	**6L (4L)** **10R**	10				
		6	**12**	**12**	30	**10L and 10R**	**10L and 10R** (1.8L & 1.8R)	**1.8-10L** **4-10R (1-1.8R)**	**10L &** **10R**	10				
See FDM 11-35-1.2.3 for bridge width criteria for urban roadways.											Lateral Clearance is important to provide on all roadways			

Upper values are shown in **bold** and Lower values are shown in parentheses.

See page 2 of this attachment for superscript notes.

NOTES:

A For Corridors 2030 Backbone and Connector Routes.

B For Other Principal and Minor Arterials.

1 The top of the traffic volume range for design class UA2 is 17,000 ADT and for design class UA3 is 39,000 ADT for Corridors 2030 Routes (LOS threshold of 4.0) and 19,000 ADT and 42,000 ADT for a Non-corridors 2030 Routes (LOS trigger of 5.0). These volumes are based on the 2000 Highway Capacity Manual assuming; level terrain, 12-foot lanes, ≥ 6-foot shoulders, 10% trucks, K30 design factor, and 59/41 directional split,1 signal/mile, g/c=.55. See FDM 11-5-3 for additional information on thresholds and levels of service for different facility types and the respective numerical values.

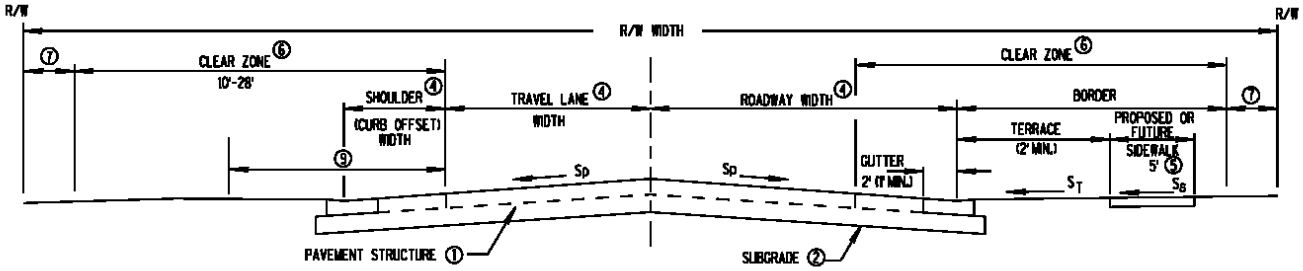
2 Design Speeds should be 5 mph greater than the posted speeds. Lower design speeds equal to the posted speed limits are acceptable if justified in the SCDs or DSR DJs.

3 Provides room for clear zones in one direction for up to 60 mph design speeds and for future cable-guard median barriers. Provides Upper width needed for single movement truck turning maneuvers.

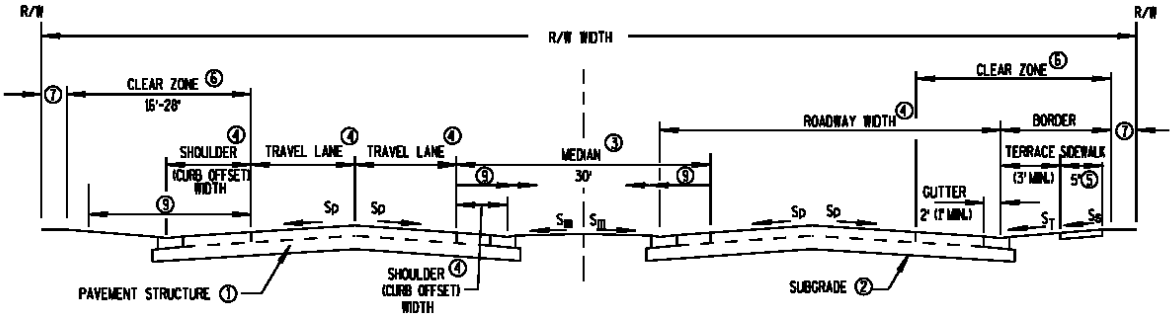
4 Curbs should be eliminated if possible. Use sloped curbs when posted speed limits are 45 mph or greater. See FDM 11-20-1.

5 Department policy is in conformance with Federal policy, Wis. Stat. Section 84.01(35) and Connections 2030 shall give due consideration to establishing bikeways and pedestrian ways on new construction and reconstruction highway projects funded in whole or part from state or federal funds. FDM 11-46 provides guidance on the process and evaluation analyses.

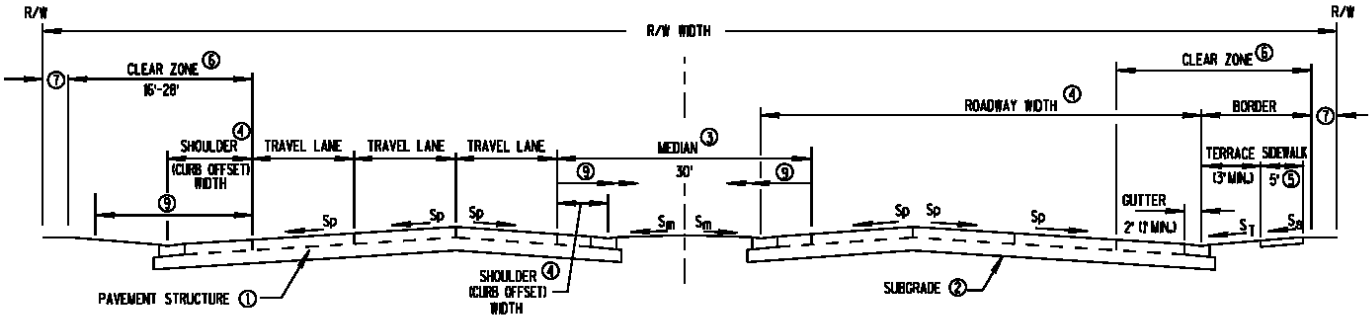
In addition, certain bicycle and pedestrian design practices are required when applicable, e.g., curb ramps and bicycle-acceptable grates.
See FDM 11-46 for additional information and guidance on bicycle and pedestrian accommodations and policies.



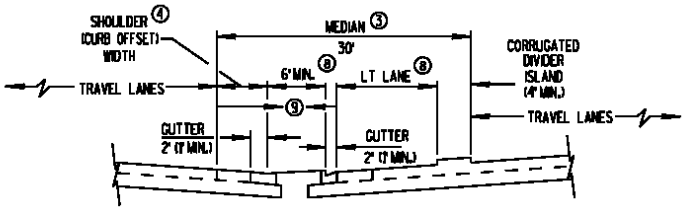
2-LANE TRANSITIONAL/HIGH SPEED URBAN CROSS SECTION



4-LANE TRANSITIONAL/HIGH SPEED URBAN CROSS SECTION



6-LANE TRANSITIONAL/HIGH SPEED URBAN CROSS SECTION



LT LANE TYPICAL CROSS SECTION

TYPICAL TRANSITIONAL/HIGH SPEED URBAN STREET CROSS SECTIONS

① Pavement structure, materials and dimensions vary according to individual project subgrade and traffic conditions.

② Subgrade slopes are parallel to pavements.

③ See discussion on “medians” for values.

⑤ Values given in FDM 11-20 Attachment 1.5

④ See FDM 11-46-5 for sidewalk information. See FDM 11-46-15.6 for shared-use path information.

⑥ See discussion on clear zones and lateral clearances in FDM 11-20 Table 1.5.

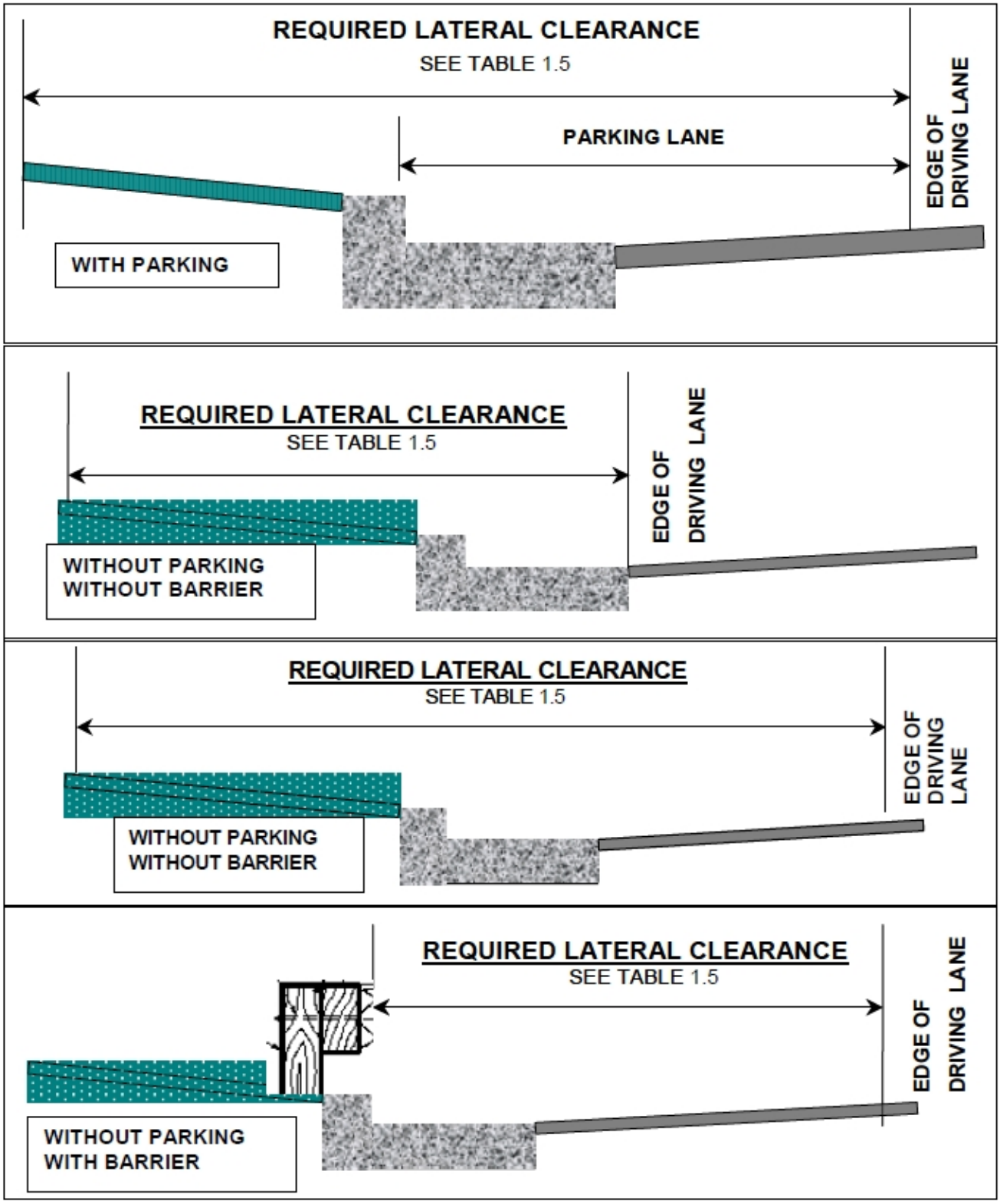
Border: S_T = Terrace cross slopes = 4% lower minimum for grass. 2% lower minimum for paved/ 2% upper minimum when adjacent to on-street parking. See FDM 11-46-05.2.2.

Border: S_S = Sidewalk cross slopes = 1.5%. $\pm$ 0.5% construction tolerance.

⑦ Additional widths as needed for utilities

⑧ Values given in FDM 11-25-5.

⑨ Lateral clearances. See FDM 11-20 Table 1.5



Urban Lateral Clearance

Run off the Road (ROR) Frequency Calculator

(The run off the road frequency spreadsheet calculator can be found at: FDM 11-20 A1.8 File1)

Run off the road frequency calculator is based on guidance provided by AASHTO Highway Safety Manual Chapter 12. Use this calculator on urban, suburban and roadways that transition from urban areas to high speed rural highways.

This calculator generates an approximate change in discreet fixed object hazard impacts for roadsides (i.e. right side of the roadway). A discrete fixed object hazard is any individual object that is 4 or more inches in diameter (e.g. poles, trees, rocks, luminaries...) or will grow to be greater than 4 inches in diameter. In addition, a discrete fixed object hazard is taller than 4 inches on a 5-foot chord. Continuous hazards (e.g. barrier systems, bridge abutments, buildings…) cannot be evaluated using this calculator.

Research indicates that it is difficult for an errant vehicle to slip between fixed objects that are spaced 25 feet or less apart. Treat similar discreet fixed object hazards that are 25 feet apart or less as a continuous hazard.

The Highway Safety Manual indicates that breakaway hazards are not to be included. However, this calculator deals with frequency of crashes and not severity of crashes. Installing breakaway hardware will increase the number of recorded run off the road crashes. Include large breakaway features (e.g. breakaway luminaries, large guide signs on breakaway features…). Individual signs installed on breakaway 4"x6" post do not need to be included in the analysis.

Include signal, railroad crossing devices, and fire hydrants in the frequency calculator. These devices typically have an exception to allow the use of non-breakaway features (See AASHTO Roadside Design Guide for more discussion). If the frequency of ROR crashes is equal to or above the threshold for documentation, provide discussion that these fixed objects have an exception in the DSR.

In certain situations, light pole can be non-break away (e.g. high mast lighting, areas where there is a high pedestrian density…). If using non-break away light poles and frequency of ROR crash is equal to or above the threshold for documentation, provide discussion on why non-break away light poles are being used. Discuss methods to mitigate the likelihood of ROR crashes with light poles.

The calculator can be set up to generate the frequency of roadside crashes for one side of the roadside (i.e. Number of Right Side(s) of the roadway =1) or both roadsides (i.e. Number of Right Side(s) of the roadway =2). If the density of fixed objects is similar on both sides of the roadway, the number of Right(s) of the roadway should be set at 2. If there is a significant difference in the density of fixed objects on one side of the roadway (e.g. utility poles are on one side of the roadway and not the other) set the Number of Right Side(s) of the roadway to 1 and analyze each side of the roadway separately.

The calculator cannot calculate increase in crash frequency due to hazards in a median. Although the calculator cannot calculate a change in crash frequency for medians, other research indicates that increasing fixed object density in the median increases ROR crashes.

Typically, use the mathematical average offset from edge of marked lane to discrete fixed object hazards in calculator. The maximum offset from edge of lane is 30 feet. If an object is beyond 30 feet from the edge of marked lane, assume the offset to that hazard is 30 feet. If a lane is not marked, follow guidance in FDM 11-45-20.5.

Review distribution of discreet hazard offsets. If the distribution is skewed by a few discreet fixed objects that are far from the roadway use median value (see example below). A few fixed object hazards that are 30 ft from the edge of marked lane can significantly change the crash frequency.

Example 1:

Roadway Type:	4-Lane Undivided
Number of Right Side(s) of Road:	2
Average Offset to Hazard (FT):	See below
Number of Hazards:	11
Length of Analysis (FT):	1000

Discrete Fixed Object Hazard Distribution

Number	Offset (FT)
1	5
2	30
3	5
4	5
5	5
6	5
7	7
8	7
9	5
10	30
11	30

		CMF
Average	12.2	1.30
Median	5	1.54

Difference in Crash Frequency	24%

Use logical segments to review run off the road frequency (e.g. intersection to intersection, intersection to bridge…). Review logical segments for areas with similar discrete fixed object hazards density. Including areas with significant differences in discreet fixed object density can dilute the change in run off the road frequency (e.g. a park within a logical segment may skew the results. See example below).

Example:

Compare two 500 ft long segments of a 2 Lane Undivided roadway

Only 1 side of the roadway is being analyzed (Number of Right Side(s) of Road=1)

Segment 1 has 2 discrete fixed object hazards 5 feet from the roadway.

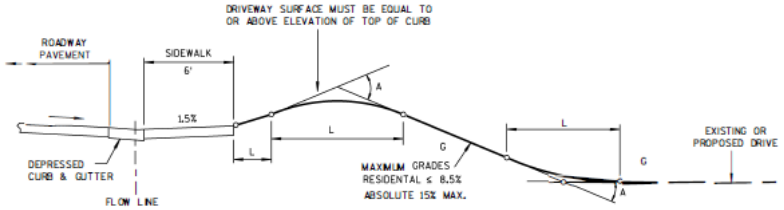
Segment 2 has 11 discrete fixed object hazards 5 feet from the roadway.

Segment 1 CMF (Crash Modification Factor) is 1.11.

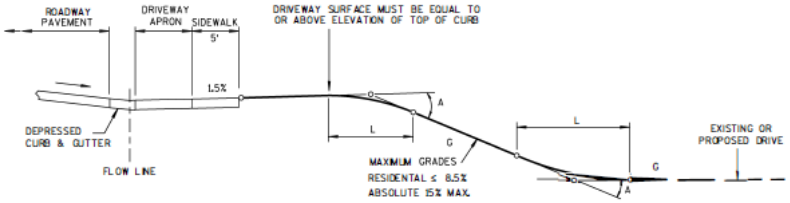
Segment 2 CMF is 1.85.

If both segments were combined in to one 1,000-foot long segment the CMF would be 1.48. Breaking the analysis into smaller segments of similar density will help project staff locate areas where adding additional fixed objects should be avoided and areas where adding fixed objects are less likely to influence ROR.

For more information on CMFs, review AASHTO's Highway Safety Manual.

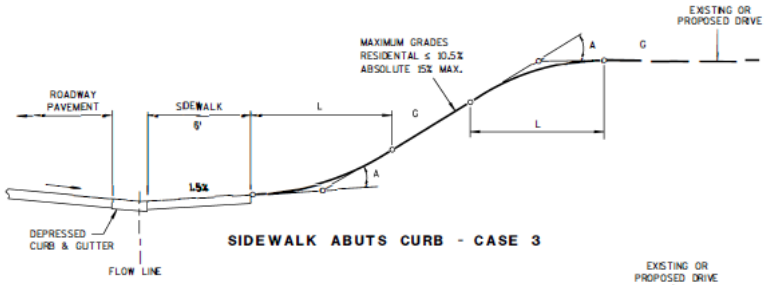


SIDEWALK ABUTS CURB - CASE 1

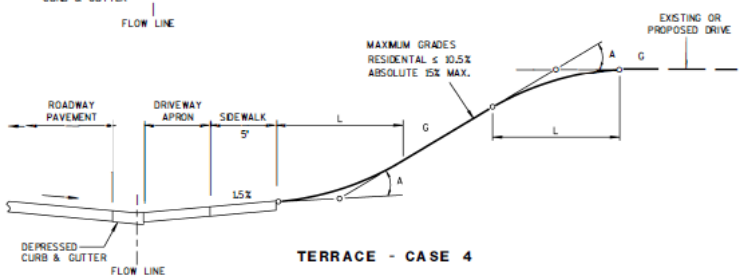


TERRACE - CASE 2

PROFILE - DRIVEWAY ON DOWNGRADE WITH SIDEWALK

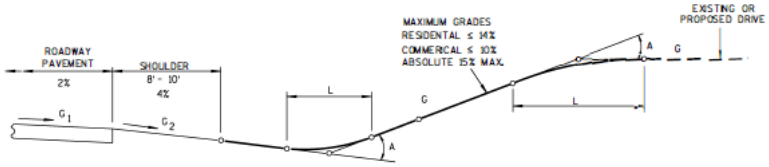


SIDEWALK ABUTS CURB - CASE 3

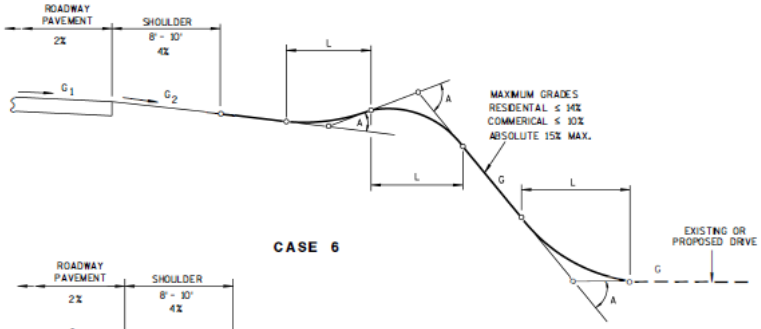


TERRACE - CASE 4

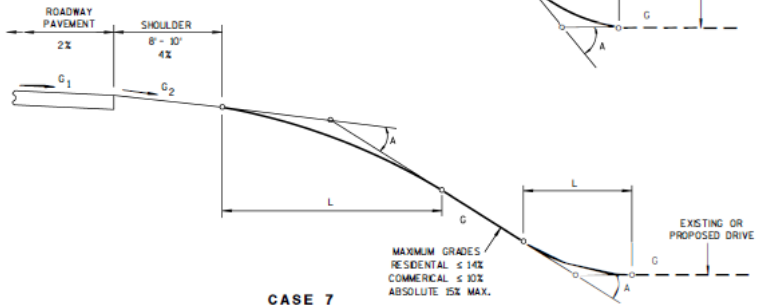
PROFILE - DRIVEWAY ON UPGRADE WITH SIDEWALK



CASE 5



CASE 6



CASE 7

DRIVEWAY PROFILES WITHOUT SIDEWALK

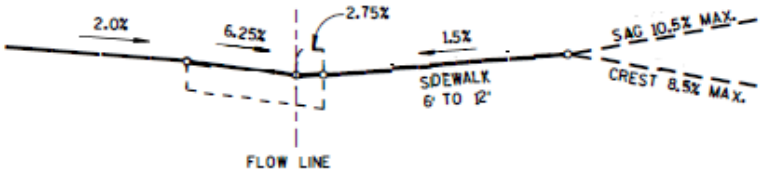
G - GRADE (%)

A - ALGEBRAIC DIFFERENCE IN GRADES (%)

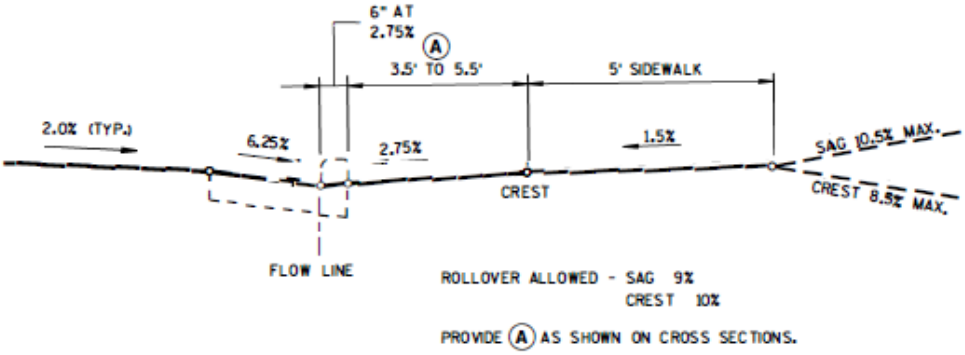
L - TRANSITION

A ≤ 6%, TRANSITION CURVE IS OPTIONAL

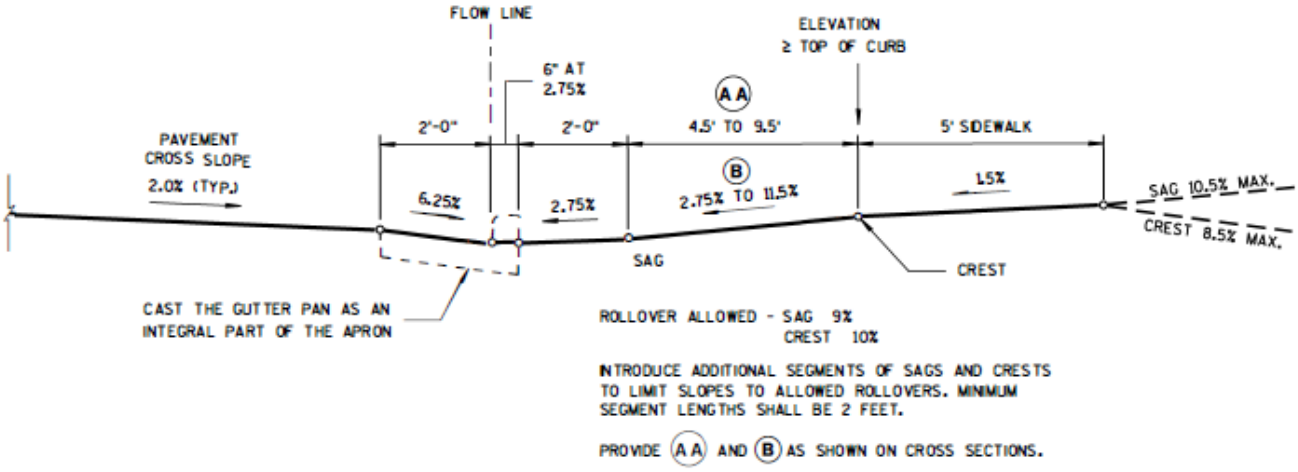
A > 6%, TRANSITION CURVE IS RECOMMENDED



TYPE X DRIVEWAY



TYPE Y DRIVEWAY



TYPE Z DRIVEWAY

FDM 11-25-1 General

August 15, 2019

1.1 Design Consideration

Design an intersection to either rural or urban design criteria depending on its location and the type of existing or planned development in the area. Design intersections located to serve a present or future residential or commercial area to urban design criteria with specific consideration of the current or eventual need for a new or a change in intersection traffic control or type cross walks, pedestrian signals, expected traffic volumes, and size of vehicles expected. Consult with the region planning staff to determine the type of development planned in the intersection.

It is very important to include Traffic Operations personnel early in the scoping of a project to assist the design team with the traffic control, signage, and pavement marking analysis and decision-making. In addition, safety countermeasure decisions and the need for facilities that serve large trucks and oversized-overweight (OSOW) vehicles must also involve Traffic Operations personnel and the Regional Freight Coordinator. Try to keep the size of intersections to a minimum, including roundabouts. Designing intersections for large trucks requires large corner radii, which substantially increases the size of the intersection. Larger intersections generally have greater crash potential, are more difficult to delineate, may be more confusing for drivers and other users, require more right-of-way, and significantly increase pedestrian and bicycle crossing times and distances.

References for this chapter include Chapter 9 of the AASHTO GDHS[1] and other sources as noted.

Specific factors and features to consider are:

- Safety - some factors that affect intersection safety include:
  - Number of approaches
  - Number of potential conflict points
  - Type of traffic control and advance signing (see FDM 11-25-3; also, see WisDOT's Traffic Engineering Operations and Safety Manual (TEOpS) and traffic signal design manual (TSDM) and consult with Traffic Operations)
  - Approach sight distance, i.e., the visibility of the intersection to an approaching driver (see FDM 11-10-5)
  - Intersection Sight distance (see FDM 11-10-5)
  - Intersection skew angle (see FDM 11-25-2.8)
  - Whether the intersection is located on a curve (see FDM 11-25-2.9)
  - Street lighting
  - Turn Lanes (see FDM 11-25-2.2 and 2.3; also see FDM 11-25-5 and FDM 11-25-10)
  - Auxiliary lanes (see FDM 11-25-35)
  - Access management (see FDM 11-25-2.5. FDM 11-25-20, FDM 11-5-5, FDM chapter 7 and HMM Chapter 91)
  - Intersection radii and channelization (see FDM 11-25-10 and FDM 11-25-25; also see SDD 9A1)
- Functional classes of the intersecting roadways (see FDM 11-25 Table 2.1; also see FDM 11-15-1 Attachment);
- Designated Long Truck Routes, 75' Restricted Truck Routes, 65' Restricted Truck routes, statewide Oversized-overweight (OSOW) Truck Route (OSOW-TR), OSOW Wind Tower (OSOW-WT), and OSOW High Clearance (OSOW-HC) routes (see FDM 11-25-1.4).
- Topography and surrounding land uses - examples:
  - The length of the crossroad available for traffic generating development including potential extensions
  - In urban and suburban or transitional areas, there is the potential for development to occur

[1] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

along the highway or adjacent frontage roads. Traffic from this development will feed into the crossroad.
    - Commercial or industrial zoned areas may attract truck terminals or other truck generators.
    - Schools, parks, residential developments are examples of destinations that should anticipate bicycle, pedestrian and transit increases as well as motor vehicles.
- Corridor Considerations
    - The appropriate design and traffic control of an individual intersection must provide a safe environment with adequate capacity, and also reflect the needs of adjacent intersections and the corridor as a whole. As such, isolated intersection designs may benefit from features not dictated by capacity alone. These features should be consistent with the overall facility, examples of which may include: turn lanes, separation of turn lanes from adjacent through lanes, raised medians, islands, and on-road bicycle accommodations. Right-of-way may also need to be preserved for future corridor-based improvements.
    - Regulatory speed limits are rarely reduced just for intersections. Guidance on "Speed Limits" is provided in the Traffic Engineering, Operations and Safety Manual TEOpS 13-5. If a speed reduction is desired for an intersection, work with Region Traffic staff, as they are responsible for any speed limit changes. Also, by statutory authority (ss 346.57 and 349.11), speed zone declarations are required when the traffic on a STH is required to reduce speed as a result of a regulatory speed limit sign installation. The development of a declaration needs to be based on an engineering study coordinated with Region Traffic staff.
- Traffic characteristics:
    - Current and expected daily traffic volumes and turning movements (see FDM 3-10-10)
    - Current and expected Design hour volumes and turning movements (see FDM 3-10-10)
    - Composition of traffic - including trucks and buses (and bicycles) (see FDM 3-10-10)
    - OSOW vehicles - including on roads that are not currently on the OSOW Truck Route (OSOW-TR), but which contain an OSOW origination point, or a recurring OSOW destination (e.g., a manufacturing plant or a gravel pit) (see FDM 11-25-1.4 and FDM 11-25-2.1.1).
    - Design vehicle (see FDM 11-25-2.1)
    - Vehicle speeds
    - Level of Service (see FDM 11-25-3 and FDM 11-5-3)
- Traffic Control Warrants and Design:
    - See FDM 11-25-1.1.2
- Crash experience – including numbers, rates, locations, types, and severity
- Road user types - motorists, transit, bicyclists, and pedestrians
- Sidewalk approaches and crosswalks (see FDM 11-46-5 and FDM 11-46-10)
- Pedestrian crossing distance and Pedestrian Clearance Time
- Geometry and cross-sections of the approach roadways and the intersection;
- Drainage requirements (see FDM chapter 13)
- Proximity and traffic volumes of driveways and other roads (see FDM 11-25-2.5; also see FDM 11-5-5 and FDM 11-25-20; Refer to FDM 11-30-1 regarding ramp terminal spacing)
- Right-of-way requirements (see FDM 11-25-1.1.1)
- Cost and Potential impacts

1.1.1 Right-of-Way Considerations

Public right-of-way at STH intersections needs to accommodate design geometrics (for existing & future conditions), operations-related infrastructure, and adequate sight distance. All WisDOT maintained signal & electrical equipment must either be located within the public right-of-way or within a permanent limited easement (PLE). Such signal equipment typically includes cabinet bases, signal/lighting bases, vehicle detection, associated conductor runs, and possibly temporary signal support guy-lines. Place this equipment in locations where it is less likely to be struck by an errant vehicle - because this can reduce crash frequency and severity, as well as maintenance costs. Also, consider the placement of this equipment in relation to existing or future sidewalks or shared-use paths.

Also, consider future capacity expansion. Examples include right- and left-turn lanes, widened medians, sidewalk, bike lanes, and future intersection or interchange type. Because of these issues, involve Regional Traffic Engineering and Planning (e.g. bike/pedestrian coordinator, access management coordinator) staff in

identifying required right-of-way at signalized intersections and interchanges early in the design process.

1.1.2 Traffic Control Warrants and Design

- See FDM 11-25-3 for guidance on the engineering study that shall be used to assist in selecting the appropriate type of intersection traffic control
- In general, terms, any intersection, urban or rural, that meets the criteria for a four-way stop condition or a traffic signal, also qualifies for evaluation as a modern roundabout. For more information on roundabouts, see FDM 11-26.
- Typically, any interchange that meets the criteria to evaluate a signalized diamond or roundabout, could also qualify for the evaluation of Reduced-Conflict Interchanges, given the traffic volumes and patterns. These interchange types include a Diverging Diamond Interchange (DDI) and a Single Point Interchange (SPI); see FDM 11-25-3.
- Consult with the region traffic section on the design and location of traffic signals. Applicable references include:
  - FHWA Manual of Uniform Traffic Control Devices (MUTCD):

    http://mutcd.fhwa.dot.gov/
  - Wisconsin Manual of Uniform Traffic Control Devices (WMUTCD):

    https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/wmutcd/wmutcd.aspx
  - WisDOT's Traffic Signal Design Manual (TSDM):

    https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/tsdm/tsdm.aspx
  - WisDOT's Traffic Engineering, Operations and Safety Manual (TEOpS):

    https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/teops/default.aspx
- A specific traffic control or intersection type may not be immediately warranted on a project but may be warranted within the project's design life. See FDM 11-25-3 for guidance on Intersection Control Evaluation (ICE) studies.

1.1.2.1 Through Highway Declaration Process

As new or modified traffic control installations at intersections take place, it is important to follow the through highway declaration process. By statutory authority (ss 340.01(67) and 349.07), a yield sign (e.g. roundabout), stop sign, or signal installation on a STH or connecting highway requires an approval process. Guidance on "Through Highway Declarations" is provided in the TGM 13-1-1. Regardless of the type of traffic control proposed, associated "through highway declarations" need to be developed and are maintained by the Regional Traffic staff.

1.2 Urban Intersections

At-grade urban intersections consist of a variety of types that cannot be grouped by a class of highway. Factors that influence intersection design are peak-hour traffic volumes, type and size of turning vehicles, traffic control, turning roadways, auxiliary lanes, number of lanes, divided or undivided cross section, pedestrian traffic, and right of way limitations. The proximity of commercial and industrial sites may require special designs.

Intersection geometry and operations need to accommodate all roadway users - including pedestrians and bicyclists - and provide safe travel and crossing (see FDM 11-46 for guidance on bicycle and pedestrian accommodations). Minimize the size of the intersection and the pedestrian crossing distance by designing intersection radii as small as possible. If the design vehicle is larger than a Single Unit (SU truck or a bus), consider using a two-or three centered curve. Use templates or automated programs to determine the vehicle path and then develop a two-or three-centered curve that closely emulates this path. Look at a range of vehicle turning radii and select the best fit for the design vehicle while minimizing the size of the intersection. [2]

A legal crosswalk exists at intersections, including "Tee" intersections, where the side road has sidewalks on one or both sides of the street and the through street has sidewalk on the opposite side of the street from the side road, whether the crosswalk is pavement marked or not[3]. FDM 11-46-10 further describes curb ramp

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[2] *ORDOT Highway Design Manual (2) ORDOT Highway Design Manual* ch. 9.0: Intersection and Interchange Design. Oregon Department of Transportation, 2008. ftp://ftp.odot.state.or.us/techserv/roadway/web_drawings/HDM/Rev_E_2003Chp09.pdf, Ch. 9, pp.14-15, "Intersection and Interchange Design"

[3] Per s.340.01 (10) (b), Wis. Stats.

installation requirements and other conditions when curb ramp installation may be desirable.

When possible, prohibit parking near the intersection on routes identified on the Long Truck Operators Map and the OSOW Truck Route to avoid conflicts with turning traffic. Large vehicles require greater turning radii and wider sweeping paths to negotiate corners. Review whether parking, roadside utilities, or street furniture will impede long truck and OSOW movements. This is of particular concern at the intersection of multiple state trunk highways in established urban environments. Certain OSOW loads (such as a bridge girder) will encroach beyond the face of curb even when the transport axles stay within the street. Refer to FDM 11-20-1 for additional Parking Lane and Border guidance.

1.3 Rural Intersections

The At-Grade Side Road Intersections standard detail drawing (SDD 9A1-a and b) illustrates six types of rural at-grade intersection: A1, A2, B1, B2, C and D. This SDD applies to two-lane undivided and multilane divided high speed rural highways. The intersection type will indicate the length of a turn lane and shall apply to both the left turning and the right turning traffic entering the same side road leg. The lengths of the turn lanes are for deceleration only. If additional storage is needed to accommodate queuing Design Hour Traffic, or there is a high volume of truck turning movements, then provide a longer turn lane based on needed storage. Attachment 1.1 lists the criteria for using each type of intersection. FDM 11-25 Attachment 5.4 shows the median opening and non-slotted turn lanes on rural expressways.

Consider other roadways users such as pedestrian, bicyclists and transit users based on existing and future land uses. Even though these users are not typically as prevalent in rural and high-speed settings as they are in urban settings, this may change with changing land uses. See FDM 11-46, “Complete Streets”, for guidance on pedestrian and bicycle accommodations. See FDM 11-25-35.3 for guidance on bus stops at intersections.

1.3.1 Intersections on Rural High-Speed Multilane Divided Highways (“Rural Expressways”)[4]

A rural high-speed (≥50 mph), multilane, divided highway with partial access control is typically referred to as a “rural expressway”[5]. Rural expressways are generally a hybrid design between a freeway and a conventional two-lane rural arterial roadway. Like freeways, rural expressways are typically four-lane divided facilities (i.e., two lanes in each direction separated by a wide, depressed, turf median), which may also have grade separations and interchanges. Like conventional two-lane undivided rural arterials, expressways have partial access control allowing at-grade intersections and limited driveway access with the potential for signalization (although signalization is typically discouraged). Expressways provide many of the mobility, travel efficiency, economic and safety benefits of freeways at a far lower cost. However, increased at-grade intersection crashes and increased intersection crash severity diminish the expected safety benefits of expressways.

The typical rural expressway intersection is an at-grade two-way stop controlled (TWSC) with the stop control on the minor (usually two-lane) roadway. Expressway interchanges are generally limited to locations that meet traffic volume warrants or that have a disproportionate rate of serious crashes, and to meet driver expectancy due to the functionality of the side road and where the additional expenditure can be justified.

TWSC rural expressway intersections often experience safety problems long before the design life of the facility and even before meeting traffic signal volume warrants. The percentage of total expressway crashes which occur at TWSC intersections increases as the mainline traffic volumes increase, and all intersection crashes increase and become more severe as minor roadway volumes increase. Right-angle collisions are the predominant crash type at conventional TWSC rural expressway intersections. The most problematic of these (with respect to severity) tend to be those occurring in the far-side intersection (i.e., after the minor road driver has traveled through the median). The underlying cause of these collisions in most cases is not failure to yield, but the inability of the driver stopped on the minor road approach to judge the arrival time of approaching expressway traffic (i.e., gap selection).

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[4] From Maze et al in NCHRP Report 650 (3) NCHRP Report 650: *Median Intersection Design for Rural High-Speed Divided Highways. Transportation Research Board of the National Academies*, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf, p.4, Background; p.147, Conclusions; pp. 1-3, Summary

[5] Some roadways in Wisconsin are “designated expressways” per Wis Stat 84.295. The term “rural expressway” is used herein to describe a rural high-speed (≥50 mph), multilane, divided highway with partial access control, regardless of whether the roadway is “designated expressway”.

1.3.1.1 Rural Expressway Intersection Safety Treatments[6]

As illustrated in Figure 1.1a, the traditional approach to addressing safety problems at expressway intersections - after addressing potential design issues such as insufficient sight distance - is to improve the traffic-control devices, implement traffic signal control (if warranted), - and eventually construct an overpass or interchange. Traffic signals in rural areas are discouraged for several reasons including violation of driver expectations and difficulty in servicing and maintaining signals in remote locations. Signals also hamper the intended mobility of expressways. In addition, traffic signals do not always improve safety - they may only change the crash type distribution. The construction of an interchange reduces the cost advantage of building an expressway as compared with building a freeway, and the mix of at-grade intersections and interchanges tends to violate driver expectations.

However, as illustrated in Figure 1.1b, non-signalized safety countermeasures have been used more often in recent years. These safety treatments for rural expressway intersections fall into three broad categories:

1. Conflict-point management strategies,
2. Gap selection aids, and
3. Intersection recognition devices.

Table 1.1 provides a listing of safety treatments by category. In general, select the most appropriate safety countermeasure based on the crash types occurring at each location. The conflict-point management strategies and the gap selection aids seem to have the most potential to improve safety at rural expressway intersections because they address the apparent underlying cause of many crashes at TWSC rural expressway intersections (i.e., far-side gap selection by crossing and left-turning minor road drivers).

[6] From Maze et al in NCHRP Report 650 (3) NCHRP Report 650: *Median Intersection Design for Rural High-Speed Divided Highways.* Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., pp. 44-63)

***Table 1.1* Potential rural-expressway intersection safety treatment[7]**

Category	Subcategory	No.	Safety Treatment
Conflict Point Management Strategies	Removal/ Reduction Through Access Control	1.	Conversion of entire expressway corridor to freeway
		2.	Isolated conversion to grade separation or interchange
		3.	Close low-volume minor road intersections and use frontage roads [See FDM 11-25-45]
		4.	Close median crossovers (right-in, right-out access only)
		5.	Convert four-legged intersection into T-intersection or initially construct T-intersections instead of four-legged intersections (Use a one-quadrant interchange [A] if necessary)
	Replacement of High-Risk Conflict-points	1.	J-turn intersections (indirect minor road crossing and left-turns) [A][See below]
		2.	Offset T-intersections (indirect minor road crossing)
	Relocation or Control	1.	Provide left/right-turn lanes or increase their length
		2.	Provide free right-turn ramps for exiting expressway traffic
		3.	Minimize median opening length
Gap Selection Aids	Vehicle Detection (Intersection Sight Distance Enhancements)	1.	Provide clear sight triangles [See FDM 11-10-5]
		2.	Modify horizontal/vertical alignments on intersection approaches
		3.	Realign skewed intersections to reduce or eliminate skew [See above]
		4.	Move minor road stop bar as close to expressway as possible
		5.	Provide offset right-turn lanes
		6.	Provide offset left-turn lanes [See FDM 11-10-5 and FDM 11-25-5]
	Judging Arrival Time	1.	Intersection decision support system (IDS) or another dynamic device [A]
		2.	Roadside markers/poles (static markers at a fixed distance) [A]
	Merging/Crossing Aids -(Promoting Two-Stage Gap Selection)	1.	Provide right-turn acceleration lanes for merging traffic
		2.	Expressway speed enforcement near intersections
		3.	Widen median to provide for adequate vehicle storage [See below]
		4.	Add centerline, yield/stop bars, and other signage in the median [See below]
		5.	Extend left edge lines of expressway across median opening [A]
		6.	Public education campaign teaching two-stage gap selection
Intersection Recognition Devices	Intersection Treatments	1.	Provide overhead control beacon reinforcing two-way stop control
		2.	Provide intersection lighting
	All Approaches	1.	Enhanced (overhead/larger/flashing) intersection approach signage
	Expressway Approaches	1.	Provide diagrammatic freeway-style intersection guide signs
		2.	Use of a variable median width (wider in intersection vicinity) [See below]
		3.	Change median type in vicinity of intersection
	Minor Road Approaches	1.	Use STOP-AHEAD pavement marking and in-lane rumble strips
		2.	Provide a stop bar (or a wider one)
		3.	Provide divisional/splitter island at mouth of intersection
		4.	Provide signage/marking for prevention of wrong-way entry

[A] SEEG and SWB approval is required. Coordinate with SWB on design and evaluation.

[7] From Maze et al in NCHRP Report 650 (3) NCHRP Report 650: *Median Intersection Design for Rural High-Speed Divided Highways.* Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf, Table 19 on p. 47). (NCHRP references from "NCHRP Report 650" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))

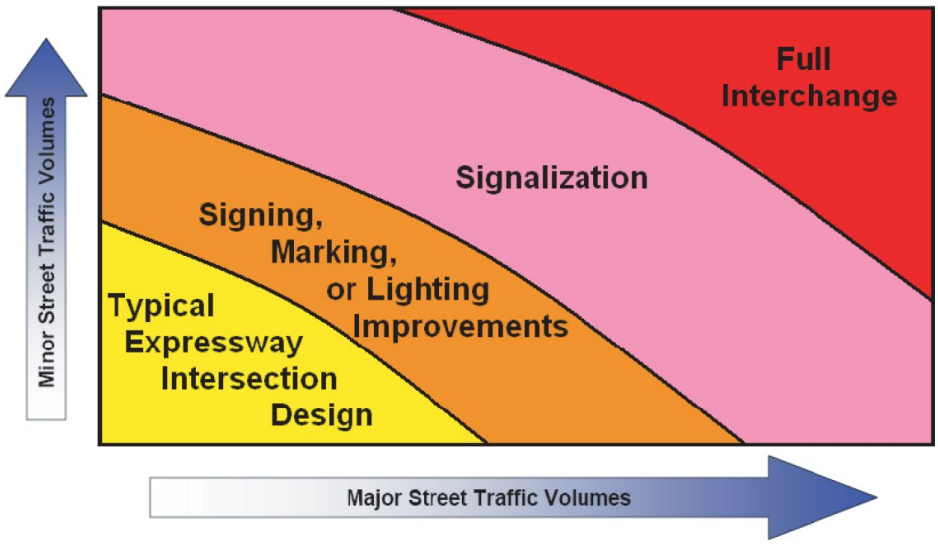


***Figure 1.1a** Traditional Countermeasure matrices for TWSC expressway intersection*

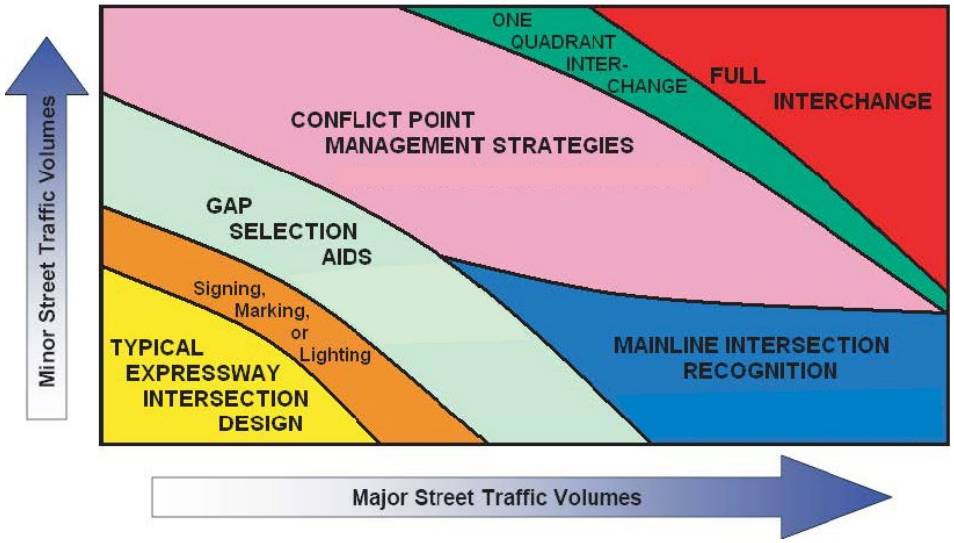
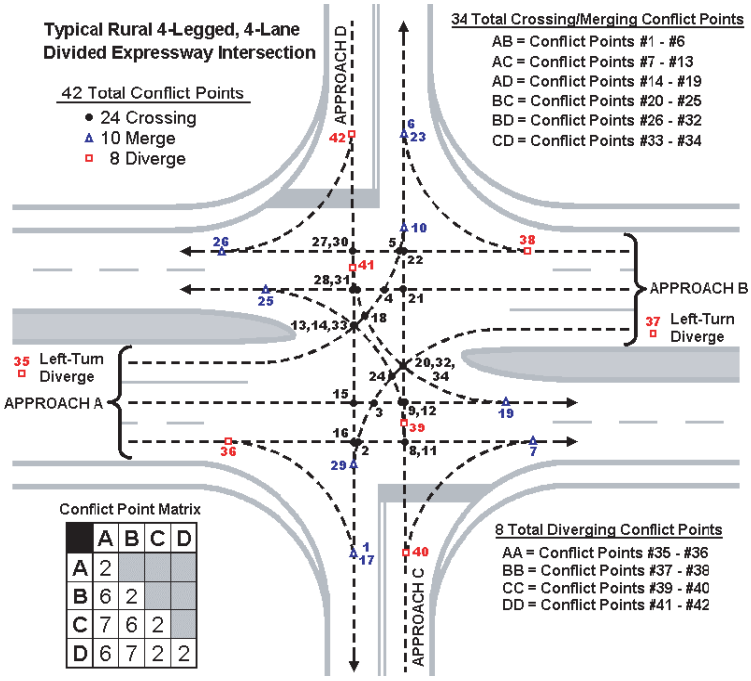


***Figure 1.1b** Updated Countermeasure matrix for TWSC expressway intersection*[8]

Conflict-point management strategies are those treatments that remove, reduce, relocate, or control the conflict-points that occur at a traditional TWSC rural expressway intersection. Conflict-points represent the locations where vehicle paths cross, merge, or diverge as they move from one intersection leg to another. A typical four-legged TWSC rural expressway intersection has 42 conflict-points, as shown in Figure 1.2 - assuming opposing left-turn paths do not overlap. Conflict-point management strategies can be expensive - and controversial because of movement restrictions and re-direction.

[8] From Maze et al in NCHRP Report 650 (3) NCHRP Report 650: *Median Intersection Design for Rural High-Speed Divided Highways.* Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf, Figure 117, p. 148) (NCHRP references from "NCHRP Report 650" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))



	A	B	C	D
A	2			
B	6	2		
C	7	6	2	
D	6	7	2	2

***Figure 1.2* Conflict Point Diagram for expressway 4-legged intersection[9]**

Intersection conflict-point analysis is a well understood means of comparing the expected safety of alternative intersection designs, which suggests that the more conflict-points an intersection design has, the more dangerous it will be. This approach is useful but limited because it assumes the crash risk is equal at each conflict point when, in fact, the crash risk associated with each conflict point varies depending on the complexity and volumes of the movements involved. The conflict-points with the greatest crash risk (i.e., those accounting for the largest proportion of crashes) at TWSC rural expressway intersections tend to be the far-side conflict-points involving minor road left-turns and crossing maneuvers (i.e., Conflict-points 15, 16, 19, 21, 22, and 25 in Figure 1.2).

The key to the effectiveness of conflict-point treatments is in eliminating the high-risk conflict-points. The conflict-point management treatments with the most potential to improve rural expressway intersection safety are those that eliminate the far-side conflict-points associated with minor road left-turns and crossing maneuvers or replace them with conflict-points of lower risk or severity.

[9] From Maze et al in NCHRP Report 650 (*3) NCHRP Report 650*: *Median Intersection Design for Rural High-Speed Divided Highways*. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., Figure 2 on p.5) (NCHRP references from "NCHRP Report 650" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))

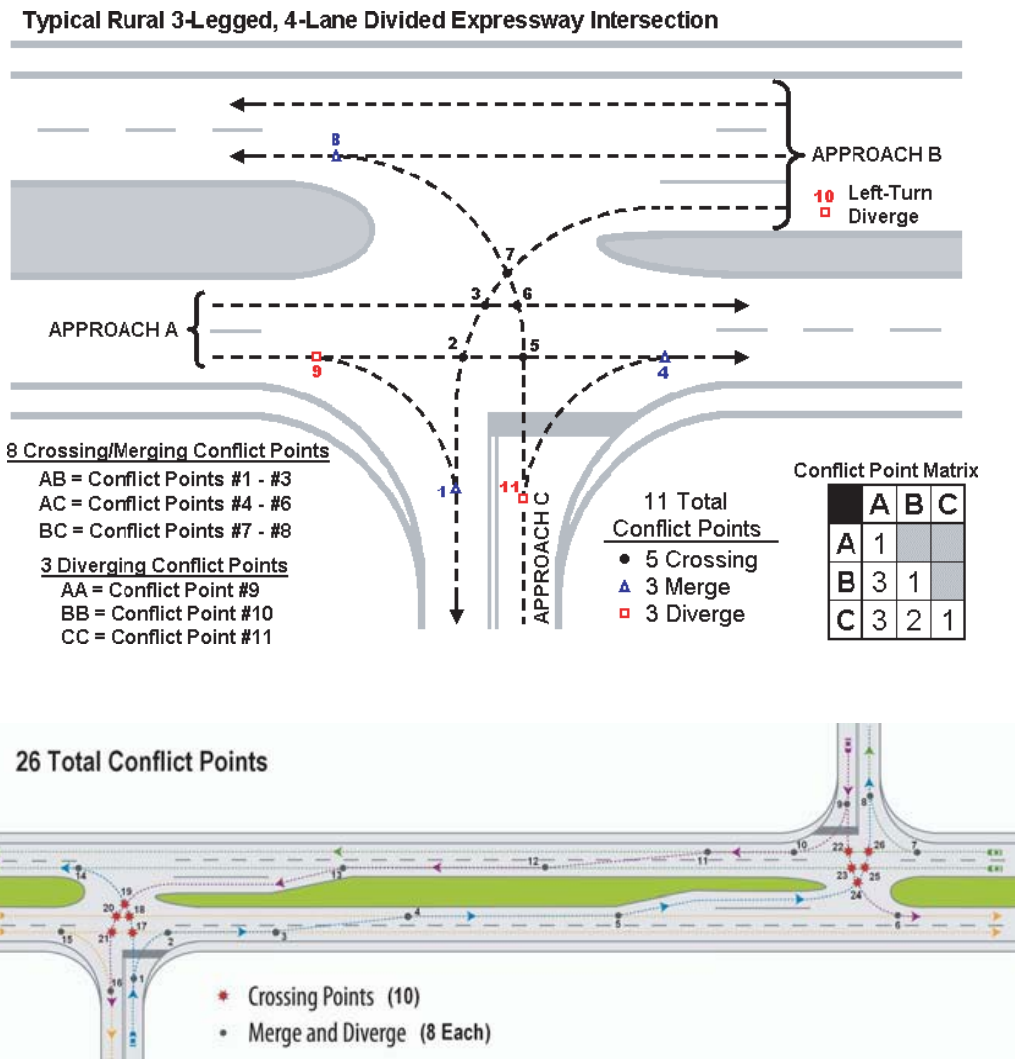


***Figure 1.3* Conflict point Diagrams for expressway T-intersections[10]**

Gap selection aids are those countermeasures intended to aid a driver in selecting a safe gap into or through the expressway traffic stream. Gap selection is a complex process. The driver must detect an oncoming vehicle, assess the size of the gap (i.e., time-to-arrival of the approaching vehicle) and determine whether there is enough time/space to complete their typical maneuver. The driver must then proceed and physically enter or cross through the expressway traffic stream.

Right-angle collisions are the primary safety issue at TWSC rural expressway intersections. The predominant cause of these crashes seems to be the failure of minor road drivers to detect approaching expressway traffic or their inability to adequately judge the speed and distance (i.e., arrival time) of oncoming expressway vehicles. These gap selection issues may be exacerbated by the presence of certain intersection geometric features (e.g., horizontal/vertical curvature on the mainline, intersection skew, median width, etc.); driver age, driver behavior (e.g., one-stage gap selection); and increasing traffic volumes on both of the intersecting roadways.

Intersection recognition devices are treatments that improve intersection conspicuity for drivers on either the minor road or expressway. Many TWSC rural expressway intersections are not readily visible to approaching drivers, particularly from the uncontrolled expressway approaches. As a result, crashes occur because approaching expressway drivers are unaware of the intersection and are not prepared to react to potential conflicts. Crashes also occur because drivers approaching on a sideroad do not stop at a stop sign because

[10] From Maze et al in NCHRP Report 650 (*3) NCHRP Report 650*: *Median Intersection Design for Rural High-Speed Divided Highways*. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., Figure 31, p.49 and Figure 65, p.86) (NCHRP references from "NCHRP Report 650" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))

they do not recognize that they are approaching a stop-controlled intersection. Providing greater intersection recognition reduces the likelihood of stop sign running and alerts the expressway driver to proceed through the intersection with caution.

Traditionally, these treatments are the first countermeasures used when right-angle crashes begin to occur at TWSC rural expressway intersections because they are relatively low-cost and easy to deploy. However, lack of intersection recognition (i.e., STOP sign violation) is not the major contributing factor in the majority of right-angle crashes occurring at TWSC rural intersections. Therefore, these treatments do not address the predominant cause of right-angle crashes, which seems to be gap selection.

1.3.1.2 Median Width at Unsignalized Median Openings on Rural Expressways

The median width at a rural expressway intersection is usually the median width for the entire expressway corridor. However, the major function of a median differs between intersections versus at intersections. The major function of the median between intersections is to separate opposing expressway traffic; the major function of the median at intersections is to provide a refuge area for left-turning and U-turning expressway traffic as well as for left-turning and crossing traffic from the minor road. A median width of 40-feet or wider is adequate for expressway drivers to experience a sense of separation from opposing traffic. However, research has shown that wider medians are safer at unsignalized TWSC rural expressway intersections, most likely because wider medians allow for two-stage gap selection (i.e., a minor road driver can safely stop in the median area to evaluate the adequacy of the gap in expressway traffic coming from the right before completing a crossing or left-turn maneuver).[11] A wider median at an intersection also serves as an intersection recognition device for expressway traffic by emphasizing the presence of the upcoming intersection.

The minimum median width at an intersection for two-stage gap selection is the length of the design vehicle plus 3-feet of clearance to the expressway thru-lanes from both the front and the rear of the vehicle. However, some drivers may perceive this as being too narrow because it places them across the expressway left-turn lane(s). These drivers may feel that they have no option but to complete the crossing or left-turning maneuver in one stage. Therefore, typically provide additional median width so that vehicles stored in the median do not block the expressway left-turn lane approaching from their right but still have a minimum 3-foot clearance from the expressway thru-lanes. Additional median width may allow more of the deceleration to take place within the median.

The median width of 50 or 60-feet will provide storage for cars or small trucks but is not adequate for storing long trucks or combinations of connected farm equipment. Provide a wide median where possible if the divided highway intersects a side road on a curve or at any location to accommodate long trucks or combinations of farm machinery. The median should be at least 100 feet wide, up to approximately 150 feet wide to accommodate long trucks like the WB-65 or combinations of farm machinery that produce a long train of connected equipment.

Median roadways wider/longer than 150 feet can cause problems as well. Consider appropriate signing to prevent Wrong Way entry onto the expressway facility.

There are fewer operational problems at rural unsignalized intersections as the median width increases, but the rate of undesirable maneuvers increases as the median opening length increases.[12] In other words, the geometrics of a wide median in combination with a smaller median opening help create the impression that there is not much choice in traversing the median except to follow the path the designer intended. Median delineation is another way to emphasize this typical path.

1.3.1.3 Median Signage and Delineation[13]

Median signage and delineation have four major objectives:

1. Inform minor road drivers that they have reached a divided highway intersection;
2. Establish the right-of-way between median and far-side expressway traffic;

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[11] See Harwood et al in NCHRP Report 375 (*4) NCHRP 375: Median Intersection Design*. TRB, National Research Council, 1995.

[12] See Harwood et al in NCHRP Report 375 (*4) NCHRP Report 375*: *Median Intersection Design*. TRB, National Research Council, 1995.

[13] From Maze et al in NCHRP Report 650 (*3) NCHRP Report 650*: *Median Intersection Design for Rural High-Speed Divided Highways*. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., pp. 58-59)

3. Communicate the appropriate gap selection process (i.e., one or two-stage); and
4. Define the proper travel paths through the median roadway.

If a median is wide enough to store a passenger car, then stop or yield bars in conjunction with STOP or YIELD signs may be used to establish right-of-way and to communicate the appropriate two-stage gap selection behavior to the minor road driver. Generally, median yield control is encouraged unless the selected design vehicle can be completely stored within the median area. Do not use this marking and signing if the median is not wide enough to store a passenger car, i.e., if all vehicles require one-stage gap selection.

On median roadways wider than 120 feet, provide double yellow pavement marking to separate the opposing traffic and provide stop bars and STOP signs at each end of the median roadway. This signing and pavement marking combination effectively provides a measure of depth perception to communicate to the minor road driver that the median is wide enough for vehicle storage, thereby promoting two-stage gap selection behavior. Often, rural expressway intersections with wide medians have large expanses of pavement that can make it difficult for drivers to decide what path to follow and to anticipate the paths other drivers will take. The double yellow median centerline should help to provide visual continuity with the centerline of the minor road approaches and to define the typical vehicle paths through the median roadway. Slotted left turn lanes are generally not typical for this configuration.

1.3.2 J-Turn Intersection

The J-turn is an example of a reduced-conflict intersection that WisDOT has used on expressways. Justify selection of a J-turn or other reduced-conflict intersections (or interchanges) using the Intersection Control Evaluation (ICE) process described in FDM 11-25-3. J-turn implementation on WisDOT projects will be on a pilot basis for the time being. Regions must coordinate with BPD and BTO in the evaluation and design. However, all expressway intersections considered for new or a change in traffic control where a J-Turn is identified as a feasible alternative, the J-Turn shall be considered as a traffic control alternative in the Intersection Control Evaluation (ICE).

The J-turn intersection combines a directional median (which allows direct left-turn exits from the expressway but prohibits sideroad traffic from entering the median) with downstream median U-turns. Left turning and crossing traffic from the sideroad makes these maneuvers indirectly by turning right, weaving to the left, making a downstream U-turn, and then returning to the intersection to complete their typical maneuver.

Since there is no indication that U-turns at unsignalized median openings constitute a safety concern[14], the J-turn intersection design effectively replaces the high risk, far-side conflict-points associated with direct minor road left-turns and crossing maneuvers (i.e., Conflict-points 15, 16, 19, 21, 22, and 25 in Figure 1.2) with less risky conflict-points associated with right-turns, U-turns, and weaving maneuvers. The J-turn intersection reduces the total number of intersection conflict-points at a typical TWSC rural expressway intersection from 42 to 24 (as shown in Figure 1.2 and Figure 1.4, respectively).

***Figure 1.4* Conflict Point Diagram for J-turn Intersection[15]**

[14] See Potts et al in NCHRP Report 524 (*5) NCHRP Report 524*: *Safety of U-Turns at Unsignalized Median Openings*. Transportation Research Board of the National Academies, 2004. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_524.pdf.

[15] From Maze et al in NCHRP Report 650 (*3) NCHRP Report 650*: *Median Intersection Design for Rural High-Speed Divided Highways*. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf,

TWSC rural expressway intersections most likely to benefit from J-turn intersection conversion include:

- Intersections with a history of far-side right-angle collisions, collisions within the median, "left-turn leaving" collisions, or combination of the three;
- Intersections with high volumes of traffic on the mainline creating infrequent safe gaps for direct crossing or left-turn maneuvers, while still having frequent enough gaps for safe right-turn entry
- Intersections with relatively low volumes of traffic crossing or turning left from the minor roads; and
- Intersections with poor horizontal or vertical alignment

The J-turn intersection design on rural expressways have shown that the design may improve safety performance as compared with a typical TWSC rural expressway intersection.

There are some potential issues in using J-turns at high-speed rural expressway intersections:

- Design guidance and criteria are still evolving.
- There are no traffic volume or level-of-service warrants.
- Signing and marking - a J-turn essentially creates three (3) separate intersections and drivers need clear and timely direction in order to make the correct decision.
- Public acceptance

J-turn design considerations include:

- Operational and safety comparison with other intersection alternatives using the ICE process described in FDM 11-25-3
  A J-turn is essentially three separate intersections. Each of these intersections are evaluated separately but compared collectively to other intersection alternatives
- Intersection Sight Distance (ISD)
  The ISD for the mainline left turn into the side road is based on Case F; the ISD for the u-turn locations is based on Case B1; the ISD for the sideroad right turns is based on Case B2 (see FDM 11-10-5.1.4)
- Separation between the sideroad intersection and the u-turn locations - this distance represents a trade-off between providing sufficient space for safe/functional weaving, U-turn storage, and approach signing, while minimizing the travel distance/time of the indirect left-turn and crossing maneuvers. Use the following guidelines:
  - As a rule of thumb, provide 7-10 seconds per lane[16] to the begin taper for the U-turn lane - and check the adequacy during design (e.g., a vehicle crossing 2-lanes at 70 mph requires 1450-feet using 7-sec per lane; and 2060-feet using 10-sec per lane);
  - Do not place median openings within the functional length of intersection of any of the three intersections comprising the j-turn;
  - Provide adequate distance for advance signing
  - Do not locate u-turns opposite driveways or streets
  - Check weaving
- Geometry
  - Provide positive offsets for opposing left turn lanes
  - Accommodate u-turning vehicles. Possible treatments include increased median width, loons, and jughandles;
  - Consider positive offsets for right turn lanes
  - Side road islands and directional median islands need to reinforce left-out and thru movement restrictions
  - Checking and accommodating OSOW vehicles if required (see Table 2.1 and Attachment 2.2; coordinate with the region freight operations unit)
  - Accommodate bicyclists and pedestrians if appropriate

Figure 48, p. 65) (NCHRP references from "NCHRP Report 650" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))

[16] *(6) Innovative Intersection Designs. (PowerPoint presentation for 2009 ACEC/WisDOT Transportation Improvement Conference).* SRF Consulting Group, Inc., 2009.

1.4 Truck Routes and Routes for Oversized-Overweight (OSOW) Vehicles

There are three (3) categories of truck routes on the STH:

1. "Designated Long Truck Routes" (no overall length limitation; MAX 53' trailer w/ 43' king pin to rear axle; MAX 28'-6" trailers on double bottoms).
2. "75' Restricted Truck Routes" (75-ft overall length limitation; MAX 53' trailer, 43' king pin to rear axle; no double bottoms).
3. "65' Restricted Truck Routes" (65-ft overall length limitation; MAX 48' trailer, no double bottoms).

See SS 348 and Administrative Code Trans 276 for requirements and definitions for these routes. Trans 276 has a listing of "Designated Long Truck Routes" and 65' Restricted Truck Routes (Note: there are non-STH routes on this list as well). If a STH is not listed as either a "Designated Long Truck Route" or a "65' Restricted Truck Route" then it is a "75' Restricted Truck Route". The "Wisconsin long truck operator map" includes these identified routes and is available at:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/planning-maps.aspx

All Federally Designated Long Truck Routes in Wisconsin (i.e. the National Network as defined in 23 CFR Part 658) are Wisconsin "Designated Long Truck Routes". Wisconsin has also identified additional "Designated Long Truck Routes" which are not all Federally Designated Truck Routes. The design requirements for Federally Designated Truck Routes differ somewhat from other Wisconsin "Designated Long Truck Routes" (See FDM 11-15-1.4, FDM 11-20-1).

In addition to the Long Truck Route Maps, WisDOT has established a statewide OSOW Truck Route (OSOW-TR).

There are three (3) categories of OSOW freight routes on the STH system:

1. OSOW-TR
2. OSOW-WT (wind tower routes)
3. OSOW-HC (high clearance routes)

Vehicles that exceed the maximum legal dimensions and weights are OSOW. These vehicles require a permit. [17] The required permits fall into two general categories:

1. single-trip (OSOW ST); and
2. multiple-trip (OSOW-MT)

See FDM 11-25-2.1.1 and FDM 11-25 Attachment 2.1 for more information on OSOW vehicles.

See the OSOW maps for routes designated as OSOW-TR located at:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/planning-maps.aspx

See sections FDM 11-25-1 and 11-25-2 for additional design guidance for intersections on the OSOW-TR.

1.4.1 OSOW High Clearance Routes

The Department has adopted OSOW High Clearance (OSOW-HC) Routes with the objective of minimizing overhead constraints for OSOW vehicles along these routes. Refer to FDM 11-10-5.4.3 for further vertical clearance guidance along the high clearance routes. If an OSOW High Clearance Route has railroad crossing(s) requiring overhead railroad signals, conduct railroad signal coordination as described in FDM 11-25-40.1.

1.4.2 OSOW for Perpetuation and Rehabilitation Projects

Improvements to accommodate OSOW vehicles will not be required for the Perpetuation and Rehabilitation projects where S-1 design criteria are applied with a pavement service life less than 18 years. OSOW improvements will be required at spot improvement locations on Rehabilitation projects where S-2 design criteria are applied. Low-cost countermeasures are encouraged on OSOW truck routes for Perpetuation and Rehabilitation projects. For projects with a longer pavement design service life equal to or greater than 18 years, improve the roadway to accommodate OSOW vehicles on the OSOW truck routes and wind-tower corridors. For

[17] *SS 348.25(1) states "No person shall operate a vehicle on or transport an article over a highway without first obtaining a permit therefore as provided in s. 348.26 or 348.27 if such vehicle or article exceeds the maximum limitations on size, weight or projection of load imposed by this chapter."*

roadways where it is not practicable to accommodate OSOW trucks due to high cost or impacts, documentation in the DSR demonstrating the non-feasibility of this decision is required.

Certain OSOW truck routes and wind-tower corridors may have multiple less-intensive pavement treatments (Perpetuation, Rehabilitation) that alone do not exceed 18 years of pavement life but when added together equals or exceeds 18 years. Evaluate OSOW improvements when the pavement treatment service life of such subsequent projects, when applying the same subsequent improvement type along a given route equals or exceeds 18 years. If determined during scoping that there is not a need to accommodate OSOW trucks, it is not mandatory to make such improvements solely based on the cumulative years of the subsequent improvement projects.

All projects that included OSOW accommodations with a DSR approved prior to January 1, 2019 will continue to include OSOW as designed.

1.5 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

2. ORDOT Highway Design Manual ch. 9.0: Intersection and Interchange Design. Oregon Department of Transportation, 2008. ftp://ftp.odot.state.or.us/techserv/roadway/web_drawings/HDM/Rev_E_2003Chp09.pdf. Accessed 8-6-2010.

3. Maze, T. H., J. L. Hochstein, R. R. Souleyrette, CTRE - Iowa State University, H. Preston, and R. Storm. NCHRP Report 650: Median Intersection Design for Rural High-Speed Divided Highways. Transportation Research Board of the National Academies, Washington, DC, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf. Accessed 5-18-2010. [18]

4. Harwood, D. W., M. T. Pietrucha, M. D. Wooldridge, R. E. Brydia, and K. Fitzpatrick. NCHRP Report 375: Median Intersection Design. TRB, National Research Council, Washington, DC, 1995.

5. Potts, I. B., D. W. Harwood, D. J. Torbic, K. R. Richard, J. S. Gluck, H. S. Levinson, P. M. Garvey, and R. S. Ghebrial. NCHRP Report 524: Safety of U-Turns at Unsignalized Median Openings. Transportation Research Board of the National Academies, Washington, DC, 2004. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_524.pdf.

6. Eyler, D. Innovative Intersection Designs. (DRAFT PowerPoint presentation for 2009 ACEC/WisDOT Transportation Improvement Conference). SRF Consulting Group, Inc., Plymouth, MN, Feb. 25, 2009.

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[18] [Dec 3, 2012 email from Ellen Chafee, Editor, CRP-TRB] The TRB through the National Academy of Sciences (NAS) grants permission to use the material listed below from Maze et al. (2010) NCHRP Report 650: Median Intersection Design for Rural High-Speed Divided Highways and J. A. Bonneson and M. D. Fontaine (2001) NCHRP Report 457: Engineering Study Guide for Evaluating Intersection Improvements in a proposed revision to Chapter 11, Section 25 of Wisconsin DOT's Facilities Development Manual (FDM 11-25).

NCHRP Report 650 Table 19 p. 47

NCHRP Report 650 Figure 117 p. 148

NCHRP Report 650 Figure 31 p. 49

NCHRP Report 650 Figure 65 p. 86

NCHRP Report 650 Figure 48 p. 65

NCHRP Report 457 Figure 2.6 p. 23

NCHRP Report 457 Figure 2-6.xls Interactive spreadsheet in online version

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LIST OF ATTACHMENTS

Attachment 1.1 Selection Criteria for Rural High-Speed Intersections

FDM 11-25-2 Design Criteria and Guidelines *February 18, 2020*

2.1 Design Vehicles

AASHTO[19] has established four (4) general classes of design vehicles:

1. *Passenger cars* - includes passenger cars of all sizes, sport/utility vehicles, minivans, vans, and pick-up trucks.
2. *Buses* - include inter-city (motor coaches), city transit, school, and articulated buses
3. *Trucks* - includes single-unit trucks, truck tractor-semitrailer combinations, and truck tractors with semitrailers in combination with full trailers
4. *Recreational vehicles* - includes motor homes, cars with camper trailers, cars with boat trailers, motor homes with boat trailers, and motor homes pulling cars.

For purposes of geometric design, each class of design vehicle has larger physical dimensions and a larger minimum turning radius than those of almost all vehicles in its class. [20]

For intersection geometric design, the most important attribute of a design vehicle is its turning radius, which affects the pavement corner radius, left-turn radii, lane widths, median openings, turning roadways, and ultimately, the size of the intersection. The design vehicle may also affect the choice of intersection traffic control or intersection type and the need for auxiliary lanes.[21]

The turning radius of a vehicle determines the ease and comfort of making the turning maneuver. The smaller the turning radius, the larger the off-tracking of the vehicle and the slower the speed. Forcing large vehicles to use very small turning radii forces the driver to perform a very slow maneuver. Tighter radii are typically chosen for low speed or urban intersections, while larger radii are selected for higher speeds and rural intersections. [22,23]

See the following sections in chapter 9 of the 2004 AASHTO GDHS[24] for guidance on turning paths, clearances, encroachments and assumed speed of turning vehicles at intersections:

Right-turning vehicles:

- Types of Turning Roadways; pp.583-621
- Turning Roadways with Corner Islands; pp.634-639
- Free-Flow Turning Roadways at Intersections; pp.639-639

Left-turning vehicles:

- Median Openings; pp.689-704

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[19] AASHTO GDHS 2004 (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., Ch. 2, p.15, "Design Vehicles / General Characteristics"

[20] Florida Intersection Design Guide 2007 (*7) Florida Intersection Design Guide*, Florida DOT, 2007. https://www.fdot.gov/, sect. 3.4, "Design Vehicles"

[21] MADOT Highway Department Project Development & Design Guide (*8 MADOT Highway Department Project Development & Design Guide ch. 6*: *Intersection Design*. Massachusetts Department of Transportation - Highway Division, 2006. http://www.mhd.state.ma.us/downloads/designGuide/CH_6_a.pdf, Sect. 6.3.3, "Motor Vehicles

[22] ORDOT Highway Design Manual (*2) Highway Design Manual ch. 9.0*: *Intersection and Interchange Design*. Oregon Department of Transportation, 2008. ftp://ftp.odot.state.or.us/techserv/roadway/web_drawings/HDM/Rev_E_2003Chp09.pdf, Ch. 9, pp.14-15, "Intersection and Interchange Design"

[23] ILDOT Bureau of Design and Environment Manual 2002 (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf sect. 36-1.08(a), "Design Vehicles Types"

[24] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

- Auxiliary Lanes; pp.713-723

2.1.1 Oversized Overweight (OSOW) Vehicles

See FDM 11-25-1.4 for a discussion of the OSOW Truck Route (OSOW-TR). OSOW vehicles are non-standard vehicles that exceed the legal vehicle dimensions and require a permit[25]. OSOW vehicles fall into two general categories:

1 Single-trip permit OSOW vehicle (OSOW-ST) (see FDM 11-25-2.1.1.1)

2 Multiple-trip permit OSOW vehicle (OSOW-MT) (see FDM 11-25-2.1.1.2)

The OSOW vehicle inventory on Attachment 2.1 shows vehicles of various configurations for which templates are available for use with truck turning software to check if the OSOW vehicles will be able to negotiate an intersection.

Attachment 2.2 shows WisDOT's policy for checking OSOW-ST and OSOW-MT vehicles at intersections. Table 2.1 shows intersections where checking OSOW-ST and OSOW-MT vehicles is required. See FDM 11-25-2.1.1.1 and FDM 11-25-2.1.1.2 for guidance on accommodating OSOW vehicles.

Use AutoTurn, AutoTurn Pro 3D or Autodesk Vehicle Tracking (AVT) software for OSOW horizontal evaluation (see FDM 11-26 Attachment 50.3) with the exception of the Wind Tower 80 M MID, Wind Tower 205', and 160' X 16'. For these vehicles, only use AutoTurn or AutoTurn Pro 3D. Use AutoTurn Pro 3D or Autodesk Vehicle Tracking for low clearance evaluation (DST lowboy). Refer to these links for videos and assistance in using these tools.

This is the link to the AutoTURN Pro tutorial videos:

https://c3dkb.dot.wi.gov/Content/c3d/dsn-chk/swept-pth/swept-pth-grnd-clrnc.htm

The following OSOW-ST vehicles in the OSOW library have rear steering capabilities:

- 55 Meter Wind Blade
- 165' Beam
- Wind Tower 80 M MID
- Wind Tower 205'
- 160' x 16'

The Wind Tower 80 MID, Wind Tower 205', and 160' X 16' are the easiest to drive because the rear steering is linked to the front. Just drive the vehicle and the rear steers itself. Designers shall not manually steer the rear components of these vehicles when evaluating movements.

The 55 Meter Wind blade and the 165' Beam can be more complicated to accommodate because they have rear steering that is completely independent of what the front axle is doing. For those vehicles, initiating a swept path command will produce a dialog box with a check box called "Manual Steer". Place a check in that box to control the steering of the rear axles (see Figure 2.1). In AutoCAD Civil 3D, the rear steering is then controlled by holding the Ctrl key and using the mouse wheel to move through the swept path. When manually steering a vehicle, the designer shall not steer the rear wheels at a rate greater than 4 Degrees for every 17 feet of travel. See the following video for guidance.

http://www.c3dkb.dot.wi.gov/video/dsn-chk/swept-pth/swept-pth-beam-trnsprt-01.mp4

[25] SS 348.25(1) states "No person shall operate a vehicle on or transport an article over a highway without first obtaining a permit therefore as provided in s. 348.26 or 348.27 if such vehicle or article exceeds the maximum limitations on size, weight or projection of load imposed by this chapter."

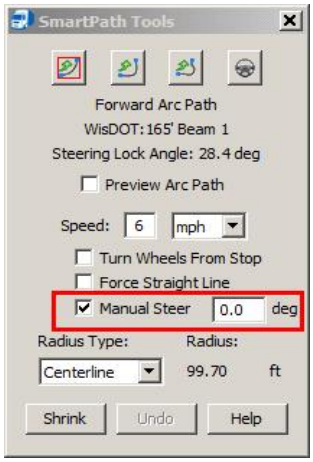

***Figure 2.1* Checkbox to Control Rear Steering**

2.1.1.1 Single-Trip Permit OSOW Vehicles (OSOW-ST)

Single-trip permit OSOW vehicles (OSOW-ST) are very large loads that exceed legal length, height, weight or width. The permits are on a load specific and route-specific basis. These vehicles generally have an overall length greater than 150 feet, and typically are required to incorporate rear steering maneuverability. Escorts are typically required.

There are three (3) representative Single-trip permit OSOW vehicles (OSOW-ST) shown on the WisDOT vehicle inventory (see Attachment 2.1):

1. DST Lowboy 5-axle expandable-deck lowboy
2. Wind Tower 205'
3. 160' x 16' Truck

WisDOT evaluated the swept path of numerous vehicles to create the OSOW-ST vehicle library. A comprehensive design vehicle has been developed which accounts for the vast majority of permitted OSOW vehicles that operate on Wisconsin Highways. The design vehicle is 160' long with a 16' wide load. It is estimated that if this vehicle is accommodated by the intersection then additional OSOW-ST vehicles will be accommodated as well within the proposed traffic control and intersection design. The DST Lowboy vehicle is used to check the vertical clearance of intersections.

On new construction, reconstruction and pavement replacement projects, identify and check the specific through and turning movements of OSOW-ST vehicles at each intersection on the OSOW-TR (or on non-OSOW-TR where OSOW-ST vehicles are known to travel), including intersections with other OSOW-TR locations (see Table 2.1). Examples include:

- Turning movements onto county or local roads to the OSOW-ST origin such as a manufacturing plant or gravel pit
- Freeway interchange off-on ramp terminals at the crossroad for a through movement,
- A turning movement where it is known that the OSOW-ST loads will turn.
- Through or turning movements at a roundabout or other alternative intersection (see FDM 11-26)
- Through movement from a stop-controlled side road across a non-stop controlled mainline

On other Perpetuation and Rehabilitation Projects it is often possible to correct impediments to freight with minor intersection improvements (e.g., paved islands, mountable noses, etc). For projects in rehabilitation or S2 areas, identify and check the specific through and turning movements of OSOW-ST vehicles at each intersection on the OSOW-TR (or on non-OSOW-TRs where OSOW-ST vehicles are known to travel), including intersections with other truck route locations (see Table 2.1 and section 11-25-1.4.2 for additional guidance). Evaluation can be completed using aerial photographs and OSOW-ST vehicle inventory. Discuss identified Impediments with the regional freight coordinator and planning unit to review scope and funding options.

There may be special design considerations to accommodate OSOW-ST vehicles. The frequency of these

OSOW-ST loads is critical when considering the type of special design that may be used. Some examples of special designs to accommodate OSOW-ST vehicles include:

- Curbs that are traversable (e.g., sloping face curbs that are 4-inches or lower) by OSOW-ST vehicles
- Paved median islands and truck aprons behind outside curb radii
- Allow counter directional travel on a right-turn bypass lane
- Provide a gated bypass lane just for the OSOW-ST vehicles to use
- Full depth shoulders
- Wide shoulders
- Stabilized/paved areas behind curbing
- Relocation of signals, poles, signs, street appurtenances, etc.
- Removable signs and street appurtenances[26]
- On new construction, reconstruction and pavement replacement projects being designed with Civil 3D software and using a 3D model, design pavement grades and cross slopes to ensure sufficient vehicle body clearance so that vehicles can make the required movements without "hanging up". This is particularly important for the 5-axle expandable-deck lowboy (DST Lowboy).

OSOW-ST vehicles are very challenging vehicles to accommodate at an intersection because of their length. Refer to Table 2.1 for intersection evaluation guidance. Same direction lane encroachments and full use of roundabout truck aprons are acceptable. Describe and document in the DSR the required OSOW-ST check movements that cannot be accommodated at an intersection without excessive impacts. Also, discuss possible alternative routes for those movements.

Contact the State Freight Engineer in the Bureau of Highway Maintenance to review OSOW movements that cannot be accommodated in order to evaluate system wide impacts.

2.1.1.2 Multiple-Trip Permit OSOW Vehicles (OSOW-MT)

Multiple-trip permit OSOW vehicles (OSOW-MT) exceed the legal semi-truck criteria to use the highway system. The permits are not load specific or route specific. Multiple Trip permits authorized by 348.27(2) and (7) may travel on any road or over any bridge (including culverts), unless the roadway or structure has been restricted in a manner consistent with various laws authorizing local or State personnel to restrict, e.g., weight posting. The envelope for these multiple trip permits are: 16' high; 15' wide; 150' long and 170k gvw[27]. OSOW-MT vehicles that have an overall length of less than 100 feet are not required to incorporate rear steering maneuverability. Escorts are typically not required. OSOW-MT vehicles that have an overall length of more than 100 feet are required to incorporate rear steering maneuverability.

The WB-92 design vehicle has been developed to account for the longest legal non-rear steer vehicle allowed by multiple-trip permits. Longer rear-steer capable vehicles will turn within the WB-92 vehicle envelope.

On new construction, reconstruction and pavement replacement projects identify and check the specific through and turning movements of OSOW-MT vehicles according to Table 2.1 (unless restricted as noted above). Also, check OSOW-MT movements at the same intersections as OSOW-ST movements (see FDM 11-25-2.1.1.1 and Table 2.1).

On other Perpetuation and Rehabilitation Projects, it is often possible to correct impediments to freight with minor intersection improvements (i.e. paved islands, mountable noses, etc). For projects in rehabilitation or S2 areas, identify and check the specific through and turning movements of OSOW-MT vehicles at each intersection on the OSOW Truck Route (OSOW-TR) (or on non-OSOW Truck Routes where OSOW-MT vehicles are known to travel), including intersections with other OSOW-TR locations (see Table 2.1 and section 11-25-1.4.2 for additional guidance). Evaluation can be completed using aerial photographs and OSOW-ST vehicle inventory. Discuss identified impediments and the intersection maneuverability checks with the regional freight coordinator and planning unit to review scope and funding options.

The WB-92 is a very challenging vehicle to accommodate at an intersection because of its length and its lack of rear steering. Refer to Attachment 2.2 for intersection evaluation guidance. Lane encroachments and full use of

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[26] NYSDOT Highway Design Manual (*10) NYSDOT Highway Design Manual ch. 5*: *Basic Design*. New York State DOT, 2006. https://www.nysdot.gov/portal/page/portal/divisions/engineering/design/dqab/hdm/hdm-repository/chapt_05.pdf., Sect. 5.7.1.3, "Oversized Vehicles"

[27] gvw = gross vehicle weight

roundabout truck aprons are acceptable. Describe and document in the DSR the required OSOW-MT check movements that cannot be accommodated at an intersection without excessive impacts. Also, discuss possible alternative routes for those movements.

2.1.1.3 Wind Tower Vehicles

Wind Tower vehicles are very large loads that exceed legal length, height, weight, or width. The permits are on a load specific and route-specific basis. These vehicles generally have an overall length greater than 150 feet, and typically are required to incorporate rear steering maneuverability. Escorts are typically required. WisDOT has created a truck (Wind Tower 205') that is generally representative of the largest wind tower component that is transported on the Wisconsin wind tower corridors. It is estimated that if this vehicle is accommodated by the intersection then additional wind tower components will be accommodated as well within the proposed traffic control and intersection design.

2.1.2 Selecting Vehicles for Intersection Design[28] and OSOW Vehicle Checks

Turning movements control the operations, safety, and efficiency of an intersection. If intersection geometry restricts vehicles from properly completing turning maneuvers then capacity is reduced, crash potential increases and the break down potential of the intersection increases. Each leg of an intersection handles the turning movements of various vehicle types with varying degrees of encroachment.

Intersection Design Vehicle (IDV). An Intersection Design Vehicle for an intersection turning movement is the largest standard vehicle that frequently makes that turning movement. An Intersection *Design Vehicle* makes the turning movement *without* encroaching onto other lanes (including a contiguous bike lane between a right turn lane and a travel lane - as illustrated in Figure 2.2 on the EB approach leg) and *without* encroaching onto the shoulder or gutter. Such designs help reduce collisions and operational delays from lane encroachments. (Note: A *right-turning* Intersection *Design Vehicle* may encroach onto a bike lane that is contiguous to the gutter, i.e., to the right of a right-turning vehicle- as illustrated in Figure 2.2 on the EB departure leg).

Intersection Check Vehicle (ICV). An Intersection Check Vehicle for an intersection turning movement is larger than the Design Vehicle and makes the turn less frequently than the Design Vehicle. An Intersection *Check Vehicle* makes the turning movement by swinging wide and encroaching onto other traffic lanes (including bike lanes) without disrupting traffic significantly. An Intersection Check Vehicle generally should not encroach into opposing travel lanes or leave the roadway (i.e., drive up on the curb or encroach beyond the shoulder), but this is not always practical or cost effective - particularly for OSOW vehicles or for turns made from/to low-speed, low-volume local streets in urban areas.

For design purposes, assume that parking stalls are occupied and therefore unavailable for the movements of Intersection Design Vehicles and Intersection Check Vehicles.

Figure 2.2 illustrates the concept of Intersection Design Vehicle vs. Intersection Check Vehicle.

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[28] ORDOT Highway Design Manual (*2) ORDOT Highway Design Manual ch. 9.0*: *Intersection and Interchange Design*. Oregon Department of Transportation, 2008. ftp://ftp.odot.state.or.us/techserv/roadway/web_drawings/HDM/Rev_E_2003Chp09.pdf, Ch. 9, pp.14-15, "Intersection and Interchange Design"

NYSDOT Highway Design Manual (*10) NYSDOT Highway Design Manual ch. 5*: *Basic Design*. New York State DOT, 2006. https://www.nysdot.gov/portal/page/portal/divisions/engineering/design/dqab/hdm/hdm-repository/chapt_05.pdf, Sect. 5.7.1, "Design Vehicle"

ILDOT Bureau of Design and Environment Manual 2002 (*9 ILDOT Bureau of Design and Environment Manual* ch. 36: Intersections. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf sect. 36-2.01(c), "Encroachment"

MADOT Highway Department Project Development & Design Guide (*8) MADOT Highway Department Project Development*

& Design Guide ch. 6: *Intersection Design*. Massachusetts Department of Transportation - Highway Division, 2006. http://www.mhd.state.ma.us/downloads/designGuide/CH_6_a.pdf, Sect. 6.7.2, "Pavement Corner Radius"; Sect. 6.7.2.1, "Simple Curb Radius"

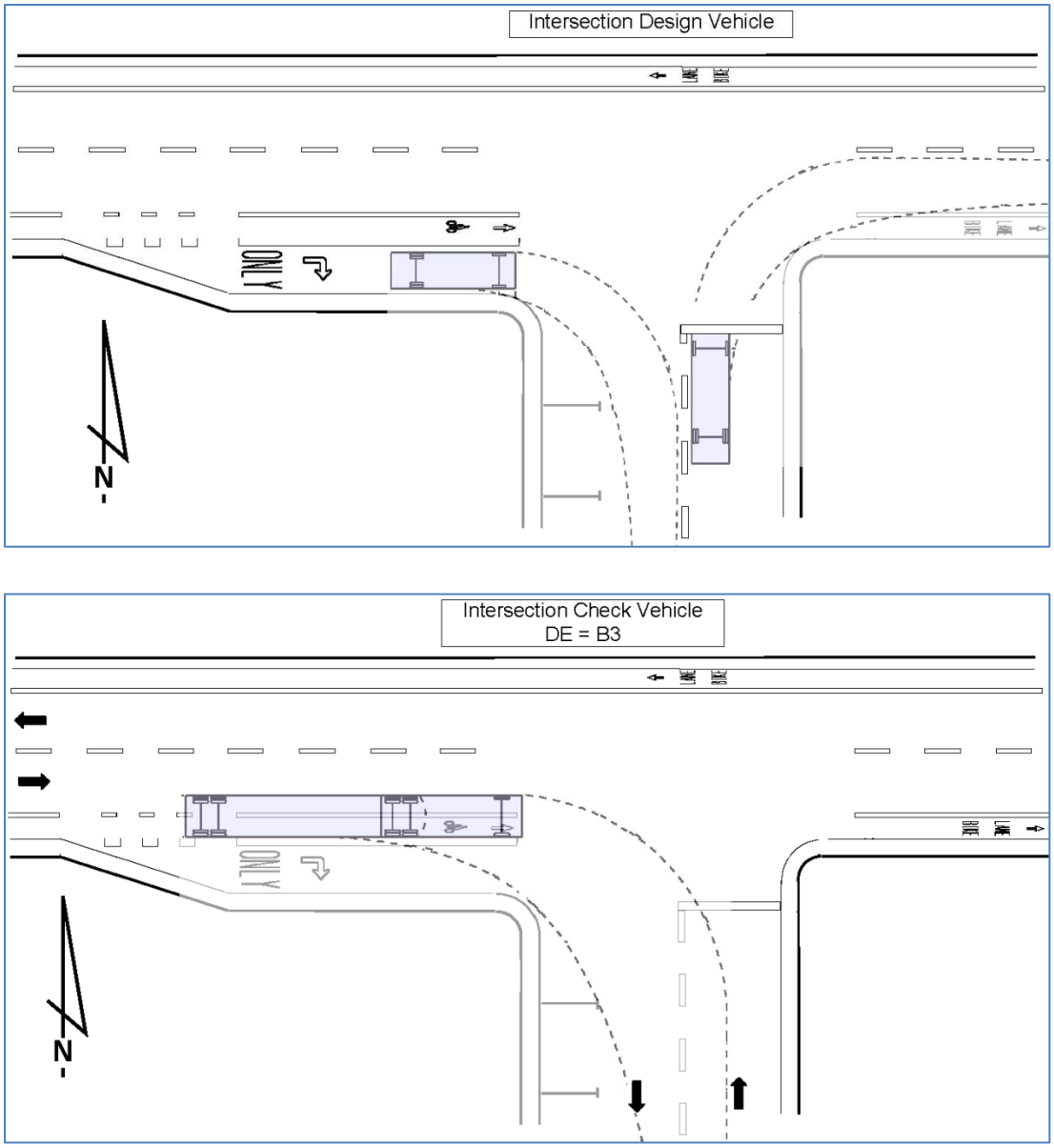

Figure 2.2 Illustrative Turning Movements for Intersection Design and Check Vehicles

Figure 2.3 illustrates and defines the possible degrees of encroachment for intersection turning movements. The acceptable degree of encroachment for a particular vehicle type varies significantly depending on roadway type and balances the operational impacts to turning vehicles with the safety of all other users of the street.

Figure 2.4 illustrates “effective” pavement width on approach and departure legs. The “effective” pavement width is the pavement width usable under the permitted degree of encroachment. At a minimum, effective pavement width is always the right-hand lane and therefore usually at least 11-12 feet, on both the approach and departure legs. Typically, legs with on-street parking have an effective pavement width that ranges from about 20-feet, if there is no bike accommodation, to about 25-feet if there is a bike accommodation. The effective width may include encroachment into adjacent or opposite lanes of traffic, where allowed.

Table 2.1 shows the default Design Vehicle for intersection turning movements, based on the functional classifications of the intersecting highways. Potentially, each turning movement at an intersection could have a different Design Vehicle.

Table 2.1 also shows Check Vehicles and their acceptable degrees of encroachment (see Figure 2.3), based on the functional classifications of the intersecting highways.

Use Table 2.1 in conjunction with Figure 2.3 and 2.4 as a starting point for planning and design. Verify the acceptable degree of encroachment during the project development process. Considerations include traffic volumes, one-way or two-way operations, urban/rural location, construction impacts, right-of-way impacts and the type of traffic control.

Attachment 2.2 shows WisDOT's policy on checking criteria for OSOW-ST and OSOW-MT vehicles at intersections. Table 2.1 shows intersections where checking OSOW-ST and OSOW-MT vehicles is required. See FDM 11-25-2.1.1.1 and 11-25-2.1.1.2 for guidance on accommodating OSOW vehicles.

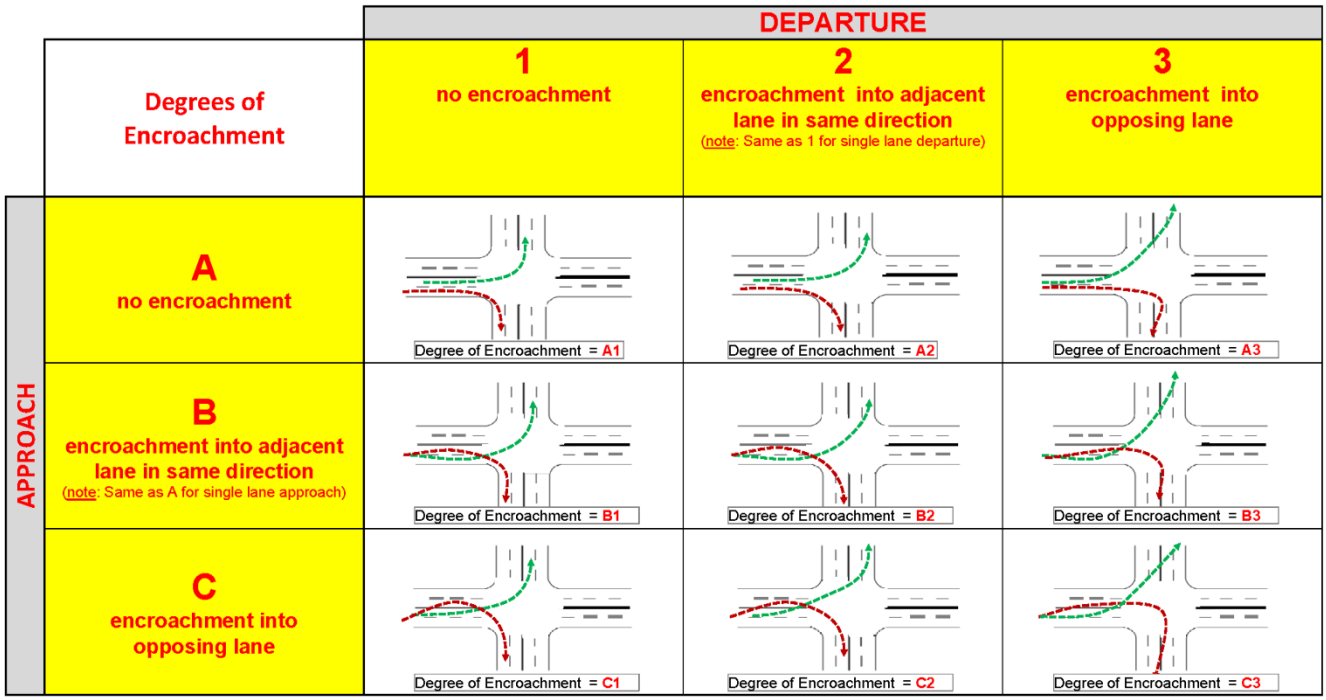

***Figure 2.3* Degrees of Encroachment[29]**

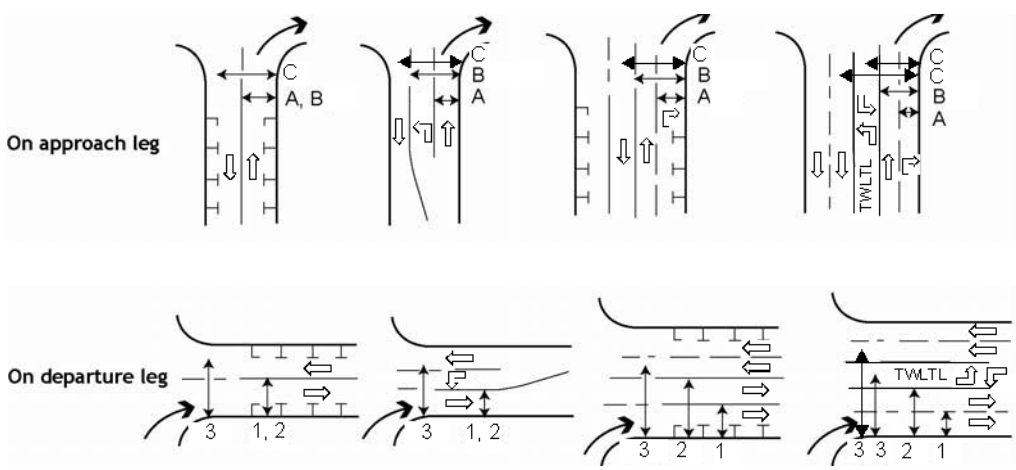

***Figure 2.4* Effective Pavement width and effect on degree of encroachment[30]**

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[29] Adapted from MADOT Highway Department Project Development & Design Guide (*8) MADOT Highway Department*

Project Development & Design ch. 6: *Intersection Design*. Massachusetts Department of Transportation - Highway Division, 2006. http://www.mhd.state.ma.us/downloads/designGuide/CH_6_a.pdf, Sect. 6.7.2, "Pavement Corner Radius", Exh. 6-15, "Typical Encroachment by Design Vehicle"

[30] MADOT Highway Department Project Development & Design Guide (*8) MADOT Highway Department Project*

Development & Design Guide ch. 6: *Intersection Design*. Massachusetts Department of Transportation - Highway Division, 2006. http://www.mhd.state.ma.us/downloads/designGuide/CH_6_a.pdf, Sect. 6.7.2, "Pavement Corner Radius", Exh. 6-17, "Effective Pavement Widths"

***Table 2.1* Default Intersection Design and Check Vehicles & Degree of Encroachment [DE] [A]**

For Turn Made		Intersection Design Vehicle(s) [DE=A1] [C], [D],	Intersection Check Vehicle(s) [DE=[XX]] [C] [D]
From (Approach) [B]	**Onto (Departure)** [B]		
Ramp	Major Arterial or Minor Arterial or Collector or Local	WB-65 [E] [F]	
Principal Arterial or Minor Arterial or Collector or Local	Ramp	WB-65 [E] [F]	
Principal Arterial or STH	Principal Arterial or STH	WB-65 [E] [F]	OSOW-MT [B2]
Principal Arterial or STH	Minor Arterial	WB-40, SU-40 [F]	WB-65 [A2] [I]
Principal Arterial or STH	Collector	WB-40 [F]	WB-65 [A2] [I]
Principal Arterial or STH	Local	SU-30 [F]	WB-65 [A2] [I]
Minor Arterial	Principal Arterial or STH	WB-40, SU-40 [F]	WB-65 [A2] [I]
Minor Arterial	Minor Arterial	WB-40, SU-40 [F]	WB-65 [A2] [H]
Minor Arterial	Collector	WB-40 [F]	WB-65 [A2] [H]
Minor Arterial	Local	SU-30 [F]	WB-40 [A2] [H] WB-65 [B2] [G], [I]
Collector	Principal Arterial or STH	WB-40 [F]	WB-65 [B2] [G], [I]
Collector	Minor Arterial	WB-40 [F]	WB-65 [B2] [G], [I]
Collector	Collector	SU-30 [F]	WB-40 [A2] [H] WB-65 [B2] [G], [I]
Collector	Local	SU-30 [F]	WB-40 [A2] [H] WB-65 [B3] [G]
Local	Principal Arterial or STH	SU-30 [F]	WB-40 [B2] WB-65 [C2] [G]
Known OSOW Route by OSOW-ST	Known OSOW Route by OSOW-ST	N/A [L]	Known OSOW vehicle [K] or OSOW-MT
OSOW-TR	OSOW-TR	OSOW-MT	OSOW-ST
OSOW-TR	Any	N/A [L]	OSOW-MT
Any	OSOW-TR	N/A [L]	OSOW-MT
OSOW-WT	OSOW-WT	N/A [L]	OSOW-WT

Notes for Table 2.1:

[A]. Intersection geometrics shall be designed using turning templates or software such as AutoTURN or Auto Track. Submit the intersection plan with turning template overlay to the Regional Traffic Unit for review.

Coordinate with the Regional freight operations unit if there will be OSOW vehicles using an intersection.
See Attachment 2.2 for WisDOT's policy on checking criteria for OSOW-ST and OSOW-MT vehicles at intersections.
See FDM 11-25-2.1.1.1 and FDM 11-25-2.1.1.2 for guidance on accommodating OSOW vehicles.
See the OSOW maps for truck routes designated as OSOW-TR located at:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/planning-maps.aspx

Also see FDM 11-25-1.4 and FDM 11-26-10.2.2.

[B]. Functional Classification Systems Maps can be found at:

https://wisconsindot.gov/Pages/projects/data-plan/plan-res/function.aspx

Truck routes are shown on the Wisconsin truck operators map available at

https://wisconsindot.gov/Pages/dmv/com-drv-vehs/mtr-car-trkr/truck-routes.aspx

Also see FDM 11-25-1.4.

Designers should consult with region freight coordinators to attain a list of permitted OSOW-ST trips.

[C]. See Figure 2.2, 2.3 and 2.4 for definitions and illustrations of Degree of Encroachment (DE)

[D]. A smaller Intersection Design Vehicle than shown in Table 2.1 may be appropriate at some locations but must be justified in the DSR. Conditions that might justify consideration of a smaller Intersection Design Vehicle include:

- Right-of-way is limited
- Trucks are prohibited on cross streets
- Current and projected Traffic counts show a small number of both the default Intersection Design Vehicle and vehicles that are larger than the default Intersection Design Vehicle (<1/day total) making the turn(s)
- Cross street volume is minimal (< 400 AADT) and the route is unlikely to be used as a detour route for a nearby higher volume roadway.

A larger Intersection Design Vehicle than shown in Table 2.1 may be appropriate at some locations but must be justified in the DSR. Conditions that might justify consideration of a larger Intersection Design Vehicle include:

- Current and projected Traffic counts show a significant number of vehicles that are larger than the default Intersection Design Vehicle making the turn(s)
- The encroachment of even a few large vehicles will cause significant traffic disruption

The following conditions apply if an Intersection Design Vehicle other than shown in Table 2.1 is used:

- Use the default Intersection Design Vehicle from Table 2.1 as an Intersection Check Vehicle and verify that it can make the turn(s) - by encroaching onto other traffic lanes if necessary - without significantly disrupting traffic. For signalized intersections, if the default Intersection Design Vehicle is a WB-65, verify that the WB-65 can make the turn(s) with a DE=A2.
- The SU or school bus design vehicles are the smallest Intersection Design Vehicles used in the design of intersections on the STH. This design reflects that, even in residential areas, garbage trucks, delivery trucks, and school buses will be negotiating turns with some frequency.
- Verify that WB-65 trucks can physically make the turns at an intersection of two truck routes without backing up and without impacting curbs, parked cars, utility poles, mailboxes, traffic control devices, or any other obstructions, regardless of the selected Intersection Design Vehicle or allowable encroachment.

For Perpetuation and Rehabilitation projects, the Intersection Design Vehicle may be site specific, if necessary, and may have a less restrictive turning radius than those for new construction and reconstruction projects.[31] See FDM 11-25-1.4.2 for further guidance.

[E]. Check right turns with a WB-67 vehicle using DE=A1 - except encroaches onto curb flag

[F]. At signalized intersections, DE=A2 is acceptable for left turns from a single left turn lane if:

- Left turns are only allowed during protected phase, or
- There are no opposing vehicles (e.g., on the non-crossing leg of a T-intersection)

[31] (9) ILDOT Bureau of Design and Environment Manual ch. 36: Intersections. Illinois DOT, 2002.

http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf. sect. 36-1.08(b), “Selection”

[G]. At signalized intersections, for the WB-65 Intersection Check Vehicle, use a preferred degree of encroachment (DE) = A2, with a minimum DE as shown.

[H]. A Degree of Encroachment (DE) = A3 may be acceptable for right turns by an Intersection Check Vehicle if there is a right-turn lane on the approach. This allows the vehicle to wait outside of the approach travel lane until traffic clears from the opposing lane on the departure leg. Use only if this is an infrequent occurrence and does not cause backups or other traffic disruptions.

[I]. At right-turn lanes with a contiguous bike lane between the turn lane and the travel lane, check the swept path of the WB-65 Intersection Check Vehicle to see if it is possible to avoid encroaching into the bike lane without significantly disrupting traffic or going outside of the roadway. Otherwise, consider:

- accepting infrequent bike lane encroachments but consider a warning sign that right turning large trucks pull left before turning.
- If bike lane encroachment is frequent enough to be potentially dangerous, consider:
  - parking restrictions or a larger curb radius
  - Marking as a shared bike/right-turn lane instead of a separate bike lane or right-turn lane
  - Re-design to reduce or eliminate the conflict

[J]. Usually, the “ramp-off / ramp-on” movement (i.e., mainline to exit ramp thru crossroad to entrance ramp to mainline) only needs to be checked if the mainline cannot accommodate the movement due to less than lower minimum roadway or structure design (e.g., low vertical clearance).

[K]. The primary objective is to maintain existing accommodations.

[L]. Not applicable. No vehicle type entered for OSOW Intersection Design Vehicle because OSOW vehicle does not apply. The underlying intersection design vehicle(s) of the roadways approaching the intersection would apply along with the OSOW intersection check vehicle(s). Refer to FDM 11-25-2.1.2.1 for guidance on OSOW vehicles at alternative intersections.

Acronym Key for Table 2.1:

OSOW = Oversized Overweight Vehicle

OSOW TR = OSOW Truck Route

OSOW-ST = OSOW Single Trip

OSOW-MT = OSOW Multiple-Trip

OSOW-WT = OSOW Wind Tower

SU = Single-unit Truck

WB = Wheelbase (effective wheelbase of vehicle) DE = Degree of Encroachment

2.1.2.1 OSOW Vehicles at Alternative Intersections

If an alternative intersection type is being considered, (such as; a roundabout, diverging diamond interchange (DDI), single-point urban interchange (SPUI), or three-leg intersection) special consideration must be made for OSOW vehicles. During preliminary design, check with local officials and the public to determine if there are any special OSOW vehicles that use the intersection. This research must include evaluating the use of the intersection by low-clearance vehicles. The region freight coordinator can provide a list of permitted OSOW-ST trips. Design truck aprons, paved islands, and mountable noses to accommodate the OSOW-ST or ‘known-use’ vehicles at alternative intersections.

2.2 Physical and Functional Areas of an Intersection

Figure 2.6 shows the Physical and Functional Areas of an intersection.

The Physical Area of an Intersection is the pavement area where the intersecting roads coincide. The points of curvature of the intersection radii define the outer boundaries of the area[32].

The Functional Area of an Intersection includes the physical area, but also extends upstream and downstream

[32] AASHTO GDHS 2004 (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., pp. 556-557)

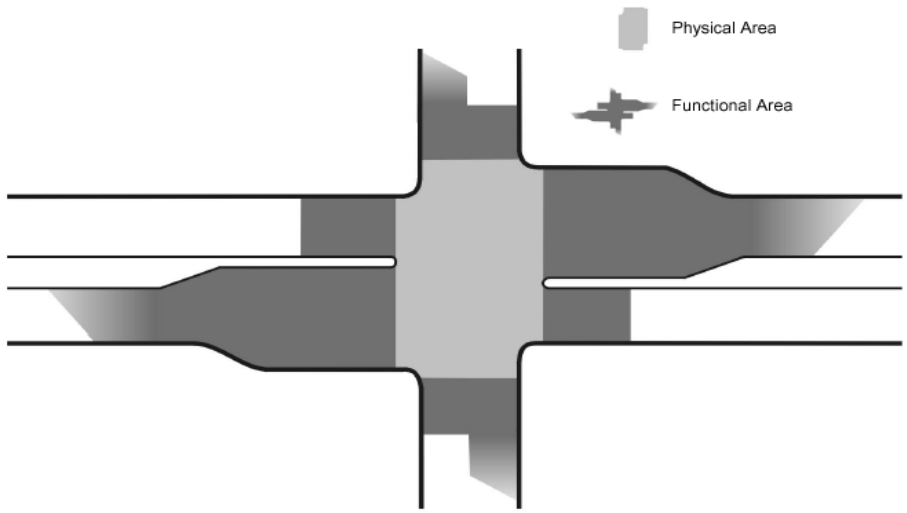


Figure 2.6 Physical and Functional Areas of an Intersection [33]

2.2.1 Downstream Functional Length of Intersection

The downstream functional length of intersection is the length of road downstream from an intersection - as measured from the sideroad edge of pavement on the downstream side of the intersection - needed to reduce conflicts between through traffic and vehicles entering and exiting the roadway. See Table 2.3 for the minimum requirements. See Figure 2.7 for illustrations of downstream functional length of intersection.

Table 2.3 Downstream Functional Length of Intersection Minimum Requirements

Traffic Control on Approaches (Upstream Thru Road Leg / Upstream Intersection Leg)	**Downstream Functional Length**
No control / No control or Stop Sign	Stopping Sight Distance (SSD) based on thru road design speed
Signalized / Signalized	
Roundabout / Roundabout	Stopping Sight Distance (SSD) based on 25 mph
Stop Sign / Stop Sign	
Stop Sign / No control and unchannelized turn	
No upstream leg (e.g., non-crossing leg of T-intersection) / Stop Sign	
No upstream leg (e.g., non-crossing leg of T-intersection) / No control and unchannelized turn	
Stop Sign / No control and channelized turn	Stopping Sight Distance (SSD) based on the greater of 25 mph or the speed of the channelized turn
No upstream leg (e.g., non-crossing leg of T-intersection) / No control and channelized turn	

[33] See TRB Access Management Manual (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 8-12, p 132 (TRB references from the "Access Management Manual" are reproduced with permission of the Transportation Research Board)

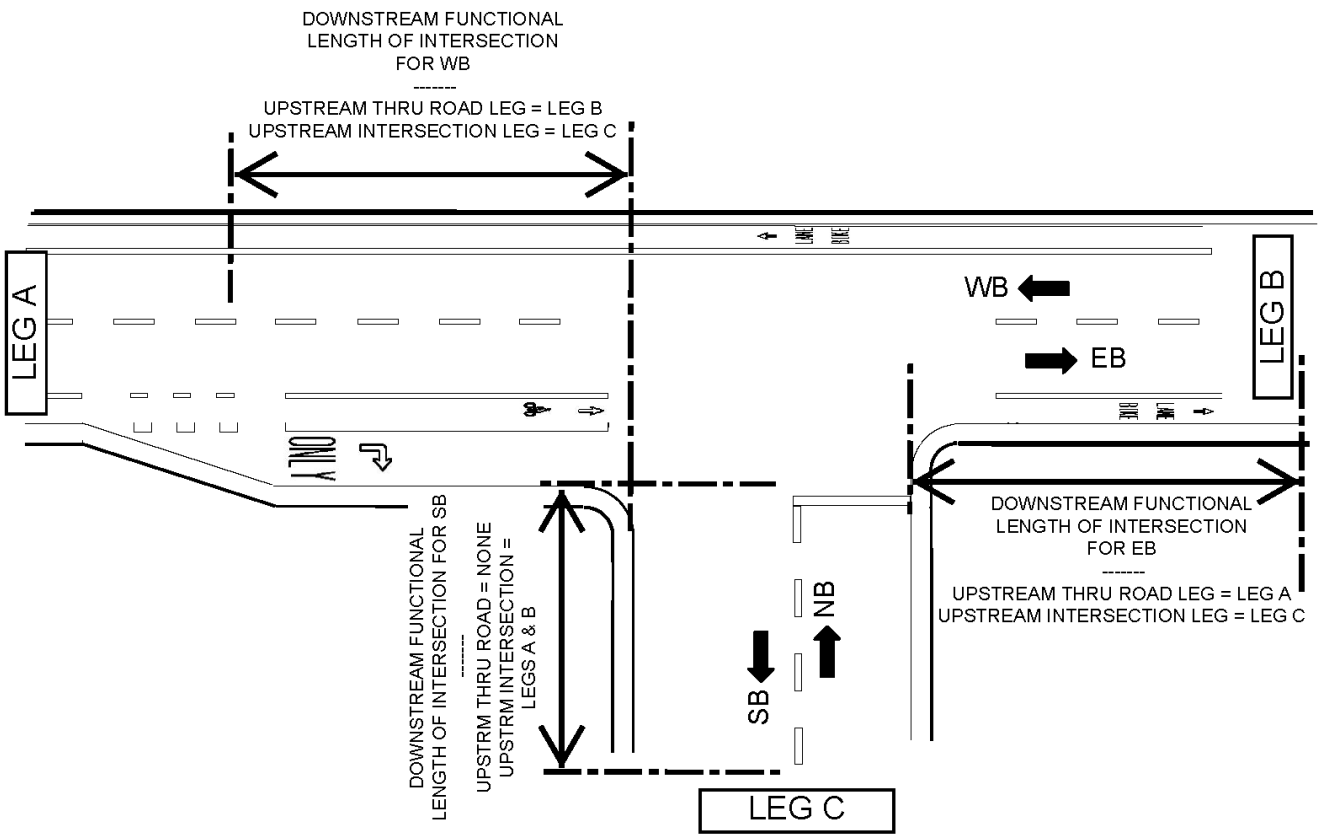


***Figure 2.7* Downstream Functional Lengths of Intersection**

The downstream functional length is also a parameter for access control in determining acceptable locations for median openings and minimum separation between private accesses and public road intersections (i.e., corner clearance - see FDM 11-25-2.5). Drivers making a turn at an intersection need adequate space to complete the maneuver before encountering vehicles turning into a downstream driveway. The left turn is the more complex maneuver because the driver is making it without positive guidance and must adjust speed, path, and direction.

2.2.2 Upstream Functional Length of Intersection

The upstream functional length of intersection is composed of four (4) elements as shown in Figure 2.8:

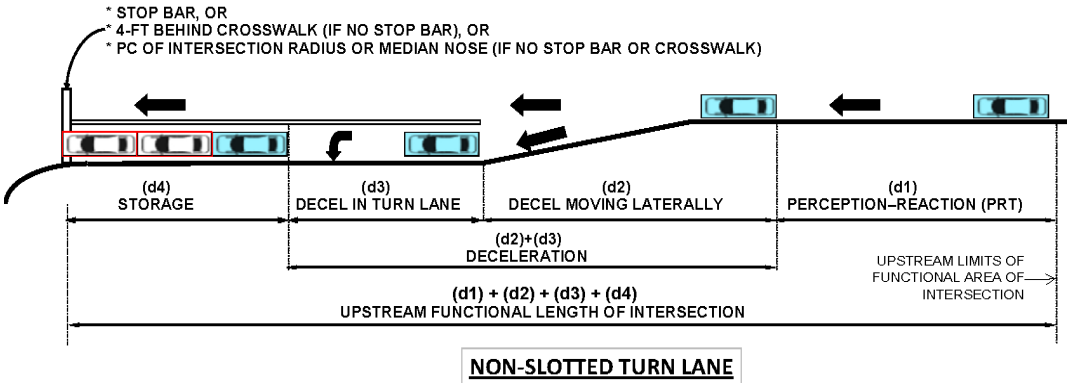
d1 = distance traveled at operating speed during the driver's perception–reaction time (PRT). See Table 2.4.

d2 = distance traveled as a vehicle clears a thru-lane and enters a turn lane by moving laterally 9-feet while braking. This is a more complex and demanding driving task than changing lanes only or braking only. See Table 2.4.
This element does not apply (i.e., d2=0-feet) to vehicles continuing in a thru-only lane or a shared turn-lane/thru-lane because there is no lateral movement).

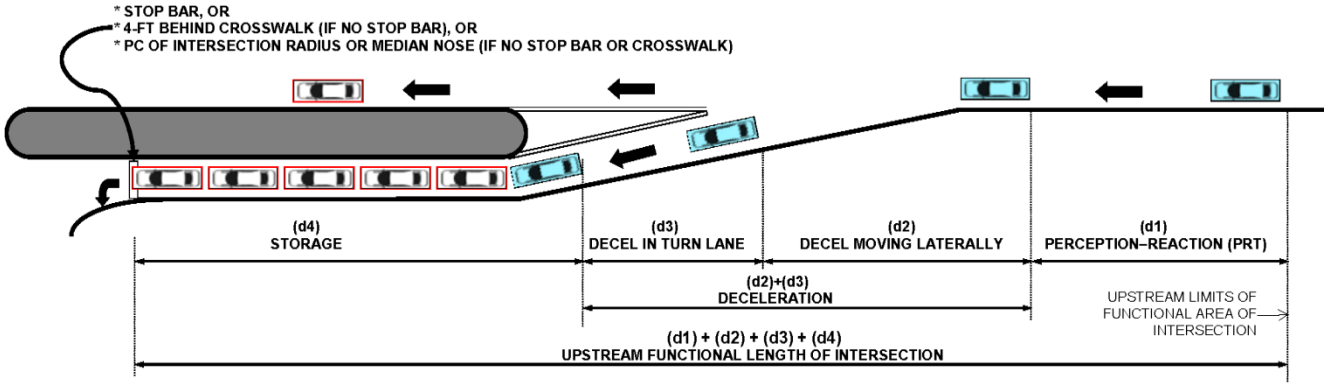
d3 = distance traveled by vehicles in a turn lane while braking to a stop after a lateral shift from thru lane. For vehicles in a shared turn-lane/thru-lane or vehicles in a stopped/signalized thru-only lane, it is the distance traveled while braking to a stop after PRT. See Table 2.4.
This element does not apply (i.e., d3=0-feet) to vehicles continuing in an unstopped/unsignalized thru-only lane because there is no deceleration).

d4 = queue storage length. Typically, use Highway Capacity Manual (HCM) or other modeling software to compute the queue storage requirement, but other methods are available. Confer with the Region traffic engineer on the appropriate software or method. Note that the decelerating vehicle is the last vehicle in the queue. See Table 2.5 and Table 2.6 for queue storage requirements.
This element does not apply (i.e., d4=0-feet) to vehicles continuing in an unstopped/unsignalized thru-only lane because vehicles do not stop.

On the OSOW Truck Route (OSOW-TR), the storage distance (d4) may need to be adjusted to accommodate one OSOW vehicle, depending on load frequency. Increased storage distance would not be required at intersections with non-TR routes.



NON-SLOTTED TURN LANE



SLOTTED TURN LANE

***Figure 2.8* Upstream Functional Length of Intersection Elements[34]**

[34] Adapted from (*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., p.5-43, Figure 5-20

Table 2.4 Upstream Functional Length of Intersection Elements d1, d2, and d3 [A]

	Perception-Reaction Distance		Maneuver Distance		
	d1 (feet) **typical** (lower min)		**d2** (feet) **typical** (lower min)	**d3** (feet) **typical** (lower min)	
Speed mph [B]	Rural [C] [E]	Urban / Suburban [C] [F]	[C] [G]	Turn lane [D] [H]	Thru lane [C] [I]
25	**90** (55)	**55** (35)	**75** (75)	**25** (25)	**100** (75)
30	**110** (65)	**65** (45)	**95** (95)	**75** (50)	**145** (105)
35	**130** (75)	**75** (50)	**110** (110)	**100** (75)	**195** (145)
40	**145** (90)	**90** (60)	**130** (130)	**150** (100)	**255** (185)
45	**165** (100)	**100** (65)	**150** (150)	**200** (150)	**325** (235)
50	**185** (110)	**110** (75)	**165** (165)	**250** (175)	**400** (290)
55	**200** (120)	**120** (80)	**185** (185)	**325** (225)	**485** (355)
60	**220** (130)	**130** (90)	**205** (205)	**400** (300)	**580** (420)
65	**240** (145)	**145** (95)	**225** (225)	**475** (350)	**680** (495)
70	**255** (155)	**155** (105)	**240** (240)	**575** (425)	**785** (575)

Notes for Table 2.4

[A] See Table 2.5 for guidance on Upstream Functional Length of Intersection element **d4** (Queue storage length)

[B] Use operating speed of travel lanes (except, not < 25 mph and not > design speed) - either as observed or as calculated using HCM or other appropriate method - Confer with the Region traffic engineer. Assume that free flow speed does not exceed Design Speed.

[C] All dimensions rounded to nearest 5-feet

[D] All dimensions rounded to nearest 25-feet

[E] Typical distance based on a perception-reaction-time (PRT) of 2.5s.
Lower minimum distance based on a perception-reaction-time (PRT) of 1.5s.

[F] Typical distance based on a perception-reaction-time (PRT) of 1.5s.
Lower minimum distance based on a perception-reaction-time (PRT) of 1.0s.

[G] Applies only to turn-lanes
The **d2** distance is based on an assumed deceleration rate of 5.8 fps^2 based, which is based on a vehicle moving laterally 9-feet at an assumed lateral shift rate of 3 to 4 fps, while reducing its speed by 10 mph.
A vehicle is assumed to have cleared the thru traffic lane when it has moved laterally 9-feet. The speed differential between the turning vehicle and following thru vehicles is 10 mph when the turning vehicle clears the thru traffic lane. .[35]

[H] Applies only to turn-lanes
Distance to decelerate from [Speedminus10 mph] to [stop]
Typical **d3** distance based on a deceleration rate of 6.7 fps^2, which is the observed 85th-percentile rate.
Lower minimum **d3** distance based on a deceleration rate of 9.2 fps^2, which is the observed 50th-percentile rate.

[I] Applies only to shared turn-lane/thru-lanes or stopped/signalized thru-only lanes
Distance to decelerate from [Speed] to [stop]
Typical **d3** distance based on a deceleration rate of 6.7 fps2, which is the observed 85th-percentile rate.
Lower minimum **d3** distance based on a deceleration rate of 9.2 fps2, which is the observed 50th-percentile rate.

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[35] Research shows that the crash rate is 3.3 times higher for a 20-mph speed differential than for a 10-mph speed differential; 23 times higher for a 30-mph speed differential; and 90 times higher for a 35 mph speed differential, as documented by Stover & Koepke (*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., p.5-37).

Crashes resulting from excessive speed differential can occur up to several hundred feet from the intersection as well as at the intersection itself.

Table 2.5 Queue Storage (d4) for STH Intersections [36] [A] [B] [C]

Design Class	Approach Control	Thru-only Lanes **typical** (lower min)	Left Turn **typical** (lower min)	Right Turn **typical** (lower min)
Rural A2, A3	**No control**	no storage required	**greater of 90th pctl or 4-veh** (greater of 90th pctl or 2-veh	**90th pctl**
	Stop Sign	**greater of 90th pctl or 4-vehicles** (greater of 90th pctl or 2-vehicles)		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95th pctl or 4-vehicles** (greater of 95th pctl or 2-vehicles)	
Rural other	**No control**	no storage required	**greater of 90th pctl or 2-vehicles**	**90th pctl**
	Stop Sign	**greater of 90th pctl or 2-vehicles**		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95th pctl or 2-vehicles** (greater of 90th pctl or 2-vehicles)	
Urban transitional/high-speed UA2, UA3	**No control**	no storage required	**greater of 90th pctl or 4- veh** (greater of 90th pctl or 2- veh	**90th pctl**
	Stop Sign	**greater of 90th pctl or 4-vehicles** (greater of 90th pctl or 2-vehicles)		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95th pctl or 4-vehicles** (greater of 95th pctl or 2-vehicles	
Urban transitional/high-speed other	**No control**	no storage required	**greater of 90th pctl or 2-vehicles**	**90th pctl**
	Stop Sign	**greater of 90th pctl or 2-vehicles**		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95th pctl or 2-vehicles** (greater of 90th pctl or 2-vehicles)	
Urban low-speed 3, 4, 5	**No control**	no storage required	**greater of 90ctl or 4- veh** [D] (greater of 90th pctl or 2- veh [D]	**90th pctl**
	Stop Sign	**greater of 90ctl or 4 vehicles** [D] (greater of 90th pctl or 2 vehicles) [D]		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95ctl or *4 vehicles** [D] (greater of 90th pctl or 2-vehicles) [D]	
Urban low-speed other	**No control**	no storage required	**greater of 90th pctl or 2 vehicles** [D]	**90th pctl**
	Stop Sign	**greater of 90th pctl or 2-vehicles** [D] (greater of 85th pctl or 2-vehicles) [D]		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95th pctl or 2-vehicles** [D] (greater of 90th pctl or 2 vehicles) [D]	
all	**Roundabout**	see FDM 11-26		

Notes for Table 2.5:

[A] pctl = percentile

[B] Assume vehicle length = 25-feet

[C] On the OSOW Truck Route (OSOW-TR), storage distance (d4) may need to be adjusted to accommodate one OSOW vehicle, depending on load frequency. Increased storage distance is not being required at intersections with non-TR routes.

[D] one (1) vehicle if peak turning volume < 20 vph

[36] Adapted from Bonneson & Fontaine in NCHRP Report 457 (*13) NCHRP Report 457*: *Engineering Study Guide for Evaluating Intersection Improvements*. TRB, National Research Council, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf, pp.23-25); see also Stover & Koepke (*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., pp. 5-50 to 5-53)

An intersection approach may have a different upstream functional length for the thru lane(s), left-turn bay, and right-turn bay because of different queue storage requirements for those lanes. Each lane of a multi-lane approach can have a different upstream functional length. The upstream functional length for a thru lane is the longer of the functional length calculated for the thru lane and the functional length(s) calculated for the turn bay(s) adjacent to that thru lane.

The upstream functional length of intersection is not a static dimension, particularly on urban roads. It can vary because operating speeds and queue storage requirements vary during the course of a day. For example, during peak conditions, the queue storage requirement (**d4**) might be longer because there are more turning vehicles; but the PRT (**d1**) and maneuver distances (**d2** & **d3**) might be shorter because operating speeds are lower. The opposite might be true during non-peak conditions.

Use the upstream functional length of intersection to design and evaluate turn bay lengths (see Table 2.5, "Turn Bays" for additional guidance).

In addition, upstream functional length of intersection is a parameter for access control when determining acceptable locations for median openings and minimum separation between private accesses and public road intersections (i.e., corner clearance). See the sections below on "Median Opening Locations" and "Driveways and Corner Clearance".

2.3 Turn Bays

Turn bay length includes both the approach taper and the full width turn lane (see Figure 2.9). Providing adequate turn bay length is important because it minimizes deceleration in the thru travel lanes by turning vehicles [37], and it reduces the probability of "spillback" into the travel lane by queued turning vehicles.

Use the following guidance for determining turn bay length:

- Use the upstream functional length to design and evaluate turn bay lengths (see Figure 2.9 for the correlation of Upstream Functional Length of Intersection and Turn Bay elements).
- Calculate for both the peak and non-peak conditions and use the longer of the two to determine the length of turn bay.
    - See Table 2.4 for functional length elements **d1**, **d2**, and **d3** (i.e., PRT and deceleration)
    - See Table 2.5 for functional length element **d4** (i.e., queue storage);
    - See Table 2.6 for full-width turn lane lengths
    - See Attachment 2.3 for turn bay taper lengths.
- If possible, provide a turn bay length that meets typical criteria. A design based on typical criteria will maximize the safety, operational efficiency and capacity of an intersection approach – and provide a margin of error when conditions exceed design assumptions.
- If it is not possible to meet typical criteria because of physical constraints or existing development then, if possible, provide a turn bay length that exceeds minimum criteria.
- If it is not possible because of physical constraints or existing development to exceed minimum criteria then provide a turn bay length that meets minimum criteria.
- If it is not possible to meet minimum criteria, look at removing or relocating the physical constraint. If that is not possible, it may be necessary to close the median opening or restrict movements if it is not possible to provide a proper left turn lane. As a last resort, with the approval of the Regions access coordinator and traffic engineer, provide a shorter turn bay rather than no turn bay at all. Try to provide enough queue storage to minimize spillback into the thru lanes.

[37] As documented by Stover & Koepke (*12) Transportation and Land Development*, 2nd edition. ITE, 2006, (p.5-37, Table 5-12): The crash rate is 3.3 times higher for a 20-mph speed differential vs. a 10 mph speed differential; 23 times higher for a 30 mph speed differential vs. a 10 mph speed differential; and 90 times higher for a 35 mph speed differential vs. a 10 mph speed differential.

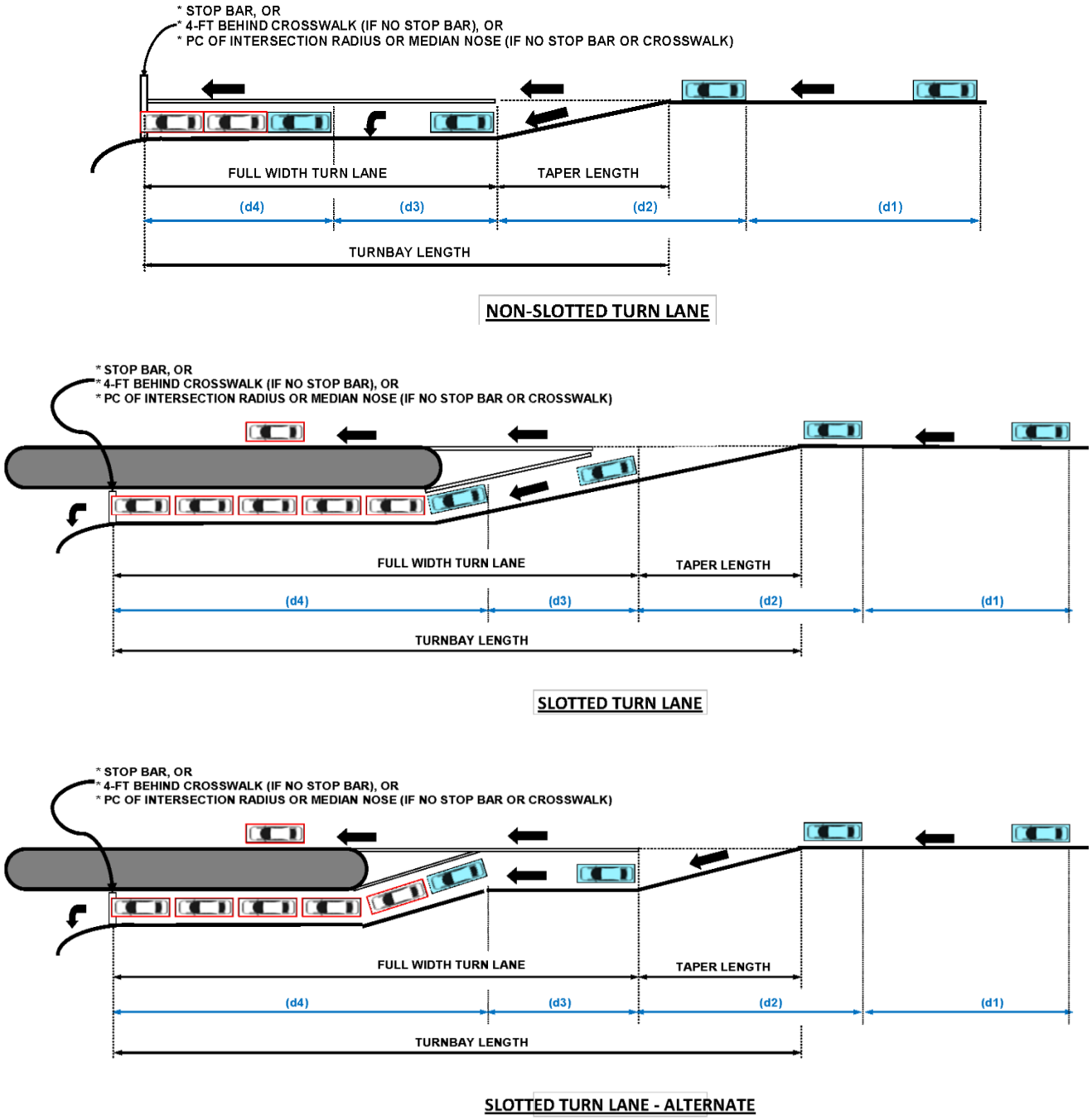

***Figure 2.9** Turn Bay Elements and Correlation with Upstream Functional Length of Intersection*

Table 2.6 Full-Width Turn-Lane Length for Urban Streets and Low Speed Rural [A] [38]

Approach Control	Left Turn Lane		Right Turn Lane	
	Rural	Urban	Rural	Urban
No control (i.e., un-stopped)	**d3+d4** [B] [C] [D]	Posted speed<=30 mph **d3+d4** (d4) Posted Speed>30 mph **d3+d4** [B] [C] [D]	**d3+d4** [B] [C] [D]	Posted speed<=30 mph **d3+d4** (d4) Posted Speed>30 mph **d3+d4** [B] [C] [D]
Stop Sign	**d4** [B] [C] [D] [E] [F]			
Signalized	**d3+d4** [B] [C] [D] [F]	Posted speed<=30 mph **d3+d4** (d4) Posted Speed>30 mph **d3+d4** [B] [C] [D] [F]	**d3+d4** [B] [C] [D] [F]	Posted speed<=30 mph **d3+d4** (d4) Posted Speed>30 mph **d3+d4** [B] [C] [D] [F]

Notes

A See FDM 11-25 Attachment 1.1 for guidance on high-speed rural turn lanes

B On the OSOW priority network, full-width turn lane length may need to be adjusted to accommodate one OSOW vehicle, depending on load frequency. Increased length would not be required at intersections on OSOW secondary routes.

C See FDM 11-25-2.2.2, "Upstream Functional Length of Intersection" for definitions of dimensions **d3** and **d4**.

See Table 2.4 for **d3** dimension; see Table 2.5 for **d4** dimension.

D **Vertical Alignment:** A crest vertical curve can hide the beginning of a turn bay. Avoid this by extending the full width turn-lane so that the turn lane is perceptible from the PRT distance. Do this by lengthening the full width turn-lane rather than lengthening the taper.

E Both thru and turning vehicles decelerate on the approach to a stop sign, which minimizes the potential speed differential.

F **Length of queue in the adjacent thru lane:** The thru lane queue can sometimes block entry into a turn bay. This can have a negative effect on the operation and capacity of the intersection if it occurs on a regular basis. Avoid this by extending the length of full-width turn-lane so that it is at least as long as the longest expected queue in the adjacent thru lane. (This is normally more critical for a left turn bay than a right turn bay).

2.3.1 Left Turn Lanes

See FDM 11-25-5 for additional guidance on left-turn lanes.

2.3.2 Right Turn Lanes

See FDM 11-25-10 for additional guidance on right-turn lanes.

2.4 Taper Design

Tapers commonly used around at-grade intersections can be classified as follows.

- Shifting taper
- Merge taper
- Add lane taper

[38] Adapted from (*13) NCHRP Report 457*: *Engineering Study Guide for Evaluating Intersection Improvements*. TRB, National Research Council, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf.

- Turn bay taper (see FDM 11-25-2.3)
- Shoulder taper

See Attachment 2.3 for descriptions of these features as well as guidance for designing them. Much of the guidance in Attachment 2.3 comes from the FHWA MUTCD[39] and the AASHTO GDHS 2004[40].

2.4.1 Lane Reduction at Intersection

It is typical to continue a full-width thru lane beyond an intersection and then terminate the lane with a lane-drop taper (i.e., merging taper) than to terminate the lane at the intersection as a turn-only lane (i.e., "trap" lane).

The table in Attachment 2.3 shows both the typical and minimum length of tangent section that is to precede a merging taper on the downstream side of an intersection. The typical distance provides enough room for placing two signs (W9-1R and W4-2R) upstream from the merge point. The minimum distance provides enough room for placing only one sign (W4-2R).

The minimum tangent length comes from the Condition 'A' column of Table 2C-4 of the Wisconsin Supplement to the MUTCD at:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/wmutcd/wmutcd.aspx

and represents the distance between the W4-2R sign and the start of the merge taper. This distance varies according to the posted speed of the road. The typical tangent length equals the minimum tangent length plus 200-feet.

WisDOT's standard practice is to provide for two signs in advance of a merging taper. The first sign is the W9-1R and is located at the typical distance upstream from the start of the merging taper - either on the signal pole on the downstream side of the intersection or on a separate post just beyond a non-signalized intersection. The second sign (W4-2R) is located at the minimum distance upstream from the start of the merging taper and 200 ft downstream from the first sign. For example, at a posted speed of 55 mph, a W9-1R sign is located 950-feet ahead of the start of the merging taper; and a W4-2R sign is located 750-feet ahead of the start of the merging taper.

Consider a longer tangent distance if the approach roadway has less than the minimum Stopping Sight Distance (SSD) required by FDM 11-10-5.

2.5 Corner Clearance to Driveways

Driveways are, in effect, intersections. Their design and location merit special consideration because crashes are disproportionately higher at driveways. Ideally, driveways are not located within the functional area of an intersection or in the influence area of an adjacent driveway"[41] Access connections too close to intersections can cause serious traffic conflicts that impair the function of the affected facilities. Drivers require sufficient time to address one potential set of conflicts before facing another.

Traffic conflicts occur when the paths of vehicles intersect and may involve merging, diverging, stopping, weaving, or crossing movements. Each conflict point is a potential collision. Each new access point introduces conflicts and friction into the traffic stream. As conflicts increase, driving conditions become more complex, drivers are more likely to make mistakes, crash potential increases, and the resulting friction translates into longer travel times and greater delay. Conversely, simplifying the driving task contributes to improved traffic operations and reduces collisions. Separating conflict areas helps to simplify the driving task and contributes to improved traffic operations and safety. [42]

"Corner clearance represents the distance that is provided between an intersection and the nearest driveway."[43] Marginal corner clearance (Figure 2.10) is the distance between an intersection and the nearest driveway along the same side of the highway. Median corner clearance (Figure 2.11) is the distance between an intersection and the nearest median opening for a driveway. See FDM 11-25-20.4 for median opening location criteria and

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[39] (*14) Manual on Uniform Traffic Control Devices.* Federal Highway Administration, 2009., chapters 3 & 6

[40] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., pp.715-716)

[41] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., p.729)

[42] (*11)Access Management Manual*. Transportation Research Board, 2003., pp.8, 143

[43] (*11)Access Management Manual*. Transportation Research Board, 2003., p.155)

requirements.

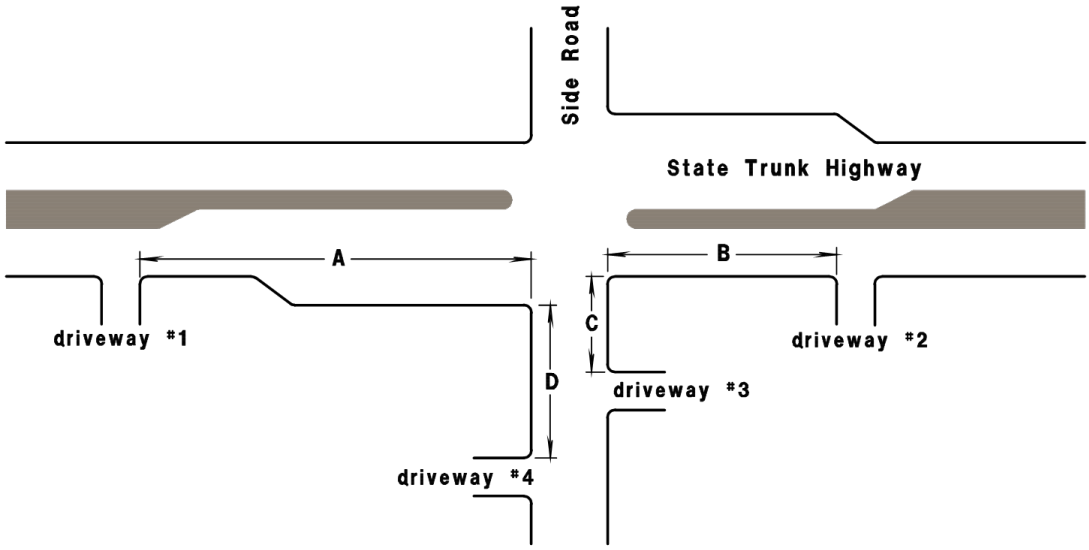

***Figure 2.10** Intersection Marginal Corner Clearances[44] (See Table 2.7)*

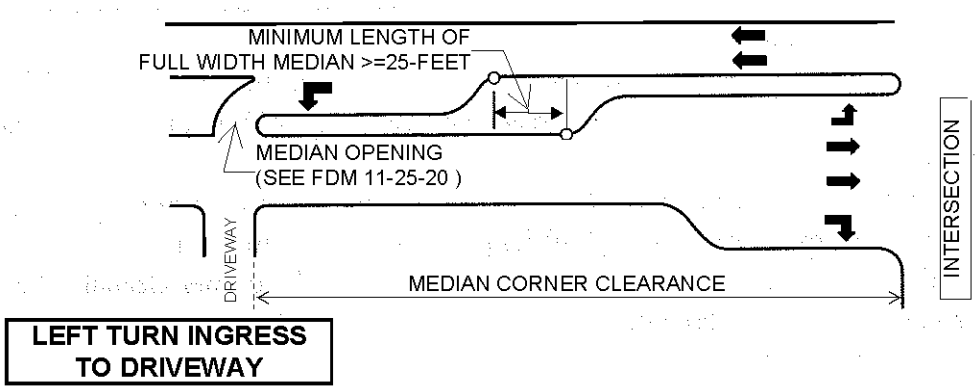

***Figure 2.11** Intersection Median Corner Clearances[45]*

Inadequate corner clearances can result in traffic operation, safety, and capacity problems. These problems can be caused by blocked driveway ingress and egress, conflicting and confusing turns at intersections, insufficient weaving distances, and backups from a downstream driveway into an intersection.

[44] (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 9-10, p 157 (TRB references from the "Access Management Manual" are reproduced with permission of the Transportation Research Board)

[45] Adapted from Stover & Koepke (*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., p.6-24 to 6-35 and Figure 6-19). © 2012 Institute of Transportation Engineers, 1627 Eye Street, NW, Suite 600, Washington, DC 20006 USA, www.ite.org. Used by permission.

Table 2.7 Marginal Corner Clearance Distances

Corner Clearance Description	Urban	Rural
A Approach (nearside) on the STH *	The upstream functional length for the STH (FDM 11-25-2.2.2)	Typical The greater of the upstream functional length of intersection for the STH (FDM 11-25-2.2.2), **OR** the distance for private intersections from FDM 11-5 Attachment 5.1 Minimum The distance for private intersections from FDM 11-5 Attachment 5.1
B Departure (farside) on STH *	Typical The greater of the downstream functional length of intersection for the STH (FDM 11-25-2.2.1), **OR** the upstream functional length for the proposed driveway. Minimum The greater of the downstream functional length of intersection for the STH (FDM 11-25-2.2.1), **OR** the right-turn queue storage length (d4) for the proposed driveway.	Typical The greater of the downstream functional length of intersection for the STH (FDM 11-25-2.2.2), **OR** the upstream functional length for the proposed driveway, **OR** the distance for private intersections from FDM 11-5 Attachment 5.1 Minimum The greater of the downstream functional length of intersection for the STH (FDM 11-25-2.2.1), **OR** the right-turn queue storage length (d4) for the proposed driveway, **OR** the distance for private intersections from FDM 11-5 Attachment 5.1
C Approach (nearside) on the side road	**STH side road *** The corner clearance requirement is equal to that of corner clearance “A”. **Non-STH side road **** Typical The greater of the upstream functional length of intersection for the side road approach to the STH, **OR** the upstream functional length for left-turns from the side road into the proposed driveway Minimum The greater of the downstream functional length of intersection for the side road (FDM 11-25-2.2.1), **OR** the queue storage length (d4) for left-turns from the side road into the proposed driveway, **OR** the queue storage for the side road approach to the STH (Table 2.5).	
D Departure (farside) on the side road	**STH side road *** The corner clearance requirement is equal to that of corner clearance “B.” **Non-STH side road **** Typical The greater of the downstream functional length of intersection for the side road (FDM 11-25-2.2.1), **OR** the upstream functional length for the proposed driveway Minimum The greater of downstream functional length of intersection for the side road (FDM 11-25-2.2.1), **OR** the right-turn queue storage length (d4) for the proposed driveway	

* For corner clearance on a STH’s, use Table 2.7 and apply the conditions shown in section 2.5.1, “Corner Clearances on STH’s”.

** For corner clearance on non-STH side roads, use Table 2.7 and apply the conditions shown in section 2.5.2, “Corner Clearances on non-STH’ roads”.

2.5.1 Corner Clearance on-STH's

Use the following guidance for corner clearance on STH's:

1. If possible, provide a driveway on corner parcels from the side road instead of from the STH. This requires safe and convenient alternative access and reasonable internal site circulation
2. If it is necessary to provide a driveway from the STH, then limit a corner parcel to one (1) driveway on the STH. If possible, locate this driveway at or beyond the corner clearance requirement shown in Table 2.7. If the corner parcel has insufficient frontage, then it may be possible to accomplish this by consolidating driveways with an adjacent property. Follow the guidance in FDM 11-20 Attachment 10.1 for driveway placement near a property line.
3. If it is necessary to provide driveway access from the STH and it is not possible to construct the driveway at or beyond the corner clearance requirement shown in Table 2.7, then limit a corner parcel to one (1) driveway on the STH that meets all of the following conditions:
    - Locate the driveway as far from the intersection as possible. Follow the guidance in FDM 11-20 Attachment 10.1 for driveway placement near a property line. Always consider consolidating driveways to increase the corner clearance distance.
    - Do not allow left-turn ingress and egress at driveways within the functional area of intersection on the STH, except as provided in Table 20.1. Provide a physical (non-traversable) median on the STH to preclude left turns into or out of driveways. For divided highways, this means not allowing a median opening for a driveway within the functional area of intersection, except as provided in Table 20.1. For undivided highways, this means providing short sections of a median divider or adopting a driveway design that discourages or prevents left turn maneuvers.
    - Do not locate a driveway inside a right-turn bay unless all of the following apply:
        - Alternative access is not possible,
        - The driveway is low-volume (<15 vpd),
        - A non-traversable median prevents left turns into or out of the driveway,
        - Vehicles cannot maneuver into the left-turn lane from the driveway, and
        - The successive separate right-turn bays would either be undesirably short or too close together.
    - If possible, restrict a nearside driveway to right in if it is within the queue storage limits of the downstream intersection.
    - If possible, restrict a far-side driveway to right out if it is closer than stopping sight distance from the upstream intersection.
    - Do not locate a driveway within the physical area of the intersection (see Figure 2.6). Provide at least 25-feet between the PC of the intersection curb radius and the PC of the driveway curb radius.
    - Do not locate a nearside driveway at or downstream from the stop bar for the downstream intersection. Provide at least 25-feet between the stop bar and the PC of the driveway curb radius.
    - Do not locate a driveway within the limits of a legal crosswalk, or within the limits of a curb ramp for a crosswalk.
4. If possible, relocate the driveway if joint or alternate access becomes available that meets or exceeds corner clearance requirements.

2.5.2 Corner Clearance on Non-STH Roads

WisDOT may not have the same degree of control on non-STH side roads as it does on the STH and may need to work with the local jurisdiction to achieve adequate corner clearances.

WisDOT's main concern with driveways on non-STH side roads is that they do not adversely affect the STH roadway (see Figure 2.12). Drivers making a turn onto a sideroad from a STH need adequate space to complete the maneuver before encountering vehicles turning into a downstream driveway on the side road. The left turn from the STH is the more complex maneuver because the driver is making it without positive guidance and must adjust speed, path, and direction

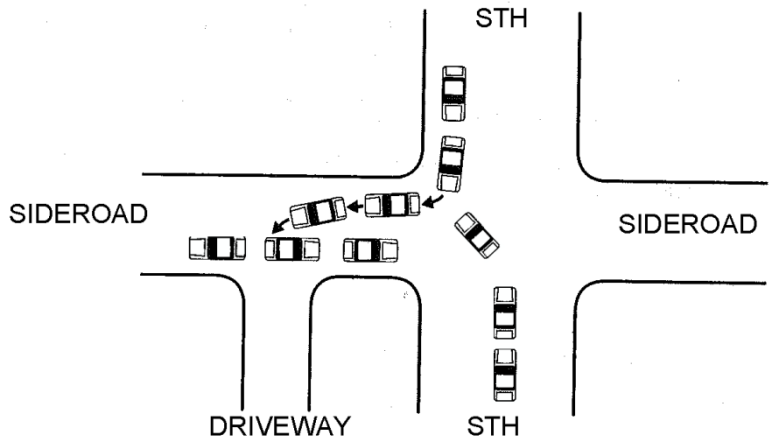

Figure 2.12 Inadequate Corner Clearance on Sideroad[46]

If it is not possible to provide the minimum corner clearance shown in Table 2.7 for a non-STH side road, then:

- Locate the driveway as far from the intersection as possible. Follow the guidance in FDM 11-20 Attachment 10.1 for driveway placement near a property line. Always consider consolidating driveways to increase the corner clearance distance.
- If possible, restrict a nearside driveway (corner clearance 'C') to right-in/right-out (i.e., no left-turn ingress or egress).
- If possible, restrict a far-side driveway (corner clearance 'D') to right-out.
- Do not locate a driveway within the physical area of the intersection (Figure 2.6). Provide at least 25-feet between the PC of the intersection curb radius and the PC of the driveway curb radius.
- Do not locate a nearside driveway at or downstream from the stop bar for the downstream intersection. Provide at least 25-feet between the stop bar and the PC of the driveway curb radius.
- Do not locate a driveway within the limits of a legal crosswalk, or within the limits of a curb ramp for a crosswalk.

2.6 Intersection Vertical Alignment

See pp.582 and 279-282 of the 2004 GDHS[47].

If possible and practical, avoid grades in excess of 3% within the intersection area and on the portion of approaches where vehicles are required to stop because this complicates intersection design. Typically, grades will be flatter than the maximum values allowed (see FDM 11-10-5.4.1 and Attachment 5.3).

On the OSOW Truck Route (OSOW-TR), check the roadway profile to avoid abrupt grade transitions that may affect OSOW-ST vehicles with low ground clearance. OSOW-ST vehicles with very low ground clearance can hang up on the roadway crown or the rollover between a superelevated section and a side road profile at intersections.

Additionally, on the OSOW-TR, some loads on OSOW-ST vehicles are susceptible to torsion or twisting forces that can exceed the torsional shear capacity of a blade, beam, or concrete member. If possible, design the vertical alignment and cross slopes in the intersection area to help avoid excessive shear forces created by torsion forces as the OSOW-ST Vehicle maneuvers the intersection.

Avoid locating intersections just beyond the crest of vertical curves.

2.7 Intersection Sight Distance

For information about intersection sight distance, refer to FDM 11-10-5.

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[46] Adapted from (*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., Figure 6-20 on p. 6-30. © 2012 Institute of Transportation Engineers, 1627 Eye Street, NW, Suite 600, Washington, DC 20006 USA, www.ite.org. Used by permission.

[47] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

2.8 Angle of Intersection[48]

It is preferable for intersecting streets to meet at an angle as close to 90°as possible. On the OSOW-TR, it is preferable for roadways to intersect at an angle as close to 90° as possible, thus reducing the impact of those vehicles with a large turning radius.

It may be necessary to shift the intersection and to realign part of the sideroad in order to improve the angle of intersection. This usually requires inserting a horizontal curve on the sideroad in close proximity to the intersection. See FDM 11-10-5.1.1.4, "Sight Distance on a Stop Sign Controlled Approach" and FDM 11-10-5.2.2, "Horizontal Curve on a Stop Sign Controlled Approach".

2.8.1 Angle of Intersection for New Intersections

The following applies to new intersections on all projects

2.8.1.1 Intersection on Tangent or on Outside of Curve:

- Typical: between 75° and 105°
- Minimum: 70°
- Maximum: 110°

2.8.1.2 Intersection on Inside of Curve

Table 2.8 Angle of Intersection for Intersection on Inside of Curve

Road	Radius (ft)	Typical angle	Minimum angle	Maximum angle
High Speed and Transitional	>6000	between 75° and 105°	70°	110°
	4000-6000	between 80° and 100°	75°	105°
	<4000	between 85° and 95°	80°	100°
Low Speed	>3000	between 75° and 105°	70°	110°
	2000-3000	between 80° and 100°	75°	105°
	<2000	between 85° and 95°	80°	100°

2.8.2 Angle of Intersection for Existing Intersections on Modernization Projects

2.8.2.1 Intersection on Tangent or on Outside of Curve

Improve the intersection angle using the guidelines for NEW intersections if the existing intersection meets any of the following conditions:

- The existing angle is less than minimum or greater than maximum angle for NEW intersections and the angle is contributing to intersection crashes, or
- The existing angle is less than 65°or greater than 115°.

2.8.2.2 Intersection on Inside of Curve

Improve the intersection angle using the guidelines for NEW intersections if the existing intersection meets any of the following conditions:

---

[48] *(15)* Intersection Angle Geometry and the Driver's Field of View. In *Transportation Research Record 1612: Highway Geometric Design Issues* TRB, National Research Council, 1998, pp.10-16.,

(16) Highway Design Handbook for Older Drivers and Pedestrians. FHWA-RD-01-103. Federal Highway Administration Turner-Fairbank Highway Research Center, 2001. http://www.tfhrc.gov/humanfac/01103/coverfront.htm.

(17) Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians. FHWA-RD-01-051. Federal Highway Administration, 2001. http://www.tfhrc.gov/humanfac/01105/cover.htm.

(18) Older Driver Highway Design Handbook [ch.1 - Intersections (At-Grade)]. FHWA-RD-97-135. Federal Highway Administration, 1998. http://www.tfhrc.gov/safety/pubs/97135/index.htm#intro.

- The existing angle is less than minimum or greater than maximum angle for NEW intersections and the angle is contributing to intersection crashes, or
- The existing angle is less than the minimum angle for new construction by 5° or more, or
- The existing angle is greater than the maximum angle for new construction by 5° or more.

2.8.3 Angle of Intersection for Existing Intersections on Rehabilitation Projects

2.8.3.1 Intersection on Tangent or on Outside of Curve

When the angle of intersection is an observed and documented safety issue, consider the following to address the safety needs. Improve the intersection angle using the guidelines for NEW intersections if the existing intersection meets the following condition:

- The existing angle is less than minimum or greater than maximum angle for NEW intersections and the angle is contributing to intersection crashes.

2.8.3.2 Intersection on Inside of Curve

When the angle of intersection is an observed and documented safety issue, consider the following to address the safety needs. Improve the intersection angle using the guidelines for NEW intersections if the existing intersection meets the following condition:

- The existing angle is less than minimum or greater than maximum angle for NEW intersections and the angle is contributing to intersection crashes.

2.9 Intersections on Curves

Intersections on curves of any facility are problematic and are discouraged for the following reasons:

- Drivers have more difficulty judging the speed of vehicles approaching on a curve than on a tangent.
- Superelevation complicates the intersection geometry.
- More right-of-way may be required to ensure adequate intersection sight distance (ISD), particularly on the inside of curves where the line of sight for intersection sight distance may be a considerable distance outside the roadway.
- Intersections on the inside of a curve require drivers on the side road to turn their heads more to see approaching traffic. This can be difficult for some drivers, including older drivers.

If an intersection must be on a curve, then use a flatter radius curve, if possible, and align to make the intersection as close to radial as possible. For example, on high speed roads, using a curve that requires a superelevation of 3% or less will make it easier to match into the side road profile and to transition the cross slope on auxiliary lanes. It will also keep the ISD line of sight closer to the roadway. A radial intersection in combination with a flat radius will reduce the amount drivers have to turn their heads to see approaching traffic.

Intersections on curves of high-speed (posted speed greater than 55 mph) expressways require additional design considerations. Crash history shows that there is no difference in whether the side road intersection approaches the expressway from the outside or the inside of the curve. Providing more than the minimum intersection sight distance at these intersections appears to have no impact on the number or severity of crashes. If there appears to be no alternative to designing an intersection on a curve then provide a wide median. If a wide median for intersections on curves is not possible then it is important to restrict intersection movement by closing the median or at least not allowing side road traffic to turn left onto the expressway.

2.10 References

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LIST OF ATTACHMENTS

Attachment 2.1	WisDOT Vehicle Inventory of Oversized Overweight (OSOW) Vehicles
Attachment 2.2	WisDOT Policy on Checking Criteria for OSOW-ST and OSOW-MT Vehicles at Intersections
Attachment 2.3	Taper Length Criteria

FDM 11-25-3 Intersection Control Evaluation

August 15, 2019

3.1 Intersection Control Evaluation (ICE)

The goal of the Intersection Control Evaluation (ICE) process is to document, justify, and provide support for the intersection/interchange design decisions made through the course of a project. The ICE allows for a consistent, objective, and defensible assessment of alternative forms of control and geometry. It is a rigorous process that considers existing and future traffic operational and safety needs along with other site-specific issues and constraints. The documentation provided as part of the ICE can prove beneficial in the event WisDOT faces public or legal challenges.

The region shall perform an ICE study for all intersections on the State Trunk Network (STN), including those

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[49] [Aug 17, 2004 email from Javy Awan, Director of Publications, Transportation Research Board] TRB references are reproduced with permission of the Transportation Research Board, From Access Management Manual, Transportation Research Board, National Research Council, Washington, D.C., 2003

[50] [Dec 5, 2012 email and attached letter from Zach Pleasant, Information Services Director, ITE] The Institute of Transportation Engineers grants permission to use Figures 6-19, P6-27 and 6-20, P6-30 from Transportation and Land Development, 2nd Edition for the Wisconsin DOT's Facilities Development Manual (FDM 11-25).

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along connecting highways, regardless of the funding mechanism, where consideration is being given to an alternative form of traffic control or type of intersection/interchange. To ensure the project proceeds smoothly, it is important to complete the ICE process during the appropriate time of the facilities development process (typically during the project definition phase). Refer to Attachment 3.1 for an illustration of how the ICE process relates to the overall facilities development process. Attachment 3.2 highlights the key steps of the ICE process. FDM 7-45 Attachments 1.4 to 1.7 illustrate how the ICE fits into the National Environmental Policy Act (NEPA) process, specifically for an Interstate Access Justification Report (IAJR).

For any questions or clarifications related to the ICE process, contact the Bureau of Traffic Operations – Traffic Analysis and Safety Unit via the DOT ICE Review mailbox (DOTICEReview@dot.wi.gov). For the remainder of the policy, the Bureau of Traffic Operations – Traffic Analysis and Safety Unit will be referred to as BTO.

3.1.1 ICE Project Triggers

Situations that generally trigger the need for an ICE study include, but are not limited to, the following:

- New traffic control
- A change in traffic control (see FDM 11-25-3.1.2 for exemptions)
- A new or alternative type of intersection or interchange (e.g., reduced conflict intersection/interchange)
- Introduction of access/median restrictions on the STN (e.g., converting a full access intersection to right-in-right-out only)
- Off-setting intersections (e.g., converting one 4-legged intersection into two T-intersections)

These scenarios typically arise through means of the highway improvement program, the highway maintenance program or the highway permitting process. This can include, but is not limited to, projects identified or funded through the following programs or processes:

- Mega/Major Highway Development Program
- State Highway Rehabilitation Program
- Highway Safety Improvement Program (HSIP)
- Traffic Impact Analysis (TIA)

3.1.1.1 Traffic Impact Analysis (TIA) and ICE

A TIA is part of the highway permitting process and provides a means to assess traffic impacts due to a development. If the TIA finds that a development has an impact at an intersection along the STN, it will provide recommendations for how the developer can mitigate the potential impact. Since the TIA could include recommendations for improvements to the traffic control at intersections located on the STN it shall comply with the ICE process. For ICE guidance as it relates to a TIA, see the TIA Guidelines, Chapter 5 Part F - Traffic Control Needs.

3.1.1.2 Local Projects and ICE

The ICE process may also prove beneficial for projects identified by counties, municipalities, or other local units of government. Thus, although not a requirement, WisDOT encourages local projects, specifically those interested in receiving federal or state funds, to follow the ICE process. WisDOT recommends that local projects complete at least the Phase I: ICE Brainstorming Guide (Attachment 3.5). See FDM 11-25-3.2.1 for specifics regarding the Phase I: ICE Brainstorming Guide.

If applicable, the completion, review, and approval of the ICE documentation for local projects will be the responsibility of the local agency.

3.1.2 ICE Process Exemptions

Scenarios that are typically exempt from the ICE process include the following:

- There are no operational or safety concerns (existing or future) – in this case the existing intersection traffic control can be replaced in kind as part of a perpetuation or rehabilitation project without triggering the need for an ICE
- Introduction of stop control on the minor street (one-way or two-way stop control) if the minor street is not part of the STN – this scenario introduces the least restrictive form of traffic control on the STN and thus generally does not warrant the completion of an ICE
- Introduction of only minor improvements to the intersection (e.g., adding turn lanes or modifying signal phasing) – unless turning movement restrictions or alternative forms of traffic control are also being considered, this scenario will generally not require the completion of an ICE
- Addition of new pedestrian signals at mid-block locations - since this scenario does not impact the intersection, an ICE is not necessary

Contact BTO for additional clarification as to when the completion of an ICE study is or is not required.

3.1.3 Guidance and Criteria for Traffic Control Options and Intersection/Interchange Types

Stop control, traffic signal control, roundabout, and reduced conflict intersection/interchange designs are common types of traffic control and intersection/interchange layouts. Attachment 3.3 highlights the key elements to consider when selecting each type of intersection; interchange and traffic control option; and identifies some of the potential benefits and concerns for each option. Additional details on these intersection/interchange types and traffic control options follow.

1. Stop Control

   Stop controlled intersections consist of one-way, two-way, or all-way stop control (OWSC, TWSC or AWSC)[51]. The OWSC or TWSC control is most common and requires traffic to stop on the minor road connection(s) to a major highway. Typically, OWSC or TWSC control is the existing traffic control alternative in the ICE study.

   The use of AWSC on the STN is generally not recommended; however, if AWSC warrants are met and the addition of AWSC will improve intersection safety, AWSC may be a viable traffic control alternative, especially as an interim solution. Refer to Chapter 13, Section 26-5 of the Traffic Engineering Operations and Safety Manual (TEOpS 13-26-5) for AWSC criteria that considers both WisDOT and MUTCD policies. Utilize the AWSC warrant spreadsheet located in TEOpS 13-26 to assess whether there is justification for the installation of AWSC.

2. Traffic Signal Control

   Traffic signal warrants are the guiding principle for when to consider the installation of a traffic signal. See MUTCD - Section 4C and the Traffic Signal Design Manual (TSDM) Chapter 2 for traffic signal warrants (TSDM 2-3). Also, see the TSDM for design, capacity, and operational guidance for traffic signal control.

   The region shall complete the ICE process and the State Traffic Signal Systems Engineer shall approve the new installation of a traffic signal along all state trunk highways and connecting highways. New pedestrian signals at mid-block locations also require approval from the State Traffic Signal Systems Engineer; however, these locations would not trigger the need for an ICE. After completion of the ICE process, the region shall submit the Traffic Control Signal Approval Request form (DT1199) to the State Traffic Signal Systems Engineer for review. Completion of the ICE process and submittal of the DT1199 are required prior to making any commitments concerning the installation of new traffic signal control.

3. Roundabout

   Consider the modern roundabout as a traffic control alternative when the minimum vehicular volume warrants for either all-way stop control or traffic signal control are met. There may also be situations where it is appropriate to consider a roundabout where an intersection has unique safety (e.g., significant right-angle crashes, limited intersection sight distance, etc.) or geometric concerns (e.g., significantly skewed intersection, 5 plus approaches, etc.).

   Careful consideration and coordination among region traffic engineers and designers as well as local entities must be part of the project development process when considering a roundabout and the proposed roundabout design. Refer to NCHRP Report 672 (Second Edition) Section 3.3 for considerations in selecting a roundabout as an alternative. Refer to FDM 11-26 for design and operational guidance on roundabouts.

   The consideration of three-lane roundabouts (i.e. roundabouts with three circulating lanes) is up to the discretion of the region. However, if the region's recommendation is to construct a three-lane roundabout, the BTO State Traffic Engineer and Bureau of Project Development (BPD) Design Standards and Oversight Chief shall approve the roundabout as the recommended traffic control alternative.

4. Reduced Conflict Intersections/Interchanges

   Traffic engineers and designers have additional options in intersection/interchange types that

[51] One-Way Stop Control (OWSC) applies to Tee-Intersections or ramp terminals; Two-Way Stop Control (TWSC) applies to 4-legged intersections; All-Way Stop Control (AWSC) applies to any intersection

combined with traffic control may be appropriate for a given situation. These designs may have advantages over traditional intersection and interchange types, depending on the existing and future safety and operational concerns.

For some reduced conflict intersections/interchanges, microsimulation may be necessary to supplement the HCM-based analysis. Refer to FDM 11-5-3.7 and TEOpS 16-20 for a description of the supported microsimulation software and their appropriate use.

The Department recognizes the evolving-nature of design and analysis criteria for reduced conflict intersections and interchanges, but this should not discourage the selection of these types of designs as the recommended alternative. The expected future demands on many facilities, as well as the benefits reduced conflict intersections and interchanges may bring for a location, could favor the implementation of these types of intersections or interchanges. Consider the reduced conflict intersection and interchange types listed in Attachment 3.3, as well as other innovative design concepts, as applicable during the ICE process.

The region shall facilitate an independent peer review of the design for all proposed reduced conflict interchanges prior to making any commitments towards the construction of the new interchange design.

3.2 ICE Process

The ICE study shall be prepared by, or under the supervision of, a professional engineer, registered in Wisconsin, with experience in traffic engineering. Either the region or a consultant, through coordination with the region, may complete the ICE.

The ICE process consists of two phases.

1. Phase I: Scoping ICE

   The analyst shall complete the Phase I: Scoping ICE early in the project development process - typically in the project definition phase. See Attachment 3.1 for an illustration of how the Phase I: Scoping ICE relates to the facilities development process.

   The purpose of the Phase I: Scoping ICE is to identify all possible traffic control alternatives and recommend those alternatives to carry forward for further evaluation in the Phase II: Alternative Selection ICE. If the Phase I: ICE identifies only one viable alternative, there is no need to proceed with the Phase II: ICE.

2. Phase II: Alternative Selection ICE

   The Phase II: Alternative Selection ICE involves a more detailed evaluation of the feasible alternatives identified in the Phase I: Scoping ICE. Completion of the Phase II: ICE generally occurs during the project definition phase of the facilities development process. See Attachment 3.1 for an illustration of how the Phase II: Alternative Selection ICE relates to the facilities development process.

   The purpose of the Phase II: ICE is to assist the Department in selecting a traffic control, lane configuration and intersection/interchange type for the studied location. The Phase II: ICE should result in the identification of only one alternative to carry forward.

After each phase, the region shall submit the ICE report to BTO for review via the DOT ICE Review mailbox (DOTICEReview@dot.wi.gov). BTO will review the ICE and provide comments to the region within 20 business days.

3.2.1 Phase I: Scoping ICE

All projects that trigger the need to follow the ICE process shall complete the Phase I: Scoping ICE prior to proceeding with the Phase II: Alternative Selection ICE. The Phase I: Scoping ICE consists of a memorandum which documents all intersection types and traffic control alternatives under consideration. See Attachment 3.4 for a template of the Phase I: ICE memorandum.

To assess the feasibility of various alternatives, the analyst shall use the Phase I: ICE Brainstorming Guide (Attachment 3.5). Only fill out the information on the guide for those alternatives that are applicable to the project (i.e., you only need to assess interchange alternatives if an interchange already exists or if grade separation is under consideration). Expand upon the list of traffic control alternatives provided within the guide as appropriate. Reference the Phase I: ICE Brainstorming Guide (Attachment 3.5), within the Phase I: ICE memorandum as needed.

The Phase I: ICE memorandum shall provide justification as to why each alternative is or is not feasible and should identify which alternatives to carry forward for further evaluation in the Phase II: Alternative Selection

ICE. If the Phase I: ICE identifies only one viable alternative, there is no need to proceed with the Phase II: ICE.

The specific content of the Phase I: ICE memorandum will vary depending on the project's location, scope, and the available data. The Phase I: Scoping ICE shall provide the following information:

- Project Description
- Description of Alternatives
- Safety Considerations
- Operational Considerations
- Other Considerations
- Feasibility of Alternatives
- Conclusions/Recommendations

The following provides details regarding the specific content to include under each of the above-mentioned topics. Although it is acceptable for the Phase I: Scoping ICE to include additional information other than that listed above, exercise caution when it comes to providing additional analysis. It is important not to overanalyze any of the alternatives in the scoping phase, as it is possible to eliminate some alternatives from consideration without going into detailed analysis.

Refer to Attachment 3.7 for a checklist of the required and optional items to include in the submittal of the Phase I: ICE. This checklist should serve as a guide only and does not need to be included with the submittal of the Phase I: ICE. Contact BTO for specific examples of what to include in the Phase I: ICE memorandum.

3.2.1.1 Project Description

Provide a brief description of the project background, the need for the project, the scope of the project, the project type, and a summary of the existing conditions of the intersection and surrounding area.

3.2.1.2 Description of Alternatives

List all alternatives under consideration and provide a brief description of each. Reference the Phase I: ICE Brainstorming Guide (Attachment 3.5) as appropriate.

3.2.1.3 Safety Considerations

Fill out the crash summary table showing the number, type, and severity of crashes using up to five years of data, as appropriate. Attach a crash diagram showing the location, type, severity, and other information about the crashes at the intersection. Summarize the crash trends and contributing factors for the crashes at the intersection (crash trends and contributing factors are patterns in the crash data such as the type or severity of crashes, or any human, roadway, or environmental factors which influence the crash). If following the Safety Certification Process (SCP) (FDM 11-38), it is acceptable to use the information contained in the Safety Certification Worksheet. For each alternative, identify which crash trends and contributing factors will be mitigated and how the frequency, type, and severity of crashes is anticipated to change.

Crash information is available through the Wisconsin Traffic Operations and Safety Laboratory (TOPS Lab) WisTransPortal. Access to the WisTransPortal requires a user account which is available by request through the TOPS Lab.

3.2.1.4 Operational Considerations

At a minimum, this section should provide a qualitative discussion on the existing and future operational and capacity concerns for the existing condition and each alternative. Field surveys or photographs taken during the peak periods are some ways to demonstrate capacity concerns if the data needed for detailed operational analysis is not available. Average annual daily traffic volumes (AADT), which are available through the coverage count program and planning-level forecasts from WisDOT Traffic Forecasting, can also provide insight into potential capacity concerns. Consideration should be given to all modes of transportation (passenger vehicles, bicycles, pedestrians, freight, etc.) when assessing the operational or capacity needs.

Ideally, the Phase I: ICE memorandum should provide a summary of the quantitative capacity analysis conducted using the methodologies from the most recent version of the Highway Capacity Manual (HCM). Refer to FDM 11-5-3 for details on the traffic analysis methodologies and analysis tools to use when conducting the quantitative capacity analysis. Ensure that the analysis is reflective of the appropriate design hour volumes (FDM 11-5-3.5.1) for the project under study. If the Phase I: ICE incorporates quantitative capacity analysis, the region shall conduct an independent peer review (i.e., someone other than the analyst shall conduct the review) of the traffic analyses in accordance with the procedures outlined in TEOpS 16-25. In most cases, the peer review will consist of a region-level review of the analysis.

If the alternative is only restricting turning movements (e.g., right-in/right-out only, J-Turn, etc.), a detailed

operational analysis of the study intersection may not be necessary. However, the Phase I: ICE memorandum should provide an assessment (qualitative or quantitative) of the potential impacts to any nearby intersections (e.g., restricting the study intersection to right-in/right-out may add traffic to a nearby intersection and the ICE should document if the nearby intersection can accommodate the additional traffic).

Data permitting, conduct AWSC and traffic signal warrants when considering the addition of new AWSC, roundabout, or traffic signal control as a possible traffic control alternative. Summarize the findings of the warrant analysis within the Phase I: ICE memorandum and attach a copy of the warrant worksheets. If the data is not available to conduct the warrant analysis, provide a qualitative assessment as to whether AWSC, roundabout, or traffic signal control should remain a viable alternative for further evaluation.

3.2.1.5 Other Considerations

Provide a brief description of any other factors taken into consideration during the Phase I: ICE analysis. Additional factors could include overall corridor and geometric considerations, pedestrian/bicycle facilities, oversize-overweight (OSOW) routes, potential environmental issues, right-of-way concerns and real estate impacts, expected costs for each alternative, coordination with local government, and any other important consideration that may be unique to the project or location.

3.2.1.6 Feasibility of Alternatives

Highlight the advantages and disadvantages of each alternative. Identify and justify whether each alternative is feasible or not. Some scenarios that may eliminate an alternative from further consideration include, but are not limited to, the following:

- The intersection is part of a traffic signal corridor and an alternative form of traffic control would disrupt traffic flow
- The intersection requires railroad preemption as determined by WisDOT Bureau of Transit, Local Roads, Railroads and Harbors (BTLRRH) and BTO, which may make unsignalized traffic control options undesirable
- Right-of-way needs, environmental concerns, or construction cost of the alternative under consideration have far greater adverse impacts when compared to other intersection control alternatives

If the region requires assistance in determining if a traffic control alternative requires further evaluation in the Phase II: Alternative Selection ICE, consult with BTO.

3.2.1.7 Conclusions

Summarize the findings of the analysis, document the process followed to evaluate the alternatives, and recommend the viable alternatives to carry forward for further evaluation in the Phase II: Alternative Selection ICE. If there is only one feasible alternative, there is no need to proceed with the Phase II: ICE.

The region shall submit the Phase I: ICE memorandum and supporting documents to BTO (DOTICEReview@dot.wi.gov) for review prior to proceeding with the Phase II: ICE.

The Phase I: ICE memorandum findings are valid for four years. If the region does not initiate the Phase II: Alternative Selection ICE or the project has not entered the project delivery phase within four years after completion of the Phase I: Scoping ICE, the region shall reassess the findings of the Phase I: ICE memorandum. A reassessment of the Phase I: Scoping ICE is necessary to ensure that changes in traffic volumes or other traffic conditions do not alter the recommendations. If the conclusions of the original Phase I: Scoping ICE are still valid, the region does not need to update the Phase I: ICE. However, if changes in traffic volumes or other traffic conditions alter the findings of the study, the region shall update the Phase I: ICE memorandum and resubmit to BTO for review. Consult with BTO to verify the extent of the revisions needed or the need to update the Phase I: Scoping ICE.

3.2.2 Phase II: Alternative Selection ICE

The Phase II: Alternative Selection ICE provides additional, in-depth analysis of the feasible alternatives identified during the Phase I: Scoping ICE. As such, the region shall not complete the Phase II: Alternative Selection ICE until after BTO's review of the Phase I: ICE memorandum. At a minimum, the Phase II: ICE should provide an assessment of the following factors (listed in no particular order):

- Practical Feasibility
- Operational Analysis
- Safety
- Pedestrians and Bicycles

- OSOW
- Right-of-Way (ROW) Concerns and Real Estate Impacts
- Environmental Impacts
- Costs

The analyst shall address each of these factors for all feasible alternatives and document the findings within the Phase II: ICE worksheet (Attachment 3.6). Contact BTO prior to completing a separate technical report or memorandum for the Phase II: ICE, as in most cases the Phase II: ICE worksheet should sufficiently capture all the necessary details of the analysis. The region shall submit the Phase II: ICE to BTO (DOTICEReview@dot.wi.gov) for review prior to final selection of the recommended alternative.

The following provides details regarding the specific content to include under each section of the Phase II: ICE worksheet (Attachment 3.6). Refer to Attachment 3.7 for a checklist of the required and optional items to include with submittal of the Phase II: Alternative Selection ICE. This checklist should serve as a guide only and does not need to be included with the submittal to BTO. For specific examples of a Phase II: Alternative Selection ICE, contact BTO.

3.2.2.1 Project and Analyst Information

In this section, provide the project identification number, name, and agency of the analyst, and the completion date of the analysis. Use the drop-down list to select the project improvement type or funding source for the project and briefly describe the location of the project.

3.2.2.2 Background Information

In this section, identify the primary need and the objectives for the project (e.g., safety concerns, operational issues, etc.). Provide a brief description of the project background information including the scope of the project, previous work associated with the subject intersection/interchange, and a summary of the existing conditions of the intersection or interchange and surrounding area. Identify whether the intersection/interchange improvements are part of a larger corridor study. Additionally, note any local constraints or considerations that could potentially affect the alternative selection.

3.2.2.3 Existing Crash Information

Fill out the crash summary table showing the number, type, and severity of crashes using the same crash data as the Phase I: ICE. Attach a crash diagram showing the location, type, severity, and other information about the crashes at the intersection. Summarize the crash trends and contributing factors for the crashes at the intersection (crash trends and contributing factors are patterns in the crash data such as the type or severity of crashes, or any human, roadway, or environmental factors which influence the crash). If following the SCP (FDM 11-38), it is acceptable to use the information contained in the Safety Certification Document (SCD). Information may be copied from the Phase I: ICE.

3.2.2.4 Additional Modes of Transportation

This section provides an overview of the pedestrian, bicycle, OSOW, or other modes of transportation to consider during evaluation of each alternative. Complete the table to identify whether there are any nearby generators and existing facilities for each mode of transportation identified (e.g., bike trail, transit stop, a large distribution facility, Amish community, etc.). Indicate whether the intersection is part of a Safe-Route-to-School (SRTS) or is part of the bicycle network. This information is available through review of comprehensive land use plans, Wisconsin bike maps, OSOW permitting history, and other planning documents. Information pertaining to OSOW routes is available in FDM 11-25-1.4.

Approximate the existing magnitude of each mode of transportation (e.g., number of OSOW vehicles per year, number of pedestrians/bicycles at the intersection during the peak period, etc.). Existing pedestrian and bicycle count data is generally included as part of the overall intersection turning movement count.

Use the space below the table to elaborate on any concerns or limitations a specific mode of transportation may have on the alternative selection or intersection design. Identify any plans to construct additional facilities to accommodate the alternative mode(s) of transportation within, or near, the project limits and note whether these plans are dependent on the alternative selection. Refer to FDM 11-46 for additional guidance on providing pedestrian and bicycle accommodations.

3.2.2.5 Summary Tables

This section provides a quick overview of each of the traffic control alternatives under consideration. Identify the traffic control and describe any geometric changes (e.g., addition of a left turn lane, etc.) for each alternative. Fill out the table to identify the total construction cost for each alternative, as well as any real estate, right-of-way (ROW), or environmental costs and impacts. Provide detailed cost estimates, ROW and environmental impact

maps, and conceptual drawings of the proposed alternatives as attachments to the Phase II: ICE worksheet (Attachment 3.6). Summarize the safety performance measures, including the analysis period, number of property damage only (PDO) crashes, fatal and injury (KABC) crashes, and total number of crashes.

3.2.2.6 Recommendation

In this section, identify the preferred/recommended alternative and provide justification for the recommendation (e.g., explain why one alternative is superior to the others). Document any unique considerations, concerns, or other factors that influenced the selection of the recommended alternative.

3.2.2.7 Practical Feasibility

This section highlights the practical feasibility of each traffic control alternative. Common factors that influence the practical feasibility include, but are not limited to, the following:

- Public Opinion - Summarize feedback received from the public information meetings (PIMs) as well as any other comments/opinions from local officials, businesses, and the traveling public.
- Business Impacts - List major potential impacts to businesses, including access restrictions and parking availability.
- ROW Impacts - List the type of land use (residential, business, etc.) and amount of right-of-way acquisition required. Identify the number of relocations, by land use category, required for each alternative. Provide a map/diagram illustrating the ROW impacts.
- Utility Impacts - Identify the extent of any additional utility needs or utility relocations required for each alternative.
- Cost Estimate - Provide a summary of the factors that influenced the cost estimates (construction costs, operation/maintenance costs and right-of-way/real estate costs) provided in the summary table section of the worksheet.
- Additional Considerations - List any other considerations, such as geometric constraints, OSOW, pedestrian/bicycle facilities or accommodation of other modes of transportation that influence the practical feasibility of the alternative. Note whether the intersection is part of a diversion route, a signalized corridor, or larger corridor study, and the implications this may have on the design (e.g., alternative selection, design vehicle, lane configuration, etc.). Additionally, identify if there are any major historical, archeological, hazardous materials or other environmental or unique impacts that effect the practical feasibility of the alternative.

3.2.2.8 Safety Analysis

In this section, provide a summary of the key safety considerations associated with each traffic control alterative. Specifically, this section should address the following:

- Crash Trends and Contributing Factors – Identify which crash trends and contributing factors will be mitigated with the alternative. Trends and contributing factors are patterns in the crash data such as the type or severity of crashes, or any human factors, roadway factors, or environmental factors which influence the crash.
- Conflict Points – Identify any change in the number, type, or angle of conflict points associated with each alternative.
- Vulnerable Users – Identify how each alternative will impact vulnerable users, such as pedestrians and bicyclists.
- Safety Performance – Provide the total number of crashes, fatal and injury (i.e., KABC) crashes, and property damage only crashes for a ten-year analysis period, with the construction year being the first. The safety analysis should follow the methods outlined in the Performance Based Safety Engineering Analysis Process in FDM 11-38-10.5.2.2. If following the SCP, it is acceptable to use the analysis results from the SCD.

When performing the safety analysis, if the chosen method requires a Crash Modification Factor (CMF), refer to the WisDOT CMF Table to obtain CMFs and TEOpS 12-3-1 for how to apply CMFs. For assistance, contact BTO.

3.2.2.9 Operational Analysis

In this section, provide a brief summary of the key operational and capacity considerations associated with each traffic control alternative. Specifically, this section should address the following:

- Warrant Analysis Results – Conduct the AWSC and traffic signal warrant analysis, as appropriate, for

each alternative (see FDM 11-25-3.1.3 for more information as to when a warrant analysis is required). Note that both the AWSC and traffic signal warrant analyses are required for consideration of a new roundabout. Summarize the results of the warrant analyses here (e.g., satisfies traffic signal warrants 1 and 2, etc.) and attach copies of the warrant analyses worksheets as an appendix to the Phase II: ICE worksheet.

- Queue Impacts – Based on the 95th-percentile back-of-queue length, assess whether the existing or future queues will block access to a left or right turn lane, a driveway, another intersection, a railroad crossing, a lift bridge, or any other critical location. Note how the queuing affects the intersection design (e.g., turn bay lengths) and alternative selection.
- Additional Capacity – Conduct a sensitivity analysis to assess how much additional capacity above the design-year traffic volumes (if any) each traffic control alternative can accommodate. Summarize the findings of the sensitivity analysis here.
- Railroad/Lift Bridge Influences – Identify the location of any railroad crossings and lift bridges that may affect the operations of the intersection. Note whether the spacing between the intersection and the railroad crossing/lift bridge favors or precludes an alternative from consideration. Indicate whether any special design features (e.g., traffic signal coordination, railroad preemption, etc.) are necessary to support the traffic control alternative.
- Additional Considerations – Identify any other factors that could potentially influence (either positively or negatively) the intersection capacity or operation. These additional considerations include, but are not limited to, high seasonal traffic variations, nearby special generators, approach angles and grades, sight distance concerns, access management control, elderly population, and the ability to accommodate U-turn movements. Additionally, use this section to note any unique input features into or findings from the operational analysis (e.g., use of HCM 2000 results) for each alternative.
- Level of Service (LOS) Analysis – Use the methodologies outlined in the most recent version of the Highway Capacity Manual (HCM) to conduct the level of service (i.e., capacity) analysis for existing and design year traffic conditions. Refer to FDM 11-5-3 for details on the traffic analysis methodologies and analysis tools to use when conducting the quantitative capacity analysis. Ensure that the analysis is reflective of the appropriate design hour volumes (FDM 11-5-3.5.1) for the project under study. The region shall conduct an independent peer review (i.e., someone other than the analyst shall conduct the review) of all traffic analyses provided in the Phase II: Alternative Selection ICE, as outlined in TEOpS 16-25. Unless the analysis involves microsimulation models, the peer review will generally consist of a region-level review (i.e., typically the review can be done in-house without the need to involve an outside consultant). To assist the region with the peer review, the analyst shall provide the region with the traffic model files (e.g., HCS, Synchro, Sidra).
- Upon completion of the level of service analysis, fill out the tables indicating the analysis year, lane configurations, LOS, delay, volume-to-capacity ratio (v/c), 95th percentile queue length, and the available storage/turn bay length for each movement. Provide copies of the LOS analysis worksheets as an attachment to the Phase II: ICE.

3.2.3 Appendices

The Phase I: Scoping ICE and Phase II: Alternative Selection ICE shall include all data, diagrams, and software input/output reports that support the findings of the evaluation. Refer to Attachment 3.7 for a checklist of the required and optional items to include with submittal of the Phase I: Scoping ICE and Phase II: Alternative Selection ICE. Contact BTO for examples of the Phase I: ICE and Phase II: ICE.

3.2.4 ICE Amendments

If, after receipt of BTO concurrence, additional information becomes available which alters the recommendations of the ICE (either the Phase I: ICE or Phase II: ICE); the region shall amend the ICE and submit to BTO (DOTICEReview@dot.wi.gov) for review.

The content and format of the amendment will vary depending on the extent of the changes and could range from an email documenting the rationale for the modifications (typically adequate for minor geometric changes) to a complete revision of the ICE (may be necessary if recommending an alternate intersection type or traffic control). The region should coordinate with BTO to verify the appropriate content and format of the ICE amendment.

LIST OF ATTACHMENTS

Attachment 3.1	Relationship between the Facilities Development Process and the ICE Process
Attachment 3.2	Intersection Control Evaluation (ICE) Process Flow Chart

Attachment 3.3 Traffic Control Summary Tables
Attachment 3.4 Phase I: ICE Memorandum
Attachment 3.5 Phase I: ICE Brainstorming Guide
Attachment 3.6 Phase II: ICE Worksheet
Attachment 3.7 ICE Submittal Checklist

FDM 11-25-5 Left Turn Lanes

August 15, 2019

5.1 Introduction

A left-turn lane at intersections where left turns are frequent is always typical from a safety and capacity standpoint because exclusive left turn lanes are the safest and most effective way to separate left turning traffic from through traffic.[52] A left-turn bay can significantly improve operations and safety at an intersection by effectively separating those vehicles that are slowing or stopping to turn from those vehicles in through traffic lanes. This minimizes turn-related crashes and unnecessary delay to through vehicles. [53]

5.2 Warranting Criteria

Exclusive left-turn lanes are provided in order to enhance the safety and to facilitate the movement of through traffic. The primary factors to consider when determining the need for an exclusive left-turn lane are the left-turn traffic volume, opposing traffic volume, crash history and experience. A capacity analysis is generally used to determine turn lane requirements at signalized urban intersections. Additional factors to consider include:

- Median width,
- Available right of way,
- Roadway geometry (e.g., shifting of adjacent travel lanes),
- Impacts to other roadway features (e.g., bike accommodations, terrace, and sidewalk),
- Construction and right of way costs, and
- Design classes of the intersecting roadways.

As a general policy, provide exclusive left-turn lanes at the following locations (if a left turn or u-turn is permitted at that location):

- All median openings on rural divided highways[54] and on urban transitional and high-speed divided highways[55]
- At median openings on urban low-speed roadways unless left-turn PHV<20 vph or sideroad/driveway AADT<400 vpd[56]
- All intersections on a 2-lane community bypass[57]

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[52] MNDOT Road Design Manual ch. 5 (*19)* Rural Intersections - Turn lanes - Left-Turn Bypass Lanes. In *MNDOT Road*

Design Manual ch. 5: At-Grade Intersections Minnesota DOT, 2000, sect. 5-4.01.04, pp.5-4(2). http://www.dot.state.mn.us/design/rdm/english/5e.pdf.

[53] See Bonneson & Fontaine in NCHRP Report 457 (*13) NCHRP Report 457: Engineering Study Guide for Evaluating Intersection Improvements*. TRB, National Research Council, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf, pp. 21-22)

[54](*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., p.5-47, "Warrants for Left-Turn Bays"

[55] *(20) Minimum Required Turn Lane Storage Lengths & Tapers For Left & Right Turn Lanes At Signalized & Non-signalized Intersections. (DRAFT).* Wisconsin DOT, 2010.

[56] *(20) Minimum Required Turn Lane Storage Lengths & Tapers For Left & Right Turn Lanes At Signalized & Non-signalized Intersections. (DRAFT).* Wisconsin DOT, 2010.

[57] *(21) Review of Wisconsin Bypass Road Design Practices February 13-14, 2006. (Final).* Federal Highway Administration Resource Center, 2006. http://www.dot.wisconsin.gov/library/publications/docs/wis-bypass-report.pdf, pp.5-6, "Left Turn Lanes - Part 1:

- Intersections meeting the warrants of Table 5.1
- Signalized intersections
- To replace TWLTLs at non-signalized intersections/driveways where the left turn volume exceeds100 vph[58]

Generally, consider providing an exclusive left-turn lane if the construction year AADT on the main road exceeds 4,000 and the side road AADT exceeds 400. Left turn lanes for OSOW movements on OSOW routes should be provided independent of the AADT guidance, depending on frequency of load.

Left turn lanes in the middle of the highway have a strong proven safety benefit at intersections, whether they are signalized or unsignalized. Left turn lanes should be a standard at all intersections on bypass roads. Left turn lanes are not "bypass lanes" installed to the right of the through lane at an intersection; rather left turn lanes are positioned to the left of the high speed through traffic lane."

Also, Appendix B, p. i, "Geometric Design – Intersections:

1. Left turn lanes with positive offset on the bypass at all at-grade intersections to enhance left turn safety""

[58] *(22) Rationale for Median Type Recommendations.* Kentucky Transportation Cabinet, 2008. http://www.planning.kytc.ky.gov/congestion/medians/Median%20Type%20Guidelines.pdf.

Table 5.1 Operational Warrants for Left-Turn Lanes at Intersections on Two-Lane Highways [59]

	Advancing volume to warrant a left-turn lane (veh/hr)			
Opposing Volume (veh/hr)	**with 5 percent left turns**	**with 10 percent left turns**	**with 20 percent left turns**	**with 30 percent left turns**
	40-mph Operating Speed			
800	330	240	180	160
600	410	305	225	200
400	510	380	275	245
200	640	470	350	305
100	720	515	390	340
	50-mph Operating Speed			
800	280	210	165	135
600	350	260	195	170
400	430	320	240	210
200	550	400	300	270
100	615	445	335	295
	60-mph Operating Speed			
800	230	170	125	115
600	290	210	160	140
400	365	270	200	175
200	450	330	250	215
100	505	370	275	240

5.3 Design Criteria

See FDM 11-25-2.1 for guidance on Intersection *Design Vehicles* and Intersection *Check Vehicles* (including *OSOW Vehicles)*.

The assumed speed of a vehicle making a minimum radius left turn is 10-15 mph.[60]

Develop Intersection designs, including the location and shape of the median nose and median opening, by using design vehicle turning templates and an appropriate control radius. Design the intersection so that the Design Vehicle(s) for the turning movement(s) stays in lane (see Table 2.1). Larger vehicles may encroach on other lanes as shown in Figure 2.2 and Table 2.1.

Design movements to allow vehicles to turn with a smooth continuous radius. Simultaneous opposing left turns must be able to complete their turns with a clearance between them as they pass each other of typically 10 feet / 3 feet minimum for opposing single left turn lanes (see FDM 11-25-5.4.3.1 for guidance on multiple left turn

[59] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., p. 685, Exh. 9-75, "Guide for Left Turning Lanes on Two-Lane Highways"

[60] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., chapter 9, p.690

lanes). [61]

Restrict on-street parking near the intersection if needed to aid in truck turning movements.

5.3.1 Widths

The width of a left-turn lane should typically be the same as the width of the through lane. Curb adjacent to the left-turn lane is offset to at least the width of the gutter. Provide a turn-lane width of 12 ft on high-speed and transitional rural and suburban arterial highways. Typically, fully develop the median width upstream from a left-turn lane taper before introducing the taper (i.e., fully shadow the left -turn lane).

Narrower turn lanes are often necessary on urban arterials because of restricted right-of-way and median widths. The minimum and typical widths for non-slotted left-turn lanes are shown in Table 5.2 below.

The upper minimum separator width at a signalized intersection is 8 feet face to face; the lower minimum width is 6 feet face to face. This width is required for signal and sign/structure placement, and pedestrian refuge

Table 5.2 Median, Separator, and Turn Lane Widths for non-slotted Left Turn Lanes on Low-Speed Urban Arterials (Lower Minimum Widths)

		Highly Developed Area	**Outlying Area**	
Left-turn lane Width (to gutter flange line)	Lower Minimum	10 ft		
	Typical	11-12 ft		
Separator Width (f/c-f/c)* *	Lower Minimum	The greater of 6 feet OR Fixed object width (e.g., sign or signal head) + 2 feet on each side.	The greater of 8 feet OR Fixed object width (e.g., sign or signal head) + 2-feet on each side.	
	Typical	10 feet or greater but not less than Fixed object width (e.g., sign or signal head) + 2 feet on each side.		
Total Median Width between opposing traffic lanes where cross traffic storage is **NOT** required.		Separator width (f/c – f/c*) + gutter width on each side of separator + left-turn lane width.		
Total Median Width between opposing traffic lanes where cross traffic storage **IS** required.		**Low Speed Urban Roadways** **Typical**: the greater of f/c – f/c* width + gutter width on each side + left-turn lane width, or 30 feet. Lower **Minimum**: the greater of f/c – f/c* width + gutter width on each side + left-turn lane width, or 24 feet. **Transitional and High Speed Urban Roadways** the greater of f/c – f/c* width + gutter width on each side + left-turn lane width, or 30 feet.		

* f/c-f/c width is the face of curb to face of curb distance between the curb adjacent to the left-turn lane and the curb adjacent to the opposing traffic lane.

See FDM 11-20-1 under “Medians” for further guidance on median widths.

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[61] Desirable Minimum clearance per (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf., sect. 36-3.03, “Left Turn Lane Designs”

(*23) A Policy on Geometric Design of Highways and Streets 2011*, 6th edition. AASHTO, 2011. www.transportation.org., p.9.138

5.3.2 Median End Treatment

A typical intersection does not have a continuous physical edge of traveled way delineating the left-turn path. Instead, the beginning and end of the left-turn path are delineated by:

1. The centerline of an undivided crossroad or the median edge of a divided crossroad, and
2. The curved median end

Under these circumstances, a simple curve for the minimum assumed edge of left turn - known as the control radius - is satisfactory. The larger the control radius, the better it will accommodate a given design vehicle, but the resulting layout will have a greater length of median opening and greater paved areas than a minimum radius. These may result in erratic maneuvering by small vehicles, which may interfere with other traffic. On the other hand, a smaller control radius will require wider pavement on the receiving leg to accommodate larger vehicles.

The following control radii can be used for lower minimum practical design of median ends:

- 40 ft accommodates P vehicles and occasional SU vehicles with some swinging wide;
- 50 ft accommodates SU-30 vehicles and occasional SU-40 and WB-40 vehicles with some swinging wide;
- 60-ft is usually appropriate for right-angle urban intersections (see Attachments 5.1 and 5.2);
- 75 ft accommodates SU-40, WB-40 and WB-62 vehicles with minor swinging wide at the end of the turn.
- 80 ft is the lower minimum for rural high-speed 4-lane divided highways (see Attachment 5.4)
- 130 ft accommodates WB-62 vehicles and occasional WB-65 vehicles with minor swinging wide at the end of a turn.[62]

For a median width of 10 ft or more, the bullet nose is superior to the semicircular end and is the preferred design. A bullet nose is designed to closely fit the path of a turning vehicle and results in less intersection pavement and a shorter median opening than the semicircular shape. The bullet nose is formed by two symmetrical portions of control radius arcs (see R3 - R6 in Attachment 5.1 to 5.3). These arcs need to be large enough to accommodate the turning path of the design vehicle. Assume that the inner wheel of each design vehicle clears the median edge and centerline of the crossroad by 2 ft at the beginning and end of the turn without encroachment on adjacent lanes.

On the OSOW Truck Route (OSOW-TR), use the vehicle inventory of OSOW check vehicles, Attachment 2.1 that may require alternative intersection geometrics See the OSOW maps for routes designated as OSOW-TR available at:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/planning-maps.aspx

Alternative nose configurations may be warranted that allow passage of OSOW vehicles while providing direction to turning vehicles.

Median refuge increases safety for pedestrians and bicyclists crossing a street. A median cut-through is the recommended design for accommodating pedestrians/bicyclists - especially at unsignalized intersection. The face-face median width for pedestrian/bicyclist refuge is typically 8-feet or greater and minimally 6-feet. See FDM 11-46 for additional guidance on pedestrian accommodations and crossings.

5.3.3 Length

See FDM 11-25-2.3 for guidance on calculating the length of a left turn bay. The length of a median left-turn lane must be adequate for storage or speed change of left-turning vehicles and the entering taper.

Coordinate with the region traffic engineer's staff in determining the required storage length at signalized intersections. Consider using traffic control devices with left-turn indicators when the number of left-turning vehicles exceeds 100 per hour. For additional information, see pp 713-723 of the 2004 GDHS[63] and the Highway Capacity Manual.[64]

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[62] (*23) A Policy on Geometric Design of Highways and Streets 2011*, 6th edition. AASHTO, 2011. www.transportation.org, section 9.8.2

[63] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[64] (*24) Highway Capacity Manual 2010*, 5th edition. Transportation Research Board of the National Academies, 2010.

Attachment 5.1 and Attachment 5.2 provide guidance on the length and design of turn lanes for urban highways and streets.

Attachment 5.4 illustrates a left-turn lane on a typical rural expressway and includes a table that relates the length of a left-turn lane to the type of rural at-grade intersection into which the traffic is turning.

5.4 Special Designs

5.4.1 Slotted Left-Turn Lanes

A problem with left-turn lanes is the inability of drivers in opposing left-turn bays to see past each other to detect oncoming traffic and pick an adequate gap to complete their maneuver. Although it is typical to provide a positive offset, as shown in Attachment 5.3 this may not be possible at all locations. Typically, keep the turning lane as far to the left as practical on wider medians, thus creating a slotted or channelized left-turn lane, as shown in Figure 5.1.

One possible consequence of poor alignments is that protected left turn arrows will need to be prematurely added for low volume left turn movements because of crashes resulting from the poor visibility. This will increase the delay at the intersection.

The total width of a left-turn island is defined as the distance between the right edge of the turn lane and the median edge of the travel lane.

If the f/c – f/c width of a left-turn island would be less than 4 feet, then install a flush left-turn island of contrasting pavement or color to delineate the turning lane from the through lane. Otherwise, install a raised left-turn island and make the lateral offset between the curb face of the left-turn island and the adjacent through lane equal to the offset from the curb face of the median to the same adjacent through lane. See Figure 5.1.

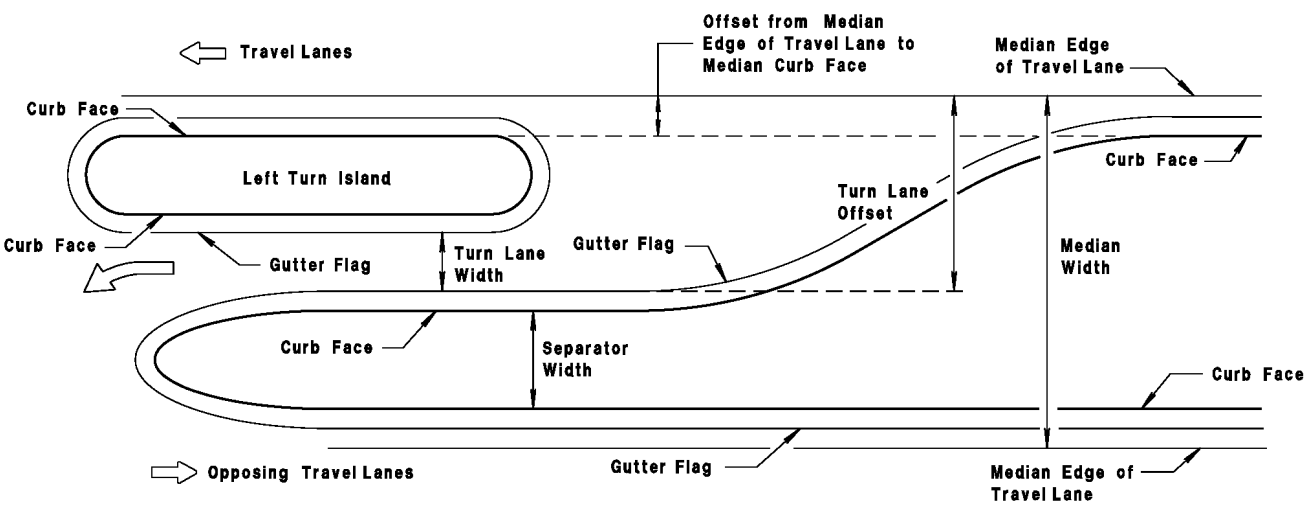

Figure 5.1 Urban Slotted Left Turn Lane with Left-Turn Island

The width of the channelized turn lane is typically 14-feet / 12-feet lower minimum between the gutter flag of the left turn island and the gutter flag of median separating the left turn lane from the opposing travel lanes (see Figure 5.1). The typical f/c/ - f/c width is18-feet (using a 14-ft lane and 2-foot gutter on both sides), which provides some potential for passing a stalled vehicle[65]. The lower minimum f/c/ - f/c width is 16-feet - except, 14-feet may be considered under the following conditions:

- Sloping face curb is used (if appropriate) on both sides, or
- Trucks are prohibited on the cross street, or
- Current and projected Traffic counts show a small number of SU-trucks (less than 10/week total) and WB-trucks (less than 0.5/week total) making the turn

However, if the intersection is on the OSOW-TR, this width may need to be increased to accommodate OSOW vehicle turning movements.

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[65] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004. "Design Widths of Pavements for Turning Roadways" - Case IIA (tangent) can be interpreted as 18-ft between two vertical-face curbs.

An offset and slotted left-turn design is illustrated on Attachment 5.3. For additional guidance, see pp 723-724 of the GDHS66.

5.4.2 Two-Way Left-Turn Lane (TWLTL)

Two-way left-turn lanes (TWLTLs) consist of a traffic lane in the median area, 14-16 feet in clear width, delineated by pavement marking strips. The lane serves as a separation for opposing lanes of travel, an acceleration lane for vehicles turning left to enter the street from midblock driveways and can be utilized as a detour route for maintenance work in adjacent lanes. It also allows easier and safer emergency vehicle movement, particularly during peak-hour periods.

TWLTLs are intended for use by vehicles traveling in either direction for *deceleration* and *refuge* while making a *midblock left-turn* maneuver. Use of two-way left-turn lanes for passing maneuvers is prohibited and must be signed appropriately.

In general, only use TWLTLs in an urban setting where operating speeds are relatively low and where there are no more than two through lanes in each direction. Consider installing a two-way left-turn lane (TWLTL) in existing commercial or residential areas where the existing roadway is undivided (flush median) and where there is a combination of traffic congestion and numerous left-turn maneuvers, coupled with rear-end accidents. Provide median refuge at intersections, particularly unsignalized intersections, for pedestrian crossing. Urban or suburban arterials and collectors are common candidates for a TWLTL. A TWLTL mid-block treatment is less typical on major arterials and arterials with access management priorities.

Use the following design criteria for TWLTLs[67]:

- Posted speed: Only use on roads with posted speeds <=45 mph
- TWLTL widths: 14.0-ft Typical; 12.0-ft Lower Minimum; 16.0-ft Maximum
- Design year AADT:
    - 3-Lane TWLTL: between 8,000 and 17,500 vpd
    - 5-Lane TWLTL: 24,000 vpd maximum
    - 7-Lane TWLTL: **NOT ALLOWED**
- Length of TWLTL: The length of the TWLTL should have sufficient length to operate properly at the posted speed. Site conditions and the types of intersection treatments will also influence the length of the TWLTL. Use the following guidelines:
    - Posted speed of 30 mph or less: 500-feet lower minimum uninterrupted length
    - Posted speed of greater than 30 mph: 1000-feet lower minimum uninterrupted length
- Railroad Crossings: Do not extend a TWLTL across a highway/railroad grade crossing. Terminate the TWLTL 150 ft to 200 ft in advance of the crossing and provide a raised-curb median adjacent to the railroad. Coordinate with the Region railroad coordinator.
- Intersection Treatment:
    - At signalized intersections and at non-signalized intersections/driveways with left-turning turning volumes > 100vph, convert a TWLTL to an exclusive left-turn lane (see FDM 11-25-2.3 for guidance on turn bay length). Use a raised median at intersections and driveways with a high concentration of left turning vehicles and at other locations as needed for pedestrian and bicycle refuge.
    - If turning volumes to a non-signalized minor street/driveway are low, it is not necessary to convert the TWLTL to an exclusive left-turn lane. However, pedestrians and bicyclists may still need median refuge.
- Operational/Safety Factors: For traffic to move safely through intersections, drivers need to be able to see stop signs, traffic signals, and oncoming traffic in time to react accordingly. Do not locate a TWLTL where there is inadequate stopping sight distance. Provide decision sight distance, where practical, in advance of stop signs, traffic signals, and roundabouts. Appropriate design speed intersection sight distance should be provided for the drivers of vehicles that are stopped, waiting to cross or enter a through roadway.
- Marking and Signing: Mark and sign TWLTLs in accordance with the Manual on Uniform Traffic

[66] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[67] *(25) Two Way Left Turn Lane (TWLTL).* Wisconsin DOT, 2007.

Control Devices to identify the lane and regulate its proper use. Additional delineation is possible by either using a different type of pavement material with contrasting color or texture, or a mountable raised median. See MUTCD Figure 3-5 for typical details of marking for two-way left-turn channelization. Two-way left-turn lanes are also discussed in the GDHS[68] on pp 474-478

5.4.2.1 Conversion from 4-Lane Undivided to 3-lane TWLTL ("Road Diet")

Consider converting a four-lane facility to a 3-lane TWLTL - commonly referred to as a "Road Diet" - if the following conditions exist:

- High accident rates involving left turning movements, sideswipes, rear-ends, or crossing traffic
- The need for traffic calming (Lowering the average through traffic speeds and reducing weaving)
- Pedestrian and bicyclist safety issues
- The existing four-lane facility actually operates similar to a 3-lane facility. The inside lanes operate as the left turn lane and the outside lanes operate as the through lane.
- Projected traffic volumes do not show a drastic increase

Converting a four-lane undivided section to a three-lane cross section may result in less right of way impacts, less environmental impacts and less costs than converting to a wider TWLTL or raised median cross section. The conversion from four to three lanes may also allow the use of wider or designated bike lanes.

Roadways with stop and go traffic such as school buses and delivery trucks or where slow moving heavy vehicles such as long trucks and farm machinery will result in increased through traffic delays. An increased delay for access from side roads may also result with the conversion to three-lanes. A design year ADT of 15,000 - 17,500[69] is typically the maximum capacity for a three-lane TWLTL cross section but check for adequate Level of Service (LOS) (see FDM 11-5-3).

5.4.3 Multiple Left Turn Lanes

Use multiple left-turn lanes at signalized intersections where traffic volumes exceed the capacity of a single left-turn lane. Fully protected signal phasing is required for multiple left turns (refer to TSDM 3-4-1 https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/tsdm/tsdm.aspx for guidance on left turn phasing). Multiple left turn lanes increase capacity for left turning movements and usually improve overall intersection delay and level of service by allowing a shorter cycle length and reallocation of green time to other movements. However, multiple left turns add to the complexity of the driving task. In addition, because multiple left turns increase exposure for cyclists and pedestrians, adequate clearance times for bicycles and pedestrians is critical.

Multiple left turn lanes are usually NOT appropriate where[70].

- A high number of vehicle-pedestrian conflicts may occur.
- Left-turning vehicles do not queue evenly among the left turn lanes because of downstream conditions (e.g., a high potential for downstream weaving may exist).
- Channelization markings within the intersection may become obscured or confusing
- There is insufficient right-of-way to provide adequate turning maneuver space for the design vehicle

5.4.3.1 Design Considerations for Multiple Left Turn lanes

Consider dual left turn lanes at any signalized intersection where left turn demand exceeds 300 vehicles per

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[68] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[69] (*26)* Geometric Design of Lanes - Continuous Two-Way Left-Turn Lanes (TWLTLs). In *Design Manual ch. 6: Geometric Design* Iowa DOT, 2001, sect. 6C-6, pp.1-4. http://www.iowadot.gov/design/dmanual/06c-06.pdf.,(*27)* Facility Selection / Two - Way Left - Turn Lanes. In *MODOT Engineering Policy Guide ch. 200: Geometrics* Missouri DOT, 2012, sect. 232.3. http://epg.modot.org/index.php?title=232.3_Two_-_Way_Left_-_Turn_Lanes.

[70] *(28)* Criteria for the Geometric Design of Triple Left-Turn Lanes. *ITE Journal,* vol. 64, no. 12, 1994, pp.27-33. http://turnlanes.net/files/criteria_for_the_geometric_design_of_triple_left-turn_lanes.pdf.,(29) Individual Movement Treatments / Multiple Left-Turn Lanes. In *FHWA-HRT-04-091: Signalized Intersections: Informational Guide* Federal Highway Administration Turner-Fairbank Research Center, 2004, ch. 12.1.2, pp.318-319. http://www.tfhrc.gov/safety/pubs/04091/04091.pdf.

(30) Triple Left Turn Lanes At Signalized Intersections. BC131 *(FINAL).* Florida DOT, 2002. http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_TE/FDOT_BC131rpt.pdf.

hour or if the storage length exceeds 300 feet; consider triple left turns where left turn demand exceed 600 vehicles per hour[71]: Determine the actual need by performing a signalized intersection capacity analysis.

Turn lane widths for multiple turn lanes are 12-ft typical and 11-ft lower minimum.

Provide adequate throat width on the intersection leg receiving the multiple left turns to compensate for turning vehicles offtracking and for the relative difficulty of side-by-side left turns. On the other hand, avoid excessive pavement width, because this can mislead drivers. An Intersection where the turning angle is greater than 90-degrees may require a wider throat width than an Intersection where the turning angle is 90-degerees or less[72].

Provide a separation between vehicles turning side-by-side of 4-feet typical / 3-feet lower minimum (see Figure 5.3). Provide a clearance between simultaneous opposing left- turns as they pass each other of 10 feet typical / 3-feet lower minimum. It may be necessary to offset opposing approaches to avoid conflicts in turning paths. If opposing left-turns have inadequate clearance between them then provide separate protective signal phases.

Use lane line extensions to delineate the turning path through an intersection in order to reduce the potential for sideswipe collisions and to increase the efficiency of left-turn operations. This is particularly important where less than typical clearances are used. Determine lane line (or guideline) and width requirements by plotting the swept paths of the selected design vehicles. There should be no conditions that obscure, or result in, confusing pavement markings within the intersection.

Check all turning paths of multiple left turn lanes with truck turning templates allowing 2-ft. between the tire path and edge of each lane.

Provide adequate signing and marking to make the intended operation clear to every road user. Each turn lane should be marked with turn arrows and "ONLY" legends as appropriate.

Provide a raised median island on the receiving leg of the intersection to provide drivers on the inside lane with a visual point of reference to guide the vehicle through the left-turn maneuver.

Because of the added width, signal-timing intervals for bicycle and pedestrian movements require special attention,

5.4.3.1.1 Dual Left Turn Lanes

For details on dual left turn lanes, see Figure 5.4 and Table 5.3.

The receiving roadway needs to carry two through lanes a sufficient distance to allow the effective utilization of both lanes (As a lower minimum, use the typical values from the “Tangent Prior to Merge” column in Table A.2.2, from Attachment 2.2).

Assume that the Design Vehicle from Table 2.1 will turn from the outside lane of the dual left turn lanes. Typically, the inside vehicle should be a SU but, as a lower minimum, the other vehicle can be a passenger car, [73] if any or all of the following conditions are present:

- Right-of-way is limited
- Trucks are prohibited on cross streets
- Cross street volume is minimal (< 400 ADT) and route is unlikely to be used as a detour route for a nearby higher volume roadway

Table 5.3 shows throat width guidelines for dual lane left turn lanes where the left turning vehicles have a turning angle of 90-degerees or less.

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[71] Same references as in previous footnote

[72] (*31) NYSDOT Highway Design Manual ch. 5*: *Basic Design*. New York State DOT, 2011. https://www.dot.ny.gov/divisions/engineering/design/dqab/hdm/hdm-repository/chapt_5_final.pdf., sec. 5.9.8.2 B, p.5-125

[73] ILDOT Bureau of Design and Environment Manual 2002. (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf. sect. 36-3.05(b), “Dual Turn Lanes / Design”

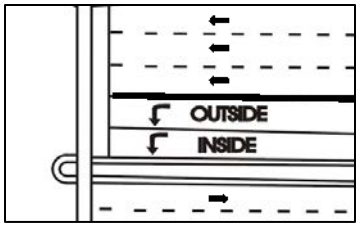

***Figure 5.2* Outside and Inside Lanes for Dual Left Turn Lanes**

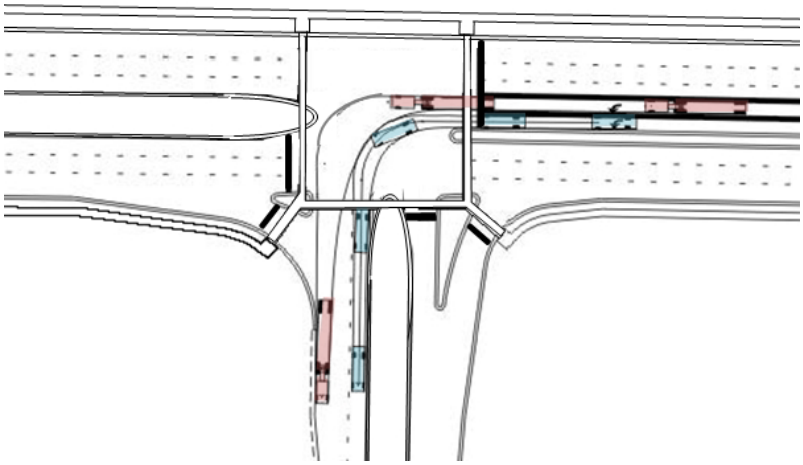

***Figure 5.3* Dual Left Turn Lane with Throat Widening on Departure Leg - Design Vehicle & Single Unit Vehicle Turning Together**

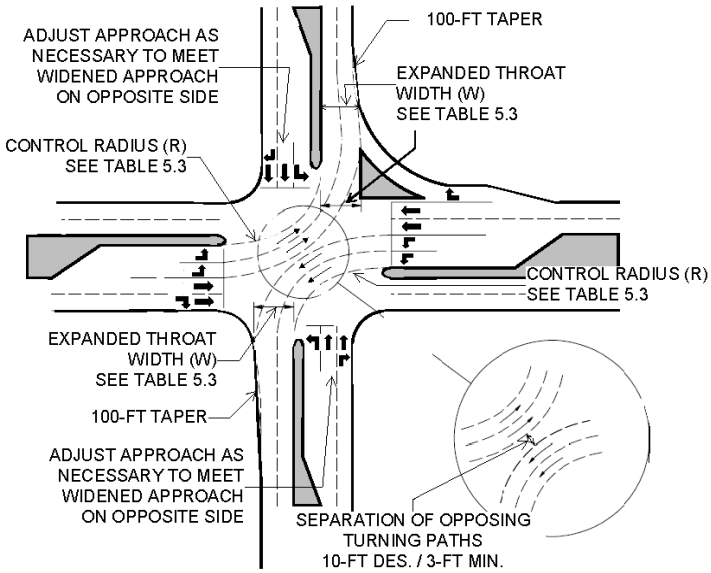

***Figure 5.4* Dual Left Turn Lanes[74]**

[74] Adapted from (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf, Figure 36-3U.

Table 5.3 Expanded Throat Width (W) Guidelines for Dual Left Turn Lanes [75]

Control Radius (R) (feet)	Intersection Design Vehicle =	Expanded Throat Width (W) (feet)	
		'SU' truck or Passenger Car	'WB' truck
75		33 + gutter width(s)	38 + gutter width(s)
100		31 + gutter width(s)	35 + gutter width(s)
150		30 + gutter width(s)	33 + gutter width(s)
200		30 + gutter width(s)	30 + gutter width(s)

5.4.3.1.2 Triple Left Turn Lanes

Consider triple left turn lanes only if meeting the following conditions[76]:

- An operational analysis of the intersection shows that a triple left turn lane would correct a situation in which the overall capacity of the intersection is seriously deficient, and that no other geometric or signal modifications would correct the deficiency. Take into account the effects of adjacent intersections, including:
  - Traffic backup from a downstream signal on the receiving roadway
  - Relative turning movement distribution at a downstream intersection that would compromise the ability of the receiving lanes to store the left turning vehicles
  - The receiving roadway also accommodates heavy volumes from other approaches.
  - Upstream features that would make it difficult to distribute approaching left turning vehicles over the three left turn lanes (e.g. a heavy single lane exit ramp from a freeway).
- Triple left turn lanes would not cause a safety problem or aggravate an existing safety problem - including bicycle and pedestrian safety.
- The signal-timing plan must be able to provide adequate pedestrian clearance intervals for all phases.

Typically, design triple left turn lanes using the Design Vehicle from Table 2.1 in both the outside and middle lanes, and an SU vehicle in the inside lane. Typically, design triple left turn lanes using a WB-65 vehicle (WB-67 if near a freeway) in both the outside and middle lanes, and an SU vehicle in the inside lane. As a lower minimum, design triple lane turns using an SU vehicle and two P vehicles turning simultaneously with a lower minimum 4 feet separation between the swept paths of the vehicles. The SU vehicle should be able to turn in all lanes.

Triple left turn configurations featuring three exclusive left turn bays (Type A) are preferable to either two exclusive left turn bays plus an exclusive left turn trap lane (Type B), or two exclusive left turn bays plus an optional through-left lane (Type C)[77].

Although three continuous downstream receiving lanes are typical in order to avoid a lane drop, the receiving roadway needs to carry three through lanes a sufficient distance to allow the effective utilization of those lanes -

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[75] Adapted from (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf, Figure 36-3T, and (32) *OHDOT Location Design Manual, Vol.1, Roadway Design ch.400*: *Intersection Design*. Ohio DOT, 2006. http://www.dot.state.oh.us/roadwayengineering/standards/Publications/LDM/2006-07-21/400_jul06.pdf, Figure 401-11E

[76] *(30) Triple Left Turn Lanes At Signalized Intersections.* BC131 *(FINAL).* Florida DOT, 2002. http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_TE/FDOT_BC131rpt.pdf, p6-7 to 6-9 / 132-134pdf

(33) Development of Guidelines for Triple Left and Dual Right-Turn Lanes: Technical Report. FHWA/TX-11/0-6112-1. Texas Transportation Institute, Texas A&M University, 2011. http://tti.tamu.edu/documents/0-6112-1.pdf, pp.6-5 to 6-9 / 121-125pdf

[77] *(28)* Criteria for the Geometric Design of Triple Left-Turn Lanes *ITE Journal,* vol. 64, no. 12, 1994, pp.27-33. http://turnlanes.net/files/criteria_for_the_geometric_design_of_triple_left-turn_lanes.pdf.

and at least two continuous downstream lanes exist beyond that point. As a lower minimum, use the typical values from the "Tangent Prior to Merge" column in Table A.2.2, from Attachment 2.2.

5.4.4 Shared left-turn/thru lanes at Signalized Intersections

Shared left-turn/thru lanes are not typical at signalized intersections. Only use shared left-turn/thru lanes on minor low-speed streets or on intersection legs where it is physically impossible to provide separate lanes. If used, monitor their crash history, especially along principal roads.

5.5 Tee Intersection Bypass Lane

A Tee intersection bypass lane (also known as a "SHOULDER BYPASS AT THREE-WAY (T) INTERSECTION" and as "LEFT TURN BYPASS LANE") allows a through vehicle to bypass a left-turning vehicle that is stopped in the traffic lane. See SDD 9A1-a for a detail.

A Tee intersection bypass lane is not as safe as an exclusive left-turn lane because left turning motorists need to stop or slow down in the thru travel lane. This makes them vulnerable to rear end collisions by inattentive following motorists. However, a Tee intersection bypass lane is preferable to no left-turn treatment at all and can improve the efficiency of traffic operations.

Use a Tee intersection bypass lane at the following locations on **non-community bypass** 2-lane roads:

- Type A intersections if a left-turn lane is not warranted, or if the construction of a warranted left-turn lane is not technically feasible, leaving no left-turn treatment as the only other alternative,
- Non-Type A intersections if the construction of a warranted left-turn lane is not technically feasible, leaving no left-turn treatment as the only other alternative,
- Consider at non-Type A intersections where a left-turn lane is not warranted.

Do not use a Tee intersection bypass lane at a four-legged intersection.

Use exclusive left turn lanes with positive offsets at all intersections on a 2-lane community bypass. Do not use Tee intersection bypass lanes.[78]

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LIST OF ATTACHMENTS

Attachment 5.1	Urban Median Opening and Intersection Guidelines
Attachment 5.2	Median Openings and Left Turn Lanes in Urban Roadways
Attachment 5.3	Details for Slotted Left Turn Lanes and Median Opening Openings at Urban Intersections
Attachment 5.4	Median Opening with Left Turn Lane on Rural High-Speed 4-Lane Divided Highway

FDM 11-25-10 Right-Turn Lanes

August 15, 2019

10.1 Introduction

These guidelines apply to right-turn lanes at intersections without channelizing islands. See FDM 11-25-15 for

guidance about channelized right-turn lanes.

A right-turn bay can significantly improve operations and safety at the intersection because it effectively separates those vehicles that are slowing or stopping to turn from those vehicles in the through traffic lanes. This separation minimizes turn-related collisions (e.g., angle, rear-end, and same-direction-sideswipe) and unnecessary delay to through vehicles.[79]

The selection of a right turn radius requires consideration of design speed, types of turning vehicles, type of intersection by location (rural, urban or suburban), pedestrian needs and whether the through highway is divided or undivided.

The assumed speed of a vehicle making a right turn at an intersection designed for lower minimum-radius turns is less than 10 mph.[80]

When providing a designated right turn lane, continue the bicycle accommodation adjacent to the turn lane and thru the intersection (as shown in SDD 15C29). This is particularly important at signalized intersection and intersections with pork chop islands. See FDM 11-46-15 for additional guidance. The Intersection Design Vehicle (see FDM 11-25-2.1 and Table 2.1) does not encroach into a contiguous bike lane between a right-turn lane and a travel lane. Check the swept path of the Intersection Check Vehicle(s) (e.g., a WB-65) to see if it is possible to avoid encroaching into the bike lane without significantly disrupting traffic or going outside of the roadway. Otherwise, consider:

- accepting infrequent bike lane encroachments but consider a warning sign that right turning large trucks pull left before turning.
- If bike lane encroachment is frequent enough to be potentially dangerous, consider:
  - parking restrictions or a larger curb radius
  - mark as a shared bike/right-turn lane instead of a separate bike lane and right-turn lane
  - re-design to reduce or eliminate the conflict

10.2 Intersections in Rural and Developing Areas

Refer to Attachment 1.1 for guidance about right turn lanes on rural high-speed highways.

10.2.1 Storage Length

The right-turn lane lengths in typical rural intersection designs (discussed in Attachment 1.1) are for deceleration of turning vehicles. Where cross road traffic volumes are high, additional length may be needed to accommodate vehicle storage. Storage requirements should also be evaluated where signals are added to the intersection. See FDM 11-25-2.2 for guidance on queue storage requirements.

The length of turn lane required for vehicle storage should be determined in cooperation with the region traffic engineer's staff based on a length of 25 feet per vehicle stored. If the intersection is on the OSOW Truck Route (OSOW-TR), depending on frequency of load, it may be appropriate to consider additional length for OSOW vehicles.

10.3 Two-Way Stop-Controlled Intersections on Urban Low Speed and Transitional Roads

Check with traffic operations on the need for right turn lanes. Accommodate transit, pedestrian and bicyclists roadway users.

Use the charts in Figure 10.1 as an aid in determining whether to add a right-turn bay on the major road at a two-way stop-controlled intersection.

See FDM 11-25-10.4 below for guidance on signalized intersections.

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[79] See Bonneson & Fontaine in NCHRP Report 457 (*13) NCHRP Report 457*: *Engineering Study Guide for Evaluating Intersection Improvements*. TRB, National Research Council, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf., pp. 22-23)

[80] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., p.583, "Minimum edge of Traveled Way Designs"

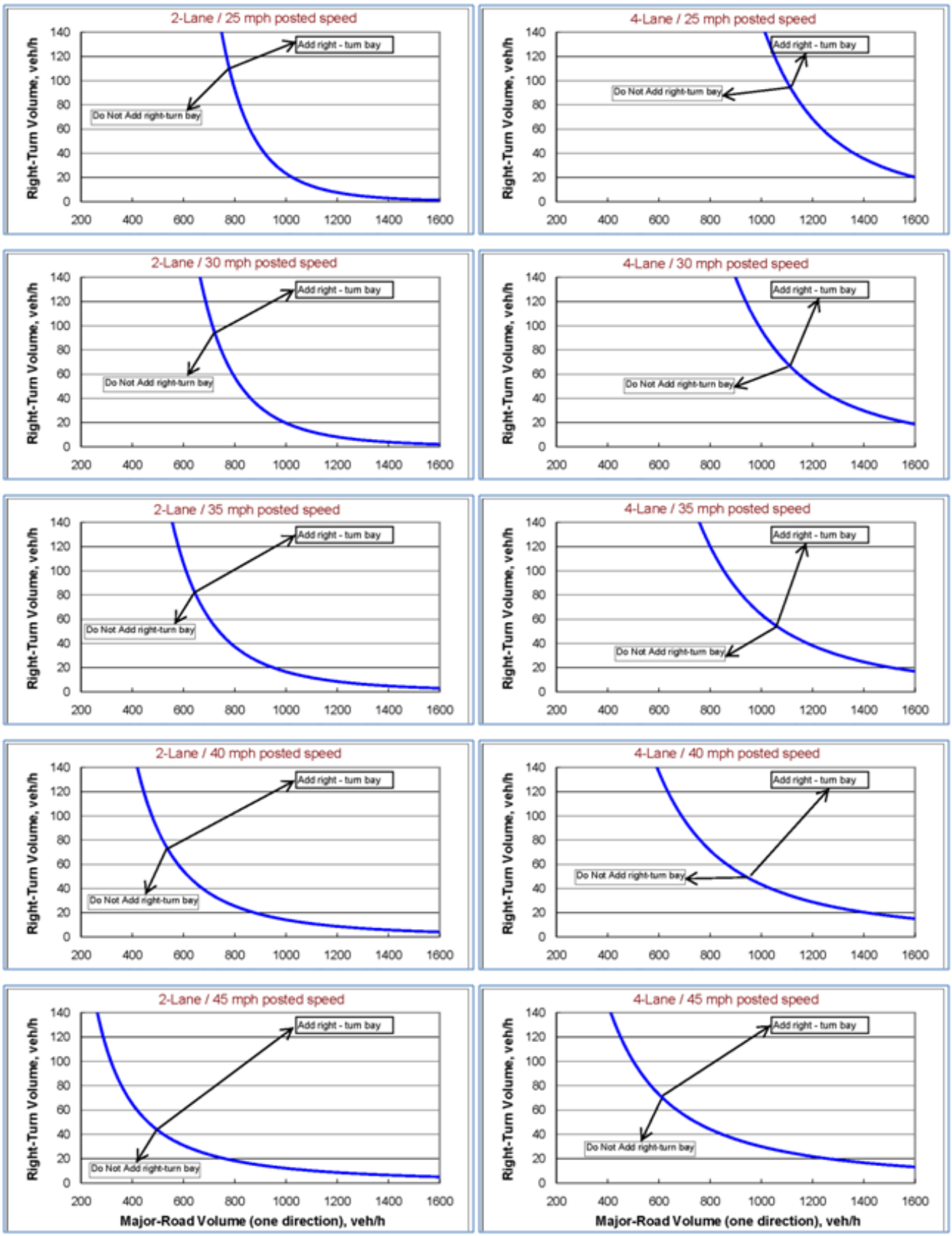

***Figure 10.1** Guidelines for a Major-road Right-turn Bay at Urban Two-way Stop-controlled Intersections*[81]

10.3.1 Corner Curb Radius

Central Business District (CBD) streets are typically undivided and often operate as one-way roadways. A lower

minimum corner radius of 10 feet may be adequate for these streets especially where there is pedestrian activity and little truck traffic. Progressively larger corner radii are required depending on the functional classification of the intersecting street; at least 15 feet for locals, 20 feet for collectors and 25 feet for arterials. Large trucks can be accommodated with these radii if encroachment into the opposing traffic lane can be allowed and parking can be held back from the corner by at least two spaces. See Chapter 9 of 2004 AASHTO GDHS sections, "Effect of Curb Radii on Pedestrians" and "Corner Radii into Local Urban Streets".[82]

Where there are a significant number of trucks turning and encroachment into the opposing lanes cannot be allowed, the corner should be designed using an appropriate turning template or three centered compound curves. See 2004 AASHTO GDHS Exhibit 9-42, "Typical Designs for Turning Roadways". Pedestrian, bicycle and transit accommodations and signal locations need to be included in the design accordingly.

Where truck volumes are not significant, the right turn radius can be as small as 10 feet in downtown streets and 25 feet at intersections with arterial streets. Intersections that handle large numbers of turning trucks require a lower minimum corner radius of 30 feet to turn onto a four-lane divided highway where the semitrailer can encroach into the median lane. Truck drivers will use the median lane when necessary which is allowed under state law for large trucks. A larger radius should be provided where possible. However, a radius greater than 45 feet should not be used because it can cause substantial problems with the location of stop signs, traffic signals, pedestrian push buttons, and crosswalk locations. A large radius also causes crosswalks to be extra-long which results in more pedestrian exposure and visibility problems.

The corner radius can be shorter where the intersection is on a street where parking is permitted. However, future growth in traffic volumes may demand that the parking lane be converted to a traffic lane. If this is foreseeable, a large radius should be provided.

For additional guidance, see 2004 AASHTO GDHS sections," Minimum Edge of Traveled Way Design" and "Design for Specific Conditions (Right Angle Turns"[83].

10.3.2 Lane Width

The width of a non-channelized right turn lane should generally be the same as the width of the through lane. For guidance on the use of narrower lanes, see Table 5.2. The typical width for channelized right turn lanes is discussed in FDM 11-25-15.

10.3.3 Lane Length

See FDM 11-25-2.3.

10.4 Signalized Intersection Considerations

Consider providing exclusive right turn lanes for all approaches at a signalized intersection. A right turn lane provides refuge for safe deceleration outside a high speed through lane and provides storage for right-turning vehicles to assist in optimizing traffic signal phasing.

Improperly designed right turn radii most likely will result in traffic signal knockdowns. A flat corner curb radius (i.e.,>70 feet) creates a traffic signal design problem when locating the near right traffic signal. The preferred solution is to design a small pork chop island (lower minimum of 150 square feet) to place the traffic signal and lighting bases, pull boxes, pedestrian pushbuttons, and pedestrian walkways. The island also facilitates channelization of the right turn movement (see FDM 11-25-15 for guidance on channelized right turns).

10.4.1 Dual Right Turn Lanes

Dual right-turn lanes have typically been installed at signalized intersections and at roundabout right-turn bypass lanes on urban arterial roadways and interchange ramps. Determine the actual need by performing a signalized intersection capacity analysis. Use dual right-turn lanes only if necessary because they are particularly difficult

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[81] (*13) NCHRP Report 457: Engineering Study Guide for Evaluating Intersection Improvements*. TRB, National Research Council, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf, Figure 2.6, p.23 - see also interactive spreadsheet included in on-line version, "http://onlinepubs.trb.org/onlinepubs/nchrp/esg/figure 2-6.xls" (NCHRP references from "NCHRP Report 457" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))

[82] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., pp.614-621

[83] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., pp.634-639

for bicyclists and pedestrians[84]. Dual right-turn lanes at signalized intersections are required to be signal-controlled. See FDM 11-26 for guidance on dual right-turn lanes at roundabout right-turn bypasses.

There are generally two reasons for using dual right-turn lanes[85]:

1. To accommodate high right turn volumes and provide enhanced capacity at intersections where a single right-turn lane is not adequate, and a free-flow right turn lane is not advisable
2. To mitigate weaving traffic conflicts, e.g. drivers who are making a left-turn at the next downstream intersection would make their turn from the left-hand lane of the dual right-turn lanes

Research has shown that a well-designed dual right-turn lane does not cause significantly higher crash frequency or severity compared to a single right-turn lane[86] and will usually improve the operations of intersections. The additional deceleration and storage space helps prevent spillover into adjacent through lanes. Right-turning traffic requires less green time, and this time thus can be allocated to other movements. However, because of the added width, signal-timing intervals for bicycle and pedestrian movements require special attention,

Consider using dual right-turn lanes at an intersection with a single right-turn lane - and where the receiving leg has at least two lanes - if one of the following conditions exists[87]:

- The right-turn volume is greater than 500 vph;
- There is not sufficient space to provide the necessary length of a single turn lane because of restrictive site conditions (e.g., closely spaced intersections),
- The required length of a single turn lane becomes excessive (usually about 300-ft or greater)
- The volume to capacity ratio for a single right-turn lane is greater than or equal to 0.90, or LOS is worse than D
- Right-turn green time and green time from an overlap are not sufficient to handle the right-turn volume

There are two (2) types of dual right-turn lane configurations:

1. Shared dual right-turn lanes: the right-hand lane (i.e., the curb lane) is an exclusive right-turn lane and the left-hand lane is a shared right-turn/thru lane
2. Exclusive dual right-turn lanes: both the right-hand lane and the left-hand lane are exclusive right-turn lanes

Exclusive dual right-turn lanes are generally preferable because they provide more capacity enhancement. Exclusive dual right-turn lanes also allow for placement of a bicycle lane between the through lane and the right-turn lanes.[88]

The shared right-turn/thru lane has lower lane utilization than an exclusive right-turn lane because thru vehicles block right-turning vehicles during protected right-turn phases; the lower lane utilization may result in the need for longer storage in the curb right-turn lane. In addition, shared dual right-turn lanes, do not allow for placement of a bicycle lane between the shared right-turn/thru lane and the exclusive right-turn lane (or between the exclusive thru lane and the shared right-turn/thru lane). However, shared dual right-turn lanes are preferred where:

- More flexibility is needed to use an optional lane
- Less impacts on the adjacent through movement is desired
- Right-of-way for providing an additional turn lane is restricted

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[84] *(33) Development of Guidelines for Triple Left and Dual Right-Turn Lanes: Technical Report.* FHWA/TX-11/0-6112-1. Texas Transportation Institute, Texas A&M University, 2011. http://tti.tamu.edu/documents/0-6112-1.pdf, p.6-2

[85] *(34) Development of Warrants for Installation of Dual Right-Turn Lanes at Signalized Intersections.* SWUTC/12/161141-1. Texas Transportation Institute, Texas A&M University, 2012. http://d2dtl5nnlpfr0r.cloudfront.net/swutc.tamu.edu/publications/technicalreports/161141-1.pdf, p.91-95 / 107-111pdf

[86] Reference (34), p.18 / 34pdf

[87] Reference (34), p.91 / 107pdf

[88] Reference (34), pp34-35, 94 / 50-51, 110pdf

By statute[89], Right turns on red (RTOR), when permitted, are allowed from the right-hand (i.e., curb) lane and the leftmost right-turn lane of a roadway that provides two right-turn lanes provided that it is into a lawfully available lane that is second to the rightmost lane for traffic moving to the right. Except for a vehicle turning right from the leftmost right-turn lane of a roadway that provides two right-turn lanes, no turn may be made on a red signal if lanes of moving traffic are crossed.

Pull the curb lane out beyond the left-hand turn lane so drivers in the curb lane have a clear unobstructed view of approaching traffic. Consider prohibiting right-turn-on-red (RTOR) from a dual right-turn lane if one or more of following conditions exist:[90]

- Insufficient sight distance
- Frequent presence of pedestrians
- Use of split phase
- Significant U-turns from right-hand cross-street
- High crash history
- High-speed road, onto which subject RTOR vehicles turns
- Inadequate capacity of receiving lanes

There are some potential issues with dual right-turn lanes, including[91]:

- Sideswipes between turning vehicles are a possibility at double turn lanes. This is especially an issue if the turn radius is tight and large vehicles are likely to be using the turn lanes. Delineation of turn paths should help address this issue.
- Impaired intersection sight distance (ISD) for drivers in the right-hand turn lane due to vehicles in the left-hand lane obstructing their view of on-coming traffic
- Right-of-way acquisition may be expensive.
- Possible access restrictions to adjacent properties
- Dual right-turn lanes make crosswalks longer, which can affect lower minimum cycle time, increase pedestrian exposure, and precipitate long pedestrian clearance intervals that may or may not work with coordination timing plans.
- Pedestrian movement may also be less safe because a vehicle in the curb lane whose driver is yielding to a pedestrian can block sight lines for drivers in the left-hand turn lane

Design considerations for dual right-turn lanes include[92]:

- Check all turning paths of dual right-turn lanes with truck turning templates allowing 2-ft. between the tire path and edge of each lane.
- Provide a separation between vehicles turning side-by-side of 4-feet typical / 3-feet lower minimum.
- Turn lane widths for dual right-turn lanes are 12-ft typical and 11-ft lower minimum.
- The lower minimum width of channelized roadway for dual right-turn lanes is 30-feet, not including gutters.
- Determine the length of dual right-turn lanes as discussed in FDM 11-25-2.
- WisDOT's practice[93] is to assume that the Intersection Design Vehicle (see Table 2.1) turns from the left-hand lane of the dual right turn lanes (see Figure 10.2). However, there may be locations where it is appropriate to assume that the Intersection Design Vehicle turns from the right-hand lane (for example, a significant number of the vehicles are making a right turn at a close by downstream intersection or driveway). Typically, the vehicle in the other lane (typically, the right-hand lane) should

[89] Section 346.37(1)(c)3, Wis. Stats

[90] Reference (34), p.95 / 111pdf

[91] Reference (34), pp5, 41-42 / 21, 57-58pdf

[92] Reference (34), pp5-14 / 21-30pdf

[93] per interim TSDM 3-3-4, July 2009

be a SU truck but, as a lower minimum, can be a passenger car[94], if any or all of the following conditions are present:

- Right-of-way is limited
- Trucks are prohibited on cross streets
- Cross street volume is minimal (< 400 ADT) and route is unlikely to be used as a detour route for a nearby higher volume roadway

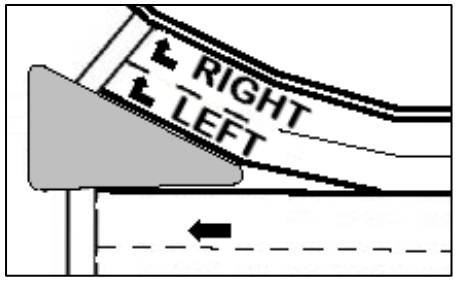


***Figure 10.2** Dual Right-Turn Lanes*

- Dual right-turn lanes require sufficient turn radii to allow a smooth turn from both turn lanes, but not so large as to encourage excess speed.
- Provide adequate throat width on the intersection leg receiving the dual right turns to compensate for turning vehicles offtracking and for the relative difficulty of side-by-side right turns. Provide throat widening comparable to that used for dual left-turn lanes (see FDM 11-25-5.4.3.1.1, including Table 5.3 and Figure 5.4). Consider how throat widening will affect the traffic approaching from the other side. Make sure that the through lanes line up relatively well to ensure a smooth flow of traffic through the intersection.
- The receiving roadway needs to carry two through lanes a sufficient distance to allow the effective utilization of both lanes (As a lower minimum, use the typical values from the “Tangent Prior to Merge” column in Table A.2.2, from Attachment 2.2) - but not less than 150-ft.
- Truck traffic utilization is an issue when designing dual right-turn lanes. Like a roundabout, if designed too wide to accommodate truck traffic, then traffic may create a "third turn lane", especially during snowy conditions.
- Avoid installing dual right-turn lanes near access points (e.g., from gas stations, parking lots, or other traffic generators).
- For closely spaced intersections, if a downstream intersection uses dual right-turn lanes, do not align the curb right-turn lane with any through lane at the upstream intersection.
- Provide adequate signing and marking to make the intended operation clear to every road user. Each turn lane should be marked with turn arrows and "ONLY" legends as appropriate. Use lane line extensions to delineate the turning path through an intersection in order to reduce the potential for sideswipe collisions and to increase the efficiency of right-turn operations. Determine lane line (or guideline) and width requirements by plotting the swept paths of the selected design vehicles. There should be no conditions that obscure, or result in, confusing pavement markings within the intersection.

10.5 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

2. Bonneson, J. A. and M. D. Fontaine. NCHRP Report 457: Engineering Study Guide for Evaluating Intersection Improvements. TRB, National Research Council, Washington, DC, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf

3. Cooner, S. A., S. E. Ranft, Y. K. Rathod, Y. Qi, L. Yu, Y. Wang, and S. Chen. Development of Guidelines for Triple Left and Dual Right-Turn Lanes: Technical Report. FHWA/TX-11/0-6112-1. Texas Transportation

[94] ILDOT Bureau of Design and Environment Manual 2002 (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf, sect. 36-3.05(b), “Dual Turn Lanes / Design”

Institute, Texas A&M University, College Station, TX, Jan 2011 Published July 2011. http://tti.tamu.edu/documents/0-6112-1.pdf

4. Yi, Q., C. Xiaoming, D. Li, and Center for Transportation Training and Research - Texas Southern University. Development of Warrants for Installation of Dual Right-Turn Lanes at Signalized Intersections. SWUTC/12/161141-1. Texas Transportation Institute, Texas A&M University, College Station, TX, Apr 2012. http://d2dtl5nnlpfr0r.cloudfront.net/swutc.tamu.edu/publications/technicalreports/161141-1.pdf

FDM 11-25-15 Turning Roadways (Channelized Right)

August 15, 2019

15.1 Criteria

At intersections with a considerable number of turning movements, especially by trucks, and where it is typical to maintain a turning speed for passenger vehicles of roughly 15 mph (25 km/h) or greater, a separate turning roadway or channelized right-turning lane should be provided between intersection legs. Check the turning movements of OSOW vehicles if needed. Verify that OSOW vehicles are not prohibited from turning at the intersection where needed.

The term "turning roadways" also applies to ramps and ramp terminals, particularly at the crossroad. Refer to FDM 11-30 Attachment 1.3, 1.4, 1.5, and 1.6 for geometrics at ramp terminals.

15.2 Speed and Curvature

The speed maintained on the free flow segment of turning roadways is governed by the radius of curve and superelevation (see FDM 11-10-5 for superelevation guidance). "Free-Flow Turning Roadways at Intersections" are discussed on pages 639-649, GDHS.

Compound curves should be used at the downstream connection with the departure leg of the intersection to avoid vehicle encroachment onto the curb or shoulders. Three-centered compound curves for vehicles of different design classification are shown in Exhibit 9-20, pages 584-591, GDHS[95]. It is typical that the right turn radius be kept as small as possible to avoid excess speed, while still accommodating the Intersection Design Vehicle.

15.3 Design Guides

The width of turning roadways should accommodate the design class of vehicle that is anticipated. For turning lanes that are longer than 50 feet, provisions should be made to pass a stalled vehicle in the turning lane. The design width of pavement for turning roadways is shown in Exhibit 3-51, page 220, GDHS[96] with 15 feet as a lower minimum plus the gutter width. "Turning Roadways with Corner Islands" are discussed on pages 634-639 GDHS.

Channelized right turns should be brought in as close to perpendicular as possible for vision to the left. Right turn lanes separated by islands having intersecting angles less than 60 degrees with the cross street require the driver to look back over their left shoulder to view oncoming traffic, which is particularly difficult for older drivers. Design right turn islands in urban/suburban areas with the right-turn lane at an angle as close to 90-degrees as possible, based on the guidance in FDM 11-25-2.7, “Angle of Intersection”, and as shown in Figure 15.1.

[95] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[96] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

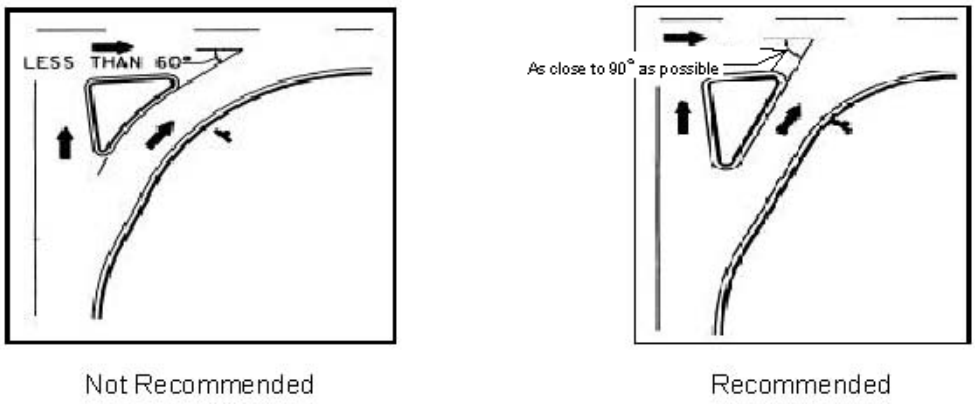


Figure 15.1 Intersection Angle for Channelized Right Turn

The taper on the approach to the turn is dependent upon design speed, but 20:1 is typical with 10:1 as a practical lower minimum for most urban streets. Use this taper on the receiving leg of the turning roadway as well.

Consider the type of controls to use for channelized right turns. Typically, it is preferred to use a less restrictive method and increase the degree of control as volumes, safety, and geometric conditions dictate. Refer to TSDM 3-4-2 (https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/tsdm/tsdm.aspx) for guidance on control of channelized right turns at signalized intersections.

Provide offsets to raised curb islands as described in FDM 11-25-25.2.1.

15.4 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

FDM 11-25-20 Median Openings

August 15, 2019

20.1 Introduction

Median openings, whether they are located at major intersections or serve traffic generators between intersections, all tend to interrupt through traffic flow. On arterial streets, it is highly typical to maintain a free flow of traffic without interruptions.

Median openings accommodate left-turn movements, U-turn movements from the highway, cross traffic movements, and left-turn movements from a side road or driveway. A full median opening allows all movements. A directional median opening (Figure 20.1 and Figure 20.2) allows some but not all movements - but has fewer conflict points - and has been found to reduce crash rates.

Provide a pedestrian crossing where the side road has sidewalks on one or both sides of the street and the through street has sidewalk on the opposite side. This condition establishes a legal crosswalk whether the crosswalk is pavement marked or not per ss340.01 (10) (b). Also providing median refuge for pedestrian and share-use path crossings may influence median nose design. See FDM 11-25-5 and FDM 11-46-10.

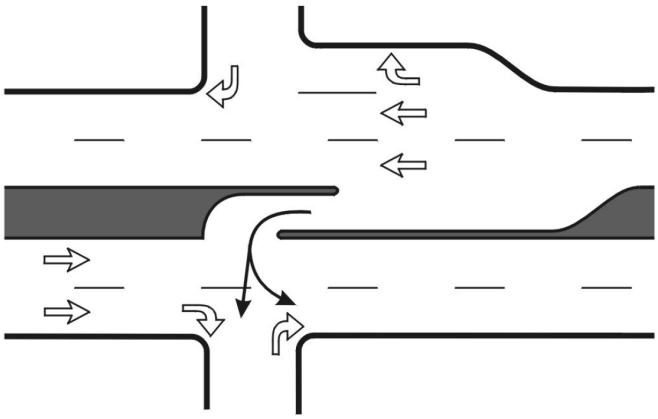


***Figure 20.1* Directional Median Opening[97]**

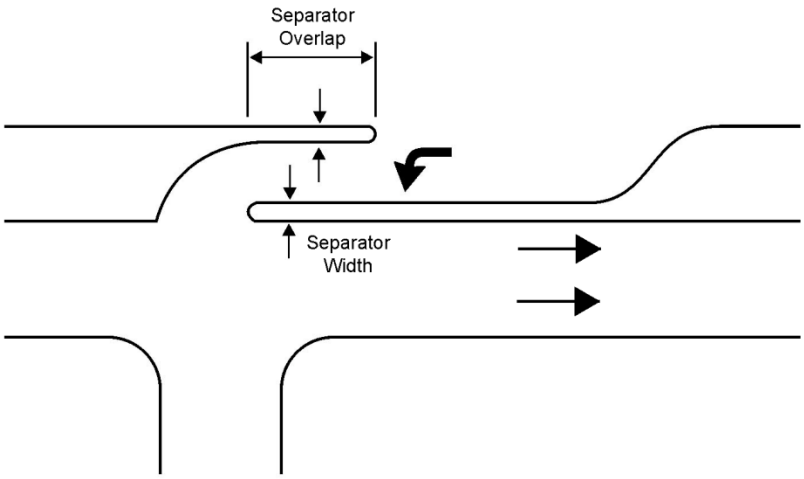
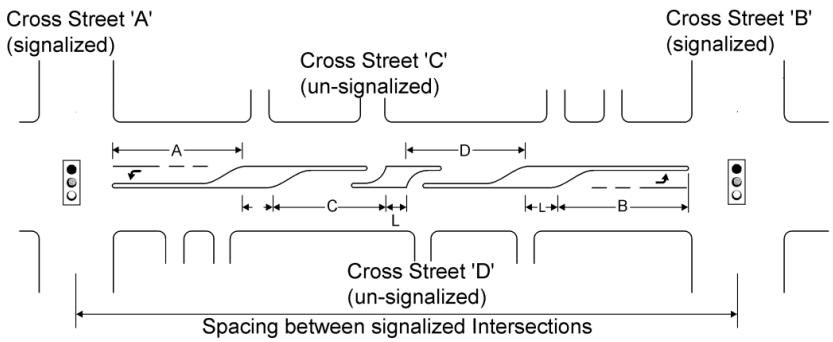


***Figure 20.2* Separator Overlap for Directional Median Opening[98]**

If there is sufficient space, providing unsignalized directional openings between signalized intersections facilitates access to abutting properties and reduces U-turns / left turns at the signalized intersections. The operations of the adjacent signalized intersections are of greater importance than the midblock opening(s). The midblock opening(s) must not compromise the design or operations of the signalized intersections.

[97] Adapted from (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 11-4 on p.207. Copyright, National Academy of Sciences, Washington, D.C., 2003. Reproduced with permission of the Transportation Research Board.

[98] Adapted from (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 11-7, p. 209. Copyright, National Academy of Sciences, Washington, D.C., 2003. Reproduced with permission of the Transportation Research Board.



Legend
A = Westbound Left Turn Bay at cross-street 'A'
B = Eastbound Left Turn Bay at cross-street 'B'
C = Eastbound Left Turn Bay at Directional Median Opening for cross-street 'C'
D = Westbound Left Turn Bay at Directional Median Opening for cross-street 'D'
L = Length of full-width median (minimum = 25-feet)

Figure 20.3 Examples of Directional Median Openings between Signalized Intersections[99]

See Table 20.1. Also, see AASHTO GDHS, pp.689-712[100] for additional guidance on median openings.

20.2 U-Turns

Median openings for U-turns may be appropriate at some locations, such as:

- In advance of some signalized intersections,
- Downstream from intersections where side road traffic thru movement is not allowed

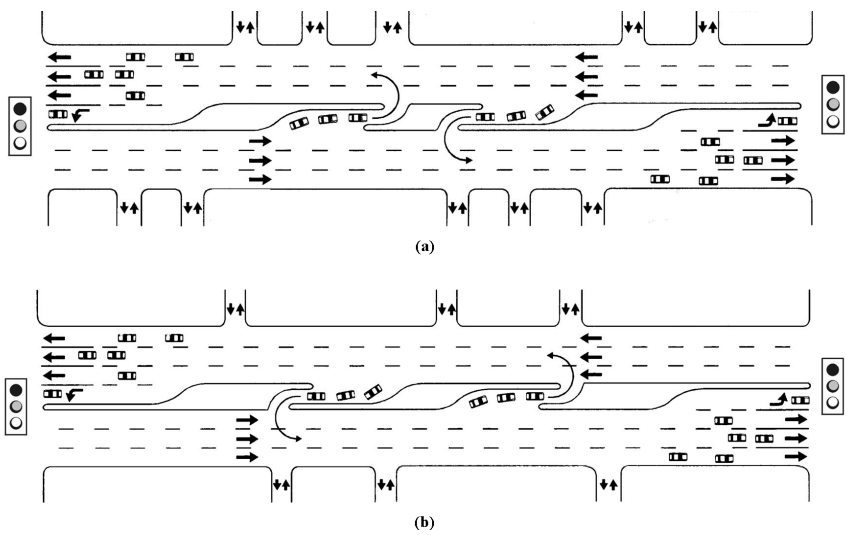


Figure 20.4 Directional Median Openings for U-turns[101]
(a) Downstream from Signalized Intersection
(b) Upstream from Signalized Intersection

See Table 20.1. Also, see AASHTO GDHS, pp.709-712[102] for additional guidance, including lower minimum

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[99] Adapted from (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 11-5, p. 208. Copyright, National Academy of Sciences, Washington, D.C., 2003. Reproduced with permission of the Transportation Research Board.

[100] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[101] (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 11-8, p.210. Copyright, National Academy of Sciences, Washington, D.C., 2003. Reproduced with permission of the Transportation Research Board.

[102] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

widths of medians required to accommodate U-turns. Also, see chapter 11 of the TRB Access Management Manual.

20.3 Length of Opening

Use the control radii for vehicles making a left-turn or making a U-turn to determine the length of a median opening. The lower minimum median opening length is 40-feet. See AASHTO GDHS, Exhibits 9-76 to 9-83[103]. Also, see FDM 11-25-5.3 for guidance on control radii and median end design.

20.4 Spacing

Provide median openings only at locations that are safe for all allowed movements. Also, provide adequate spacing for traffic weaving to preserve traffic flow and for safe lane changes and turns.

At a signalized intersection, do not provide a median opening that crosses a left turn lane or left turn storage.

The functional area of an intersection is the critical area where motorists are responding to the intersection, decelerating, and maneuvering into the appropriate lane to stop or complete a turn. Access connections too close to intersections can cause serious traffic conflicts that impair the function of the affected facilities. Drivers need sufficient time to address one potential set of conflicts before facing another.

Ideally, do not place a median opening for a public access intersection (street or alley) or a private access intersection (driveway or private road) within the upstream functional area of another intersection. A median opening within the limits of an exclusive left-turn bay or within the downstream functional area of an intersection is especially undesirable because it violates driver expectancy and can have a negative effect on the safety, operation and capacity of an intersection.

See Table 20.1 for guidance on evaluating existing and proposed median openings.

[103] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

***Table 20.1** Median openings – allowable locations (applicable to STH and connecting highways)*

Median Opening location Relative to Functional Area of intersection [B]	Conditions and Requirements for Median Openings [A]	
	Existing opening (includes formerly undivided roadways on which a new median is added)	**New Opening**
Inside downstream functional area of intersection for approach lanes or for opposing lanes	* **Consider closing** median openings at these locations; and * Evaluate and improve the operation and geometry of adjacent intersection to accommodate any increase in turning movements resulting from closing the median opening.	In unique situations, consider if low safety implications
upstream of (d1) AND Outside of Functional Areas for adjacent intersection	* Construct a separate turn bay for the opening if the opening is inside the left-turn bay for the downstream median opening; and * Make any modifications necessary to correct safety, design, and operational deficiencies.	* The proposed location meets applicable access, intersection and median opening spacing design criteria; and * Sufficient sight distance, turning geometry, storage and deceleration can be provided for all allowed movements; and * The projected design year level of service is D or better for all allowed movements; and * Either a full or a directional median opening is allowed. The opening and its associated turn bay(s) must be separate from the left-turn bay(s) for the adjacent median opening(s).
Inside (d1)	* Construct a separate turn bay if the opening is inside the left-turn bay for the downstream median opening; and * Do not allow additional movements at a directional median opening. * Close or restrict a full median opening to a directional median opening if level of service is worse than D or if there is a crash problem associated with the opening; and * Close or restrict a directional median opening if level of service is worse than D or if there is a crash problem associated with the opening; and * Make any modifications necessary to correct safety, design, and operational deficiencies.	* The proposed location meets applicable access, intersection and median opening spacing design criteria; and * Sufficient sight distance, turning geometry, storage and deceleration can be provided for all allowed movements; and *The opening and its associated turn bay(s) must be separate from the left-turn turn bay(s) for the adjacent median opening(s); and * The projected design year level of service is D or better for all allowed movements; and * Do not allow left-outs and thru movements from side roads / driveways and left-ins from the opposite-direction mainline unless meeting the conditions in Note [D] below.
Inside (d2)	It meets the conditions in Note [C] below.	**SHOULD NOT ALLOW**
Inside (d3)	* **Consider closing** median openings at these locations;.and * Evaluate and improve the operation and geometry of adjacent intersection to accommodate any increase in turning movements resulting from closing the median opening.	
Inside (d4)		
Inside Mainline design hour queue		

Notes

[A] Evaluate each opening for both directions of travel, and for both peak and non-peak conditions. If movement restrictions or prohibitions are ineffective or impractical then close median opening.

[B] The upstream functional lengths for the thru lane(s), left turn bay, and right turn bay determine the boundary for the upstream functional area of intersection.

Upstream functional length of intersection elements d1, d2, d3, and d4 are independent of turn bay elements although, ideally, they correlate as shown in FDM 11-25-2, Figure 2.9. However, this correlation is not always possible, or may change because of changes in traffic at an intersection.

[C] Consider allowing an existing opening to remain for Perpetuation and Rehabilitation projects if the Safety Certification Process does not identify a discernable safety issue or there is a written request from a municipality to do so. This municipal request must contain acceptable documentation for all of the following:

- Design alternative for closing the existing opening that evaluates alternate accesses, operations and safety and includes a good faith comparison showing that keeping the existing median opening is the preferred alternative.
- Minimum of the most recent available 5-year crash history showing that there is not a crash problem associated with the existing median opening. Crashes that might be associated with the opening can occur at the opening but also up to several hundred feet from the opening in both directions of travel. Examples include:
  - Crashes involving vehicles in the approach thru lane forced to decelerate or stop because of spillback from the median opening.
  - Crashes involving vehicles from a side road or driveway that are making left-out or thru movements.
  - Crashes involving vehicles from the opposing lane that are making left-in or u-turn movements.
  - Crashes involving vehicles unable to clear the intersection because of queuing in the opposite-direction mainline at the median opening.
  - Crashes involving vehicles from the turn lane that are making left-in movements.
- The existing opening is not within the design storage queue of either the turn lane or the mainline.
- Evaluation and proposed improvements of adjacent intersections capability to accommodate increased turning movements resulting from restrictions at the existing median opening.
- There is adequate storage and deceleration length available for same-direction left-in movement at the existing median opening.
- Prohibit left-outs and thru movements from side roads / driveways and left-ins from the opposite-direction mainline unless meeting the conditions in Note [D] below.
- The design hour level of service for any of the allowed movements at the existing opening is C or better, and the design hour level of service for the intersection is C or better.
- The municipality agrees to close the opening if:
  - the design hour level of service deteriorates to D or worse, or
  - there is a crash problem, or
  - the design storage queue for either the turn lane or the same-direction mainline extends into the median opening

[D] Movements that are prohibited during certain times of day can be allowed during other times of day if all of the following conditions are met:

- Sufficient median width and turn bay length must be available for all allowed movements.
- Levels of service for all allowed movements shall be C or better.
- Signing that prohibits these movements at all other times shall be installed.

20.5 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

11. TRB Committee on Access Management (ed.) (ed.). Access Management Manual. Transportation Research Board, Washington, DC, 2003. [104]

[104] [Dec 6, 2012 email from Phyllis Barber, Transportation Research Board Publications Office / Javy Awan, Director of Publications, Transportation Research Board] The Transportation Research Board grants permission to the Wisconsin DOT to reproduce 4 figures from the TRB Access Management Manual, in a proposed revision to Chapter 11, Section 25 of Wisconsin DOT's Facilities Development Manual, as identified in your request of December 3, 2012, subject to the following conditions:

1. Please credit as follows:

FDM 11-25-25 Channelization

August 15, 2019

25.1 General

Traffic can be channelized by using various combinations of islands, pavement markings, rumble strips, contrasting pavement, traffic signals, etc. The design guides for providing left- and right-turn lanes (FDM 11-25-5 and FDM 11-25-10) are also methods of channelizing traffic.

25.2 Islands

This discussion assumes that islands are raised by using curb and gutter. The use of islands for directing traffic should be held to a practical minimum, as they in themselves can present problems, especially for winter maintenance activities. The lower minimum size for islands is 150 square feet; the lower minimum size is 100 square feet. The approach end of the island should provide sufficient warning to identify the island's existence. This can be accomplished by using a raised delineator (non-rigid) or a rumble strip. To prevent damage to snowplows or errant vehicles, a mountable curb should be constructed on the approach nose.

Islands may also need to provide for pedestrian crossing. The crossing area needs to be unobstructed with a flat, level surface.

Minimize channelization islands, raised islands and other raised features that may inhibit turning movements of OSOW vehicles on the OSOW Truck Route (OSOW-TR).

25.2.1 Offsets

The approach nose of a curbed island needs to be conspicuous to approaching drivers - and clear of the vehicle path, both visually and physically, so that drivers will not shy away from the island. Where possible, offset median islands 8 feet from the travel lane and transition to a normal curb offset, - typically 2 feet. The transition length is dependent on the design speed.

Offsets from the edge of thru travel lane to the face of a curbed channelizing island for a turning roadways are as follows (these offsets include a continuation of the width provided for on-street bicycle accommodation (see SDD 15C29)):

Low speed urban roadways (posted speed of 40 mph or less)

- If the offset to curb face from the outside edge of approach travel lane is <=2-ft then offset the approach nose of the right turn channelizing island by 4-ft from the outside edge of the travel lane and taper down to a 2-ft offset at the departure nose.
- If the offset to curb face from the outside edge of approach travel lane is >2-feet then offset the approach nose of the right turn channelizing island by an additional 2-ft from the outside edge of the travel lane and taper down to the normal offset at the departure nose.

Transitional and high speed urban roadways (posted speed of 45 mph or greater)

- If the offset to curb face from the outside edge of approach travel lane is <=6-ft then offset the approach nose of the right turn channelizing island by 8-ft from the outside edge of the travel lane and taper down to a 6-ft offset at the departure nose.
- If the offset to curb face from the outside edge of approach travel lane is >6-feet then offset the approach nose of the right turn channelizing island by an additional 2-ft from the outside edge of the travel lane and taper down to the normal offset at the departure nose.

Rural roadways

- If the outside finished shoulder width is <=6-ft then offset the approach nose of the right turn channelizing island by 8-ft from the outside edge of the travel lane and taper down to a 6-ft offset at the departure nose.
- If the outside finished shoulder width is >6-feet then offset the approach nose of the right turn channelizing island by an additional 2-ft from the outside edge of the travel lane and taper down to the normal shoulder width at the departure nose.

Offset the edge of a channelized turning roadway by 2-3 feet from the face of a curbed channelizing island at the approach nose and continue this offset to the departure nose.

From Access Management Manual, Figure 11-4, p. 207; Figure 11-5, p. 208; Figure 11-7, p. 209; and Figure 11-8, p. 210. Copyright, National Academy of Sciences, Washington, D.C., 2003. Reproduced with permission of the Transportation Research Board.

2. None of this material may be presented to imply endorsement by TRB of a product, method, practice, or policy.

25.2.2 Signalized Intersection Considerations

As discussed in FDM 11-25-10, right-turn pork chop islands are typically provided for delineation, pedestrian refuge, and traffic signal placement at intersections with flat radii. Revisions to a signalized intersection will typically be needed at some point in the future. Therefore, the construction of islands is very important. Monolithic concrete islands are not typical because installing a pull box or base would require removing concrete.

25.3 Pavement Markings

Painted islands should not be offset from the through lane except where the lane width is insufficient. For additional discussion, refer to pages 621-639 of GDHS[105].

25.4 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

FDM 11-25-35 Auxiliary Lanes

March 14, 2016

35.1 Auxiliary Lanes

An auxiliary lane is defined as the portion of roadway adjoining the through lanes for speed change, turning, storage for turning, weaving, truck climbing, and other purposes that supplement through traffic. (2011 AASHTO GDHS, p 10-76).

Truck climbing lanes and passing lanes are considered auxiliary lanes. For more information on truck climbing lanes and passing lanes see FDM 11-15-10.

35.2 Acceleration Lanes

For design details of acceleration lanes refer to FDM 11-30-1. Acceleration lanes may also be used at non-signalized intersections with turning roadways, particularly for right-turning vehicles entering an arterial. In some cases, a length of the parking lane may become the acceleration lane. For details relating to a tapered or a parallel type of acceleration lane, refer to pages 688-689, GDHS[106].

35.3 Bus Stops

Bus transit is an integral part of the operation of many urban streets and highways. The existing operating policies and the future transit needs of communities should be given design consideration where applicable, particularly where bus movements caused by bus stops will affect intersection capacity.

A bus stop area, landing pad or platform is the portion of roadway designated for transit users to facilitate boarding and alighting[107]. A bus stop connects to an intersection corner, sidewalks, or paths by an accessible route. Connections directly to the roadway are not permitted because roadways are not pedestrian facilities. The lower minimum requirements for a bus stop site are:

- A firm, stable surface with a 2% cross slope;
- A lower minimum clear length of 96 inches, measured from the curb or vehicle roadway edge;
- A lower minimum clear width of 60 inches, measured parallel to the vehicle roadway;
- A bus stop area, landing pad or platform must meet ADA design standards.

Other transit facilities that should be considered for buses are bus passenger shelters, park-and-ride lots, and turnouts (separate loading lane). The decision to include bus turnouts should be based on the volume and turning movements of both the bus traffic and through traffic, the distance between bus stops, and right-of-way

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[105] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[106] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[107] *(35) Toolkit for the Assessment of Bus Stop Accessibility and Safety.* Easter Seals Project ACTION, 2006.
http://www.transitaccessproject.org/InternalDocs/TransitFacilities/06BSTK_Complete_Toolkit.pdf,
http://www.nelsonnygaard.com/Documents/Articles/Complete_Toolkit-new.pdf

Note: This is listed as a reference by FHWA at http://safety.fhwa.dot.gov/ped_bike/ped_transit/ped_transguide/ch1.cfm, "Pedestrian Safety Guide for Transit Agencies

limitations. The design features for turnouts should be based on the size and turning radius of the bus. Generally, turning radii should be such that buses can remain in the outer lane during the full turn. For a more complete discussion of bus considerations, see pages 367-373, GDHS[108].

FDM 11-25-40 Railroad Crossings

August 15, 2019

40.1 General

If there is a railroad crossing on a project, include the region railroad coordinator early in project scoping and thereafter during project design.

FDM 17-60-5 establishes railroad grade crossing design criteria. FDM 17-40-5 explains factors to consider when evaluating the potential need for a grade separation structure. All signing, marking, signals, and gate installations shall conform to the Manual on Uniform Traffic Control Devices, FHWA, 2000 and the Wisconsin Supplement. Additional information can be found on pages 731-739, GDHS[109]

Sight distance triangles should be provided for vehicles approaching a crossing, but a separate sight distance triangle must be provided for vehicles such as buses and trucks, which are required to stop. Stopped vehicles need additional sight distance to proceed safely across a railroad crossing. An additional lane should be considered for stopped vehicles, particularly on multi-lane highways.

On modernization and rehabilitation projects being designed with Civil 3D software and using a 3D model check the 5-axle expandable-deck lowboy (DST Lowboy) OSOW-ST vehicle at railroad crossings on the OSOW Truck Route (OSOW-TR) to ensure sufficient vehicle body clearance so that vehicles can cross the tracks without "hanging up". See FDM 11-25-1.4 for information on the OSOW-TR. See FDM 11-25-2.1.1 and Attachment 2.1 for information on OSOW vehicles.

Consult with the Region Railroad Coordinator along with the State Grade Crossing Safety Engineer and Bureau of Highway Maintenance early in the design process to address overhead railroad signal clearance along the OSOW High Clearance Routes. The Department's goal is to provide a lower minimum vertical clearance of 20'-0" at railroad crossings along these routes.

40.2 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

FDM 11-25-45 Frontage Roads

August 15, 2019

A service road (also commonly referred to as a frontage or backage road) is a public or private street or road that runs generally parallel to but is separated from the major roadway by a physical barrier. Its primary function is to provide access to the abutting properties. Service roads are also referred to commonly as frontage or backage roads.

A frontage road is a service road between the right-of-way of the major roadway and the front building setback line. It provides access to properties while separating them from the principal roadway. Frontage roads will "front" on the major roadway.

A backage road is a service road that is separated from the major roadway by intervening land uses. The arterial abuts the rear lot line and buildings may face the backage road. Buildings on backage roads face away from the major roadway.

Freeway/expressway interchange areas that have frontage road access to the crossroad outside the ramps are addressed in FDM 11-5-5.

Service roads provide the following benefits:

- Effectively control access to the through lanes on the arterial street,
- Provide access to adjoining property,
- Separate local traffic from through traffic, and
- Permit circulation of local traffic adjacent to the arterial.

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[108] (1) A Policy *on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

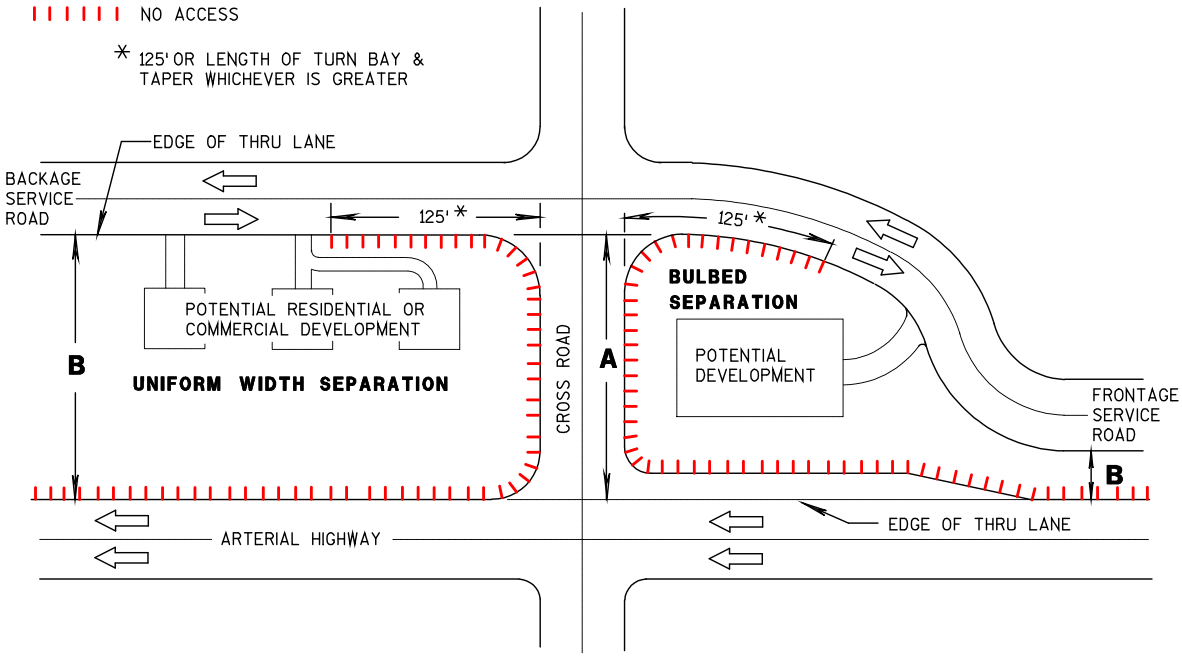
[109] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

From an operational and safety standpoint, one-way service roads on each side of an arterial may be preferred to two-way service roads.

Maximize the separation distance between the service road/crossroad intersection and the arterial/crossroad intersection to ensure sufficient storage for traffic on the crossroad between the service road and the arterial. At some time the arterial/crossroad intersection may be signalized or include a roundabout. Provide adequate storage for queued vehicles.

The lower minimum separation distance (Dimension A in Figure 45.1) is 150 feet in a tightly constrained urban environment with low crossroad traffic volumes. This is the shortest length for placing signs and other traffic control devices. Greater distances are needed to provide adequate vehicle storage and to separate operation of the two intersections. Spacing of at least 300-feet, preferably more, in urban areas enables turning movements to be made from the arterial lanes onto the service road without seriously disrupting arterial traffic. High crossroad traffic volumes with high service road volumes will typically justify a greater separation distance. This may be achieved by taking the service road around an existing or proposed development as shown in the “bulbed separation” area, in effect developing a backage road for that portion of the otherwise frontage road. A greater separation than those shown in Figure 45.1 may be needed if signalization is required. The recommended separation distance between signals is about 1,300 feet, unless the signals are coordinated like the close spacing between interchange ramps. The separation between properly designed roundabouts may be 300 feet or less in tight situations.

Away from the arterial intersection consider the distance separating the service road travel lanes from the arterial travel lanes, distance “B” on the bulbed separation” side of Figure 45.1. Headlight glare, driver confusion about the location of an approaching vehicle and errant vehicles are safety concerns that suggest keeping that distance as wide as practical. In tight built-up urban areas, this distance may be as low as 45 feet. In situations that present a safety concern, glare fence or other protective shielding may be required between the service road and the arterial.



Lower Min. Distance **A**[110] (stop control)		
Crossroad Design year AADT	Distance (ft)	
	Urban	Rural
< 100	150	300
100 – 1,000	300	300
> 1,000	600	600

	Distance B	
	Urban	Rural
Typical	85 ft	115 ft
Lower Minimum	45 ft	85 ft
Greater distances may be warranted where noise barriers, berms or landscaping are located along the arterial. Distance 'B' for a backage road does not necessarily equal Distance 'A' along the crossroad.		

***Figure 45.1* Frontage Road Offset Guidelines**

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March 4, 2013

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NCHRP Report 650 Table 19 p. 47

NCHRP Report 650 Figure 117 p. 148

NCHRP Report 650 Figure 31 p. 49

NCHRP Report 650 Figure 65 p. 86

NCHRP Report 650 Figure 48 p. 65

NCHRP Report 457 Figure 2.6 p. 23

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Selection Criteria for Rural High-Speed Intersections (Posted Speed >= 50 mph)

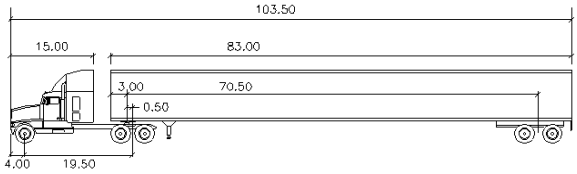
INTERSECTION TYPE [A]	TYPE OF THROUGH HIGHWAY	
	FOUR LANE DIVIDED	TWO LANE
A1 450-ft full-width turn lane, exclusive of storage [C]	**For posted speed of 65 or 60 mph**: Use if: The intersection design vehicle is a WB-62 or larger, or Current traffic volume on the side road exceeds 1,000 AADT regardless of the design traffic volume on the through highway, or Current traffic volume on the side road is between 400 and 1,000 AADT and the design traffic volume on the through highway exceeds 4,000 AADT.	Do not use on two-lane highways.
A2 350 ft full-width turn lane exclusive of storage [C]	**For posted speed of 55 mph or 50 mph:** Use if: The intersection design vehicle is a WB-62 or larger, or Current traffic volume on the side road exceeds 1,000 AADT regardless of the design traffic volume on the through highway, or Current traffic volume on the side road is between 400 and 1,000 AADT and the design traffic volume on the through highway exceeds 4,000 AADT.	Use if: The intersection design vehicle is a WB-62 or larger, or Current traffic volumes exceed 2500 AADT on the through highway and 1000 AADT on the side road.
B1 300 ft full-width turn lane exclusive of storage [C]	**For posted speed of 65 or 60 mph:** Use at all intersections not meeting the criteria for Intersection Type A1 **For posted speed of 55 mph or 50 mph:** Use at all intersections not meeting the criteria for Intersection Types A2 or B2	Use if current traffic volumes on both the through highway and the side road exceed 500 AADT and the sum of both exceeds 2500 AADT.
B2 200 ft full-width turn lane exclusive of storage [C]	**For posted speed of 55 mph or 50 mph:** Use if the design traffic volume on the through highway is less than 7000 AADT and the current traffic volume on the side road is less than 100 AADT.	Use if the current traffic volumes on both the through highway and the side road exceed 100 AADT and the sum of both exceeds 1250 AADT. [B]
C or D	Do not use on divided highways.	Use at all intersections not meeting the criteria for intersection Types A, B1 or B2.

A See SDD 9A1 for intersection details.

B If the acquisition of new right of way or substantial earthwork would be required for Resurfacing and Pavement Replacement projects, the merits of improved traffic flow should be weighed against increased construction costs, lengthened project development time to acquire R/W, disruptions to adjacent property, etc. If a Type B2 intersection cannot be justified at a specific location, the designer should evaluate using a Type C or D intersection.

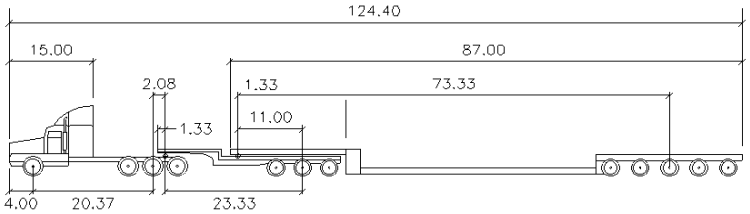
C These full-width turn lane lengths apply to both left turn lanes and right turn lanes for traffic entering the same side road leg of the intersection. Additional lengths are necessary to store turning vehicles - see FDM 11-25-1, and FDM 11-25-5. Also, see FDM 11-25-5 attachments.

NOTE: Data depicted on this sheet was current as of time of production. Vehicle dimensions, capabilities, and overall design may vary by transit carrier and manufacturer. Different characteristics may result in more or less maneuverable vehicles than those depicted here. THE USER IS RESPONSIBLE for confirming a vehicle's specific capabilities and dimensions for their specific project.



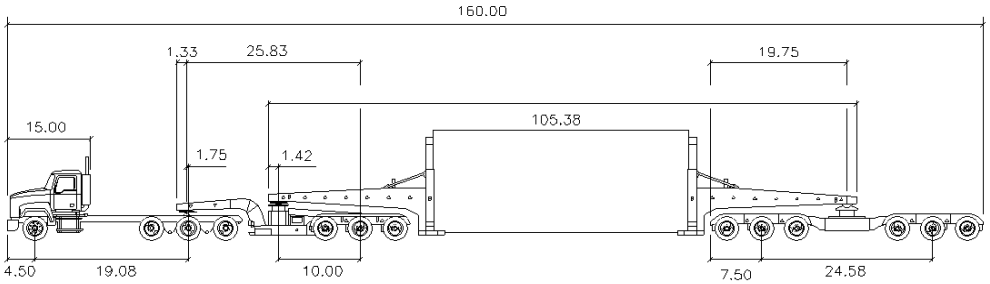
Overall Length	103.50 ft
Overall Width	8.50 ft
Max Track Width	8.50 ft
Lock to Lock Time	6.00 sec

OSOW - MT
WB-92



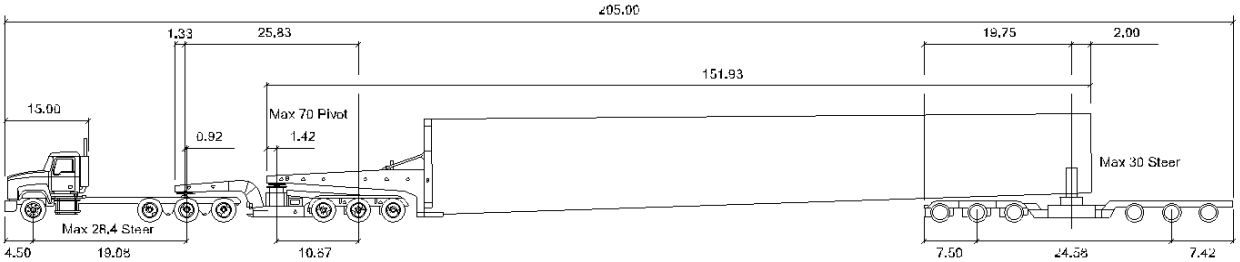
Overall Length	124.40 ft
Overall Width	12.50 ft
Max Track Width	10.00 ft
Min Body Ground Clearance	5.0 Inches

OSOW - ST
DST LOWBOY



Overall Length	160.00 ft
Overall Width	16.00 ft
Max Track Width	10.00 ft
Lock to Lock Time	6.00 sec

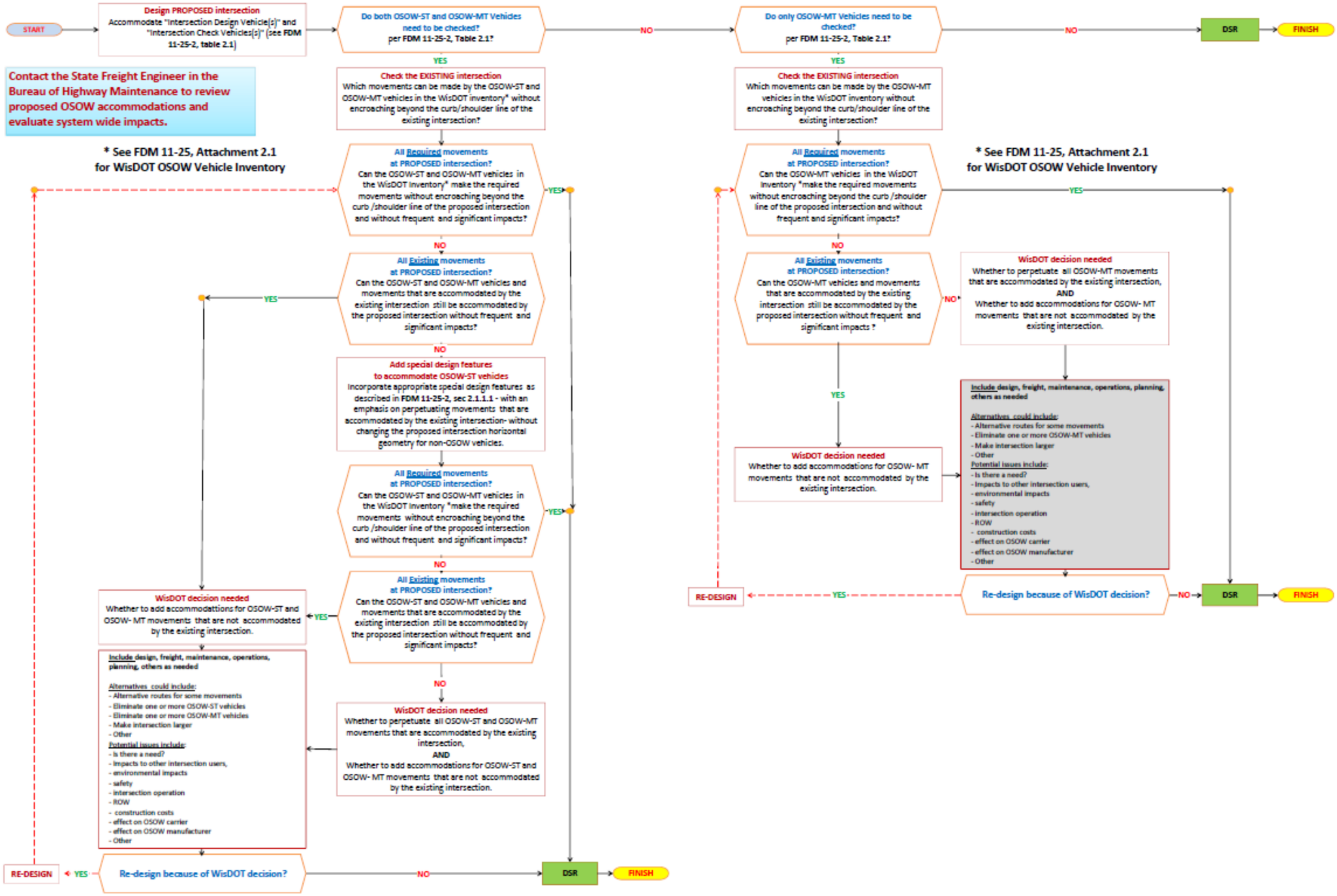
OSOW - ST
160' x 16' *



Load: Wind Tower 205'	
Overall Length	205.00 ft
Overall Width	13.00 ft
Max Track Width	10.00 ft
Lock to Lock Time	6.00 sec

OSOW - WT
Wind Tower 205' *

* REAR-STEER CAPABLE


START
Design PROPOSED intersection
Accommodate "Intersection Design Vehicle(s)" and "Intersection Check Vehicles(s)" (see FDM 11-25-2, table 2.1)
Do both OSOW-ST and OSOW-MT Vehicles need to be checked? per FDM 11-25-2, Table 2.1?
NO
Do only OSOW-MT Vehicles need to be checked? per FDM 11-25-2, Table 2.1?
NO
DSR
FINISH
YES
Contact the State Freight Engineer in the Bureau of Highway Maintenance to review proposed OSOW accommodations and evaluate system wide impacts.
Check the EXISTING intersection
Which movements can be made by the OSOW-ST and OSOW-MT vehicles in the WisDOT inventory* without encroaching beyond the curb/shoulder line of the existing intersection?
* See FDM 11-25, Attachment 2.1 for WisDOT OSOW Vehicle Inventory
All Required movements at PROPOSED intersection?
Can the OSOW-ST and OSOW-MT vehicles in the WisDOT inventory* make the required movements without encroaching beyond the curb /shoulder line of the proposed intersection and without frequent and significant impacts?
YES
NO
All Existing movements at PROPOSED intersection?
Can the OSOW-ST and OSOW-MT vehicles and movements that are accommodated by the existing intersection still be accommodated by the proposed intersection without frequent and significant impacts?
YES
NO
Add special design features to accommodate OSOW-ST vehicles
Incorporate appropriate special design features as described in FDM 11-25-2, sec 2.1.1.1 - with an emphasis on perpetuating movements that are accommodated by the existing intersection- without changing the proposed intersection horizontal geometry for non-OSOW vehicles.
All Required movements at PROPOSED intersection?
Can the OSOW-ST and OSOW-MT vehicles in the WisDOT inventory *make the required movements without encroaching beyond the curb /shoulder line of the proposed intersection and without frequent and significant impacts?
YES
NO
All Existing movements at PROPOSED intersection?
Can the OSOW-ST and OSOW-MT vehicles and movements that are accommodated by the existing intersection still be accommodated by the proposed intersection without frequent and significant impacts?
YES
NO
WisDOT decision needed
Whether to add accommodattions for OSOW-ST and OSOW- MT movements that are not accommodated by the existing intersection.
WisDOT decision needed
Whether to perpetuate all OSOW-ST and OSOW-MT movements that are accommodated by the existing intersection,
AND
Whether to add accommodations for OSOW-ST and OSOW- MT movements that are not accommodated by the existing intersection.
Include design, freight, maintenance, operations, planning, others as needed
Alternatives could include:
- Alternative routes for some movements
- Eliminate one or more OSOW-ST vehicles
- Eliminate one or more OSOW-MT vehicles
- Make intersection larger
- Other
Potential issues include:
- Is there a need?
- Impacts to other intersection users,
- environmental impacts
- safety
- intersection operation
- ROW
- construction costs
- effect on OSOW carrier
- effect on OSOW manufacturer
- Other
RE-DESIGN
YES
Re-design because of WisDOT decision?
NO
DSR
FINISH
Check the EXISTING intersection
Which movements can be made by the OSOW-MT vehicles in the WisDOT inventory without encroaching beyond the curb/shoulder line of the existing intersection?
* See FDM 11-25, Attachment 2.1 for WisDOT OSOW Vehicle Inventory
All Required movements at PROPOSED intersection?
Can the OSOW-MT vehicles in the WisDOT Inventory *make the required movements without encroaching beyond the curb /shoulder line of the proposed intersection and without frequent and significant impacts?
YES
NO
All Existing movements at PROPOSED intersection?
Can the OSOW-MT vehicles and movements that are accommodated by the existing intersection still be accommodated by the proposed intersection without frequent and significant impacts ?
NO
YES
WisDOT decision needed
Whether to perpetuate all OSOW-MT movements that are accommodated by the existing intersection,
AND
Whether to add accommodations for OSOW- MT movements that are not accommodated by the existing intersection.
WisDOT decision needed
Whether to add accommodations for OSOW- MT movements that are not accommodated by the existing intersection.
Include design, freight, maintenance, operations, planning, others as needed
Alternatives could include:
- Alternative routes for some movements
- Eliminate one or more OSOW-MT vehicles
- Make intersection larger
- Other
Potential issues include:
- Is there a need?
- Impacts to other intersection users,
- environmental impacts
- safety
- intersection operation
- ROW
- construction costs
- effect on OSOW carrier
- effect on OSOW manufacturer
- Other
RE-DESIGN
YES
Re-design because of WisDOT decision?
NO
DSR
FINISH

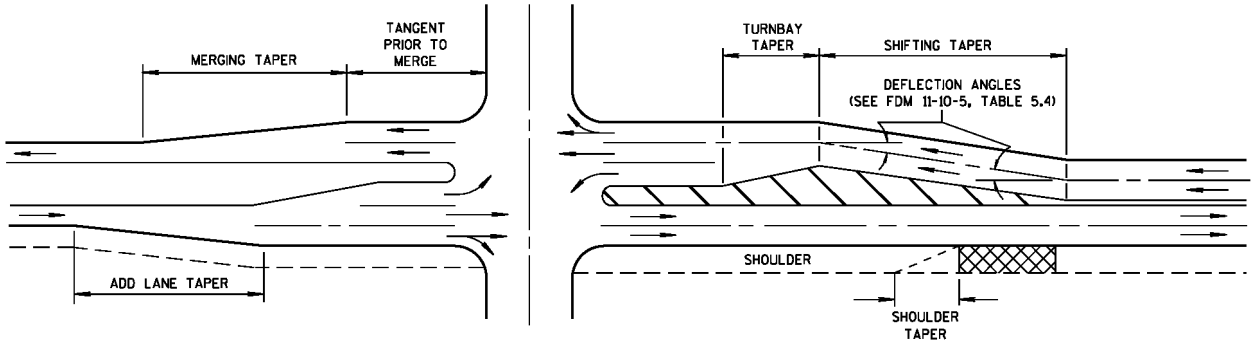


Table A2.1 Taper Descriptions and Formulas

Type of Taper	Definition of "W" (feet)	S* (mph)	L=Taper Length (feet)	
			Desirable	**Minimum**
Merging Taper **	The difference in travel way width from the beginning to the end of the taper	<=40	$L = W \times (S + 5)$	$L = W \times S$
		>=45	$L = W \times (S + 5)$	$L = W \times S$
Add Lane Taper **	The difference in travel way width from the beginning to the end of the taper	<=40	$L = (W \times (S + 5)^2)/60$	$L = (W \times S^2)/60$
		>=45	$L = W \times (S + 5)$	$L = W \times S$
Shifting Taper	The distance (left or right) a vehicle path is shifted from the beginning to the end of the taper	<=40	L = greater of 100-feet or $(W \times (S + 5)^2)/60$	L = greater of 100-feet or $(W \times S^2)/60$
		>=45	L = greater of 200-feet or $W \times (S + 5)$	L = greater of 200-feet or $W \times S$
Shoulder Taper	The difference in Shoulder width from the beginning to the end of the taper	<=40	$L = (W \times (S + 5)^2)/180$	$L = (W \times S^2)/180$
		>=45	$L = \big(W \times (S + 5)\big)/3$	$L = (W \times S)/3$
Turn Bay Taper	The distance (left or right) a vehicle path is shifted from the beginning to the end of the taper See Table A2.2 below for Turn Bay taper rates			

S* = Posted speed or off-peak 85th percentile speed

**Add Lane and Merging tapers for passing and climbing lanes are shown in SDD 15C8.

Table A2.2 Tangent Prior to Merge and Turn Bay Taper Rates

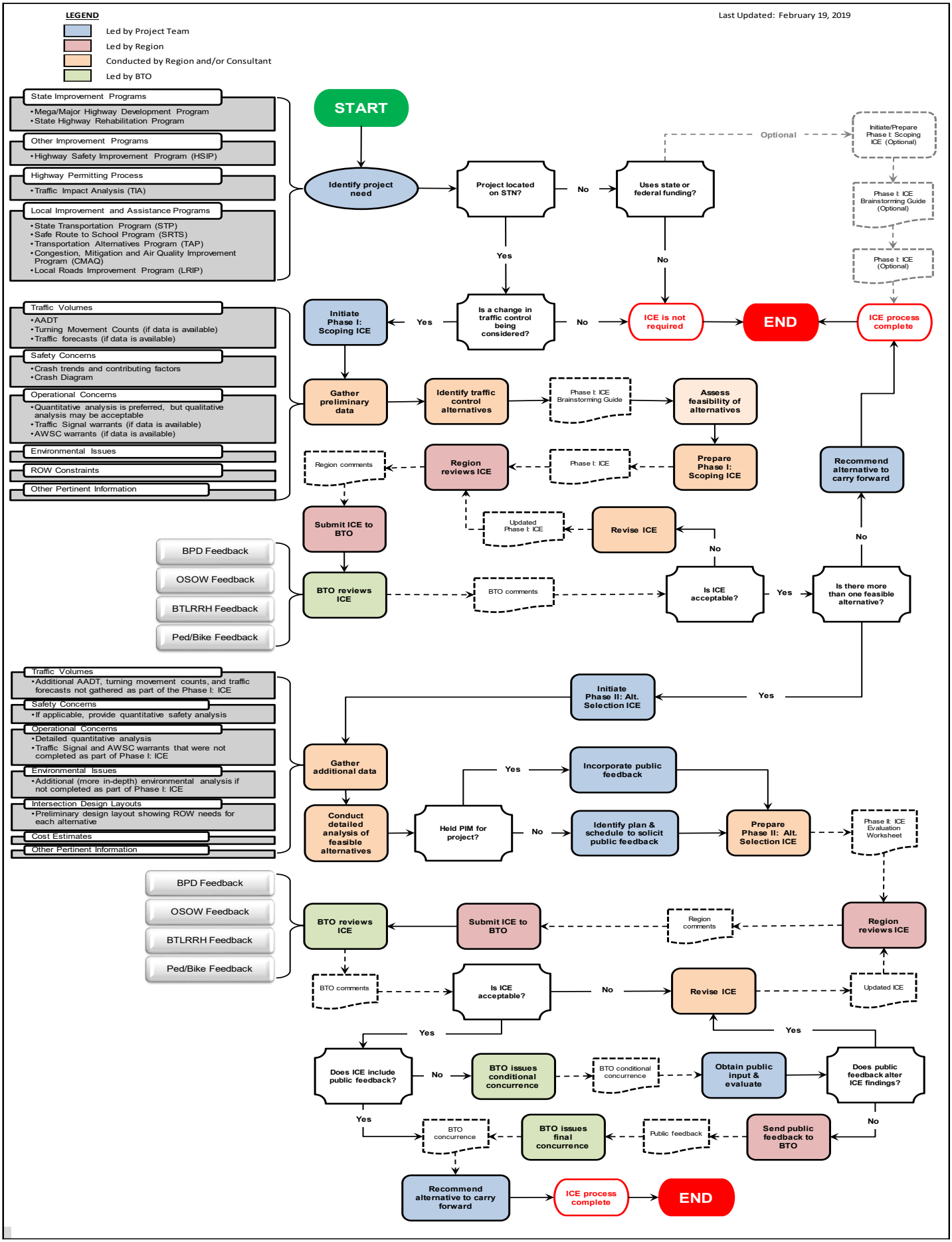
Posted Speed (mph)	**Tangent prior to merge**[1] **(feet) Desirable (**Minimum**)**	**Turn Bay taper rates** *** Normal **(**Minimum**)**	
		Rural	**Urban**
25	**525** (325)	**8:1**	8:1 (6:1)
30	**660** (460)	**8:1**	8:1 (6:1)
35	**765** (565)	**12.5:1**	**8:1** (6:1)
40	**870** (670)	**12.5:1**	**8:1** (6:1)
45	**975** (775)	**12.5:1**	**12.5:1**
50	**1085** (885)	**12.5:1**	**12.5:1**
55	**1190** (990)	**12.5:1**	**12.5:1**
65	**1400** (1200)	**12.5:1**	**12.5:1**

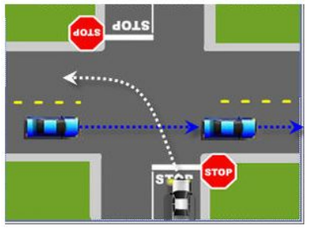
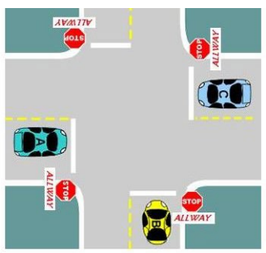
*** Use the same turn bay taper rate for single, dual and triple turn lanes.

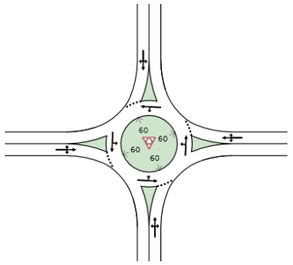
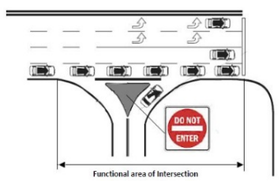
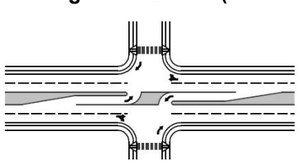
[1] Minimum values from (*1)* Placement of Warning Signs. In *Manual on Uniform Traffic Control Devices Chapter 2C: Warning Signs and Object Markers* Federal Highway Administration, 2009, Section 2C.05. http://mutcd.fhwa.dot.gov/pdfs/2009/part2c.pdf., Table 2C-4 on p.108. Values also shown in Wisconsin MUTCD Table 2C-4.

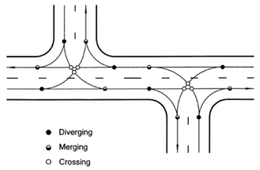
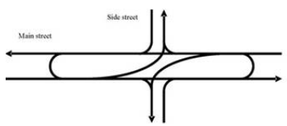
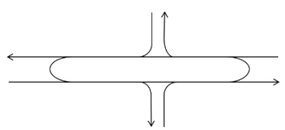
Relationship between the Facilities Development Process and the ICE Process

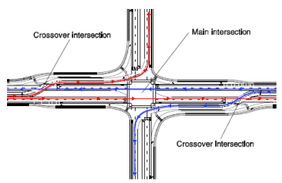
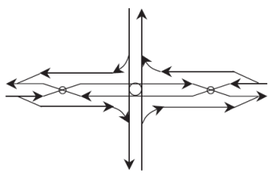
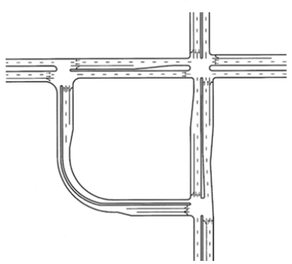
Phase Elements / Phase Names			Project Initiation	Project Definition		Project Delivery			Project Proposal Execution		
Life Cycle (Construction ID)			00	10		11	12	15	20		40
Milestone			Project Initiation Complete	Prelim. Scope Complete		Final Scope Certification Approved	Resourcing Complete / Start Final Delivery	Design Study Report Approved	PS&E Submitted	Project LET	Project Award
Deliverables (Deliverables listed may have been started in a previous phase but must be completed prior to advancing to the next phase)	Project Management Plan	Scope	• Conceptual Scope	• Prelim. Scope	• Final Scope	• Implement Scope					
		Schedule	• Conceptual Milestone Schedule • APLP Target Goals & Schedule • Program Let Schedule	• Final Milestone Schedule • Final Work Breakdown • Final APLP Schedule • Final Let Schedule Date • Non-let Schedule Dates		• Monitor and Manage Schedules					
		Budget	• Conceptual Const.Estimate	• Design Delivery Budget • Const. Estimate • Non-Let Estimate		• Refine Const. Estimate • Refine Non-Let Estimate					
	Phase Deliverables		• Design ID(s) loaded • Construction ID(s) loaded • Design ID(s) Authorized • Highway Improvement Type • Structures Identified • Signed SMFA (design connect.hwy.)	**Phase I: ICE** • Purpose and Need • Resource Assignments • Safety Certification • Improvement Strategy • Risk Assessment	**Phase II: ICE** • Signed Pavement Design Report • Draft Env. Document • Utility Impacts • R/W Impacts • Structure Certification • Railroad Proj. Submittal Package • Signed SMFA & SMMA (const.) • Risk Assessment	• Final Delivery Resourcing	• Prelim. Plan • Structure Survey Report • Prelim. Structure Plan • Signed Env. Document • Signed DSR • Recordable Plat • Risk Assessment	• PS&E package • Permits • Risk Assessment	• Plan Revisions • Bid Advertisement • Addenda (if required)	• Bid Review	• Design ID Closed • Design Files Archived
Phase Activities			see FDM Chapter 3 - attachment 1.2								
Change Management			Establishes original baseline for applying Change Management process.			Change Management process in effect.					

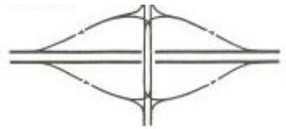
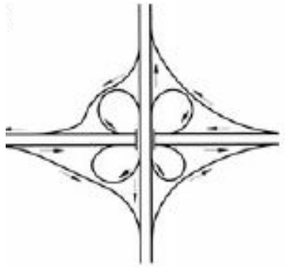

LEGEND
Led by Project Team
Led by Region
Conducted by Region and/or Consultant
Led by BTO
Last Updated: February 19, 2019
State Improvement Programs
•Mega/Major Highway Development Program
•State Highway Rehabilitation Program
Other Improvement Programs
•Highway Safety Improvement Program (HSIP)
Highway Permitting Process
•Traffic Impact Analysis (TIA)
Local Improvement and Assistance Programs
•State Transportation Program (STP)
•Safe Route to School Program (SRTS)
•Transportation Alternatives Program (TAP)
•Congestion, Mitigation and Air Quality Improvement Program (CMAQ)
•Local Roads Improvement Program (LRIP)
START
Identify project need
Project located on STN?
No
Uses state or federal funding?
Optional
Initiate/Prepare Phase I: Scoping ICE (Optional)
Phase I: ICE Brainstorming Guide (Optional)
Phase I: ICE (Optional)
Yes
No
Is a change in traffic control being considered?
Yes
No
ICE is not required
END
ICE process complete
Traffic Volumes
•AADT
•Turning Movement Counts (if data is available)
•Traffic forecasts (if data is available)
Safety Concerns
•Crash trends and contributing factors
•Crash Diagram
Operational Concerns
•Quantitative analysis is preferred, but qualitative analysis may be acceptable
•Traffic Signal warrants (if data is available)
•AWSC warrants (if data is available)
Environmental Issues
ROW Constraints
Other Pertinent Information
Initiate Phase I: Scoping ICE
Gather preliminary data
Identify traffic control alternatives
Phase I: ICE Brainstorming Guide
Assess feasibility of alternatives
Prepare Phase I: Scoping ICE
Phase I: ICE
Region reviews ICE
Region comments
Recommend alternative to carry forward
Submit ICE to BTO
Updated Phase I: ICE
Revise ICE
No
No
BPD Feedback
OSOW Feedback
BTLRRH Feedback
Ped/Bike Feedback
BTO reviews ICE
BTO comments
Is ICE acceptable?
Yes
Is there more than one feasible alternative?
Yes
Initiate Phase II: Alt. Selection ICE
Traffic Volumes
•Additional AADT, turning movement counts, and traffic forecasts not gathered as part of the Phase I: ICE
Safety Concerns
•If applicable, provide quantitative safety analysis
Operational Concerns
•Detailed quantitative analysis
•Traffic Signal and AWSC warrants that were not completed as part of Phase I: ICE
Environmental Issues
•Additional (more in-depth) environmental analysis if not completed as part of Phase I: ICE
Intersection Design Layouts
•Preliminary design layout showing ROW needs for each alternative
Cost Estimates
Other Pertinent Information
Gather additional data
Yes
Incorporate public feedback
Conduct detailed analysis of feasible alternatives
Held PIM for project?
No
Identify plan & schedule to solicit public feedback
Prepare Phase II: Alt. Selection ICE
Phase II: ICE Evaluation Worksheet
BPD Feedback
OSOW Feedback
BTLRRH Feedback
Ped/Bike Feedback
BTO reviews ICE
Submit ICE to BTO
Region comments
Region reviews ICE
BTO comments
Is ICE acceptable?
No
Revise ICE
Updated ICE
Yes
Yes
Does ICE include public feedback?
No
BTO issues conditional concurrence
BTO conditional concurrence
Obtain public input & evaluate
Does public feedback alter ICE findings?
Yes
BTO concurrence
BTO issues final concurrence
Public feedback
Send public feedback to BTO
No
Recommend alternative to carry forward
ICE process complete
END

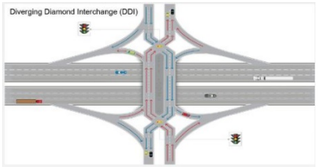
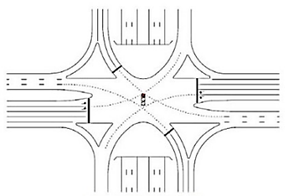
Control Type	When to Consider	Potential Benefits	Potential Concerns	Other Considerations	Additional Information
Intersection Control Types					
Minor Road Stop Control  Vehicles on the minor road stop and wait for a sufficient gap before making their desired movements, while mainline traffic does not stop.	• Major and minor road functional classification are clearly defined • Low minor road volume, especially for through and left movements • Major road mobility is the primary concern • Signal warrants not met • AWSC warrants not met	• Major road delay is nonexistent or minimal • Inexpensive to install and maintain • Clearly defines which vehicles have the priority	• Higher major road volumes reduce minor road gap availability and can result in high delays • Significant sight distance can be required when the major road operates at higher speeds • Potential for high-severity angle crashes, especially with higher major road speeds or volumes	• Least restrictive form of intersection control • Often appropriate for low-volume county or local roads that intersect with STN routes • Wide, open medians can be used for two-stage crossings	• FDM 11-25.3.1.2.1
All-Way Stop Control  All vehicles stop before making their desired movements. Priority is assigned based on arrival time.	• Balanced traffic volumes • ROW or sight distance constraints • AWSC warrants met • Signal warrants not met • Maintaining major street through movements as free flow is not the primary concern • Relatively low approach speeds	• Can be very safe • Requires minimal ROW and sight distance • Inexpensive to install and maintain	• Operationally inefficient under most conditions • Higher vehicle emissions due to required stopping	• AWSC is not preferred as a permanent solution on the STN, especially if there are other viable alternatives • AWSC may be appropriate as an interim solution • Wisconsin-specific AWSC warrants apply in addition to MUTCD AWSC warrants	• FDM 11-25.3.1.2.1 • TEOpS 13-26-5 • MUTCD 2B.07
Traffic Signal (Signal) Priority is assigned by traffic signal indications.	• Available gaps are not adequate to complete desired movements under less restrictive control • Signal warrants met • Nearby intersections are signalized, and coordination is possible	• Can be coordinated with other signals to provide desired progression • Flexibility can be achieved via timing adjustments • Adaptive control can be implemented along a signalized corridor • Pedestrians are assigned crossing times rather than having to find gaps	• Major road delay is often greater than it is under less restrictive control • Severe crashes can occur due to red light running or poor visibility of the signal heads • Dedicated turn lane requirements can result in wider approaches, meaning longer pedestrian crossings and additional ROW requirements • Can experience extensive queuing, especially with longer cycle lengths	• Preferred control when railroad or lift-bridge pre-emption is required • Can also accommodate emergency vehicle or transit pre-emption	• FDM 11-25.3.1.2.2 • TSDM Chapter 2 • Signal Warrants

Control Type	When to Consider	Potential Benefits	Potential Concerns	Other Considerations	Additional Information
Roundabout (RAB)  Vehicle speeds are reduced via geometry approaching the intersection. Entering vehicles yield to circulating vehicles.	• Relatively balanced traffic volumes • Signal or AWSC warrants met • Significant crash history, especially angle crashes • Unconventional geometry (5 or more legs, high skew, etc.) present	• Significantly reduces risk of serious crashes via geometry • Lower vehicle emissions due to limited stopping and idling • Can reduce number of approach lanes, and therefore approach width and ROW requirements along the roadways • Can have traffic calming effects • Can accommodate closely spaced intersections better than other traffic control options • Allows for convenient U-turn movement • Pedestrian crossings are shorter	• Coordination not possible • May require additional ROW at the intersection to accommodate the center island and circulating roadway • No flexibility in assigning priority • All vehicles are required to slow down from free-flow speeds • Can see operations deteriorate rapidly under congested conditions, potentially resulting in the circulating roadway becoming gridlocked • Pedestrian crossings are uncontrolled	• Accommodation of larger vehicles, including OSOW, can be challenging but may be addressed with unique design considerations • Consider need for expandable design (e.g., one lane to two lanes) • Single-lane roundabouts are preferred to multi-lane roundabouts	• FDM 11-25.1.1.2 • FDM 11-25-3.1.2.3 • FDM 11-26 • FHWA RAB Guide
Right-In/Right-Out (RI/RO)  Left turns into the minor road and through and left movements out of the minor road are not permitted.	• History of angle crashes involving minor street through/left and major street left movements • Other intersections nearby to facilitate restricted movements • Intersection encroaches on the influence area of an adjacent intersection • Signal warrants not met • AWSC warrants not met	• Crossing conflicts are eliminated so overall safety is increased • Operations at the intersection are enhanced due to elimination of minor road through and left movements and major street left movement	• Access at the intersection is severely reduced – generally not favored by businesses • Adjacent intersections may be adversely affected as vehicles will be forced to execute turning maneuvers at locations other than the restricted access intersection • Travel time may increase for drivers wanting to make minor road left/ through movements and major road left turn movements at this location	• Access restrictions like RI/RO may be more feasible in combination with nearby intersections that allow for U-turns.	
Right-In/Right-Out/Left-In (3/4 access)  Through and left movements out of the minor road are not permitted.	• History of angle crashes involving minor street through/left movements • There is not a significant history of crashes involving the major street left turn movements • Signal warrants not met • AWSC warrants not met	• Crossing conflicts are significantly reduced so overall safety is increased • Operations at the intersection are enhanced due to elimination of minor road through and left movements • Provides more access than RI/RO • All movements from the mainline are maintained	• Access at the intersection is reduced for exiting vehicles from the minor road • Adjacent intersections may be adversely affected as vehicles will be forced to execute turning maneuvers at locations other than the restricted access intersection • Travel time may increase for drivers wanting to make minor road left turn and through movements at this location	• May be more palatable to businesses than RI/RO	

Control Type	When to Consider	Potential Benefits	Potential Concerns	Other Considerations	Additional Information
Offset T  Direct minor road through movements are not possible and become a left onto the main road and right onto the other minor road, or vice versa.	• Existing four-leg intersection with a history of angle crashes for minor road through vehicles • Low minor road volumes, especially for the minor road through movement • Intersection skew present	• Removes crossing conflicts for minor road through vehicles • Can correct intersection skew	• ROW is required to accommodate the offset between the two intersections • Rear-end crashes could increase due to low vehicle speeds as minor road through movements require a series of two consecutive turns	• The location of offset intersections relative to each other can make a difference. For minor road through vehicles, the offset can be done so that either the left turn or right turn is made on the mainline. Depending on the situation, one may be preferable to the other • Offset distance will vary by location • Can be used at both unsignalized and signalized intersections	• FHWA Offset T Information
J-Turn (RCUT)  Through and left movements out of the minor road are not permitted. U-turns are provided downstream in the median to facilitate these movements.	• History of angle crashes, especially far-side • Located on a high-speed, divided facility • Located in a relatively rural area with significant intersection spacing • Signal warrants not met • AWSC warrants not met	• Crossing conflicts are significantly reduced, so overall safety is increased • Vehicles only focus on finding a gap in one direction of traffic at a time • Operations at the intersection are enhanced due to elimination of minor road through and left movements • U-turns are handled within the intersection and will not affect adjacent intersections	• Minor street through and left movements are more indirect than at a traditional intersection; travel time and distance are increased • Direct access to the major road in between the intersection and the U-turns is typically removed	• Larger vehicles may have to be accommodated with a “loon” at the U-turn • This may not be feasible on some curves • Analysis methods are currently in development • Bicycle and pedestrian crossings can be maintained through the center of the J-Turn	• FDM 11-25.1.3.2 • FHWA RCUT Informational Guide
Median U-Turn/Modified J-Turn  Left turns into the minor road and through and left movements out of the minor road are not permitted. U-turns are provided downstream in the median to facilitate these movements.	• History of angle crashes, especially far-side • Located on a high-speed, divided facility • Located in a relatively rural area with significant intersection spacing • Major street left turn volumes are low • There is a history of crashes involving the major street left turn movements • Signal warrants not met • AWSC warrants not met	• Crossing conflicts are eliminated, so overall safety is increased • Vehicles only focus on finding a gap in one direction of traffic at a time • Operations at the intersection are enhanced due to elimination of minor road through and left movements and major street left movement • U-turns are provided within the intersection and will not affect adjacent intersections	• Minor street through and left movements and major street left movement are more indirect than at a traditional intersection; travel time and distance are increased • Direct access to the major road in between the intersection and the U-turns is typically removed	• Larger vehicles may have to be accommodated with a “loon” at the U-turn • This may not be feasible on some curves • Analysis methods are currently in development	• FDM 11-25.1.3.2 • FHWA RCUT Informational Guide
Continuous Green-T Priority is assigned by traffic signal indications, with one of the major street approaches always having a green light as minor street left turns merge from the left.	• Intersection has three legs, typically two major street approaches and one minor street approach • Signal warrants are met	• One of the major street movements will be free-flow, reducing potential delay • Safety can be improved	• The minor street left movement joins major street through traffic from the left with a merge maneuver, which is contrary to driver expectations	• Analysis of operations can be difficult given software limitations	• FHWA Continuous Green T Case Study

Control Type	When to Consider	Potential Benefits	Potential Concerns	Other Considerations	Additional Information
Displaced Left Turn (DLT)/ Continuous Flow Intersection  Major street left turns cross over to the other side of the roadway upstream of a signalized intersection. They can then complete their movement while the opposing through vehicles are also moving.	• High volume of traffic • Signal warrants are met • Urban or suburban setting • Intersection expected to reach capacity for a traditional signalized intersection • Heavy left turn volumes	• Since the left turn is relocated, the left turn phase is eliminated, and thus green time can be distributed to other movements • Throughput can be increased 10-30%, based on flow balance and whether the DLT is partial or full. Delay can be reduced by 30-80% • Fewer conflict points can result in a safer intersection	• More ROW is required to accommodate the crossovers • This intersection type can be unfamiliar to drivers • Design standards are not fully developed • Coordination with other signals could be impacted • Access must be restricted within the vicinity of the intersection • Additional signals are needed	• It is possible to have a corridor of DLT intersections	• FDM 11-25.3.1.2.4 • FHWA DLT Informational Guide
Double Crossover Intersection (DXI)  Major street vehicles going through or left to cross over to the other side of the road at a signalized intersection upstream of the main intersection. Left turns are then unopposed. Remaining vehicles cross back over at a downstream signal.	• High volume of traffic • Signal warrants are met • The setting is urban or suburban • The intersection is expected to reach capacity for a traditional signalized intersection • There are heavy left turn volumes • The intersection is not part of a coordinated corridor	• Reduced-signal phasing (2 phases total) • Left turns are free-flow – conflict removed • Potential for right angle crashes reduced • Capacity can be increased over a traditional signal	• Can be disorienting to drivers who may not know where to look for conflicting traffic, and may realize they are on the “wrong” side of the road • Increased potential for wrong-way driving • Unusual pedestrian crossing patterns • Difficult to coordinate with adjacent intersections • At least one additional signal is added to the intersection	• Newer type of intersection – drivers and public may be unfamiliar or cautious • Vehicles are unable to exit and reenter mainline (Emergency, OSOW, unfamiliar drivers, etc.)	• Double Crossover Interchange TRB Article
Quadrant Roadway Intersection/Jughandle  For one approach, left turns are completed upstream of the main intersection via a right turn onto a secondary roadway followed by a left turn onto the desired roadway.	• The intersection has a high volume of through movements and left turns	• By removing turning movements, the main intersection of the two major roadways can function more efficiently • Reduced-signal phasing (2 phases total) at the main intersection • May provide safer pedestrian crossing opportunities vs. high speed interchange ramps	• A large amount of ROW is required, especially if used in more than one quadrant • Additional intersections are created and turning movements become more complex • The intersection area can be difficult to sign and confusing or unexpected for unfamiliar drivers	• The crossing roadways can be grade-separated, the loop maintains access even with the overpass • The jughandle version of this intersection implies a tighter loop that may be unidirectional and be free-flow rather than creating an additional intersection	• FHWA Quadrant Roadway Intersection Technical Summary

Control Type	When to Consider	Potential Benefits	Potential Concerns	Other Considerations	Additional Information
Interchange Control Types					
Diamond  Vehicles enter and exit the highway via ramps that start or end at the intersecting roadway. These intersections can be controlled by stop signs, roundabouts, or traffic signals.	• Traffic volumes, especially on the ramps, are not high enough to need another interchange type • The major street (freeway) has a much higher functional class than the minor street	• Less ROW is required for this interchange type than for others • There are no weaving or crossing movements between the ramp and freeway traffic • The appropriate intersection control can be chosen for the ramp terminals, allowing flexibility	• The minor street cannot be another freeway, so diamonds are only appropriate for service interchanges	• Can be built to allow vehicles to exit and re-enter freeway directly, which can be useful for low bridges or traffic events that close the bridge segment	• FDM 11-30.1.3.1
Cloverleaf  Vehicles enter and exit the highway via free-flow ramps.	• High volumes experienced for multiple movements • Significant ROW is available in the immediate vicinity of the interchange	• Ramp movements are free-flow • Reduces left turn conflicts	• A large amount of ROW is required • One-sided weaving between traffic getting on and traffic getting off occurs and is often a limiting factor • Speeds can be low on tight ramp curves • Trucks can have difficulty negotiating tight ramp curves	• Cloverleaf interchanges are not typically being installed given other available interchange options	• FDM 11-30.1.3.3
Partial Cloverleaf (Par-clo)/Loop Ramps Some vehicles enter and exit the highway via free-flow ramps while others use ramps with intersections.	• Constrained ROW in one or more (but not all) quadrants • Several high-volume movements	• Movements can be turned into free flow	• Speeds can be low on tight ramp curves • Trucks can have difficulty negotiating tight ramp curves		• FDM 11-30.1.3.3

Control Type	When to Consider	Potential Benefits	Potential Concerns	Other Considerations	Additional Information
Diverging Diamond Interchange (DDI)  Vehicles enter and exit the highway via ramps that begin or end at the intersecting roadway. These intersections are controlled by traffic signals. Intersecting roadway traffic crosses over to the opposite side of the roadway, allowing unopposed left turn movements to the highway. Remaining traffic then crosses back over.	• Volumes for left turns to or from the minor street are dominant • Volume for through movements on the arterial are relatively low	• Reduced-signal phasing (2 phases total) • Left turns are free-flow – conflict removed • Potential for right angle crashes reduced • Capacity can be increased over a traditional signal	• Can be disorienting to drivers, who may not know where to look for conflicting traffic and may realize they are on the "wrong" side of the road • Increased potential for wrong-way driving • Unusual pedestrian crossing patterns • Difficult to coordinate with adjacent intersections	• Newer type of interchange – drivers and public may be unfamiliar or cautious	• FDM 11-25.1.1.2 • FDM 11-25.3.1.2.4 • FHWA DDI Informational Guide
Single Point Interchange (SPI)  Vehicles enter and exit the highway via ramps that begin or end at a single intersection with the other roadway.	• ROW availability is limited • Left turns are a dominant movement	• Opposing left turns can move simultaneously • One signal controls the interchange so no coordination is required • ROW requirements are reduced	• Structure costs can be significant due to intersection size • Signal phasing can require longer yellow and all-red periods due to intersection size • The design is not conducive to bicycle or pedestrian traffic	• Effects on interchange safety seem to vary	• FDM 11-25.1.1.2 • FHWA Alternative Interchange Report
Echelon One approach of the intersecting roadway is elevated via a structure. Two separate intersections are created. Turning movements that require moving from one intersection to another can be accomplished via ramps.	• A large intersection is operating at or near capacity • The intersection is part of a high-volume, signalized urban street system	• Capacity is higher than at-grade intersections • ROW impacts can be limited since grade separation is introduced	• Structures are involved, which dramatically increases the cost of the intersection • Access is reduced		• FHWA Alternative Interchange Report

Phase I: ICE Memorandum Worksheet

Form available on Traffic Operation Manual website under Intersection Control Evaluations (ICE) at

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/manuals.aspx

PHASE I: ICE MEMORANDUM

BUREAU OF TRAFFIC OPERATIONS

To: DOT ICE Review
From: ICE Submitter
Date: Click here to enter a date.
RE: Project ID #
Choose an item.
Intersection Street Names
City/Town/Village, County
Region

Project Description:

Include the project need, objectives, and existing conditions.

Description of Alternatives:

Provide a description of the alternatives under consideration. Reference the Phase I: ICE Brainstorming Guide as appropriate.

Safety Considerations:

Observed Crash History Years:

Crash Type	Fatal	Injury A	Injury B	Injury C	KABC	PDO	Total
Total							

(add more rows as needed)

Crash Trends: Describe the crash trends at the intersection.

Contributing Factors: Describe the contributing factors of the crashes.

Operational Considerations:

Summarize operational concerns, evaluate warrants and conduct capacity analysis as applicable.

Other Considerations:

Include any other factors or information that affected the decisions resulting from the scoping analysis.

Feasibility of Alternatives:

Discuss the feasibility of each of the alternatives under consideration. Reference the Phase I: ICE Brainstorming Guide as appropriate.

Conclusion:

Identify if there is a need to complete a Phase II: ICE and, if applicable, summarize which alternatives are moving forward.

Attachments:

Provide attachments outlined in FDM 11-25-3 Attachment 3.7 as appropriate

Phase I: ICE Brainstorming Guide Worksheet

Form available on Traffic Operation Manual website under Intersection Control Evaluations (ICE) at:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/manuals.aspx

Phase I: ICE Brainstorming Guide

Date:
Project ID:
Control:
Major Road AADT:
Minor Road AADT:

Intersection:
Reason for ICE:

List of Alternatives:

v02

Alt. #	Control Type	Is Alt. Viable?	Meets Purpose & Need?	Performance Measures Acceptable?	ROW Impacts Acceptable?	Meets Warrants? (If Applicable)	Manual Override (Optional)	Explanation/Comments
1	Minor Road Stop Control	-						
2	All-Way Stop Control	-						
3	Traffic Signal	-						
4	Roundabout	-						
5	Right-In/Right-Out	-						
6	Right-In/Right-Out/Left-In	-						
7	Offset T	-						
8	J-turn	-						
9	Median U-Turn	-						
10	Continuous Green-T	-						
11	Quadrant/Jughandle	-						
12	Diamond	-						
13	Cloverleaf/ Partial Cloverleaf	-						
14	Diverging Diamond	-						
15	Single Point	-						
16	Echelon	-						
17	[Add more as needed]	-						

Phase II: ICE Worksheets

Form available on Traffic Operation Manual website under Intersection Control Evaluations (ICE) at:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/manuals.aspx

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Project and Analyst Information:

Project ID:	
Project Type:	Choose an item.
Location:	Intersection Street Names
	City/Town/Village
	County
	Region
Analyst:	
Agency:	
Date:	

Background Information:

Project Need:	Ex: Operations, Safety, etc.
Project Objective(s):	Describe the main objectives of this project.
Additional Information:	Describe the scope of the project, the existing conditions, any constraints, and any previous work done in the area.

Existing Crash Information:

Observed Crash History:

Years:

Crash Type	Fatal	Injury A	Injury B	Injury C	KABC	PDO	Total
Total							

(add more rows as needed)

Crash Trends:

Describe the crash trends at the intersection.

Contributing Factors:

Describe the contributing factors of the crashes.

Additional Modes of Transportation:

Mode	Need? Yes/No	Nearby Generators and Existing Facilities	Volume	
			#	Unit
PED/BIKE				
OSOW				

(add more rows as needed)

Other Information: Identify any concerns or limitations the additional modes of transportation have.

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Summary Tables:

Descriptions:

Alt.	Traffic Control	Description of Alternative
1	<Enter Type of Control 1>	
2	<Enter Type of Control 2>	
3	<Enter Type of Control 3>	
4	<Enter Type of Control 4>	
5	<Enter Type of Control 5>	
6	<Enter Type of Control 6>	

Costs and Impacts:

Alt.	Traffic Control	Construction Cost	Real Estate Impacts			Environmental Impacts	
			# Build	# Acres	Cost	Impact Type	# Acres
1	<Enter Type of Control 1>					Choose an item.	
2	<Enter Type of Control 2>					Choose an item.	
3	<Enter Type of Control 3>					Choose an item.	
4	<Enter Type of Control 4>					Choose an item.	
5	<Enter Type of Control 5>					Choose an item.	
6	<Enter Type of Control 6>					Choose an item.	

Safety Performance:

Alt.	Traffic Control	Analysis Period	KABC	PDO	Total
-	Existing Conditions	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
-	Future No-Build	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
1	<Enter Type of Control 1>				
2	<Enter Type of Control 2>				
3	<Enter Type of Control 3>				
4	<Enter Type of Control 4>				
5	<Enter Type of Control 5>				
6	<Enter Type of Control 6>				

Recommendation:

Alternative:

Influencing Factors:

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Existing & Future No-Build Conditions:

Practical Feasibility:

Public Opinion:	
Business Impacts:	
ROW Impacts:	
Utility Impacts:	
Cost Estimate:	
Additional Info:	

Safety Analysis:

Safety Performance Measures:

	Analysis Period	KABC	PDO	Total
Existing Conditions	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Future No-Build	<Analysis Period>	<# KABC>	<# PDO>	<# Total>

Operational Analysis:

Warrant Analysis:	
Queue Impacts:	
Additional Capacity:	
Railroad Impacts:	
Additional Info:	

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Operational Performance Measures:

Year:	Existing Conditions											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

Year:	Future No-Build Conditions (Design Year)											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Alt. 1: <Enter Type of Control 1>:

Practical Feasibility:

Public Opinion:	
Business Impacts:	
ROW Impacts:	
Utility Impacts:	
Cost Estimate:	
Additional Info:	

Safety Analysis:

Crash Trend(s) and Contributing Factors:	
Conflict Points:	
Vulnerable Users:	
Additional Info:	

Safety Performance Measures:

	Analysis Period	KABC	PDO	Total
Existing Conditions	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Future No-Build	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Alt. 1: <Enter Type of Control 1>:				

Operational Analysis:

Warrant Analysis:	
Queue Impacts:	
Additional Capacity:	
Railroad Impacts:	
Additional Info:	

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Operational Performance Measures:

Year:	Alt. 1: <Enter Type of Control 1>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

Year:	Alt. 1: <Enter Type of Control 1>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Alt. 2: <Enter Type of Control 2>:

Practical Feasibility:

Public Opinion:	
Business Impacts:	
ROW Impacts:	
Utility Impacts:	
Cost Estimate:	
Additional Info:	

Safety Analysis:

Crash Trend(s) being Improved with Alt.:	
Geometric Concerns:	
Additional Info:	

Safety Performance Measures:

	Analysis Period	KABC	PDO	Total
Existing Conditions	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Future No-Build	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Alt. 2: <Enter Type of Control 2>:				

Operational Analysis:

Warrant Analysis:	
Queue Impacts:	
Additional Capacity:	
Railroad Impacts:	
Additional Info:	

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Operational Performance Measures:

Year:	Alt. 2: <Enter Type of Control 2>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

Year:	Alt. 2: <Enter Type of Control 2>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Alt. 3: <Enter Type of Control 3>:

Practical Feasibility:

Public Opinion:	
Business Impacts:	
ROW Impacts:	
Utility Impacts:	
Cost Estimate:	
Additional Info:	

Safety Analysis:

Crash Trend(s) being Improved with Alt.:	
Geometric Concerns:	
Additional Info:	

Safety Performance Measures:

	Analysis Period	KABC	PDO	Total
Existing Conditions	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Future No-Build	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Alt. 3: <Enter Type of Control 3>:				

Operational Analysis:

Warrant Analysis:	
Queue Impacts:	
Additional Capacity:	
Railroad Impacts:	
Additional Info:	

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Operational Performance Measures:

Year:	Alt. 3: <Enter Type of Control 3>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

Year:	Alt. 3: <Enter Type of Control 3>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Alt. 4: <Enter Type of Control 4>:

Practical Feasibility:

Public Opinion:	
Business Impacts:	
ROW Impacts:	
Utility Impacts:	
Cost Estimate:	
Additional Info:	

Safety Analysis:

Crash Trend(s) being Improved with Alt.:	
Geometric Concerns:	
Additional Info:	

Safety Performance Measures:

	Analysis Period	KABC	PDO	Total
Existing Conditions	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Future No-Build	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Alt. 4: <Enter Type of Control 4>:				

Operational Analysis:

Warrant Analysis:	
Queue Impacts:	
Additional Capacity:	
Railroad Impacts:	
Additional Info:	

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Operational Performance Measures:

Year:	Alt. 4: <Enter Type of Control 4>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

Year:	Alt. 4: <Enter Type of Control 4>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Alt. 5: <Enter Type of Control 5>:

Practical Feasibility:

Public Opinion:	
Business Impacts:	
ROW Impacts:	
Utility Impacts:	
Cost Estimate:	
Additional Info:	

Safety Analysis:

Crash Trend(s) being Improved with Alt.:	
Geometric Concerns:	
Additional Info:	

Safety Performance Measures:

	Analysis Period	KABC	PDO	Total
Existing Conditions	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Future No-Build	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Alt. 5: <Enter Type of Control 5>:				

Operational Analysis:

Warrant Analysis:	
Queue Impacts:	
Additional Capacity:	
Railroad Impacts:	
Additional Info:	

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Operational Performance Measures:

Year:	Alt. 1: <Enter Type of Control 5>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

Year:	Alt. 1: <Enter Type of Control 5>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Alt. 6: <Enter Type of Control 6>:

Practical Feasibility:

Public Opinion:	
Business Impacts:	
ROW Impacts:	
Utility Impacts:	
Cost Estimate:	
Additional Info:	

Safety Analysis:

Crash Trend(s) being Improved with Alt.:	
Geometric Concerns:	
Additional Info:	

Safety Performance Measures:

	Analysis Period	KABC	PDO	Total
Existing Conditions	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Future No-Build	<Analysis Period>	<# KABC>	<# PDO>	<# Total>
Alt. 6: <Enter Type of Control 6>:				

Operational Analysis:

Warrant Analysis:	
Queue Impacts:	
Additional Capacity:	
Railroad Impacts:	
Additional Info:	

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Operational Performance Measures:

Year:	Alt. 1: <Enter Type of Control 6>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

Year:	Alt. 1: <Enter Type of Control 6>											
AM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
PM Peak	EB			WB			NB			SB		
	-	-	-	-	-	-	-	-	-	-	-	-
# Lanes												
LOS												
Delay (s)												
v/c												
Queue (ft.)												
Storage (ft.)												
Additional Information												

PHASE II: ICE REPORT

BUREAU OF TRAFFIC OPERATIONS

Attachments:

(Provide attachments outline in FDM 11-25-3 Attachment 3.7 as appropriate)

1.

ICE Submittal Checklist

Form available on Traffic Operation Manual website under Intersection Control Evaluations (ICE) at:
https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/manuals.aspx

ICE SUBMITTAL CHECKLIST

Level of ICE (Check Applicable Box): ☐ **Phase I: Scoping ICE** ☐ **Phase II: Alternative Selection ICE**

Documentation	Submittal Requirements		Submittal to Region		Submittal to BTO	
	Phase I ICE	Phase II ICE	Included	N/A	Included	N/A
Report						
▪ Phase I: ICE Memorandum	Required	N/A	☐	☐	☐	☐
▪ Phase I: ICE Brainstorming Guide	Required	N/A	☐	☐	☐	☐
▪ Phase II: ICE Worksheet	N/A	Required	☐	☐	☐	☐
Project Description						
▪ Project Location Map	Required	Required	☐	☐	☐	☐
▪ Aerial Photo of Intersection	Optional	Optional	☐	☐	☐	☐
Traffic Volume Data						
▪ Turning Movement Counts (field count data)	Optional	Required	☐	☐	☐	☐
▪ Segment Traffic Forecasts	Optional	Required	☐	☐	☐	☐
▪ Intersection Traffic Forecasts	Optional	Required	☐	☐	☐	☐
Safety Considerations						
▪ Intersection Crash Diagram with summary of crashes	Required	Required	☐	☐	☐	☐
▪ Predictive Safety Analysis	Optional	Required	☐	☐	☐	☐
Additional Modes of Transportation						
▪ Wisconsin Bike Map (bike rating)	Optional	Optional	☐	☐	☐	☐
▪ 5-Year Summary of OSOW and Long Truck Routes	Optional	Optional	☐	☐	☐	☐
Operational Analysis (as applicable) [(a)]						
▪ AWSC Warrants	Optional	Required	☐	☐	☐	☐
▪ Traffic Signal Warrants	Optional	Required	☐	☐	☐	☐
▪ Model Files for HCS, Sidra, & Synchro	Optional [(a)]	Required	☐	☐	Not Applicable	

(a) Completion of the operational analysis for the Phase I: ICE is optional, however, if conducted the analyst shall submit all applicable warrants, model files, and model output worksheets. Region shall submit all DT1887 and DT2291 to BTO for all HCM-based and microsimulation analyses that is conducted.

ICE SUBMITTAL CHECKLIST

Level of ICE (Check Applicable Box): ☐ **Phase I: Scoping ICE** ☐ **Phase II: Alternative Selection ICE**

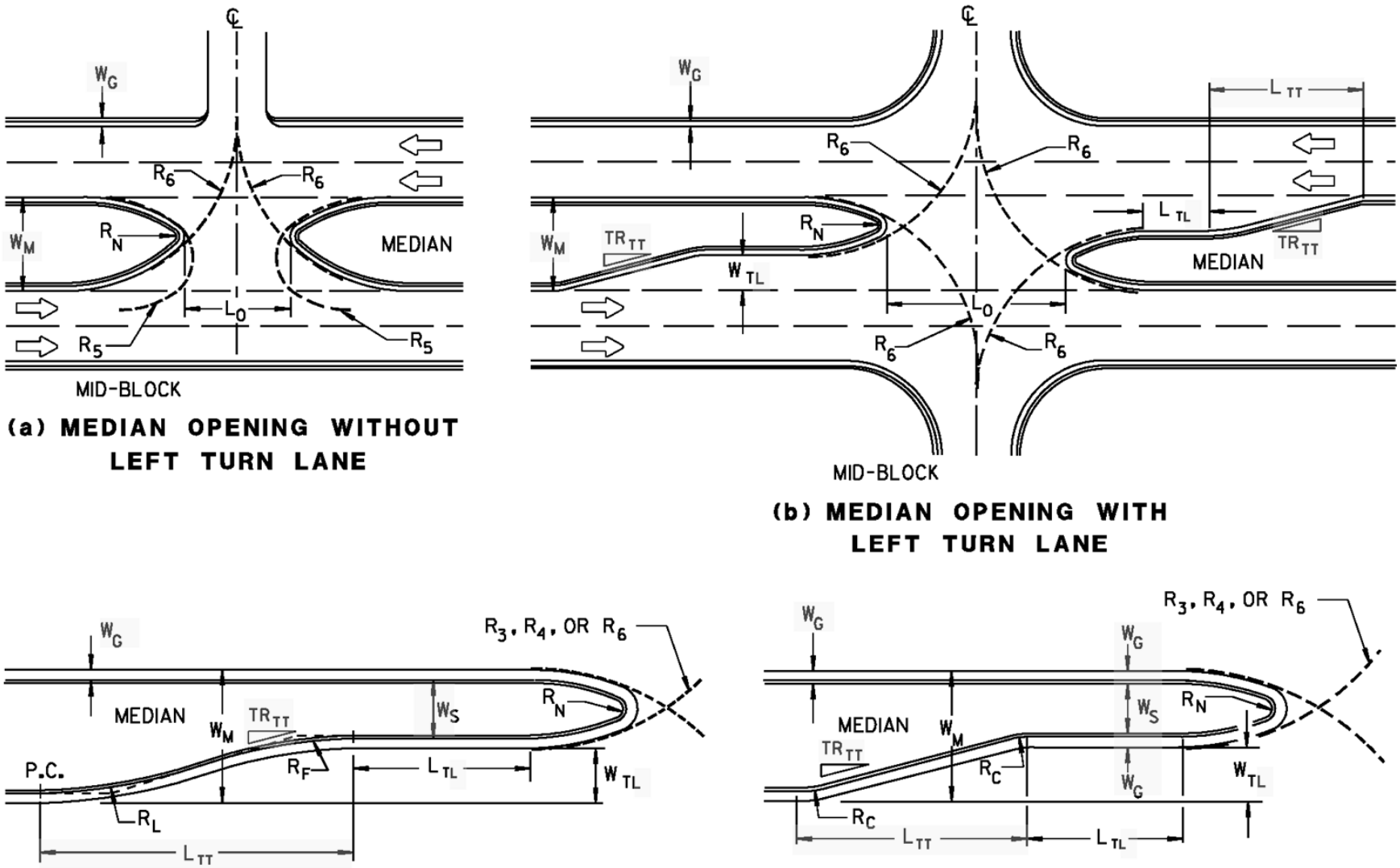
Documentation	Submittal Requirements		Submittal to Region		Submittal to BTO	
	Phase I ICE	Phase II ICE	Included	N/A	Included	N/A
▪ HCS Worksheets	Optional	Required				
~ *HCS7 Formatted Summary Report (AWSC, TWSC, Roundabouts)*			☐	☐	☐	☐
~ *HCS7 Full Formatted Report (Signals)*			☐	☐	☐	☐
▪ Sidra Worksheets (Roundabouts only) [b]	Optional	Required				
~ *Site Layout*			☐	☐	☐	☐
~ *Input Volumes*			☐	☐	☐	☐
~ *Input Comparison ("with Standard Model Defaults")*			☐	☐	☐	☐
~ *Movement Summary*			☐	☐	☐	☐
~ *Lane Summary*			☐	☐	☐	☐
▪ Synchro Worksheets [c]	Optional	Required				
~ *Signalized Intersection Report (with following data: Lane Inputs, Volume Inputs, Timing Inputs, Actuated Inputs, Queues)*			☐	☐	☐	☐
~ *HCM 6th Edition Signalized "Summary" report (with 95th percentile queue)*			☐	☐	☐	☐
~ *Unsignalized Intersection Report (with following data: Lane Inputs, Volume Inputs)*			☐	☐	☐	☐
~ *HCM 6th Edition AWSC or TWSC*			☐	☐	☐	☐
▪ SimTraffic Outputs for each run	Optional	Required	☐	☐	☐	☐
Traffic Model Peer Review (as applicable) [a]						
▪ DT 1887 for all HCM-based Analyses	Optional	Required	Not Applicable		☐	☐
▪ DT 2291 for Microsimulation Analyses (specifically SimTraffic) [d]	Optional	Required	Not Applicable		☐	☐
Region Comments						
▪ Region Comments on Phase I: ICE	Optional	Optional	Not Applicable		☐	☐
Other Reference Material (as applicable)						
▪ TIA (relevant pages)	Optional	Optional	☐	☐	☐	☐

(b) If Sidra analysis is conducted, submit copies of **all** five worksheets listed below.
(c) If Synchro analysis is conducted, submit **both** the intersection report (signalized or unsignalized as applicable) and the HCM 6th Edition report (signalized summary, AWSC or TWSC as applicable)
(d) Submit all Paramics or Vissim models to BTO for review as a separate process outside of the ICE process. BTO does not generally review the SimTraffic analyses, thus the DT 2291 form for SimTraffic models should be submitted along with the ICE report to ensure that all SimTraffic analyses referenced in the ICE report has gone through the Traffic Model Peer Review Process

Urban Median Opening and Intersection Guidelines

Design Feature	Designation	Reference	Minimum (1)	Desirable (1)
SPACING BETWEEN MIDBLOCK MEDIAN OPENINGS (CL to CL)	NA	NA	Median openings within the functional length of intersection are either not allowed or restricted. See FDM 11-25-20.4 for median opening location requirements and criteria	
LENGTH OF MEDIAN OPENING	L_O	Att. 5.2 & 5.3	See FDM 11-25-20	
NOSE RADII	R_N	Att. 5.2 & 5.3	1'	2'
TURNING RADII at Intersections				
Without islands	R_3	Att. 5.3	--	60'
With islands	R_4	Att. 5.3	--	75'
TURNING RADII At mid-block				
For U-turns	R_5	Att. 5.2	40'	50'
For turns into driveways	R_6	Att. 5.2	60'	--
TURN BAY ELEMENTS - TAPER				
Turn Bay Taper Length	L_{TT}	Att. 5.2 & 5.4	FDM 11-25 Att. 2.2	
Turn Bay Taper Rate	TR_{TT}	Att.5.3		
Radius of connecting curves Straight Line Taper				
Radius	R_C	Att. 5.2(d) & 5.3	5'	10'
Radius of connecting curves Reverse Curve Taper				
Radius of lead curve	R_L	Att. 5.2(c)	200'	300'
Radius of final curve	R_F	Att. 5.2(c)	150'	200'
TURN BAY ELEMENTS – FULL WIDTH TURN LANE				
Length of Full Width Turning Lane	L_{TL}	Att. 5.2 & 5.3	FDM 11-25-2	
Width of Full Width Turning Lane	W_{TL}	Att. 5.2 & 5.3	See FDM 11-25 Table 5.2	
Turn Lane Offset from Edge of Travel Lane	W_{TO}			
Gutter Width				
Travel Lane	W_G	Att. 5.2 & 5.3	FDM 11-20-1	
Turn Bay Taper	W_G	Att. 5.2 & 5.3	Same as travel lane	
Full Width Turn Lane	W_G	Att. 5.2 & 5.3	1.0	2.0
Separator Width				
Between left turn lane and Opposing Travel Lane (curb face – curb face)	W_S	Att. 5.2 & 5.3	See FDM 11-25 Table 5.2	
MEDIAN WIDTH REQUIRED TO PROVIDE MEDIAN OPENINGS (1) **Without Left Turn Lanes**				
For turns into driveways	W_M	Att. 5.2	20'	24'
For U-turns	W_M	Att. 5.2	20'	30'
With Left Turn Lanes				
For left turns	W_M	Att. 5.2 & 5.3	See FDM 11-25 Table 5.2	See FDM 11-25 Table 5.2
For U-turns	W_M	Att. 5.2 & 5.3	30'	42'

(1) Measured between edges of median travel lanes (includes gutters).



(a) MEDIAN OPENING WITHOUT LEFT TURN LANE

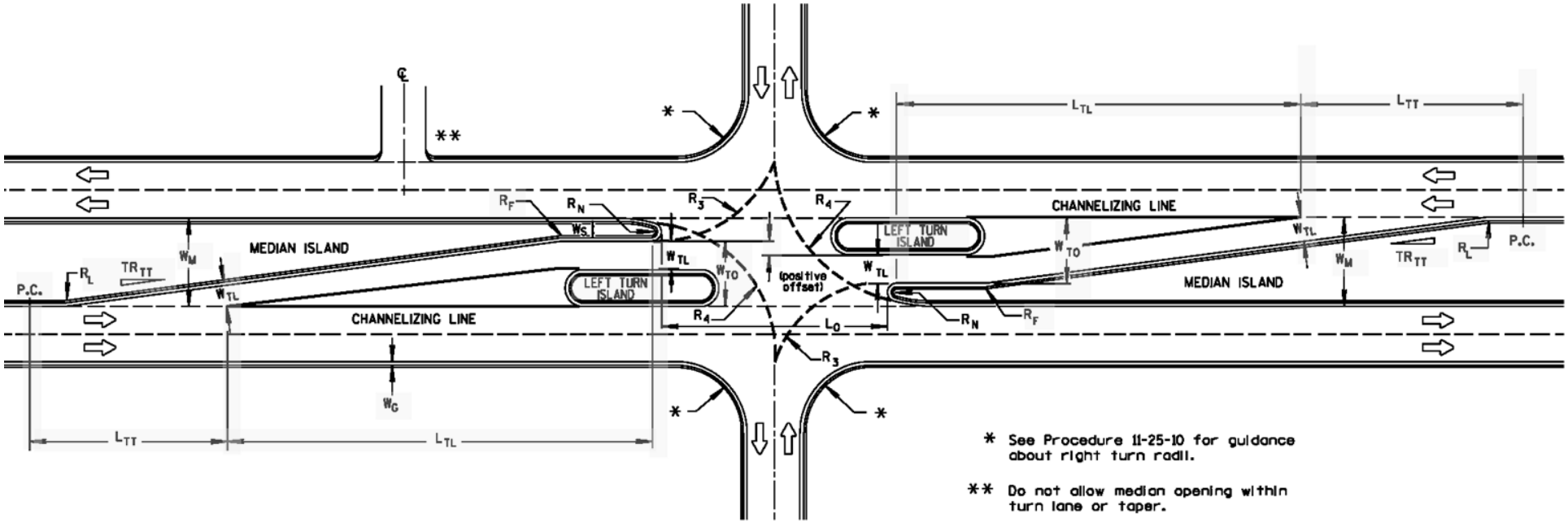
(b) MEDIAN OPENING WITH LEFT TURN LANE

(c) REVERSE CURVE TAPER

(d) STRAIGHT LINE TAPER

MEDIAN OPENINGS AND LEFT TURN LANES IN URBAN ROADWAYS

Details for Slotted Left Turn Lanes and Median Opening at Urban Intersections



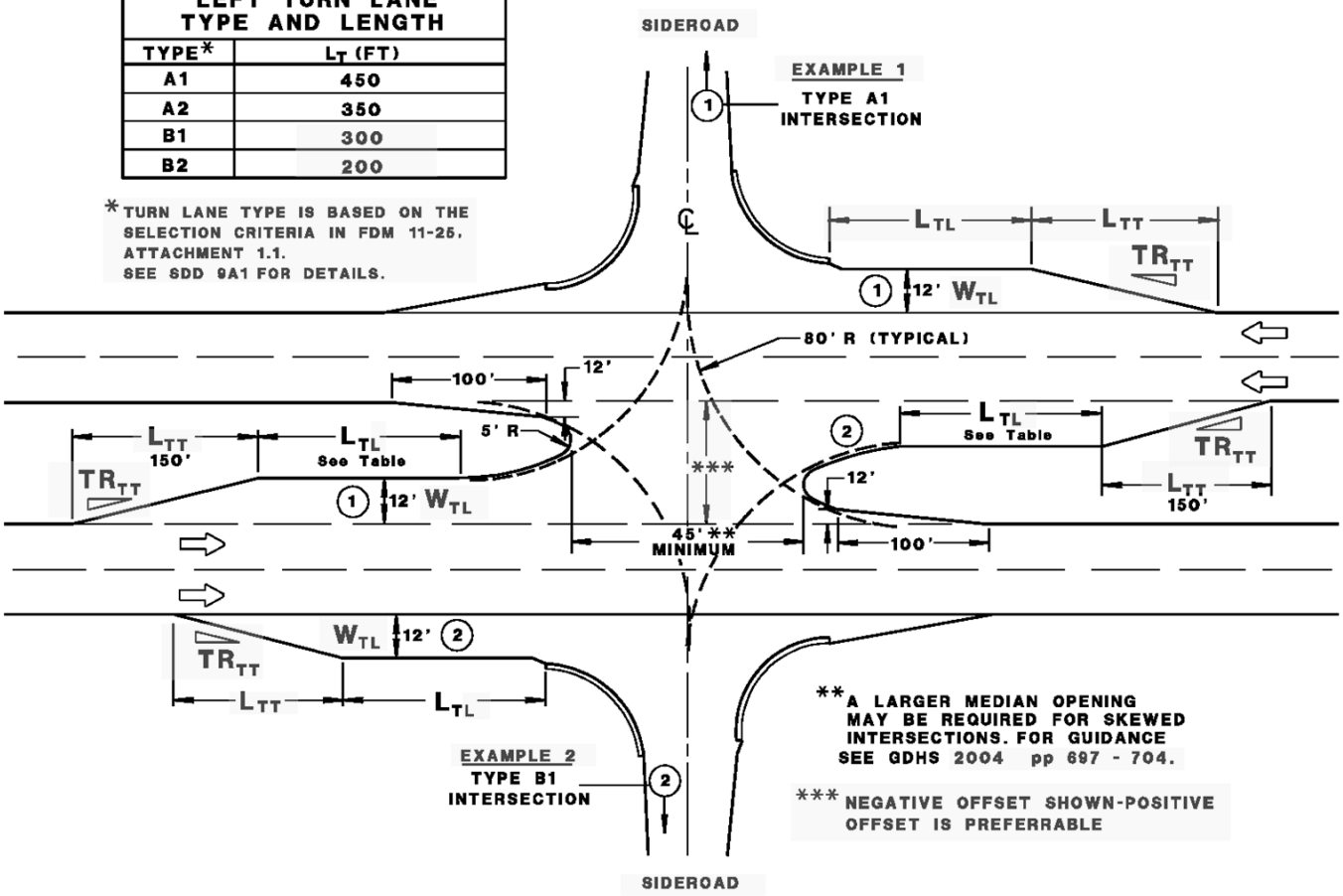
THE LEFT TURN LANE AND THE RIGHT TURN LANE SERVING THE SAME SIDEROAD SHOULD BE THE SAME LENGTH, UNLESS ONE OF THE TURN LANES REQUIRES ADDITIONAL LENGTH FOR STORAGE.

EXAMPLE 1: LEFT TURN LANE (1) AND RIGHT TURN LANE (1) ARE BOTH 450-FT. LONG BECAUSE THE SELECTION CRITERIA FOR SIDEROAD (1) CALLS FOR A TYPE A1 INTERSECTION.

EXAMPLE 2: LEFT TURN LANE (2) AND RIGHT TURN LANE (2) ARE BOTH 300-FT. LONG BECAUSE THE SELECTION CRITERIA FOR SIDEROAD (2) CALLS FOR A TYPE B1 INTERSECTION.

LEFT TURN LANE TYPE AND LENGTH	
TYPE*	L_T (FT)
A1	450
A2	350
B1	300
B2	200

*TURN LANE TYPE IS BASED ON THE SELECTION CRITERIA IN FDM 11-25, ATTACHMENT 1.1. SEE SDD 9A1 FOR DETAILS.



**A LARGER MEDIAN OPENING MAY BE REQUIRED FOR SKEWED INTERSECTIONS. FOR GUIDANCE SEE GDHS 2004 pp 697 - 704.

***NEGATIVE OFFSET SHOWN-POSITIVE OFFSET IS PREFERRABLE

MEDIAN OPENING AND TURN LANES ON RURAL HIGH SPEED 4-LANE DIVIDED HIGHWAYS

FDM 11-26-1 General

August 15, 2019

1.1 General

This section and its sub-sections are comprised of roundabout design and operations guidelines developed through research and experience. Much of the prescribed guidance has been proven through application, evaluation and refinement - a truly continuous improvement process.

The Department has updated previous versions of this guide to account for changes in national roundabout guidelines made possible through research, namely NCHRP 572 - Roundabouts in the United States, 2006 and NCHRP 672, Roundabouts: An Informational Guide, Second Edition. The NCHRP guidelines and research are heavily relied upon in this chapter. Where appropriate and justified by local experience, exceptions for use by the Wisconsin Department of Transportation are noted. Where both references are cited but differences exist, the Facilities Development Manual guidance shall govern.

The modern roundabout is a subset of many types of circular intersections. The term modern roundabout and roundabout are used interchangeably throughout this document. The roundabout is a one-way circular intersection where circulating traffic is given priority over entering traffic and where entry speeds are low relative to older unconventional circular intersections. The term “modern roundabout” is used in the United States to differentiate roundabouts from the older and often large diameter nonconforming traffic circles, rotaries or very small traffic calming circles used on residential streets.

Traffic circles fell out of favor in this country by the mid 1950’s because they encountered safety and operational problems as traffic volumes increased beyond their operational thresholds. However, substantial progress has been achieved in the subsequent design of circular intersections, and the modern roundabout should not be confused with the traffic circles of the past.

Roundabouts may be considered for a wide range of intersection types including but not limited to freeway interchange ramp terminals, state route intersections, and state route/local route intersections. Roundabouts generally process high volume left turns more efficiently than all-way stop control or traffic signals and will process a wide range of side road volumes. Roundabouts can improve safety by reducing vehicle speeds and eliminating crossing conflicts that are present at conventional intersection. The required intersection sight distance is greatly reduced from what is required for a signalized intersection due to the reduced intersection speeds.

The modern roundabout is defined by three basic principles:

1. Yield-at-Entry - Vehicles approaching the roundabout must wait for a gap in the circulating flow, or yield, before entering the circle.
2. Deflection - Traffic entering the roundabout is directed or channeled to the right with a curved entry path into the circulating roadway.
3. Geometric Curvature - The radius of the circular road and the angles of entry are designed to slow the speed of vehicles.

The following is a list of locations where a roundabout may be feasible:

1. Intersections with a high-crash rate or a higher severity of crashes
2. High-speed rural intersections
3. Freeway ramp terminals
4. Transitions in functional class or typical speed change (including rural to urban transitions)
5. Existing intersections that are failing
6. Aesthetics is an objective
7. Intersections of dissimilar functional class (arterial-arterial, arterial-collector, arterial-local, collector-collector, collector-access)
8. Four-leg intersections with entering volumes less than 5,000 vph or approximately 50,000 ADT
9. Three-leg intersections
10. Intersection of two signalized progressive corridors where turn proportions are heavy (random arrival is better than off-cycle arrival)
11. Closely spaced intersections where signal progression cannot be achieved
12. Locations where future access will be added to the intersection

13. Replacement of all-way stops
14. Intersections near schools
15. Intersections where safety is a major concern

FHWA and AASHTO have made intersection safety a high priority. The objective is to improve the safety and operation of intersections. When compared to signalized intersections, studies by the Insurance Institute for Highway Safety [1] show that roundabouts typically reduce overall delay and congestion, increase capacity, and improve safety. For example, right-angle collisions are a prominent cause of death at signalized intersections. Studies by the Insurance Institute for Highway Safety show that signalized intersections converted to roundabouts experienced on average: 75% fewer injury crashes, 90% fewer fatality crashes, and fewer crashes overall.

Wisconsin roundabout safety has been studied with encouraging results. In a study of roundabout collision history, prepared by the University of Wisconsin Traffic Operations and Safety Laboratory [4], local researchers analyzed 24 roundabouts that were built in Wisconsin in 2007 or before. Three years of before and after crash data were gathered as well as geometric and volume data. An Empirical Bayes (E-B) analysis was used to examine the safety benefits for total crashes and injury crashes. A simple before-and-after crash analysis was also completed to analyze specific types of injury crashes for each roundabout. The E-B analysis was performed using Safety Performance Functions (SPFs) from both the Highway Safety Manual (HSM) and Wisconsin specific data. The results from both values were very similar adding strength to the numbers. Using the HSM SPFs, researchers found mixed results for total crash frequency but a significant decrease in crash severity. Nationally, a 35% reduction was observed for all crashes as noted in NCHRP Report 572 while Wisconsin roundabouts showed a 9% decrease across the 24 roundabouts. Wisconsin roundabouts had a decrease of 52% for fatal and injury crashes. Roundabouts nationwide are also experiencing a significant decrease in severe crashes.

When looking at predictor variables, the speed limit of the approaches did not show a significant impact on the safety of the roundabout. While multilane roundabouts seem to be safer than single lane roundabouts when looking at fatal and injury crashes, single lane roundabouts saw a larger decrease in total crashes. Two-way stop-controlled conversions had the highest safety benefit as compared to All-way stop controlled and signalized.

According to FHWA, some or all of the following safety benefits can be realized with proper roundabout design and implementation:

- Provide more time for entering drivers to judge, adjust speed for, and enter a gap in circulating traffic, allowing for safer merges
- Reduce the size of sight triangles needed for users to see one another
- Increase the likelihood of drivers yielding to pedestrians (compared to an uncontrolled crossing)
- Provide more time for all users to detect and correct for their mistakes or mistakes of others
- Make crashes less frequent and less severe, including crashes involving pedestrians and bicyclists
- Make the intersection safer for novice users

Critical to the acceptance of the roundabout intersection is overcoming the internal and external skepticism of its advantages and value compared to stop controlled or signalized intersections. Meet with local officials and adjoining property owners early in the process to address potential political or economic impacts. Designers and traffic engineers should also coordinate presentation materials with region staff as well as the Bureau of Project Development to present a consistent unified approach for roundabout implementation throughout the State.

1.2 Modern Roundabout vs. Other Circular Intersections

On the surface, modern roundabouts, old traffic circles and rotaries look similar; however, there are subtle differences that distinguish the two intersection concepts. The fundamental difference is their differing design philosophies. Modern roundabouts control and maintain low speeds for entering and circulating traffic. This is achieved by small diameters and low-speed entry geometry. By contrast, traffic circle geometry encourages high-speed merging and weaving, made possible by larger diameters and large high-speed entry radii. Modern roundabouts control vehicle speed by geometric design elements that allow only slow speeds therefore creating safer driving conditions. The common characteristics distinguishing a modern roundabout from a traffic circle or a rotary type intersection are summarized in Table 1.1.

Table 1.1 Distinguishing Characteristics of Modern Roundabouts

Feature	Modern Roundabout	Traffic Circle or Rotary
Control at Entry	Yield at all entries. The circulatory roadway has no control	Stop, signal, or give priority to entering vehicle. Circulating vehicles yield to entering traffic.
Operational Characteristics	Vehicles are sorted by destination at the approach. Weaving within the circulatory roadway is minimized. Using proper lane line markings, lane changes are strongly discouraged in the circulatory roadway.	Weaving is unavoidable and weaving sections are provided to accommodate conflicting movements
Deflection	Large entry angle helps to create entry deflection to control speed through the roundabout	Entry angle likely to be reduced to allow higher speed at entry
Speed	Maintain relatively low circulating speeds (<25 mph)	Higher circulating speeds allowed (>25 mph)
Circle Diameter	Smaller diameters improve safety	Larger diameters allowed. Small diameter circle sometimes used for traffic calming
Pedestrian Crossing	No pedestrian activity on central island	Some large traffic circles allow pedestrian crossing to and from the central island
Splitter Island	Required	Optional
Parking	No parking on the circulatory roadway or in close proximity of the yield line	On large traffic circles, occasional parking permitted within circulating roadway

A roundabout can provide a possible solution for locations that experience high crash rates or crash trends by reducing the number of conflict points where the paths of opposing vehicles intersect. For example, over half of the crashes at conventional intersections occur when a driver either; misjudges the distance or speed of approaching vehicles while making a left turn or violates a red light or stop sign resulting in a right-angle collision. Such crashes would be eliminated with a roundabout, where left turns and crossing movements are prohibited. Furthermore, collisions at roundabouts involve low speeds and low angles of impact, and therefore, are less likely to result in serious injury for all road users. Crash evaluation is an important process to complete for any intersection improvement alternative. Crash evaluation will consist of reviewing individual crash records and will typically include factors such as location, date, type of crash, time of day, age of driver, weather conditions, severity of crash, and other important information to assess the problem(s), patterns and potential improvement need.

When considering methods to increase the capacity of an intersection, a roundabout can be an alternative to stop or signal controlled intersections. With conventional signal controls, only alternating streams of vehicles are permitted to proceed through an intersection at one time, which means a loss of capacity when the intersection clears between phases. In contrast, the only restriction on entering a roundabout is the availability of a gap in the circulating flow. The reduced speeds within the roundabout will typically allow the approaching driver to safely select a gap that is relatively small. By allowing vehicles to enter simultaneously from multiple approaches using short headways, a possible advantage in capacity can be achieved with a roundabout. This advantage becomes more prominent when the volumes of left or right turning movements are relatively high.

By constructing a pair of roundabouts at ramp terminal intersections, capacity improvements to the interchange can be accomplished without the cost of widening the structure to carry additional lanes over or under a freeway, or expressway (see FDM 11-30-1 and NCHRP Report 672, Chapter 6.10 for more information on interchanges).

Roundabouts can produce operational improvements in locations where the space available for queuing is limited. Roadways are often widened to create storage for vehicles waiting at red lights, but the reduced delays and continuous flows at roundabouts allow the use of fewer lanes between intersections. One possible application can be found at diamond interchanges, where high left turn volumes can cause signals to fail.

Conventional forms of traffic control are often less efficient at intersections with a difficult skew angle, significant offset, odd number of approaches, or close spacing to other intersections. Roundabouts may be a good fit for such intersections, because they do not require signal phasing. The ability of a roundabout to accommodate high turning volumes, make them especially effective at “Y” or “T” junctions. Roundabouts may also be useful in eliminating a pair of closely spaced intersections by combining them to form a multi-legged roundabout.

Intersection sight distance for roundabouts is about half what it is for other intersection treatments because of reduced intersection speeds.

Another possible application is where access is controlled with raised medians. Roundabouts would facilitate left turns and U-turns to access properties on the opposite side of the highway.

1.3 Advantages and Disadvantages

Table 1.2 lists advantages and disadvantages of roundabouts versus other intersection alternatives.

Table 1.2 Advantages and Disadvantages of Roundabouts vs. Other Alternatives.

Category	Advantages	Disadvantages
Safety	Reduced number of conflict points compared to other non-circular intersections. Left-turn conflicts are removed. Elimination of high angles of conflict and high operational speeds; fewer and less severe accidents. Reduction in conflicting speeds passing through the intersection. Reduced decision making at point of entry. Long splitter islands and other geometric features provide good advanced warning of the intersection. Raised level of consciousness for drivers. Facilitate U-turns that can substitute for more difficult midblock left turns.	Crashes may temporarily increase due to improper driver education. During emergencies, signalized intersections can preempt control. Multilane roundabouts present more difficulties for pedestrians with blindness or low vision due to challenges in detecting gaps and determining that vehicles have yielded at crosswalks. May reduce the number of available gaps for midblock unsignalized intersections and driveways
Operations	Traffic yields, nonstop, continuous traffic flow. Generally higher capacities experienced. Can reduce the number of lanes required between intersections, including bridges between interchange ramp terminals. During off-peak hours, signal timing can create undue delay at signalized intersections.	Coordinated signal systems can increase capacity of the network. As queues develop, drivers accept smaller gaps, which may increase crashes. Equal priority for all approaches can reduce the progression for high volume approaches. Cannot provide explicit priority to specific users (e.g., trains, emergency vehicles, transit, pedestrians) unless supplemental traffic control devices are provided.
Cost	No maintenance of signals (heads, loop detectors, controllers). Lower accident rate and severity; reduced accident costs.	Central island landscaping maintenance. Illumination cost. May have significant real estate impacts
Pedestrians & Bicyclists	Splitter islands provide pedestrian refuge and shorter one-directional traffic crossing. Pedestrians only need to consider one direction of traffic at a time. Low speed conditions improve bicycle and pedestrian safety. Depending on their skills and level of comfort, bicyclists have the option to take a lane to negotiate through a roundabout.	Pedestrians, especially children, elderly, and handicapped may experience increased delay and reduced safety in securing acceptable gaps to cross. Pedestrians with vision impairments may have the most trouble establishing safe opportunities to cross. Longer travel path. Bicycle ramps could be confused for pedestrian ramps.
Environmental	Reduced starts and stops; reduced air pollution.	Possible impacts to natural and cultural resources due to potentially greater spatial requirements at the intersection.

Category	Advantages	Disadvantages
OSOW Truck Route (OSOW-TR)	Reduction of potential obstacles at intersections (traffic signals, signing, median islands).	The geometric design may be challenging to allow the navigation of OSOW vehicles. Additional right-of-way and paved areas may be needed to accommodate OSOW vehicles.
Aesthetics	Provide attractive entries or centerpieces to communities. Used in tourist or shopping areas to separate commercial uses from residential areas. Provide opportunity for landscaping or gateway to enhance the community.	May create a safety hazard if hard objects are placed in the central island directly facing the entries.

1.4 Defining Physical Features

The defining features of a roundabout are shown in Figure 1.1 and Figure 1.2, and described in Table 1.3.

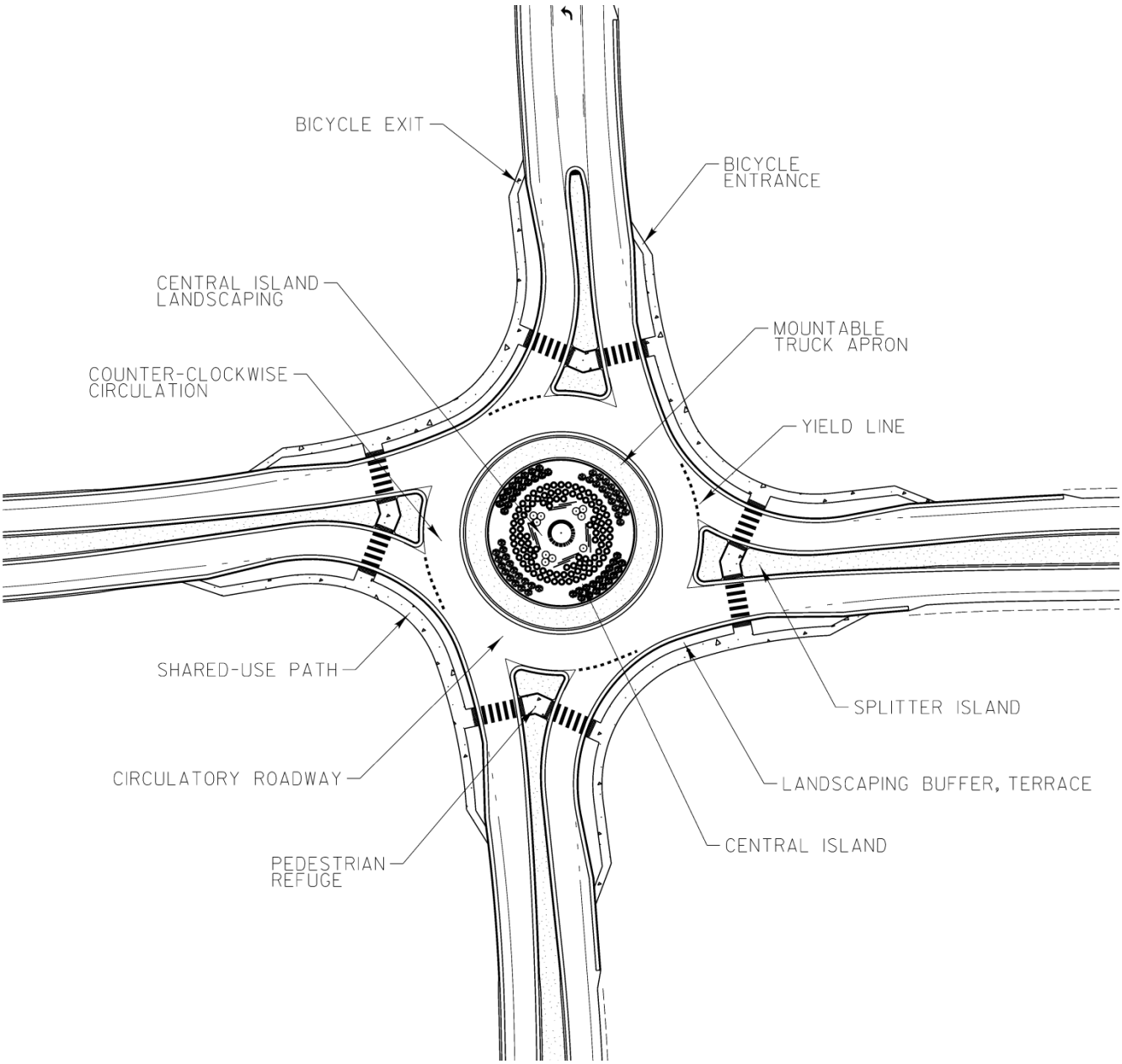


***Figure 1.1** Single-lane Roundabout Features*

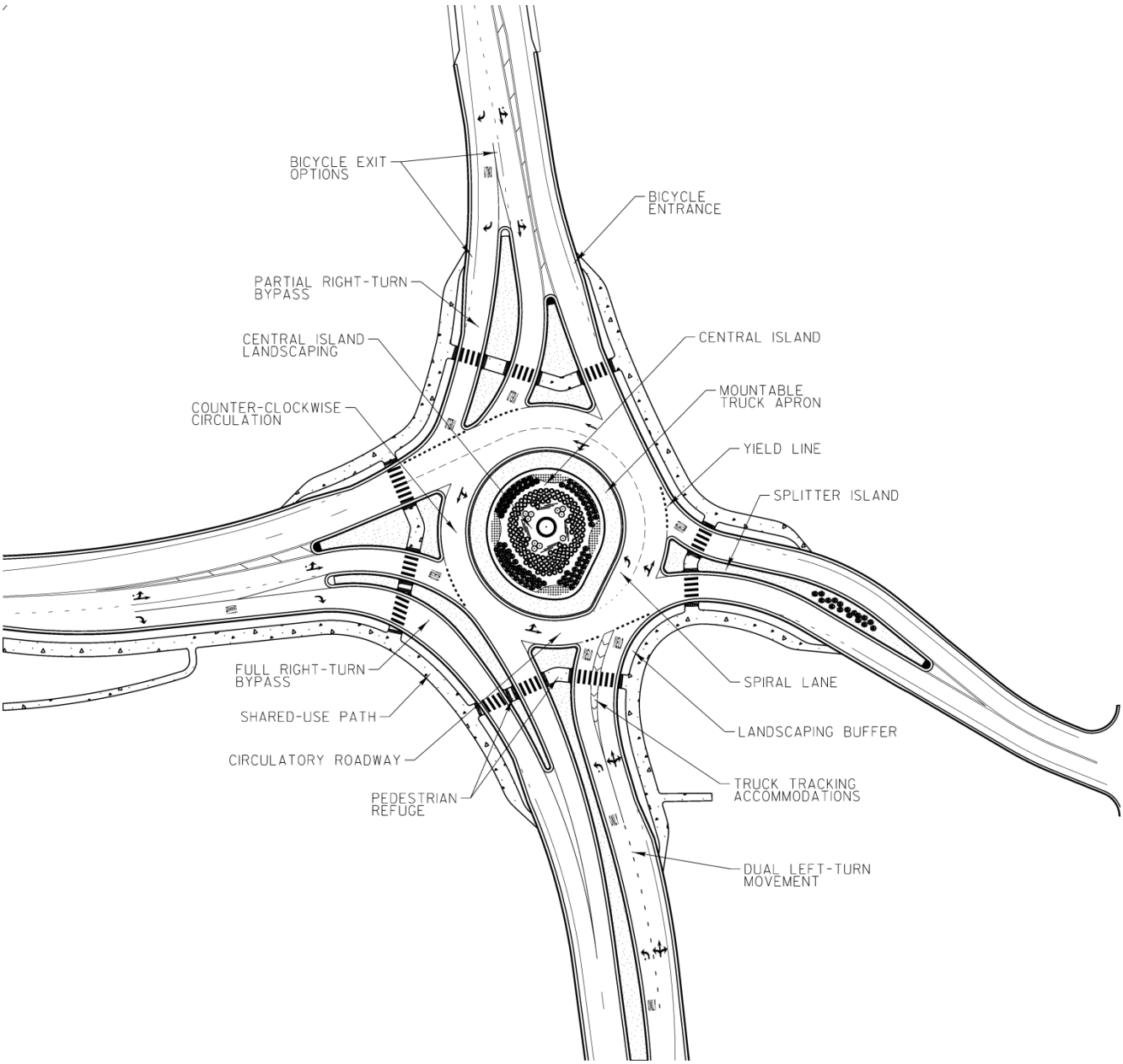


***Figure 1.2* Multilane Roundabout Features**

***Table 1.3* Roundabout Features**

Feature	Description
Central island	The raised area in the center of a roundabout around which traffic circulates. The central island does not necessarily need to be circular in shape.
Splitter island	A raised curb island (special situations may be painted) area on an approach used to separate entering from exiting traffic, deflect and slow entering traffic, and to provide refuge for pedestrians crossing the road in two stages.
Circulatory roadway (counter clockwise circulation)	The curved path used by vehicles to travel in a counterclockwise fashion around the central island. The width of the circulatory roadway is typically 1.0 to 1.2 times the width of the widest entry width.
Truck Apron	The traversable portion of the central island adjacent to the circulatory roadway and widened pavement area adjacent to outside curbs. It is required to accommodate snow plows and the wheel off-tracking of large trucks, and OSOW vehicles. It is usually paved with a contrasting color (red) to delineate the apron from the normal vehicle path.
Yield Line	A point of demarcation separating traffic approaching the roundabout from the traffic already in the circulating roadway. The yield point is usually defined by a thick, (typically 18-inch wide), dotted edge line pavement marking.
Accessible pedestrian crossings	Provide accessible pedestrian crossings at all roundabouts. The crossing location is set back from the yield line, typically one car length. The splitter island is cut to allow pedestrians, wheelchairs, strollers, and bicycles to pass through.
Bicycle treatments	Bicycle treatments at roundabouts provide bicyclists the option of traveling through the roundabout either by riding in the travel lane as a vehicle, or by exiting the roadway and using the crosswalk as a pedestrian, or as a cyclist using the shared-use path, depending on the bicyclist's level of comfort. Bicycle exit ramps should generally leave the roadway within a 25 to 35-degree angle range. Bicycle entrance ramps should generally enter the roadway within a 25 to 35-degree angle range. The entrance and exit ramps should be located approximately 50-150 feet from the circulating traffic to allow the bicyclist an opportunity to transition onto a path away from the circulatory roadway.
Landscaping buffer	Landscaping buffers are provided at most roundabouts to separate vehicular and pedestrian traffic and to encourage pedestrians to cross only at the designated crossing locations. Landscaping buffers can also significantly improve the aesthetics of the intersection as long as they are placed outside the required sight limits.
Shared-use path	Pathway for pedestrians to walk. In the urban environment, it is common to provide a shared-use path at the perimeter of the roundabout to accommodate pedestrians and bicyclists.

1.5 Roundabout Categories

Roundabouts are categorized by size and environment. The following is a list of basic categories explained in FHWA, Roundabouts: An Informational Guide [3]. (FHWA Roundabout Guide). There may be situations where categories are not applicable. The planning process and final design methodologies for roundabouts are to be based on "principles" versus strict rules or one-size fits all criteria. For example, there are no categories for transitional areas and the final design will depend on various factors.

1.5.1 Single-Lane Roundabout

1.5.1.1 Urban Single-Lane Roundabouts

A single lane roundabout is the most efficient and typical roundabout category for urban applications. This type of roundabout is characterized as having a single-lane entry at all legs and one circulatory lane. The roundabout design is focused on achieving consistent entering and circulating vehicle speeds. The geometric design includes raised splitter islands, a non-traversable central island, and may include an apron surrounding the non-traversable part of the central island to accommodate long trucks. The minimum inscribed diameter to accommodate a WB-65 is 120 feet. Where long trucks are anticipated, verify that the circulating roadway width and the truck apron can accommodate off-tracking of a WB-65 design vehicle. A truck apron is included to allow the semi-tractor to stay in the circulating roadway while the trailer off-tracks onto the apron. If the roundabout is located on the OSOW Truck Route, verify that the roundabout geometry, splitter islands, truck apron, and off-tracking can accommodate the appropriate OSOW check vehicle. Refer to FDM 11-25-2 for further discussion.

1.5.1.2 Rural Single-Lane Roundabouts

Rural single-lane roundabouts generally have high speeds on the approach roadway in the range of 45 to 55 mph. They require supplementary geometric and traffic control device treatments on the approach roadway to encourage drivers to slow to an appropriate speed before entering the roundabout. Such treatments include raised and extended splitter islands, a non-traversable central island, and adequate horizontal deflection. Rural roundabouts may have larger diameters than urban roundabouts which may allow slightly higher speeds at the entries, on the circulatory roadway, and at the exits. This is permissible if few pedestrians are expected at these intersections, currently and in the future.

Rural roundabouts which may one day become part of an urbanized area should be designed as urban roundabouts, with slower speeds and pedestrian accommodations. In the interim, design them with supplementary approach and entry features to achieve safe speed reduction. If the roundabout is located on the OSOW Truck Route, verify that the roundabout geometry, splitter islands, truck apron, and off-tracking can accommodate the appropriate OSOW check vehicle. Refer to FDM 11-25-2 for further discussion.

1.5.2 Multilane Roundabouts

1.5.2.1 Urban Multilane Roundabouts

Urban multilane roundabouts are roundabouts in urban areas that have at least one approach leg with two or more entry lanes. These require wider circulatory roadways to accommodate more than one vehicle traveling side by side. Again, it is important that the vehicular speeds be consistent throughout the roundabout. The geometric design includes raised splitter islands, a non-traversable central island, and appropriate horizontal deflection, and may include an apron surrounding the non-traversable part of the central island to accommodate long trucks. A truck apron should be included to allow the semi-tractor to stay in the inner lane and the trailer to off-track onto the apron. When long trucks are anticipated, or if the roundabout is located on the OSOW Truck Route, verify that the roundabout geometry, splitter islands, truck apron, and off-tracking can accommodate the appropriate OSOW check vehicle. Refer to FDM 11-25-2 for further discussion.

1.5.2.2 Rural Multilane Roundabouts

Rural multilane roundabouts have speed characteristics similar to rural single-lane roundabouts with approach speeds in the range of 45 to 55 mph. They differ in having two or more entry lanes, or entries flared from one or more lanes, on one or more approaches. Consequently, many of the characteristics and design features of rural multilane roundabouts mirror those of their urban counterparts. The main design differences are designs with higher entry speeds, larger diameters, and recommended supplementary approach treatments. Design rural roundabouts that may one day become part of an urbanized area for slower speeds, with design details that fully accommodate pedestrians and bicyclists. In the interim, design them with approach and entry features to achieve safe speed reduction. A truck apron should be included to allow the semi-tractor to stay in the inner lane and the trailer to off-track onto the apron. When long trucks are anticipated, or if the roundabout is located on the OSOW Truck Route, verify that the roundabout geometry, splitter islands, truck apron, and off-tracking can accommodate the appropriate OSOW check vehicle. Refer to FDM 11-25-2 for further discussion.

1.5.3 Combination Roundabouts

Combination roundabouts are roundabouts that combine single and multilane entries. This combination usually occurs when roads of different approach volumes intersect roads of two different classifications; a State Trunk Highway (STH) with a local road. These roundabouts are commonly found in suburbanized locations but can also be found in rural locations.

1.99 References

[1] Insurance Institute for Highway Safety publications, May 13, 2000; July 28, 2001; November 19, 2005; www.iihs.org

[2] Insurance Institute for Highway Safety publications, March 2001; July 17, 2011; www.iihs.org/research/qanda/roundabouts.html

[3] NCHRP 672, Roundabouts: An Informational Guide, Second Edition, December 2010, http://www.trb.org/Publications/Blurbs/164470.aspx

[4] Comprehensive Evaluation of Wisconsin Roundabouts, Volume 2: Traffic Safety, Wisconsin Traffic Operations and Safety (TOPS) Laboratory, Department of Civil and Environmental Engineering, University of Wisconsin-Madison, September 2011

FDM 11-26-5 Design Process and Qualifications *August 17, 2020*

5.1 Roundabout Design Process and Qualifications

Due to modern roundabouts' status as a relatively new and unique design form as well as the inherent complexity of their geometric and operational aspects, WisDOT has developed a roundabout design process

which requires a qualified designer participate in each roundabout design.

This section describes the 3-stage design process and the critical design elements. A qualified designer must be involved with each stage of the process. In addition, this procedure describes the various roles the qualified designer may take in completing a roundabout design.

5.2 Roundabout Designer Requirements

A qualified designer must meet the skills, knowledge and experience level determined appropriate by the Wisconsin Department of Transportation for roundabout design. A list of qualified designers for each of the following 3 levels of roundabout complexity is available from the Division of Transportation Systems Development, Bureau of Project Development.

1. Level 1 Roundabout - The design complexity at this level is limited to roundabouts where all legs (not to exceed 4 legs) are single lane entries without bypass lanes. A Level 1 designer must have an understanding of roundabout design with high confidence in designing truck aprons, developing a design with appropriate values for the six geometric parameters, design for appropriate fastest speed paths, design for truck turning paths, have the ability to properly assess the basic capacity requirements of single lane roundabouts from traffic turning movements using the approved analysis software per FDM 11-26-20. The Level 1 qualified designer shall inform the region when the roundabout design exceeds the complexity stated above for a Level 1.
2. Level 2 Roundabout - The design complexity at this level is limited to roundabouts where legs are dual lane entries or less and may have bypass lanes. A Level 2 designer must be proficient in roundabout design with ability to design truck aprons, developing a design with appropriate values for the six geometric parameters, design for appropriate fastest speed paths, design for truck turning paths, and develop special signing and pavement marking needs. The designer will have the ability to properly run the approved capacity analysis software (see FDM 11-26-20) evaluate alternative lane configurations and output from the software program. The Level 2 qualified designer shall inform the region when the roundabout design exceeds the complexity stated for a Level 2. See discussion below about dual lane roundabouts in close proximity and the potential for Level 3 involvement.
3. Level 3 Roundabout - The design complexity at this level involves all roundabout designs to include 3 or 4-lane entries or has closely spaced roundabouts where the operations of one may have an impact on the operations, signing or marking of another. See discussion below about dual lane roundabouts in close proximity and the potential for Level 3 involvement. A Level 3 designer must have the skills and knowledge for the most complex roundabout designs.

The region will use the best traffic data available to select the appropriate qualified designer (Level 1, 2, or 3). This is typically determined prior to project solicitation by the Project Development Section.

The project team will select either a Level 2 or 3 qualified designer if the region anticipates that the project will include a dual lane roundabout. There are certain situations when it is desirable for the region to involve a Level 3 qualified design on dual lane roundabout projects. Some examples include situations where:

- There are other multilane roundabouts in close proximity
- Lane assignment or lane continuity is difficult to achieve without adding another lane
- Reduction in weaving between roundabouts is desired
- Queue backup into an adjacent multilane roundabout is possible
- Other special needs that have been identified

The region will discuss the involvement of a Level 3 qualified designer for dual lane roundabout projects to determine if expertise is needed beyond that provided by a Level 2 qualified designer.

WisDOT regions, consultants, local agencies such as a counties, townships, municipalities, and developers, etc. shall have a qualified designer on staff, or contract with an approved designer, to provide the required sign-off on the Critical Design Parameters document for roundabout designs, as described below, for both WisDOT and WisDOT oversight projects.

Qualified designers may participate in different ways in order to provide the required sign-off on the Critical Design Parameters document.

1. Independently complete the roundabout design. When a WisDOT region, consultant, local agency such as a county, township, municipality etc. or a developer has a roundabout on a project they must have a qualified designer to oversee or complete all aspects of the plans, specifications and estimate (PS & E) package for the roundabout according to the 3-Stage Design Process described below.
2. Assist and mentor the project team in their completion of the roundabout design. A WisDOT region, consultant or local agency such as a county, township, municipality etc. or developer has a roundabout on the project may prefer to contract for assistance or mentoring from a qualified designer in the plans preparation process. The qualified designer must directly assist the project team

addressing the critical design elements in the 3-Stage Design Process described below.

3. Independently review the roundabout design prepared by a project team. A WisDOT region, consultant, local agency such as a county, township, municipality etc. or developer has a roundabout on the project and the design is prepared without any assistance from a qualified designer. The roundabout designer is responsible to contract with one of the qualified designers to review the critical elements of the design at each stage of the 3-Stage Design Process described below. The information to be provided to the qualified designer at each stage of plans complete is provided below.

Coordinate the proposed roundabout design with a qualified designer early in the design process. It is better to allow the qualified designer to be proactive and in a position to suggest modifications rather than to be reactive and lose design options because the design or commitments on the project are too far along.

The qualified designer's review comments shall be submitted to the project team and the WisDOT region at each Stage. The critical design recommendations from the qualified designer should be identified clearly so the roundabout design team knows what to modify on the plans. Less critical comments will likely improve the design more toward optimal and should not be taken lightly. A discussion between the qualified designer, design team, and region may be needed to properly address recommendations in the plans or document the dismissal of the comment(s).

The qualified designer in consultation with WisDOT will determine which elements of the design are critical in the situation where a dispute may take place. Department personnel are responsible to ensure that the qualified designer recommendations and comments are properly addressed by the design team.

5.3 Intersection Control Evaluation, Program Level Scoping Phase

For an explanation of the required level of analysis see FDM 11-25-3. The Program Level Scoping phase typically does not yield the final determination on the selected intersection control. However, there are early screening criteria some of which are identified in FDM 11-25-3 and typically evaluated during the Program Level Scoping phase that may eliminate the roundabout from further consideration.

A qualified designer is not required for the Program Level Scoping phase of an Intersection Control Evaluation.

5.4 The 3-Stage Roundabout Design Process

The following information, including Figure 5.1, describes each of the stages of development where it is critical to have a qualified designer involved in the roundabout design. There may be a project schedule delay or adverse cost ramifications associated with a roundabout design if each stage of the evaluation is not followed in sequence.

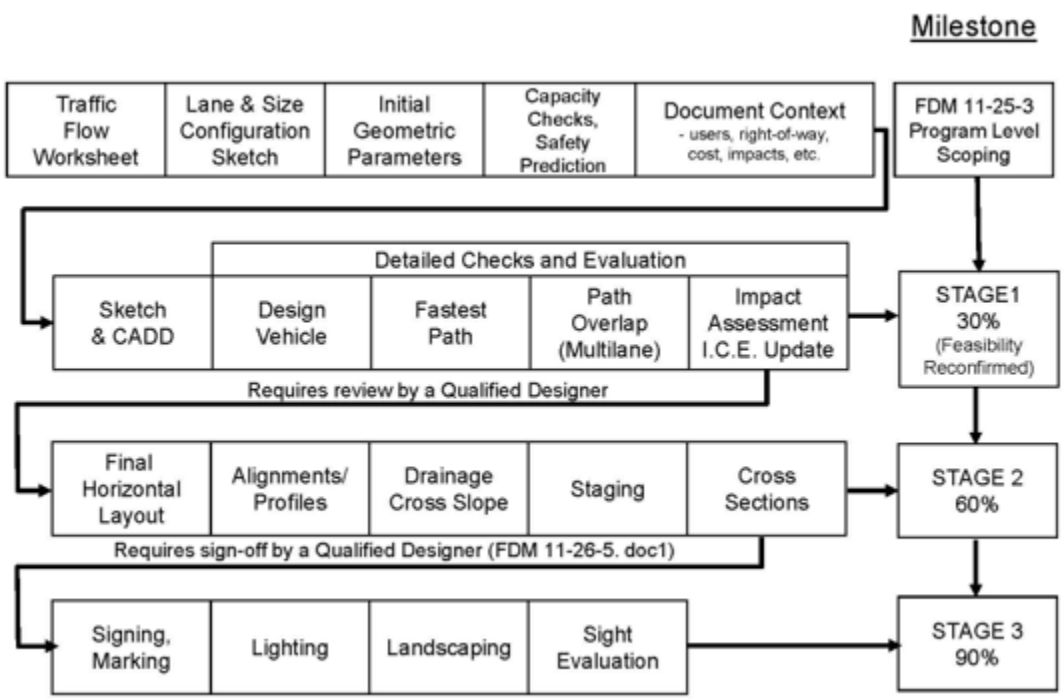


***Figure 5.1** WisDOT 3-Stage Design Process*

5.4.1 Stage 1, Roundabout Design Process

Prior to 30% plans complete. While the typical type of intersection control may still be undetermined; the roundabout has been identified as one of the viable alternatives from the Program Level Scoping phase. Complete Stage 1, requires qualified designer involvement, prior to the 30% plans complete level so the comments and design adjustments are incorporated and ready with the typical 30% plan review discussion/meeting conducted by the region. For designs prepared outside the region, submit Stage 1 plans to the region in dwg format. Generally, it is preferred to have the roundabout design developed far enough to have an idea of right-of-way needs, raised median locations identified, access, major utilities and other potential impacts prior to a Public Involvement Meeting (PIM) so relatively accurate information can be presented and discussed with property owners to include Level of Service (LOS), or delay, comparisons with other intersection control alternatives. It is advisable to include a roundabout expert or other highly experienced roundabout designer at the initial PIM. At the very least, they should be consulted in the planning process for the initial PIM. Initial project acceptance and understanding by the project stakeholders and users is key for a smooth project development process. There may be situations where the design is accurate and detailed enough showing the proper size and location of the roundabout, LOS, extent of the splitter island curb locations and type of access along the roadway that a more detailed design could be completed after the PIM.

This is a list of critical elements of design that the qualified designer needs to address at this stage of plans complete.

1. Determine optimum location of circle with inscribed diameter.
2. Use Traffic Flow Worksheet, FDM 11-26, Attachment 20.1. Completed with existing volumes, design year volumes for AM and PM peak and midday if a tourist area that may have higher mid-day than AM or PM peaks.
3. Establish lane configuration(s) and analyze the existing and forecasted traffic turning movements using the approved analysis software per FDM 11-26-20
4. Complete lane markings and pavement arrows for multilane only.
5. Complete a highly developed design that shows face of curb locations, crosswalks, splitter islands, shared-use path, bike ramps, truck apron etc. with appropriate widths.
6. Verify design vehicle movement and required check vehicles Refer to FDM 11-25-1.4 for discussion on truck routes and routes for oversized-overweight (OSOW) vehicles. Refer to FDM 11-25-2 and FDM 11-25 Attachment 2.1 for OSOW vehicle inventories and FDM 11-25 Table 2.1 for required OSOW design vehicle checks.
7. Show the fast path with speed calculations for R1 thru R5.
8. Fill out Attachment 5.1.
9. Prepare preliminary stopping sight distance for - approach, circulatory roadway, crosswalk and exit, and the intersection sight distance.
10. Prepare preliminary centerline profile of circulatory and approach roadway.
11. Prepare preliminary typical sections on the mainline roadway.

5.4.2 Stage 2, Roundabout Design Process

Prior to 60% plans complete. Complete design revisions recommended by the qualified designer from the previous 30% design. At this stage, a qualified designer is required to complete the design/review of the critical design elements identified below. Prepare the plans such that the environmental documents may be completed, DSR approved and plat work may begin. Complete Stage 2, including all qualified designer involvement prior to the 60% plans complete level so the review comments and design adjustments are incorporated and ready for the region in preparing for the typical 60% plan review discussion/meeting. For designs prepared outside the region, submit Stage 2 plans to the region in dwg format. At this stage, the qualified designer shall sign the Critical Design Parameters document (Attachment 5.1) for attachment to the DSR. One of the primary critical elements of design at this stage is the vertical control with each leg having vertical profiles, circulating roadway profile, crown location, slope intercepts, central island grading, drainage consideration with inlet locations, and spot elevations.

This is a list of critical elements of design that the qualified designer needs to address at this stage of plans complete.

1. Finalize horizontal design changes implemented
2. Establish roadway profiles on each leg
3. Establish circulating roadway profile
4. Show crown location, cross slopes, spot elevations
6. Consider central island grading design

7. Consider drainage design/inlet locations
8. Show preliminary light standard locations
9. Identify the need for large green and white guide signs, overhead guide signs, or other non-typical installations
10. Finalize lane pavement marking and lane assignment pavement marking for multilane roundabouts
11. Identify major utility conflicts (i.e. utility conflicts that may result in relocating the circle)
12. Prepare preliminary typical sections
13. Consider preliminary construction staging layout and identify potential staging conflicts, such as access control, large grade differences between stages, etc. that may impact the design

5.4.3 Stage 3, Roundabout Design Process

Prior to 90% plans complete. Finalize the vertical, drainage, pavement marking, signing, lighting, landscaping plans, work zone traffic control, and utility coordination. In preparation for PS & E complete Stage 3, including all qualified designer involvement, prior to the 90% plans complete level so the review comments and design adjustments are incorporated and ready for the region in preparing for the typical 90% plan review discussion/meeting. This is the final design with construction staging or detour plan.

This is a list of critical elements of design that the qualified designer needs to address at this stage of plans complete.

1. Complete final plan and profile with any vertical and horizontal control details included for field layout
2. Prepare final signing and pavement marking plan
3. Prepare final landscaping and lighting plan (refer to TEOpS 11-1 for lighting policy)
4. Prepare final construction staging plan.

LIST OF ATTACHMENTS

Attachment 5.1 Roundabout Critical Design Parameters Document

FDM 11-26-10 User Considerations *August 15, 2019*

10.1 Pedestrian and Bicyclist Accommodations

Accommodating non-motorized users is a Department priority. Therefore, give special consideration to locations where:

- Pedestrian volumes are high
- There is a presence of young, elderly or blind or low vision impaired citizens wanting to cross the road
- Pedestrians are experiencing particular difficulty in crossing and being delayed excessively

Also, consider the adjacent land use near the roundabout location, such as schools, playgrounds, hospitals, and residential neighborhoods. These sites may warrant additional treatments as presented below. Prior to determining whether bicycle or pedestrian concerns will be a factor in the design of the roundabout, the designer is strongly encouraged to contact the region or state bicycle and pedestrian coordinator for their guidance.

10.1.1 Pedestrians

Research conducted in the U.S. and Europe as presented in the NCHRP 672 [1] indicates fewer pedestrian accidents with less severity occur at roundabout intersections when compared to signalized and unsignalized intersections with comparable volumes. Design principles need to be applied that provide for slow entries and exits for pedestrian safety.

Due to relatively low operating speeds of 15 to 20 mph, pedestrian safety is generally better with a roundabout design than with other intersection types. Table 10.1 lists the advantages and disadvantages of roundabouts as related to pedestrians.

***Table 10.1* Roundabout Advantages and Disadvantages for Pedestrians**

Advantages	Disadvantages
Vehicle speed is reduced as compared to other intersections.	Vehicle traffic is yield controlled so traffic does not necessarily come to a full stop. Therefore, pedestrians may be hesitant to use the cross walk at first.
Pedestrians have fewer conflict points than at other intersections. Pedestrians are responsible for judging their crossing opportunities. This requires more alertness and may be considered an advantage.	May be unsettling to the pedestrian, depending on age, mobility, visual impairments, and ability to judge gaps in traffic.
The splitter island gore allows pedestrians to resolve conflicts with entering and exiting vehicles separately and simplifies the task of crossing the roadway. Crossing is often accomplished with less wait than at signalized intersections.	Pedestrians at first glance may have to adjust to the operation of a roundabout. Part of this adjustment includes the crosswalk location, which is behind the first stopped vehicle or approximately 20 feet from the yield point.

Choosing the appropriate crossing location for pedestrians is a delicate balance between their safety and convenience, and operation of the roundabout. Pedestrians want crossing locations as close to the intersection as possible to minimize out-of-direction travel. The further the crossing is from the roundabout, the more likely that pedestrians may choose a shorter route that may put them in greater danger. Both crossing location and crossing distance are important. Minimize crossing distance to reduce exposure to pedestrian-vehicle conflicts.

The continual movement of traffic, and the inability of some pedestrians to judge gaps in an oncoming travel stream, reduces the perception of safety for pedestrians at roundabouts. This is especially true of children, the elderly or the disabled. These types of pedestrians generally prefer larger gaps in the traffic stream and walk at slower speeds than other pedestrians. In recognition of pedestrians with disabilities, pedestrian crossings at roundabouts should be designed to comply with Americans with Disabilities Act (ADA) mandated accessibility standards. Refer to the following guides for further information:

- FDM 11-26-35.5.13, for non-motorized users
- NCHRP 672, Chapter 6, §8.1
- NCHRP 672, Chapter 7, §5.3
- MUTCD, §3B.18
- Wisconsin MUTCD (WMUTCD), 3B.18

The pedestrian hybrid beacon (also commonly referred to as High-Intensity Activated Crosswalk or HAWK) may be considered for installation at roundabouts where there is an identified need to facilitate pedestrian crossings, such as accommodating blind or low-vision pedestrians. Contact the regional traffic operations unit and the Bureau of Traffic Operations if considering the pedestrian hybrid beacon to determine if appropriate and to complete a permit. A factor for installation may be the distance the device is set back from the entrance and installed upstream from the exit. At this time, the guidance for set back at the entrance may be up to165 feet in advance of the yield line, and the distance upstream from the theoretical exit (end of the splitter island) may also be up to165 feet.

10.1.2 Bicyclists

The experience in other countries with bicyclists at roundabouts has been mixed with regard to safety. The Insurance Institute for Highway Safety reports that roundabouts provide a 10 percent reduction in bicycle crashes at 24 signalized intersections that were converted to roundabouts in the U.S. Multilane entry roundabouts may be more problematic than single lane entries.

The complexity of vehicle interactions within a roundabout could leave a cyclist vulnerable, and for this reason, designated bike lane markings within the circulatory roadway shall not be used (WMUTCD, 9C.04). Effective designs that constrain motorized vehicles to speeds more compatible with bicycle speeds, around 15 - 20 mph, are much safer for bicyclists.

The operation of a bicycle through a roundabout presents challenges to the bicyclist similar to that of traditional signalized intersections especially for turning movements. As with pedestrians, one of the difficulties in accommodating bicyclists is their wide range of skills and comfort levels. While experienced bicyclists may have no difficulty maneuvering through a roundabout, less experienced bicyclists may have difficulty and discomfort mixing with vehicles and may feel safer on a roundabout sidepath.

Design features such as proper entry curvature and entry width help slow traffic entering the roundabout. Providing a ramp from the roadway to a roundabout sidepath or shared-use path prior to the intersection allows

a bicyclist to exit the roadway and proceed around the intersection safely through the use of crosswalks.

Bicyclists are often less visible and therefore more vulnerable when merging into and diverging from multilane roundabouts. Therefore, it is recommended that a wider shared-use pedestrian-bicycle path, separate from the circulatory roadway, be built where bicycle use is expected. While this will likely be more comfortable for the casual bicyclist, the experienced commuter bicyclist will be slowed down by having to cross as a pedestrian at the cross walk and may choose to continue to traverse a multilane roundabout as a vehicle. Refer to FDM 11-26-30.5.13 for design guidance.

10.2 Transit, Large Vehicle, Oversize Vehicles and Emergency Vehicle Considerations

10.2.1 Transit

Transit considerations at roundabouts are similar to those for any other intersection configuration. A properly designed roundabout will readily accommodate buses. For rider comfort, transit vehicles should not have to use the truck apron.

Bus stops on the far side are preferred and should be constructed with pull-outs. They should be located beyond the pedestrian crossing to improve visibility of pedestrians to other exiting vehicles. Far-side stops result in the crosswalk being behind the bus, which provides for better sight lines for vehicles exiting the roundabout to pedestrians and keeps bus patrons from blocking the progress of the bus when they cross the street.

The use of bus pull-outs has some trade-offs to consider. A positive feature of a bus pullout is that it reduces the likelihood of queuing behind the bus into the roundabout. A possible negative feature is that a bus pullout may create sight line challenges for the bus driver to see vehicles approaching from behind when attempting to merge into traffic. It may also be possible at multilane roundabouts in slow-speed urban environments to include a bus stop without a bus pullout immediately after the crosswalk, as exiting traffic has an opportunity to pass the waiting bus. In a traffic-calmed environment, or close to a school, it may be appropriate to locate the bus stop at a position that prevents other vehicles from passing the bus while it is stopped.

If a bus stop must be located upstream of the roundabout (near side), it should be placed far enough away from the splitter island, such that a vehicle overtaking the stationary bus has adequate space. If the approach is a single lane and capacity is not an issue, the bus stop could be placed at the pedestrian crossing. Nearside stops provide the advantage of having a potentially slower speed environment where vehicles are slowing down, compared to a far-side location where vehicles may be accelerating upon exiting the roundabout. Nearside stops are not recommended for entries with more than one lane because vehicles in the lane next to the bus may not see pedestrians.

The decisions in regard to transit stop location must be coordinated with the local transit authority.

10.2.2 Legal Large Vehicles

Design roundabouts for the largest vehicle that is anticipated to use the roundabout on a regular basis. All roundabouts on the State Highway system must accommodate a WB-65 design vehicle, which is the largest vehicle allowed on the State Highway system without a permit (legal large vehicle). Refer to FDM 11-25 and FDM 11-25 Attachment 2.1 for description of OSOW-MT design vehicles and their inventories. Refer to FDM 11-25 Table 2.1 for required intersection design vehicle checks for various trucking route scenarios. Designing a roundabout for a large legal semi to stay in-lane at entry and within the roundabout presents challenges such as the possibility of:

- A larger diameter
- Wider entries
- Wider circulating lanes
- Increased right-of-way needs
- Increases in certain types of crashes
- Other unique design features

In rare cases, roundabouts have been designed with a gated bypass roadway to accommodate turns.

Load shifting may be problematic for the contents of any vehicle while navigating a turning maneuver. Load shifting is a common concern for liquid or semi-liquid loads where the weight of the load may shift in a manner to exacerbate overturning. It is not uncommon for a vehicle with a high center of gravity to overturn when navigating a turn at speeds that exceed the laws of mechanics. A roundabout is designed to minimize load-shifting problems with larger vehicles however speed is major factor related to overturning. Problems such as minimal entry deflection may lead to high entry speeds, long tangents leading into tight curves, sharp turns at exits, excessive cross slopes, and adverse cross slopes have been the principle causes of load shifting. See FDM 11-26-30.5 for geometric design of roundabouts.

10.2.3 Permitted Oversized Overweight (OSOW) Vehicles

During the preliminary design, check with local officials and the public to determine if there are any special OSOW vehicles that regularly use the route and refer to the WisDOT OSOW vehicle inventory in FDM 11-25 Attachment 2.1. Coordinate OSOW Truck Route (OSOW-TR) and routing activities with the regional freight operations engineer.

Review the truck guidance provided in FDM 11-25-1.4 and FDM 11-25-2, which includes additional information related to truck routes, the OSOW-TR and intersection design guidance. The Department produced a map showing designated state and federal truck routes, and the OSOW-TR in Wisconsin which is available on the web, see the link in FDM 11-25-1. This map may experience updates and changes therefore use the most current on-line version.

It is becoming somewhat common to widen the truck apron along the sides to accommodate OSOW vehicle through movements. Additional pavement (behind a mountable curb) may also be provided along the right side of the entries to accommodate wheel off-tracking. Sign posts may also have to be mounted in removable sleeves to provide additional lateral space for OSOW vehicles (see FDM 11-26-35.1.12).

10.2.4 Emergency Vehicles

Emergency vehicles passing through a roundabout encounter the same problem as other large vehicles and may require the use of the truck apron. On emergency response routes, compare the delay for the relevant movements with alternative intersection types and controls.

Roundabouts provide the benefit of lower vehicle speeds, which may make them safer for emergency vehicles to negotiate than conventional intersections.

The Wisconsin Motorist's Handbook provides information on what to do when the driver encounters an emergency vehicle. The driver must yield the right-of-way for emergency vehicles using a siren, air horn or a red or blue flashing light. The driver in the circulatory roadway should exit the roundabout before pulling over. Emergency vehicles will typically find the safest and clearest path to get through an intersection. This may include driving the emergency vehicle, with caution and with lights and siren on, in the opposing lane(s) or however the operator sees as the most desirable alternative path.

10.99 References

[1] NCHRP 672, Roundabouts: An Informational Guide, Second Edition

FDM 11-26-15 Agency & Public Coordination *August 15, 2019*

15.1 Public Meetings

Public meetings provide an excellent opportunity to bring the public into the design process. It is generally desirable to take the 30% preliminary plans of all feasible alternatives on an equal basis to a public meeting and explain that a roundabout appears to be a reasonable alternative. Inform the public that no preference to any alternative is indicated at that stage, but that input to all alternatives is being gathered. Try to be as specific as possible about the real estate impacts, access impacts and anticipated operations (LOS) between the various alternatives. At this level of design, it may be important to let the public know that you do not have all the answers about the various impacts. Roundabouts are a new form of intersection control that most people are not familiar with. An effective education and communication method applicable to some projects with roundabouts includes scheduling a specific time at each PIM of approximately 10-20 minutes to explain the following:

- The project time-line
- Source(s) of funding
- Concept of roundabouts
- Why the Department has included the roundabout as an alternative
- Construction duration and possible detours or road closures
- Illustrations of how pedestrians, bicyclists, and vehicles should travel through the roundabout
- Holding an open house and public information "exchange" meetings, and attending village and town board meetings or local service organizational meetings are good formats for education and consensus building

After the initial public meeting, a screening evaluation accounting for public support can be completed. Refer to FDM 11-25-3. At the next public meeting, the preferred alternative can then be presented.

15.2 Public Outreach Resources & Methods

The success or failure of a project can often be attributed to how well the Department included the public in its development. This can be particularly true when introducing the modern roundabout due to its confusion with

past circular intersections. There are excellent resources to assist the designer in explaining roundabouts to the public and to help educate drivers:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/design.aspx

Typically, in the project planning process, alternatives are considered. The alternatives generally include traffic signal, stop sign, or roundabout control; some of which are familiar to drivers and pedestrians. Presenting a comparison of traffic operations and safety between alternatives is a good way to introduce roundabouts. It is essential to inform the public of the planning process that led to the decision favoring a roundabout as the preferred traffic control. A traceable transparent planning process engenders trust and validates the process of wise investment in infrastructure. Designers are encouraged to generate project-specific roundabout outreach materials on their region's web site. Coordination of this effort must be through the Central Office (IT) coordinator and the web site content coordinator.

The common dilemmas for most agencies that want to start using roundabouts are:

- Recognized public perception of roundabouts vs. their proven performance
- Driver education: way-finding and lane choice
- Pedestrian perception of safety vs. proven conditions
- Bicyclist education
- Permitted trucking (typical large trucks)

Pitfalls in the initial push for roundabouts can be avoided by developing detailed components of project outreach resources for internal (local agency) and externally (public outreach) early and continuously. A public acceptance and education campaign is critical to the successful implementation of roundabouts at the State level and for local communities. A successful project oriented public outreach campaign involves assembling a collection of educational and acceptance resources of a general nature. Many of these are readily available through the department's website:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/design.aspx

but some require adaptation to the project location and context. Examples of the kinds of resources that should be collected and distributed through various media include:

- Case studies
- Testimonials
- National and Wisconsin-specific statistics
- How-to videos
- Web-cam
- Driver training
- Website
- Brochures
- Talking points/discussion bulletins for legislators and staff to respond to calls
- Vulnerable user training materials

A strategy to apply these components requires starting with internal staff (planning, design and maintenance operations); State legislators; District Attorney, State Patrol; then moving to external stakeholders, e.g. interest groups, trucking associations and mobility advocacy groups. Finally, once a consensus is reached with internal and external stakeholders a general public meeting or outreach contact can be arranged.

Prior to any general public outreach, a local officials meeting should be held with local council members, police and fire services, senior staff, and maintenance operations staff. The general education process is exercised with this group and the project specific presentation of the engineering study that led to the choice of a roundabout as an alternative control is made. A consensus must be the goal of the local officials meeting in order that the subsequent public contact, e.g. open house goes smoothly with upper and lower tier agency agreement on why the use of a roundabout and how the project will be implemented, including proposed education for the locally affected.

Preparation for the local project public contact requires development of context specific education and outreach components. An inventory of resources that have proven effective for local project outreach is as follows:

- Scale model (1:87, 1 inch = 7.25 feet) of the layout accompanied by scale model trucks and cars
- Animation/simulation of the expected operation of the roundabout and possibly a comparison to the alternative
- Renderings or visualizations
- A project location brochure

- How-to driver, pedestrian and bicycle user resources
- Talking points bulletins for local councilors that give a summary of the planning process, traces the results of studies and documents funding sources, schedule and staging of construction

15.99 References

[1] National Safety Council. Estimating the Costs of Unintentional Injuries, 2008. National Safety Council Website:

www.nsc.org/news_resources/injury_and_death_statistics/Pages/EstimatingtheCostsofUnintentionalInjuries.aspx

[2] Boardman, A., Greenberg, D., Vining, A., and Weimer, D. Cost Benefit Analysis: Concepts and Practice. Prentice Hall; 3rd Edition, 2005.

[3] Gómez-Ibáñez, J. A., Tye, W. B., and Winston, C. Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Mayer. Brookings Institution Press, 1999

FDM 11-26-17 System Considerations *August 15, 2019*

17.1 System Considerations

Roundabouts may need to fit into a network of intersections with the traffic control functions of a roundabout supporting the function of nearby intersections and vice versa. Because the design of each roundabout generally follows the principles of isolated roundabout design, this guidance is at a conceptual and strategic level and generally complements the planning of isolated roundabouts. In many cases, site-specific issues will determine the appropriate roundabout design elements. Closely spaced roundabouts are characterized by the operations of one roundabout having an impact on the operations of an adjacent roundabout and may have overhead lane signs and spiral designs with additional lanes for lane balance and lane continuity issues that arise with closely spaced roundabouts in a series.

17.2 Adjacent Intersections and Highway Segments and Coordinated Signal Systems

It is generally undesirable to have a roundabout located near a signalized intersection. A strategic level traffic assessment of system conditions of a series of roundabouts analysis is needed to determine how appropriate it is to locate a roundabout within a coordinated signal network. There may be situations where an intersection within the coordinated signal system requires a very long cycle which is caused by high side road traffic or large percentage of turning movements and is dictating operations and reducing the overall efficiency for the coordinated system. On rare instances, replacing a signalized intersection with a roundabout may allow for the system to be split into two systems thus improving the efficiency of both halves while also improving the efficiency of the entire roadway segment. A traffic analysis is needed to evaluate each specific location.

17.3 Roundabouts in an Arterial Network

In order to understand how roundabouts operate within a roadway system, it is important to understand their fundamental arrival and departure characteristics and how they may interact with other intersections and highway features. Lane use and lane balance on an approach can vary from ideal conditions where roundabouts are in a system and at times closely spaced. Sensitivity testing of alternative lane use patterns and lane designation alternatives in geometric design is necessary. Simulation of traffic patterns using micro simulation software is recommended for roundabouts being treated as a system.

17.3.1 Planned Network, Access Management

Rather than thinking of roundabouts as an isolated intersection or replacement for signalization, identify likely network improvements early in the planning process. This is consistent with encouraging public and other stakeholder interaction to prepare or update local comprehensive or corridor plans with circulation elements. Project planning and design are likely to be more successful when they are part of a larger local planning process. Then, land-use and transportation relationships can be identified, and future decisions related to both.

Roundabouts may be integral elements in village, town, and city circulation plans with multiple objectives of improving circulation, safety, pedestrian and bicycle mobility, and access management. Roundabouts rely on the slowing of vehicles to process traffic efficiently and safely which results in a secondary feature of “calming” traffic. It can be expected that local studies and plans will be a source of requests for roundabout studies, projects, and coordination on State arterials. A potential use of arterial roundabouts is to function as gateways or entries to denser development, such as villages or towns, to indicate to drivers the need to reduce speed for upcoming conflicts including turning movements and pedestrian crossings.

Retrofit of suburban commercial strip development to accomplish access management objectives of minimizing conflicts can be a particularly good application for roundabouts. Raised medians are often designed for State arterials to minimize left turn conflicts; and roundabouts accommodate U-turns. Left-turn exits from driveways onto an arterial that may currently experience long delays and require two-stage left-turn movements could be replaced with a simpler right turn, followed by a U-turn at the next roundabout. Again, a package of

improvements with driveway consolidation, reverse frontage, and interconnected parking lots, should be planned and designed with close local collaboration. Also, a roundabout can provide easy access to corner properties from all directions.

17.3.2 Platooned Arrivals on Approaches

Vehicles exiting a signalized intersection tend to be grouped into platoons. Platoons, however, tend to disperse as they move down-stream. Roundabout performance is affected by its proximity to signalized intersections and the resulting distribution of entering traffic. If a signalized intersection is very close to the roundabout, it causes vehicles to arrive at the roundabout in closely spaced platoons. The volume of the arriving platoon and the capacity of the roundabout will dictate the ability of the roundabout to process the platoon. Analyze these situations carefully to achieve a proper design for the situation. Discuss proposed roundabout locations with the regional traffic section staff.

17.3.3 Roundabout Departure Pattern

Traffic leaving a roundabout tends to be more random than for other types of intersection control. Downstream gaps are shorter but more frequent as compared to a signal. The slower approach and departing speeds along with the gaps allow for ingress/egress from nearby driveways or side streets. The slowing effects are diminished as vehicles proceed further downstream. However, the gaps created at the roundabout are carried downstream and vehicles tend to disperse again providing opportunities for side street traffic to enter the main line roadway.

Sometimes traffic on a side street can find it difficult to enter a main street at an un-signalized intersection. This happens when the side street is located between two signalized intersections and traffic platoons from the signalized intersections arrive at the side street intersection at approximately the same time. If a roundabout replaced one of these signalized intersections, then its traffic platoons would be dispersed, and it may be easier for traffic on the side street to enter the main street. Alternatively, when signals are well coordinated they may provide gaps at nearby intersections and mid-block for opportunities to access the main line.

If a roundabout is used in a network of coordinated signalized intersections, then it may be difficult to maintain the closely packed platoons required. If a tightly packed platoon approached a roundabout, it could proceed through the roundabout as long as there was no circulating traffic or traffic upstream from the left. Only one circulating vehicle would result in the platoon breaking down. Hence, this hybrid use of roundabouts in a coordinated signalized network needs to be evaluated carefully.

Another circumstance in which a roundabout may be advantageous is as an alternative to signal control at a critical signalized intersection within a coordinated network. Such intersections are the bottlenecks and usually determine the required cycle length or are placed at a signal system boundary to operate in isolated actuated mode to minimize their effect on the rest of the surrounding system. If a roundabout can be designed to operate within its capacity, it may allow a lowering of the system cycle length with resultant benefits to delays and queues at other intersections.

17.4 Closely Spaced Roundabouts

It is sometimes desirable to consider the operation of two or more roundabouts near each other. Closely spaced roundabouts can potentially reduce queues and balance traffic flows. The spacing between any two roundabouts is considered closely spaced if they are less than 1,000 feet from center to center (see FDM 11-26-30.5.13). They also can accommodate a wide range of access, both public and private. In any case, the expected queue length at each roundabout becomes important. Compute the expected queues for each approach to check that sufficient queuing space is provided for vehicles between the roundabouts. If there is insufficient space, then drivers may occasionally queue into the upstream roundabout, potentially causing a reduction from the typical operations. However, the roundabout pair can be designed to minimize queuing between the roundabouts by limiting the capacity of the inbound approaches.

Closely spaced roundabouts may improve safety and accessibility to business or residential access or side streets by slowing the traffic on the major road. Drivers may be reluctant to accelerate to the expected speed on the arterial if they are also required to slow again for the next close roundabout. This may benefit nearby residents.

For additional information, see NCHRP 672, §6.9.

17.5 Roundabout Interchange Ramp Terminals

Freeway ramp junctions with arterial roads are potential candidates for roundabout intersection treatment. This is especially true if the subject interchange typically has a high proportion of left-turn flows from the off-ramps and to the on-ramps during certain peak periods, combined with limited queue storage space on the bridge crossing, off-ramps, or arterial approaches. In such circumstances, roundabouts operating within their capacity are particularly amenable to solving these problems when compared with other forms of intersection control. Refer to FDM 11-25 and FDM 11-25 Attachment 2.1 for OSOW vehicle inventories and FDM 11-25 Table 2.1 for required intersection OSOW design vehicle checks, including at the junction of OSOW truck routes.

Occasionally, an OSOW vehicle may have to bypass a bridge by taking the off-ramp and making a through movement and entering the on-ramp (a.k.a. “ramp-on/ramp-off”). Design the median island to accommodate the OSOW through movement. Refer to FDM 11-30-1 for additional guidance on interchange design.

The benefits and costs associated with this type of interchange also follow those for a single roundabout. Some potential benefits of roundabout interchanges are:

- The queue length on the off-ramps may be less than at a signalized intersection. In almost all cases, if the roundabout would operate below capacity, the performance of the on-ramp is likely to be better than if the interchange is signalized.
- The intersection site distance is much less than what it is for other intersection treatments.
- The headway between vehicles leaving the roundabout along the on-ramp is more random than when signalized intersections are used. This more random ramp traffic allows for smoother merging behavior onto the freeway and a slightly higher performance at the freeway merge area similar to ramp metering.

There are no unique design parameters for roundabout interchanges. They are only constrained by the physical space available to the designer and the configuration selected. Several geometric configurations for ramp terminals with roundabouts exist:

- The raindrop form, which does not allow for full circulation around the center island, can be useful if grades are a design issue since they remove a potential cross-slope constraint on the missing circulatory road segments. However, raindrop shapes lack the operational consistency, because one entry will not be required to yield to any traffic. Because of this, an undesirable increase in speed may occur. If an additional road connects to the ramp terminal, the raindrop form should not be used.
- A single-point diamond interchange incorporates a large-diameter roundabout centered either over or under the freeway. While remaining somewhat compact, this solution may not be cost-effective, especially for retro-fit locations, as existing overpass structures may not be adequately sized or oriented.
- Dual roundabouts are the common choice for interchange locations. This design may delay or eliminate the need for overpass reconstruction, while also allowing for easier future roundabout expansion. It offers the greatest flexibility in location of the roundabouts while improving ramp geometry and minimizing the need for retaining walls. It may require additional right of way to be acquired, as this design typically requires the most space.

For additional information, see NCHRP 672, §6.10.

17.6 Traffic Signals at Roundabouts

Roundabouts typically are not planned to include metering or signalization. The “pedestrian hybrid beacon” sometimes referred to as the HAWK crosswalk signal, is discussed in FDM 11-26-10.1.1.

For additional information, see NCHRP 672, §7.5.

17.7 At-Grade Rail Crossings

Locating any intersection near an at-grade railroad crossing is generally discouraged. However, due to necessity, intersections are sometimes located near railroad grade crossings. When considering locating a roundabout within 1000 feet of a railroad, contact the region railroad coordinator early in the process. It is preferable to cross one of the legs of a roundabout and leaving a typical distance of at least 100 feet from the center of the track to the yield line. Treatment should follow the recommendations of the Wisconsin MUTCD whenever possible. Consider allowing the railroad track to pass directly through the circle center of the roundabout rather than through another portion of the circular roadway if the at-grade crossing is not on one of the legs. Also, consider the design year traffic on the roadway, the number of trains per day, speed of trains, length of trains, type of crossing warning devices, and anticipated length of vehicular queues when evaluating the intersection control needed in close proximity to the railroad.

Refer to FDM 17-1-1 for additional railway information. Expert assistance is required to address rail pre-emption requirements of roundabouts in close proximity.

17.99 References

[1] NCHRP 672, Roundabouts: An Informational Guide, Second Edition, Chapter 7, Section 6.

FDM 11-26-20 Operations

August 17, 2020

20.1 Operational Analysis References and Methods

The growing number of roundabouts in the United States (US) has led to an increase in national and local research of roundabout operations and capacity. The National Cooperative Highway Research Program

(NCHRP) published the first major study in the US on roundabout operations in the 2007 NCHRP Report 572[1]. The findings of the NCHRP Report 572 reflect 2003 data from approximately 300 roundabouts. A Federal Highway Administration (FHWA) sponsored project [5], completed in 2015, built upon the methodologies of NCHRP Report 572[1]. The 2015 FHWA report [5] incorporates 2012 data collection efforts and significantly increases the number of useable data points as compared to the NCHRP Report 572 [1].

This research found that driver behavior and the number of entry lanes has the largest effect on the performance of US roundabouts. The capacity and operations of US roundabouts is more sensitive to the interaction between drivers entering and circulating the roundabout and the number of entry lanes than the detailed geometric parameters (e.g. lane width, entry radius, phi angle, and inscribed circle diameter) used in the Australian [2] and UK models [3]. Although important to ensure the safety and efficiency of travel through a roundabout, the fine details of geometric design are secondary and less significant than variations in driver behavior when analyzing capacity at roundabouts in the US.

The Highway Capacity Manual 6th Edition (HCM6), Chapter 22, provides analytical procedures for the analysis of planned and existing roundabout. The 2015 FHWA report [5] provides the foundation for the HCM6, Chapter 22 roundabout methodology. The methods of the HCM allow traffic engineers and designers to assess the operational performance of a roundabout, given information about the demand levels for motor vehicles, pedestrians and bicycles. The following sections provide guidance on operational analysis for Wisconsin DOT projects considering the installation of a new roundabout or evaluating the capacity of an existing roundabout.

20.2 Roundabout Operation

A roundabout brings together conflicting traffic streams at reduced speeds, allowing the streams to cross paths safely, traverse the roundabout, and exit. Modern roundabouts do not have merging or weaving between conflicting traffic streams. Compactness of circle size and geometric speed control make it possible to establish priority to circulating traffic. The geometric elements, signage and pavement markings of the roundabout reinforce the rule of circulating traffic priority and provide guidance to drivers approaching, entering, and traveling through a roundabout.

Gap acceptance (i.e., headway) behavior determines the operation of vehicular traffic at a roundabout. Drivers at each approach look for and accept gaps in circulating traffic. The low speeds of a properly designed roundabout facilitate this gap acceptance process. The width of the approach roadway, the curvature of the roadway, and the volume of traffic present on a given approach govern this speed. As drivers approach the yield point, they must first yield to pedestrians and then to conflicting vehicles in the circulatory roadway. The size of the inscribed circle affects the radius of the driver's path, which in turn determines the speed at which drivers travel in the circulatory roadway.

20.2.1 Planning Level Analysis and Space Requirements

The inscribed circle diameter needed for a roundabout is one of the most critical space requirements when considering impacts to right of way, costs, design vehicle and others. The following table gives general inscribed circle diameters and daily service volumes for the different types of roundabouts. The typical daily service volumes ranges described in Table 20.1 are derived from Exhibit 3-12 in the NCHRP 672 report and are dependent on the left turn percentage of the daily service volume. For a planning level analysis, it may be appropriate to assume that three-leg roundabouts will have a capacity that is 75% of the service volumes shown in Exhibit 3-12 of the NCHRP 672 report for a planning level analysis. Use Table 20.1 for inscribed circle diameter values to help in the initial steps of considering a roundabout as a feasible alternative. Diameters will vary, and in some situations, may fall outside these typical ranges.

Table 20.1 Typical Inscribed Circle Diameters and Estimated Daily Service Volumes

Roundabout Type	Typical Inscribed Circle Diameter[1]	Typical Daily Service Volume[2,3] (vpd) 4-leg roundabouts
Single-Lane	120 -160 ft *(35 – 50 m)*	less than 25,000
Multilane (2-lane entry)	160 - 215 ft *(50 – 65 m)*	25,000 to 45,000
Multilane (3 lane entry)	215 - 275 ft *(65 – 85 m)*	45,000 or more

[1] For additional guidance based on design vehicle see Exhibit 6-9 Inscribed Circle Diameter Ranges in NCHRP Report 672

[2] Capacities vary substantially depending on entering traffic volumes and turning movements.

[3] Consult with Exhibit 3-12, “NCHRP Report 672, Roundabouts: An Informational Guide, Second

Edition" to estimate the ADT for a specific left-turn percentage.

The capacity of each entry to a roundabout is the maximum rate at which vehicles can reasonably be expected to enter the roundabout during a given time period under prevailing traffic and geometric conditions. An operational analysis considers entering and circulating traffic flow rates defined for the morning and evening peak periods for each lane at a roundabout. Analysis of the peak hour period is critical to assess the level of performance at each approach and the roundabout as a whole.

For a properly designed roundabout, the entry area is the relevant point for capacity analysis. The approach capacity is the capacity provided at the yield point. The interaction between entering and circulating streams of traffic, the basic number of entry and circulating lanes and to a lesser degree by the geometric parameters, signage and pavement markings that control entry and circulating speed determine approach capacity.

The maximum flow rate that a roundabout entry can accommodate depends on two factors: the circulating flow in the roundabout that conflicts with the entry flow, and the number of entering lanes on the approach to the circulatory roadway. When the circulating flow is low, drivers at the entry can enter the roundabout without significant delay. The larger gaps associated with low circulating flows make it easier for drivers to enter the roundabout and provide the opportunity for more than one vehicle to enter each gap. As the circulating flow increases, the size of the gaps in the circulating flow decreases, thus the rate at which vehicles can enter also decreases.

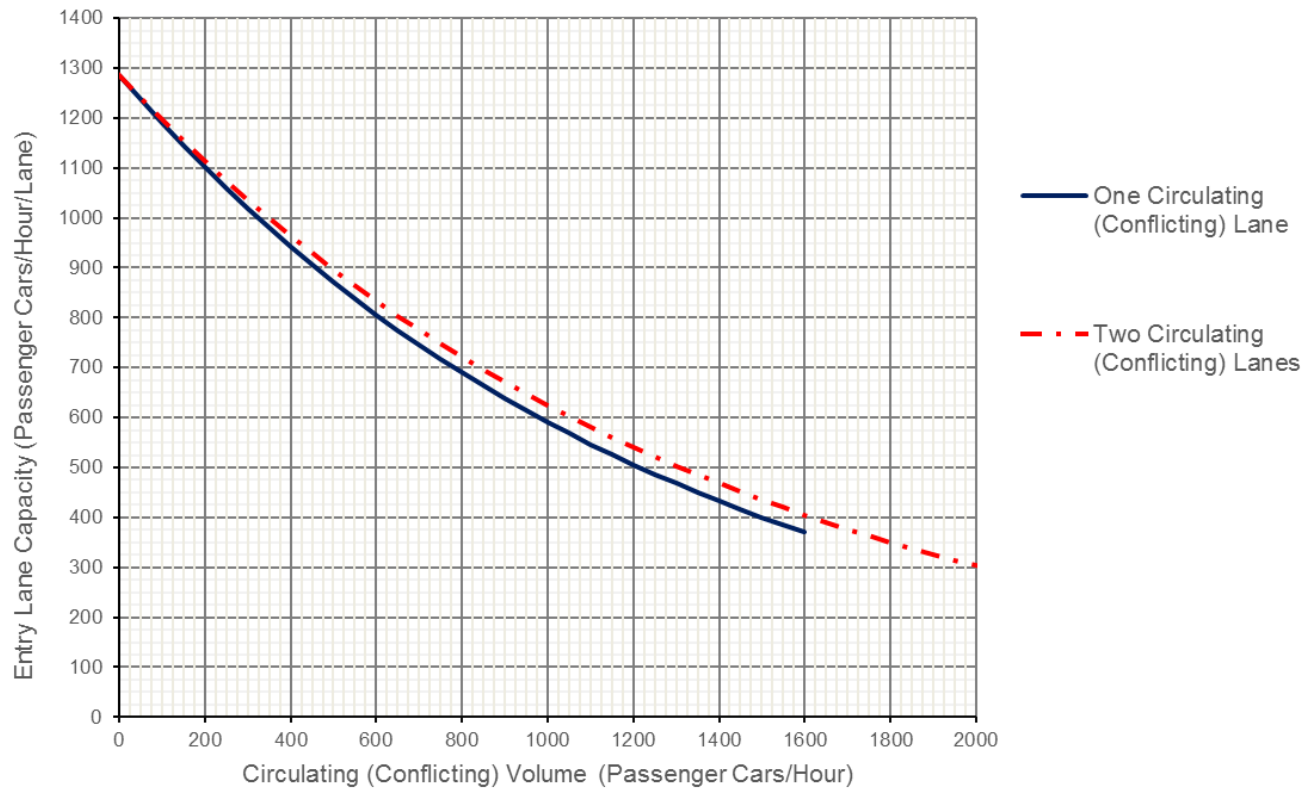
Evaluate each approach leg of the roundabout individually to determine the number of entering lanes that are required based upon the conflicting flow rates. Base the number of lanes within the circulatory roadway on the number of lanes needed to provide lane continuity. More detailed lane assignments and refinements to the lane configurations must be determined through a more formal operational analysis as described later in this section.

On multilane roundabouts, it is important to balance the traffic use of each lane to avoid overloading some lanes while underutilizing other lanes. In addition, poorly designed exits may influence driver behavior and cause lane imbalance and congestion on the opposite leg.

20.2.2 Planning Estimates of Lane Requirements

If existing or projected turning-movement data is available at the planning level, the analyst should estimate the potential lane configurations of the roundabout prior to performing detailed operational analysis. Figure 5.2 shows the capacity curves for one and two-lane roundabouts. WisDOT developed the capacity curves shown in Figure 5.2 based on a 2011 research study, conducted by the University of Wisconsin - Madison Traffic Operations and Safety (TOPS) Laboratory, on the operations of Wisconsin Roundabouts [6]. As shown in Figure 5.2, the capacity of each entry lane of the roundabout is based on the conflicting traffic flow in the circulatory roadway, which comprises the various turning movements from other approaches that pass in front of (and thus conflict with) the subject entry. For planning purposes, the analyst can use the capacity curves shown in Figure 5.2 to identify the potential lane configurations of the roundabout. As an example, for a given circulatory (conflicting) flow rate of 600 passenger cars per hour (pc/h) a one-lane roundabout could accommodate an entry capacity of approximately 810 pc/h/lane while a two-lane roundabout could accommodate an entry capacity of approximately 830 pc/h/lane.

HCM6, Chapter 22 provides additional details on how to approximate capacity and lane requirements for a roundabout, including sample calculations of roundabout volumes, conversion of vehicles per hour (vph) to passenger cars per hour (pc/h), lane use, capacity, and performance measures. Use Figure 5.2 for preliminary estimation of the number of entry and circulatory lanes per approach when considering a roundabout during the scoping phase of the Intersection Control Evaluation (ICE) and during planning studies.



Source: *Comprehensive Evaluation of Wisconsin Roundabouts, Volume 1: Traffic Operations*, Wisconsin TOPS Lab,

***Figure 5.2* WisDOT Roundabout Capacity Curves (for planning purposes) [6]**

20.3 Pedestrian Effects on Entry and Exit Capacity

Pedestrians crossing at a marked crosswalk have priority over entering motor vehicles. As such, pedestrian traffic can have a significant effect on the capacity of a roundabout entry, especially if there are high pedestrian volumes. To approximate the effect of pedestrian traffic, multiply the vehicular capacity by the entry capacity adjustment factor for pedestrians (fped) according to the relationship shown in Exhibit 22-18 and 22-20 of HCM6 Chapter 22 for single-lane and two-lane entry roundabouts, respectively.

Note that the effects of conflicting pedestrians on the approach capacity decrease as conflicting vehicular volumes increase, as entering vehicles become more likely to have to stop regardless of whether pedestrians are present. Consult the HCM for additional guidance on the capacity of pedestrian crossings if the capacity of the crosswalk itself is an issue. A similar effect in capacity may occur at the pedestrian crossing on the roundabout exit.

20.4 Operational Analysis Methodology

As is shown in Figure 20.1, the first steps to roundabout analysis and design are to gather traffic data for the existing intersection and to complete an HCM analysis. The lane configuration selected for typical operations with design year traffic conditions should be the basis of the roundabout design. Typically, a lane configuration for typical operations means that all or most movements operate at LOS D or better with a volume to capacity ratio less than one. See FDM 11-5-3.2 for further discussion on intersection LOS. For further discussion on the typical level of service evaluation, see FDM 11-5-3.5.

If the capacity analysis results in the need for a multi-lane roundabout, in the design year, the analyst should consider an interim layout with fewer circulatory lanes (i.e. 10 to 15 years traffic projection). The interim design should accommodate the future conversion to the ultimate design (e.g., the interim design may provide a large center island diameter which, when reduced, can accommodate additional circulating lane(s) in the future). This approach offers safety and operational advantages during the early years, including reduction in fastest-path maneuvers and a simpler layout that is easier for unfamiliar drivers to navigate. The determination of whether to construct the interim layout should consider the extent to which drivers in the project area already have roundabout driving experience. Additionally, the need to provide an interim layout should consider the level of uncertainty in the traffic forecasts (design-year forecasts often assume full build-out of nearby real estate

development projects, but in many cases those projects are unable to proceed as quickly as anticipated). In all cases, utilities should be cleared, and real estate should be acquired to accommodate the ultimate design.

Supplemental software analysis tools include microsimulation traffic models (see FDM 11-5-3.7.1.4); and three deterministic models SIDRA Standard, Rodel and ARCADY. Depending on the purpose and need of the project, the use of microsimulation may be appropriate for operational analysis that does not fit within the methodological limitations of the HCM (see FDM 11-5-3.7.3.5 and FDM 11-26-20.5 for additional details). Designers may use SIDRA Standard, Rodel, ARCADY or other design-aid tools to refine the roundabout geometric design. Prior to using supplemental design-aid tools, the analyst should first determine the basic lane configuration using the HCM-based operational analysis and any other pertinent considerations. Use of supplemental software tools may also be appropriate for evaluating operations for in-service roundabouts whereby collection of data under capacity conditions are available to calibrate the capacity equations. FDM 11-26-20.5 and FDM 11-26-20.6 discuss the application of supplemental tools in more detail.

Only after the analysis is completed, and the preferred lane configuration determined, should the detailed design of the roundabout begin. Exhibit 22-10 from HCM6 provides an overview of the HCM roundabout analysis. Chapter 22 of the HCM6, starting on page 22-15, provides detailed descriptions and equations for each step. Chapter 33, Roundabouts Supplemental of the HCM6 (Section 3) goes through each of the computational steps for two example problems: one for a single lane roundabout with bypass lanes and one for a multilane roundabout. These steps describe how to calculate the capacity, LOS, and queue for a roundabout by hand. The use of software makes analyzing the operations of a roundabout much quicker. Figure 20.1 provides a diagram illustrating WisDOT's approved method for analyzing roundabouts using HCM guidance with additional detail provided in the following sections.

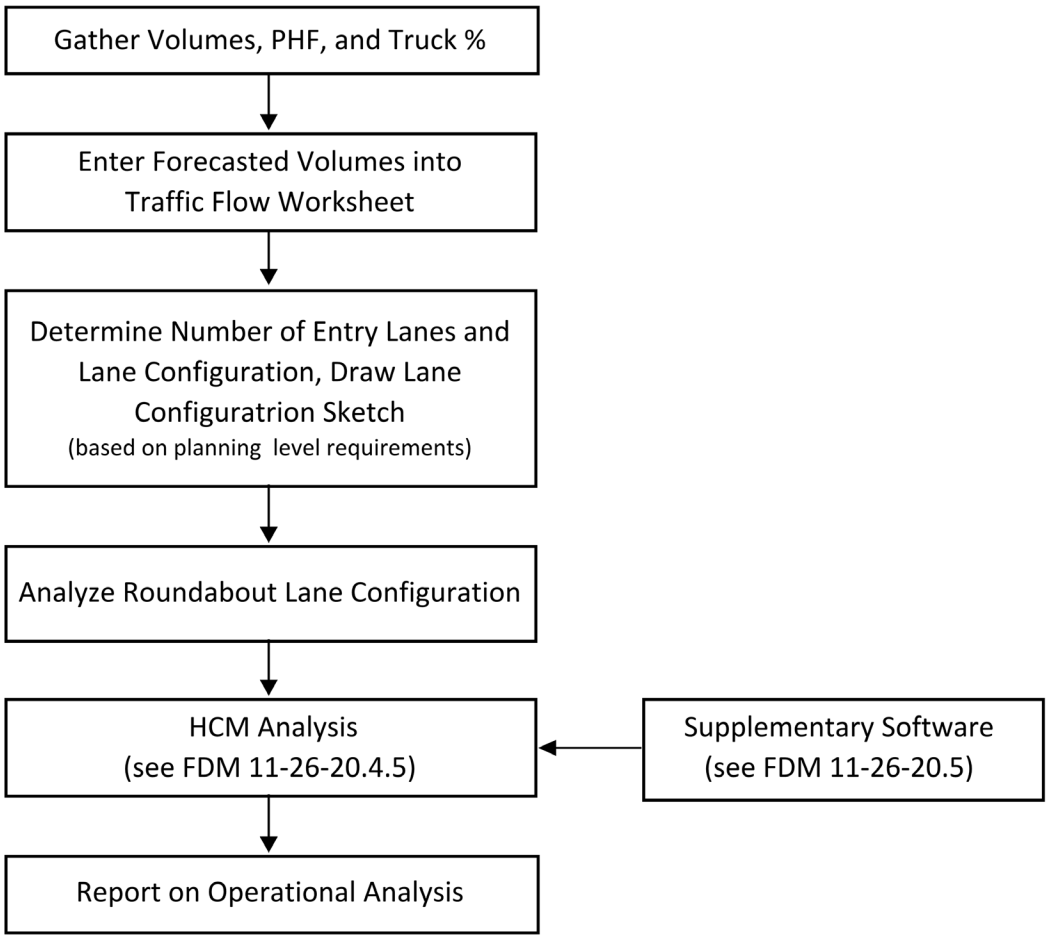


Figure 20.1 WisDOT Approved Method for Analyzing Roundabouts

20.4.1 Gather Traffic Volumes, Peak Hour Factors, and Truck Percentages

Obtain existing turning movement counts for the intersection and establish the peak traffic hours for analysis. Gather turning movement counts for off peak, midday, or special event times as applicable. Note any special lane utilizations or imbalances, especially if the existing intersection is a roundabout. Calculate the peak hour factor for each peak period. Determine percentages of trucks by approach, if present, be sure to include the number and percentage of bicycles and pedestrians, if present.

Submit existing turning movement counts to the Traffic Forecasting Section if required for development of the traffic forecast. See FDM 11-5-2 for more information on traffic forecasting. Consider intermediate design year forecasts in preparation for sensitivity analysis to determine staged improvement or capacity expansion (e.g. one to two lane entries or two to three lane entries).

20.4.2 Enter Forecasted Traffic Volumes into Traffic Flow Worksheet

A volume diagram can be developed using Attachment 20.1 to provide existing peak hour turning volumes (AM, PM, Weekend/Special Event) and design year peak hour turning volumes. Before starting the capacity analysis, a person who is familiar with the site should check the traffic forecasts for reasonableness.

For example, growth rates throughout the intersection should be consistent, unless local factors such as new development are expected to increase specific movements disproportionately. Similarly, the dominant movements in the forecasted volume set should be similar to the existing pattern, unless changes in land use or highway routing are expected. In areas with high commuter traffic, corresponding AM and PM movements should be compared, for example a high westbound left turn movement in the morning is usually accompanied by a high northbound right turn movement in the afternoon.

If the intersection is part of a corridor project, the consistency of forecasts along the corridor should also be reviewed, since the outputs of one intersection are usually the inputs to the next, plus or minus the driveway traffic in between. Attachment 20.1 provides a format for summarizing the traffic volumes at a 3-leg, 4-leg, or interchange ramp roundabout.

20.4.3 Determine Number of Entry Lanes and Lane Configuration, Draw Lane Configuration Sketch

Based on planning level capacity requirements determine how many entry lanes a roundabout would require to serve the traffic demands (see Table 20.1 and FDM 11-26-20.3.1). Determine the entry volumes for each lane of the roundabout approach. Adjust lane volumes based on observed or estimated lane utilization patterns or imbalances, if applicable. If no lane utilization patterns are observed, the HCM6 default values are 47% of entry flow in the left lane and 53% of entry flow in the right lane for left/through and left/through/right and left/through/right-right lane configurations, and 53% in the left lane and 47% in the right lane for left-left/through/right lane configurations.

A lane configuration sketch of the roundabout should accompany the traffic volumes to facilitate the selection of the number of lanes and the lane assignments. This step precedes the roundabout capacity analysis and the layout process and is critical because it affects the geometry. In Figure 20.2, the assessment of lane assignments for the example traffic flows could include three different options. Unless traffic demand for a given approach is indicative of the potential need for an exclusive left turn lane, option 1 is preferred for its simplicity of design and because the configuration should accommodate both peak and off-peak traffic demand. In the example Options 2 and 3 would require spiral geometry and marking treatment for the upstream entry left turn. Additionally, Options 2 and 3 imply a single lane exit for lane continuity of the through movement. These alternatives complicate the design and may influence driver behavior by causing confusion when navigating the circulatory roadway. Figure 20.3 is an example of the roundabout lane-configuration sketch employing Option 1.

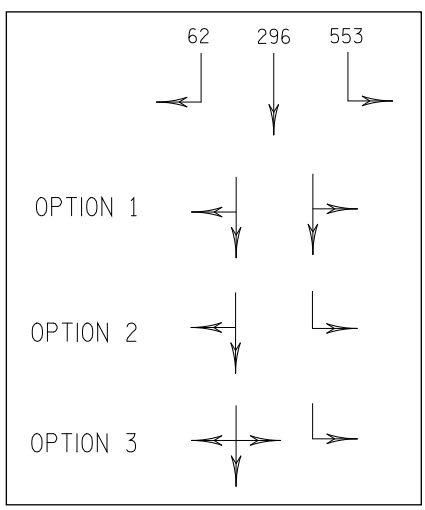


Figure 20.2 Lane Configuration Options

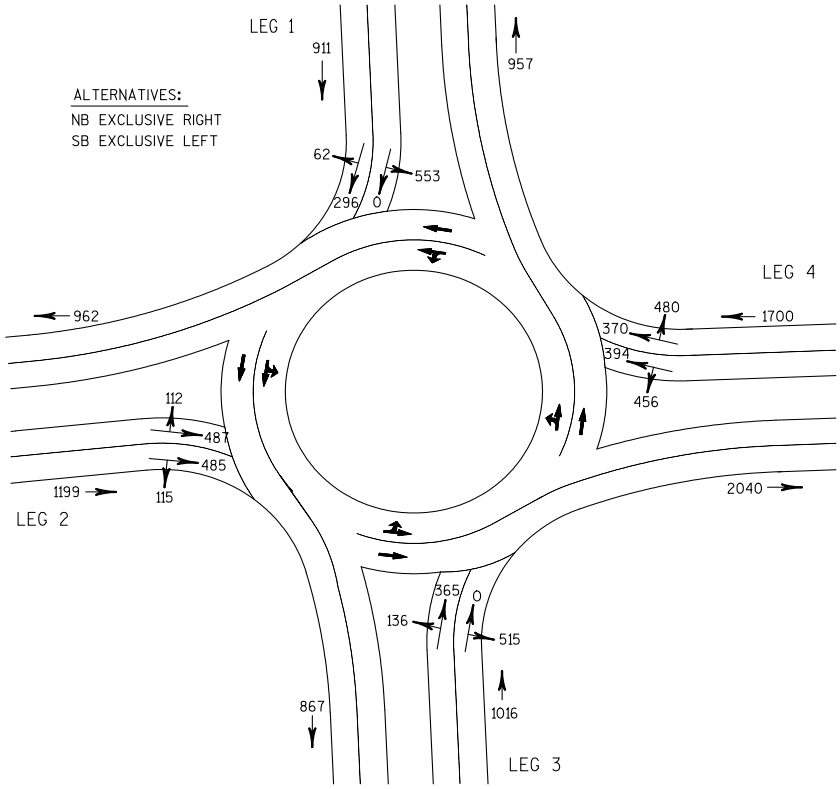


***Figure 20.3** Lane Configuration Sketch*

20.4.4 Analyze Roundabout Lane Configuration

Evaluate the preliminary lane configuration estimated in FDM 11-26-20.4.3 with HCM procedures using one of two WisDOT supported analysis tools: Highway Capacity Software (HCS) or SIDRA Intersection (see FDM 11-5-3.7.1 for the version of HCS and SIDRA Intersection that WisDOT currently supports). Consistent with the limitations of the HCM6, HCS7 is limited to no more than four approaches and two entry lanes with one or more bypass lanes. Partial right turn bypasses are restricted to single lanes. The software requires calibration with the recommended Wisconsin headway values listed in Table 20.3.

SIDRA Intersection can analyze roundabouts with multiple models. When analyzing Wisconsin roundabouts, the analyst shall use the HCM capacity and delay models. The limitations of the HCM methodology on lane configuration has been expanded by SIDRA (U.S. mode) and the analysis can be used for all roundabouts but is specifically required for evaluating roundabouts with three entry lanes, dual partial right turn bypass lanes, or five or more approaches. SIDRA applies the basic HCM procedures and provides essentially the same results HCS. Within SIDRA, there is the option to apply an HCM Roundabout Capacity Model extension to address unbalanced flow conditions. Additionally, SIDRA has an Extra Bunching parameter, that when checked, adjusts the proportion of platooned vehicles in the traffic stream according to the proximity of and level of queuing at an upstream signalized intersection. Prior to utilizing either the unbalanced flow model extension or the extra bunching parameter for operational analysis, the analyst should verify the appropriateness of their use with the regional traffic engineer or BTO-TASU. SIDRA (U.S. HCM6 mode) also requires calibration with the headway values listed in Table 20.3.

Use Table 20.2 as guidance in choosing the most appropriate approved analysis tool to use for the specific roundabout lane configuration under consideration. Refer to FDM 11-26-20.4.5 for additional details on completing the operational analysis.

***Table 20.2* Choosing Appropriate Analysis Tool**

Analysis Tool	Appropriate Situations
HCS	One or two-lane entries, single lane partial bypasses, no more than four approach legs
SIDRA Intersection	One, two or three lane entries, one or two lane partial bypasses, up to 8 approach legs
See FDM 11-5-3.7.1 for the version of HCS and SIDRA Intersection that WisDOT currently supports.	

20.4.5 HCS Analysis

Critical headway (also referred to as 'critical gap') and follow-up headway are the driver behavior parameters that influence the capacity of a roundabout approach and the roundabout as a whole. Critical headway is the smallest gap in circulating traffic that an entering driver would accept to enter the roundabout. Follow-up headway is the time between two successive entering vehicles accepting the same gap in circulating traffic. Figure 20.4 diagrams the concept of critical headway and Figure 20.5 diagrams the concept of follow-up headway.

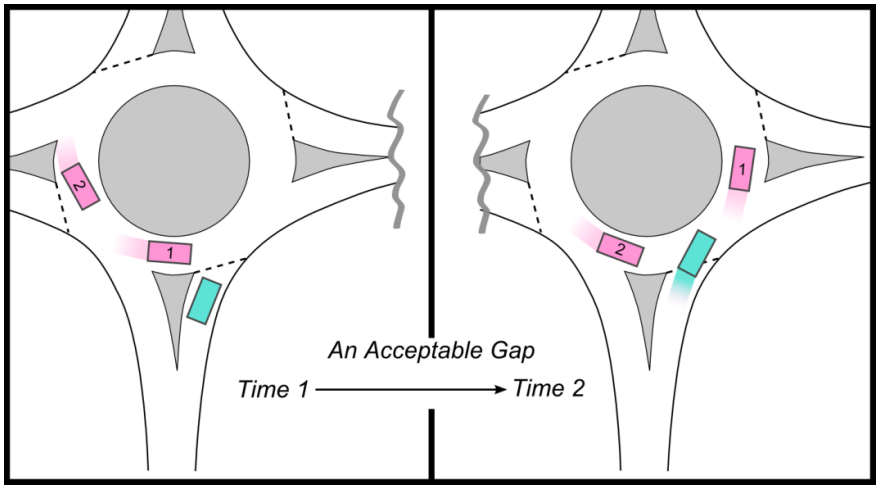


***Figure 20.4* Critical Headway**

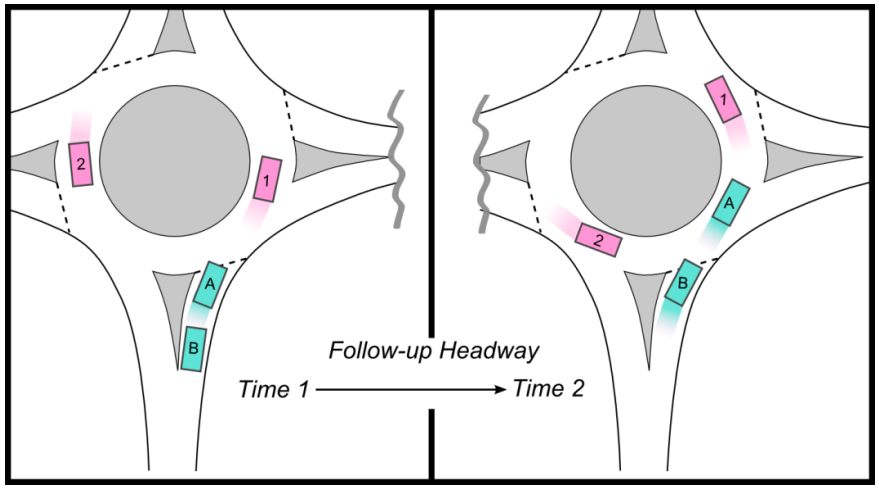


***Figure 20.5* Follow-up Headway**

As part of the NCHRP Report 572 [1] and the 2015 FHWA-sponsored report FHWA-SA-15-070[5], researchers collected and analyzed critical and follow-up headways at several roundabouts across the US. The NCHRP Report 572[1] and FHWA-SA-15-070[5] report reflect 2003 and 2012 data collection efforts, respectively. Both of these research efforts found that an exponential gap-acceptance theory combined with field determined headway values could provide an acceptable empirical capacity equation for estimating the operations of a U.S. roundabout (see HCM6 Chapter 22 and HCM6 Supplemental Chapter 33 for additional details). This method of

analyzing roundabouts is the basis for Wisconsin's driver behavior-based approach to analyzing roundabout operations.

The general form of the capacity equation for a roundabout follows below provided in Equation 20.1 - Equation 20.3:

$$c_{pce} = Ae^{(-Bv_c)} \quad \text{[Equation 20.1]}$$

$$A = \frac{3{,}600}{t_f} \quad \text{[Equation 20.2]}$$

$$B = \frac{t_c - (t_f/2)}{3{,}600} \quad \text{[Equation 20.3]}$$

where

c_{pce} = entry lane capacity, adjusted for heavy vehicles (pc/hr/ln)

V_c = lane capacity, adjusted for heavy vehicles (pc/hr)

t_c = critical headway (s), and

t_f = follow-up headway (s).

Adjusting the critical and follow-up headways allow the capacity equation in Equation 20.1 to be calibrated to reflect local site conditions. The HCM6 provides default capacity equations based on observations of critical and follow-up headways made at US roundabouts in 2012 [5].

In an effort to calibrate the HCM capacity equations to reflect conditions in Wisconsin, in 2011, WisDOT funded a research project conducted by the TOPS Lab at the University of Wisconsin - Madison to observe headways at Wisconsin roundabouts [6]. Table 20.3 lists the recommended headway values and the corresponding parameters A and B that were developed based on the findings of the study. The analyst shall use the values listed in Table 20.3 for roundabout capacity analyses statewide. The values shown in Table 20.3 represent the headway numbers based on Wisconsin research conducted in 2011.

Table 20.3 Recommended Headway Values

Number of Circulating (Conflicting) Lanes	Critical Headway, tc	Follow-up Headway, tf	Parameter A	Parameter B
One	4.2* sec	2.8 sec	1286	0.000778
Two or Three	4.0 sec	2.8 sec	1286	0.000722

* Based on NCHRP 572, not Wisconsin Research

The resulting capacity equations for Wisconsin roundabouts using the headways listed in Table 20.3 follow in Equation 20.4 for roundabout entries with one lane circulating past the entry and Equation 20.5 for roundabout entries with two lanes circulating past the entry. In theory, entries with two lanes circulating past the entry have higher capacities than entries with one lane circulating.

$$c_{e,1,pce} = 1286e^{(-0.000778)v_{c,pce}} \quad \text{[Equation 20.4]}$$

$$c_{e,2,pce} = 1286e^{(-0.000722)v_{c,pce}} \quad \text{[Equation 20.5]}$$

where;

$c_{e,1,pce}$ = entry capacity for one lane conflicting, adjusted for heavy vehicles (pc/hr),
$c_{e,2,pce}$ = entry capacity for two lanes conflicting, adjusted for heavy vehicles (pc/hr), and
$v_{c,pce}$ = conflicting flow rate, total of all lanes, adjusted for heavy vehicles (pc/hr).

The HCM6 includes separate capacity equations for the left lane and the right lane. The capacity equations listed above are appropriate for the left and right lanes of a two-lane entry and for single partial right turn bypass lanes.

In order to calibrate the model within HCS, the analyst will need to enter the headway values (both critical and follow-up) for each travel lane under the Roundabout Traffic Tab. Critical and follow-up headway values shall match the accepted Wisconsin headways listed in Table 20.3. The headway values entered depend on the number of lanes circulating past a given entry. The left lane and right lane of a two-lane entry will have the same headway values. See the HCS Users Guide for additional details on how to modify the critical and follow-up headway values.

To calibrate the model within SIDRA Intersection, the analyst, after entering the intersection geometry, will need to revise the default Parameter A and Parameter B values (located under the Roundabouts - Input - HCM6 Data tab) to reflect the Wisconsin-specific values shown in Table 20.3. Note that both the dominant and subdominant lane of the multi-lane roundabout will have the same Parameter A and B values. See the SIDRA User Guide for additional details on how to modify the Parameter A and Parameter B values.

After obtaining traffic forecasts for the study intersection, the general approach to analyzing, building, and adjusting existing roundabouts begins by establishing the general footprint of a new roundabout.

Following FDM guidance and HCM methodologies, a lane configuration for acceptable operations is determined and the detailed design completed. Existing roundabouts may need to be field adjusted to improve capacity; use of supplemental tools may be appropriate to help determine potential improvements for an existing roundabout. Figure 20.6 provides an overview of the general procedures.

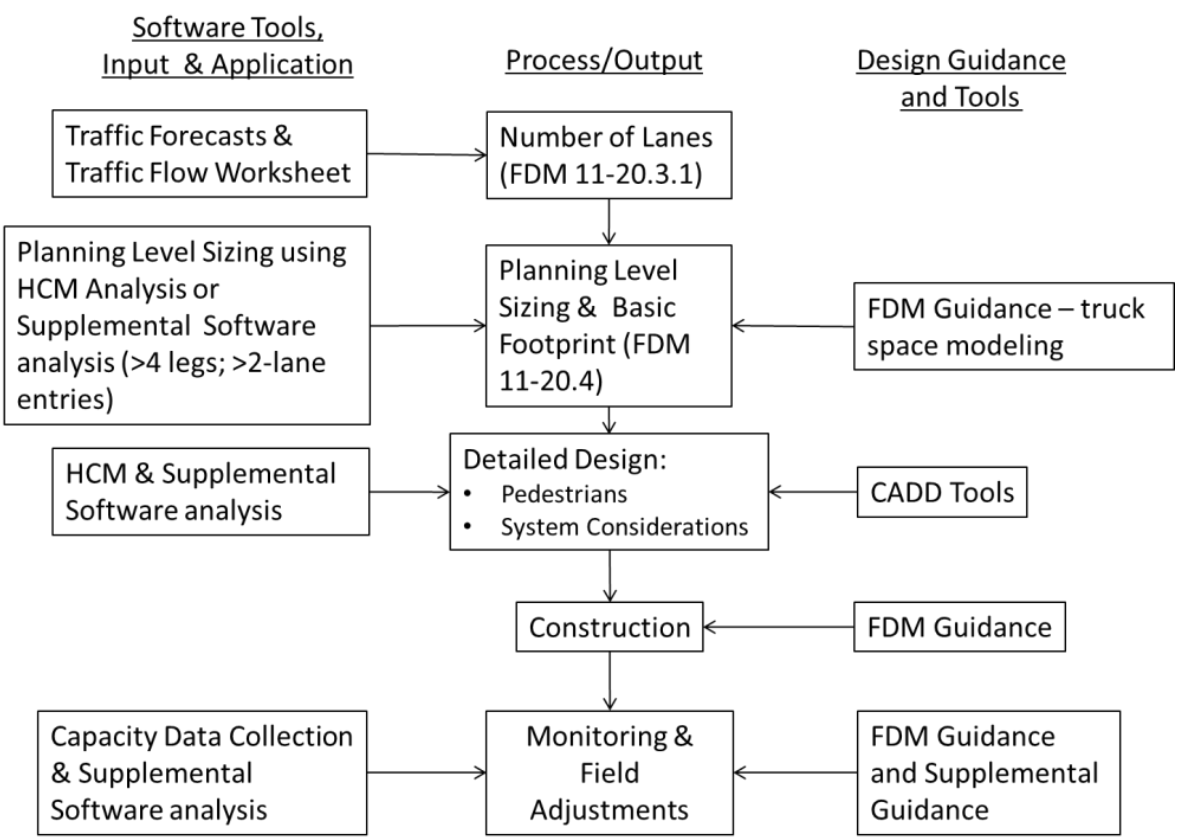


Figure 20.6 Operational Analysis Process, Inputs, and Outputs

Review the results of the analysis and adjust the lane configuration if needed. Remember to revise the headway values or Parameter A and B values if the number of circulating lanes changes. Once an acceptable lane configuration is achieved, print the formatted report. The format for results should follow the intersection control evaluation (ICE) FDM policy (FDM 11-25-3) and the Traffic Impact Analysis (TIA) guidelines for reporting on operational analysis. Include the analysis files as attachments and report all queues in feet.

Contact the regional traffic engineer or BTO-TASU via the DOT Traffic Model Peer Review (DOTTrafficModelPeerReview@dot.wi.gov) mailbox for specific guidance on how to conduct the roundabout operational analysis within any of the WisDOT supported analysis tools.

20.5 Supplemental Tools for Operational Analysis and Design

When performing roundabout operational evaluations, analysts should recognize and account for the methodological limitations of the HCM6 Chapter 22 methods. Roundabouts that are not isolated, that are part of a system or corridor of roundabouts or are located within the influence area of an adjacent signal should be analyzed with a combination of the roundabout methods of HCM6 Chapter 22 and the urban street segment procedures outlined in HCM6 Chapter 18. For closely spaced roundabouts, such as those found at freeway ramp terminals, the analyst should follow the methodology presented in HCM6 Chapter 23 for interchange ramp terminals. Depending on the scope and need of the project, the analyst may want to supplement the HCM analysis with microsimulation. Microsimulation is capable of system level analysis and allows the analyst to adjust roundabout designs indirectly. Additionally, analysis with microsimulation may help identify lane imbalances or lane use problems within a series of intersections allowing for a more robust design of any single roundabout. Since microsimulation requires significantly more time, resources and effort than HCM-based analysis, it is not appropriate to use for all roundabout analysis or design.

There are cases that may not fit within the analytical framework of the HCM, including but not limited to: volume-to-capacity ratio exceeding 0.80, high level of pedestrian or bicycle activity, priority reversal under extremely high flows and flared entry lanes. The analyst should consider the limitations of the HCM methodology when reporting results. In particular, when the volume-to-capacity ratio exceeds 0.80, the analyst should carefully consider predicted queues and delays and perform additional sensitivity analysis. Further analysis with microsimulation or design-aid tools such as SIDRA Standard, Rodel or ARCADY can supplement the study if the effort is justifiable based on the site conditions. Refer to FDM 11-5-3.7 for additional guidance on determining whether the use of a microsimulation tool would be appropriate.

SIDRA Standard, Rodel, ARCADY and any other tool that designers have available to assist them in the design process can prove beneficial for the final geometric design of the roundabout. These programs provide for geometric sensitivity testing, allowing the user to test the effects of size and key geometric parameters (i.e., inscribed circle diameter, entry radius, phi angle, lane width and flared entry) along with varied flows on an existing or proposed roundabout design.

Rodel and ARCADY apply UK research producing a model that relates geometry to capacity, for roundabout capacity calculations. The analyst may also use a calibrated microsimulation traffic model to refine the roundabout design. Microsimulation that provides for animation and visualization of operating predictions is useful for assessing lane utilization and capacity, especially when considering closely spaced roundabouts. Microsimulation may also prove beneficial for public outreach. SIDRA Intersection, when used in Standard mode, implements a capacity estimation method that assumes a dependence of gap acceptance parameters on multiple factors. Roundabout geometry, circulating flows, entry lane flows, and model designation of dominant or subdominant lanes all influence gap acceptance parameters to account for lane-by-lane capacity variation. SIDRA Standard utilizes what they call the Environment Factor as one of the main parameters to calibrate the capacity model. The recommended Environment Factor for U.S. roundabouts is 1.05 for one-lane roundabouts (approach road or circulating road has one lane) and 1.2 for two-lane roundabouts (both approach road and circulating road have two lanes). See the SIDRA Intersection User Guide for Version 7, Section 5.6.4 Calibration Parameters for Roundabout Capacity Models for details on how to apply the Environment Factor in the SIDRA capacity model.

20.5.1 Special Considerations

Lane designation or lane assignments are critical to the success of the roundabout lane configuration and design. Conditions can be very complex with subtle problems that can reduce capacity and cause severe lane imbalance. Great care and sensitivity are required to achieve lane utilization balance. Supplementary software is especially suited to these situations.

Unbalanced Conflicting Flows:

At a roundabout with unbalanced conflicting flow patterns, a traffic stream with a low flow rate enters the roundabout having to yield to a circulating stream with a high flow or visa-versa.

Unbalanced circulating flows highlight an operational condition that, in order to inform the findings on the analysis, traffic engineers and designers should understand and interpret by taking into consideration all aspects including but not limited to the results of the analysis, the existing and future field conditions and traffic patterns in order to better inform the findings on the analysis. The SIDRA Standard capacity model is sensitive to the ratio of entering to circulating flow, and therefore may be able to reflect expectations of capacity when unbalanced flow conditions are expected. A microsimulation model can also supplement the analysis, but

the level of data and effort to calibrate this model can be significant and may not be appropriate for an isolated roundabout analysis.

Capacity Considerations of Flared Entries:

In some situations, the use of appropriate lane arrows can encourage balanced lane use, thus improving capacity. Traffic often has a bias towards the right-most lane. Lane arrows either can encourage this bias or can encourage lane balance. Figure 20.7 shows the pavement marking scheme preferred to encourage balanced lane demand. It is important for the analyst not to assume that flared entries at roundabouts will always provide for balanced lane use and therefore add capacity to that entry as HCS and SIDRA will predict. This scenario may occur on the approach to a roundabout that has little to no conflicting circulating traffic (e.g. a roundabout at an interchange ramp or any roundabout with a one-way street). The suitable marking for an approach will depend on the turning volume proportions. A methodology similar to that described in FDM 11-26-20.4.3 is used to assess lane designation alternatives.

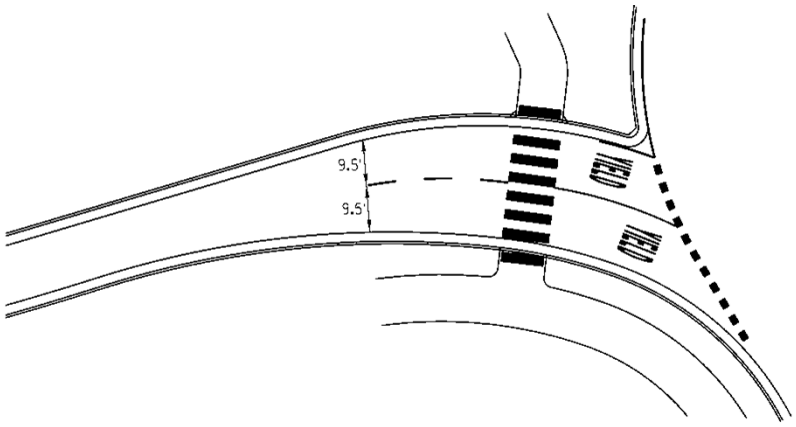


***Figure 20.7* Capacity Considerations of Flared Entries**

In addition, assessment of the potential for one lane to fill and block back across the flared lane is necessary to achieve the predicted levels of service, (i.e. the geometry must be effective to match the capacity prediction). Lane starvation is a primary failure mechanism for flared entries. Microsimulation models have various forms of lane-by-lane simulation features, which allow the analyst to test alternative lane configurations with visualization of the simulated flows accumulating and filling the flared lanes.

20.6 Capacity Analysis of an Existing Roundabout

The analyst shall use the HCM procedure to evaluate the capacity of existing roundabouts. For existing roundabouts experiencing delays or significant queuing, the analyst should collect the headway data to calibrate the HCM model. Consult with the BTO-TASU for the specifications on how to collect capacity data at existing roundabouts. The results of the HCM procedure may indicate that the existing roundabout requires additional lanes to achieve increased capacity; however, depending on the site-specific conditions, it may be possible to add capacity through changes in pavement markings, signage, geometry, or a combination of the three. Changes to pavement markings, signage and geometric parameters are often less expensive and easier to implement than the construction of additional lanes. The analyst can conduct geometric sensitivity testing using SIDRA Standard, Rodel, ARCADY or other geometric sensitive tools to determine if geometric changes will increase the capacity of the existing roundabout without adding more lanes. Although geometry is secondary to driver behavior in terms of its impact on the capacity of the roundabout, it may be beneficial to conduct geometric sensitivity testing. The ability to measure the capacity of an existing roundabout in the field allows the analyst to calibrate the models (HCM-based models, microsimulation models, and other design-aid tools) to verify the true influence of geometric parameters such as radius at the entry, inscribed circle diameter, conflict angle and flare length.

20.99 References

[1] NCHRP 572, *Roundabouts in the United States*, 2007

[2] Akcelik, R., E. Chung, and M. Besley. *Roundabouts: Capacity and Performance Analysis*. Research Report ARR No. 321, 2nd ed. ARRB Transport Research Ltd, Australia, 1999

[3] *The Traffic Capacity of Roundabouts* TRRL Report LR 942, 1980. Kimber, R.M.

[4] From *Highway Capacity Manual 2010*, Copyright, National Academy of Sciences, Washington, D.C., Exhibit 21-7, p. 21-9, reproduced with permission of the National Research Board

[5] Rodegerdts, L.A., A. Malinge, P.S. Marnell, S.G. Beaird, M.J. Kittelson, and Y.S. Mereszczak. *Assessment of Roundabout Capacity Models for the Highway Capacity Manual: Volume 2 of Accelerating Roundabout Implementation in the United States.* Report FHWA-SA-15-070. Federal Highway Administration, Washington, D.C., Sept. 2015

[6] Wisconsin Traffic Operations & Safety Laboratory, *Comprehensive Evaluation of Wisconsin Roundabouts Volume 1: Traffic Operations*, Sept. 2011

LIST OF ATTACHMENTS

Attachment 20.1 Roundabout Traffic Flow Worksheet

FDM 11-26-25 Access Control *August 15, 2019*

25.1 Access Management

Management of access to arterial roads is vital to creating a safe and efficient transportation system for motorists, bicyclists, and pedestrians. Access guidance is provided through the region access coordinator, Chapter 7 of the FDM, and the WisDOT Traffic Impact Analysis (TIA) Guidelines.

The operational characteristics of roundabouts may offer advantages when compared to existing conventional approaches to access management. Some roundabout benefits include:

- Increased capacity along arterial roads
- Reduction of traffic congestion and delay
- Improved safety
- More efficient use of land
- Savings on infrastructure investments

For example, connecting two roundabout intersections with a raised median will preclude lefts in/out from the side street or business access to protect main-line capacity and improve safety. U-Turns are not problematic at roundabouts and can increase safety. This provides the typical capacity protection and safety along the mainline with less impact to business accessibility.

The preliminary planning phase for any intersection including roundabouts should include a comprehensive access management plan for the site. Consider the possible need to realign/relocate existing driveways and include their associated costs in the project's preliminary estimate. Account for pedestrian accessibility and safety during all stages in the development of a comprehensive access management plan.

25.2 Functional Intersection Area

As addressed in FDM 11-25-2, the functional area of an intersection includes the physical area, but also extends upstream and downstream, along all of the intersection roadways, from the physical area. The functional area for a roundabout is generally less restrictive due to low speeds and less queuing, when compared to a traditional signalized intersection. Roundabouts will reduce queuing and minimize the need for exclusive turning lanes that may be required at a signalized intersection. Also, different sight requirements at a roundabout require drivers to judge gaps at higher perception-reaction time (PRT) than stated in FDM 11-25 Table 2.4. A roundabout's functional intersection area should be determined by the length of the splitter island and the estimated queue length back from the yield line. Use the approved analysis software to analyze the length of queue as discussed in FDM 11-26-20. Also, consider the sight distance and high-speed approach requirements discussed in FDM 11-26-30.5.15.

25.3 Corner Clearance and Driveway Location Considerations

Corner clearance represents the distance that is provided between an intersection and the nearest driveway. FDM 11-25-2.5 discusses the four types of corner clearance and corner clearance distances for STHs. Corner clearance for roundabouts is generally less restrictive than a signalized intersection because a roundabout reduces speed and queuing. On a case by case basis it may be feasible to consider a full access driveway closer to a roundabout than would be considered for other types of control, e.g. a traffic signal. There are three main considerations for driveway location relative to a roundabout entry or exit:

1. Volume of the driveway: If it is only occasional traffic during the peak hour, entering the driveway from the highway, i.e. a low volume case, there may be no storage required for left turns in advance of the roundabout. The driveway may be located closer to the roundabout subject to criteria 2 and 3. If the volume entering the driveway from the highway is moderate and the arterial flow impeding the driveway results in a predicted queue spillback then the queue length must be accounted for in the driveway location. In cases where a driveway location is downstream of a roundabout exit, there is a potential for the left turning traffic to back up into the roundabout.
2. Operational impacts of the roundabout (queue spillback from the entry across the driveway opening):

From the queue prediction results generated from the approved capacity analysis software, the designer can assess how often the entry queue will spill back across the driveway.

3. Sight distance between users: The driveway exit must have proper sight distance of the roundabout exit, the speed of exiting traffic from the roundabout and to the left of the approaching upstream traffic. The approach sight to the driveway from the roundabout or approaches to the roundabout must also meet intersection sight criteria for the approach speeds.

Major commercial driveways may be allowed as one leg of the roundabout. However, installation of a signal or roundabout strictly for access to private development is discouraged. They may be designed at a public road access point as an intersecting leg of a roundabout. Moreover, the roundabouts may reduce the need for additional through-lanes thus narrowing the overall footprint of the roadway system.

Minor commercial and residential driveways are not recommended along the circulating roadway unless designed as a leg of the roundabout. Some situations may dictate the need for a driveway and must be analyzed on a case-by-case basis. For a driveway to be located with direct access into the circulatory roadway of a roundabout, the following items should exist:

- No alternative access points are feasible.
- Traffic volumes are low enough that the likelihood of erratic vehicle behavior is minimal; driveways with higher traffic volumes, or higher proportion of unfamiliar drivers should be designed as a regular roundabout approach with a splitter island.
- Drivers must be able to exit facing forward; no backing into the roundabout.
- Driveways may be located along entrances and exits but need to be set back to not interfere with pedestrian movements in the crosswalks, and to minimize the number of conflict points with vehicles approaching or exiting the roundabout. Driveways located along entrances and exits may be blocked by the splitter island and will have restricted access, (right-in/right-out). Generally, these should be avoided unless minimal impacts are expected, or no other feasible alternatives exist.

25.4 Parking near Roundabouts

Prohibit on-street parking; within 75 feet of the roundabout entry/exit or further depending on site-specific conditions. Factors that influence the decision to prohibit on-street parking near a roundabout may include: adjacent access, location of pedestrian crossing, and approach or departing curvature. Generally, it is not typical to allow parking on either side of the roadway within the splitter island area or in the transition to the splitter island.

25.5 Interchange Ramps

According to FDM 11-5-5, a distance of 1320 feet between a ramp terminal and any adjacent intersection is required. This distance (1320 feet) is typically needed to provide progression for a series of signalized intersections. Roundabouts need less space between adjacent intersections to operate at a high level of service. Operational concerns at an interchange resulting from reduced access spacing, such as traffic blocking adjacent intersection, can be better understood through the analysis of forecasted queue lengths. Queue lengths for a roundabout should be predicted with the use of traffic modeling and the impacts to the adjacent intersections reviewed using other appropriate traffic modeling software. A traffic analysis is required to justify a less typical distance (1320 feet) of access control.

25.99 References

[1] A Policy on Geometric Design of Highways and Streets, AASHTO, 2004.

FDM 11-26-30 Principle Based Design Guidance *November 15, 2019*

30.1 Introduction

In a general sense, roadway engineering is often an iterative process of design exploration against a set of project constraints. The geometric design of a roundabout requires the balancing of competing interests. Design considerations of safety, capacity and cost. Roundabouts operate most safely when their geometry positively guides traffic to enter and circulate at slow speeds. Poor roundabout geometry has been found to negatively impact roundabout operations by affecting driver lane choice and behavior through the roundabout. Roundabout layouts are also governed by the space and swept path requirements of the design vehicle.

Thus, designing a roundabout is a process of determining the optimal balance between safety provisions, operational performance, and accommodation of the design vehicle.

Even though a step-by-step design process is presented in this section, the designer must understand that adherence to design principles, awareness and understanding of the inherent design tradeoffs are the central points of design regardless of whether any design procedure is followed.

The geometric design, signage and pavement markings of roundabout intersections can influence their capacity

and operational performance. Therefore, it is essential that a roundabout be properly designed to ensure that its expected capacity is not limited by the design.

30.2 Design Principles

This section describes the principles and objectives common to the design of all categories of roundabouts. Note that some features of multilane roundabout design are significantly different from single-lane roundabout design, and some techniques used in single-lane roundabout design may not apply to multilane design. However, several overarching principles should guide the development of all roundabout designs. With the primary goal of an operationally adequate facility that also provides good safety performance.

The principles that should be applied to achieve a safe and efficient roundabout design are:

- The roundabout should be clearly visible from the approach sight distance at the road operating speed in advance of the roundabout approach (See FDM 11-26-30.5).
- The number of legs should typically be limited to four (although up to six may be used at an appropriately designed roundabout).
- Legs should typically intersect at approximately 90-degrees, especially for multilane roundabouts (See also NCHRP 672, §6.3).
- It is essential that appropriate entry curvature is used to limit the entry speed (See also NCHRP 672, §6.2.1 and FDM 11-26-30.5.2).
- Exits should be designed to enable large vehicles to enter, circulate and depart efficiently either using a large exit radius or more tangent exits (See also NCHRP 672, §6.2.4). The circulating roadway with truck apron should be wide enough to accommodate the swept paths of the design vehicle (generally 1.0 to 1.2 times the widest entry).
- Entering drivers must be able to see from the left early enough to safely enter the roundabout. However, excessive intersection sight distance can lead to higher vehicle speeds that reduce the safety of the intersection for all road users (motorists, bicyclists, pedestrians). Landscaping within the central island can be effective in restricting sight distance to the minimum requirements while creating a terminal vista on the approach to improve visibility of the central island (See also NCHRP 672 and FDM 11-26-30.5).
- Provide the appropriate number of lanes and lane assignment to achieve adequate capacity, lane volume balance, and lane continuity to ensure that the roundabout operates at an appropriate level of service. (See also NCHRP 672, §6.2.2).
- Design such that the driving task is as simple as possible, avoiding the use of spiraled designs unless it's clearly warranted by traffic (i.e. high left turning traffic volume).
- Provide smooth channelization that is intuitive to drivers and results in vehicles naturally using the intended lanes. (See also NCHRP 672, §6.2.3 and FDM 11-26-30.5).
- Design to meet the needs of pedestrians and cyclists. (See also NCHRP 672, §6.2.5)

The design criteria for potential non-motorized roundabout users (e.g., bicyclists, pedestrians, skaters, wheelchair users, strollers) should be considered when developing many of the geometric components of a roundabout design. These users span a wide range of ages and abilities and can have a significant effect on the design of a facility. There are two general design principles that are most important for non-motorized users. First, slow motor vehicle speeds make roundabouts both easier to use and safer for non-motorized users. Second, one-lane roundabouts are generally easier and safer for non-motorized users than multilane roundabouts; therefore, if a single lane roundabout is feasible for most of the design life of the intersection that has pedestrian traffic then due consideration is given for the sake of pedestrian comfort and safety.

While the basic form and features of roundabouts are usually independent of their location, many of the design outcomes depend on the surrounding speed environment, typical capacity, available space, required number and arrangements of lanes, design vehicle, and other geometric attributes unique to each individual site. In rural environments where approach speeds are high and bicycle and pedestrian use may be minimal, the design objectives are significantly different from roundabouts in urban environments where bicycle and pedestrian safety are a primary concern. Additionally, many of the design techniques are substantially different for single-lane roundabouts than for roundabouts with two or more lanes. Maximizing the operational performance and safety for a roundabout requires the engineer to think through the design rather than rely upon a design template.

For additional information, see NCHRP 672, §6.2.

30.2.1 Designing with Trade-offs in Mind

The selection and arrangement of geometric design elements and their relationships to one another is referred to as design composition. Minor adjustments in geometry can result in significant changes in safety or operational performance. The relationship between safety and capacity, that exists for a roundabout is in most

cases inverse that of a typical intersection. Table 30.1 below identifies the trade-offs of adding to one element at the expense of another. When composing an initial layout, the tradeoffs of safety, capacity and cost must be recognized and assessed throughout the design process. The effect of improving one aspect of design impacts another.

Table 30.1 Effects of Design Elements on Safety and Operations

Element	Safety	Capacity	Speed
Wider entry (gore area)	Less safe	Increase	Increase
Wider Circulatory lanes	Less safe	Better	Increase
Larger entry radius	Less safe	Better	Increase
Larger inscriber circle diameter	Less safe	Better	Increase
Larger angle between approach legs	Safer	Decrease	Neutral
Smaller entry angle (phi)	Poorer sight	Better	Increase
Longer flare length	Neutral	Better	Neutral

30.2.2 Staging and Expandability

Providing excess capacity at typical intersections usually has very little (if any) negative effect on safety or crash rate and usually improves safety. Inadequate capacity, at a typical intersection could result in reduced safety and increased crash rates. These traits of typical intersections have encouraged traffic engineers to estimate future traffic volumes conservatively high. The process of providing safe roundabouts, for the public, would benefit from conservatively low traffic volume projections, design criteria which requires satisfactory levels of service for ten-year or fifteen-year projected traffic volumes (with phased designs which allow cost effective expansion, if needed).

The design and analysis process should consider the potential to stage improvements to reduce excessive capacity in the early years and improve safety, and driver/public acceptance. The capacity analysis evaluates the duration of time that for example a single-lane or dual-lane roundabout would operate acceptably before requiring additional lanes. When sufficient capacity is provided for much of the design life of a roundabout, designers should evaluate whether it is best to first construct a roundabout that is easy to convert when traffic volumes dictate the need for expansion and additional capacity. Reducing the number of entry and exit lanes reduces the number of potential conflicts and reduces navigation complexities associated with multilane roundabouts. Minimizing the necessary entry, exit and circulating lanes improves safety for all modes. Pedestrian safety is improved by minimizing the crossing distance and limiting their exposure time to vehicles while crossing an approach.

When considering an interim roundabout that may be converted, the designer should evaluate the right-of-way and geometric needs for both the interim and multilane configurations as part of the initial design exercise. Consideration should also be given to the future construction staging for the additional lanes.

Specific expansion design is a function of many variables. Some situations will dictate that expanding from the inside is more advantageous while other locations may benefit from widening to the outside.

For additional information, see NCHRP 672, §6.12.

30.2.3 Impact of Cost Reduction on Roundabouts

In many cases, the process of developing and designing a roundabout involves many design modifications, which are intended to effect cost savings. While this is common to conventional design practices it can have a hidden detrimental effect on design and operations of roundabouts.

Landscaping is often considered an aesthetic feature, which can be removed from the plan to reduce cost savings. Reduction of right-of-way take is often seen as an obvious cost reduction measure, but the trade-offs of safety and operations may not be apparent to the deciding authority. Other elements such as overhead signing (on approaches) is similarly looked at as excessive and is often replaced with terrace signing, despite the rationale that these features improve the function and safety of the intersection. Designers should be sensitive to the need for cost savings and should strive to effectively document and communicate the impact that the proposed design modifications will have on the function and safety of the roundabout. The designer should be given the opportunity to recommend an alternate modification, which will provide required cost savings while having the minimum amount of impact on function and safety.

30.3 Roundabout Design Process

The process of designing roundabouts may require a considerable amount of iteration among geometric design, operational analysis, and safety evaluation (refer to Figure 30.1). Minor adjustments in geometry can result in significant changes in safety or operational performance. Thus, the designer often needs to revise and refine the initial design to enhance the roundabouts capacity and safety. It is not typically possible to produce an optimal geometric design on the first attempt.

It is advisable to prepare the initial concept drawings at a sketch level detail. It is important that the individual components are compatible with each other so that the roundabout will meet its overall performance objectives. Before the details of the geometry are finalized, three fundamental elements must be determined in the Scoping and Feasibility stage.

1. The optimal size
2. The optimal position
3. The optimal alignment and arrangement of the approach legs

An initial estimate of the space (footprint) required for a roundabout is a common question at the planning stage and may affect the feasibility of a roundabout at any given location. At this planning level, important questions may begin to be explored including:

- Is sufficient space available to accommodate an appropriately sized roundabout?
- What property impacts might be expected?
- Is additional right-of-way likely to be required?
- Are there physical constraints that may affect the location and design of the roundabout?

Due to the need to accommodate large trucks through the intersection, roundabouts typically require more space than conventional intersections. However, this may be offset by the space saved compared with turning lane requirements at alternative intersection forms. The key indicator of the required space is the inscribed circle diameter.

There are no easy ten-steps to roundabout design. Much of the knowledge in roundabout design is counter-intuitive to the technically minded engineer. Designing roundabouts can range from easy to very complex.

Although it may appear inherently otherwise and extensively attempted, roundabouts are not homogeneous and cannot be standardized. There are many different types of roundabouts, such as single lanes, two-lanes, three-lanes, circles, ellipses, bypass lanes, “snagged” partial bypass lanes, double roundabouts, spirals, etc., in which a number of combinations or multiple combinations of the above can be in one roundabout (See Figure 1.2). Each roundabout is unique where each potential “type” of roundabout is applied in different situations in which site-specific problems require special and distinctive solutions. The major differences in design techniques and skill levels fall between single-lane roundabouts and multilane roundabouts where different principles apply.

Figure 30.1 depicts the steps and process that guide a designer through the entire Roundabout Design Process (see also NCHRP 672, Exhibit 6-1).

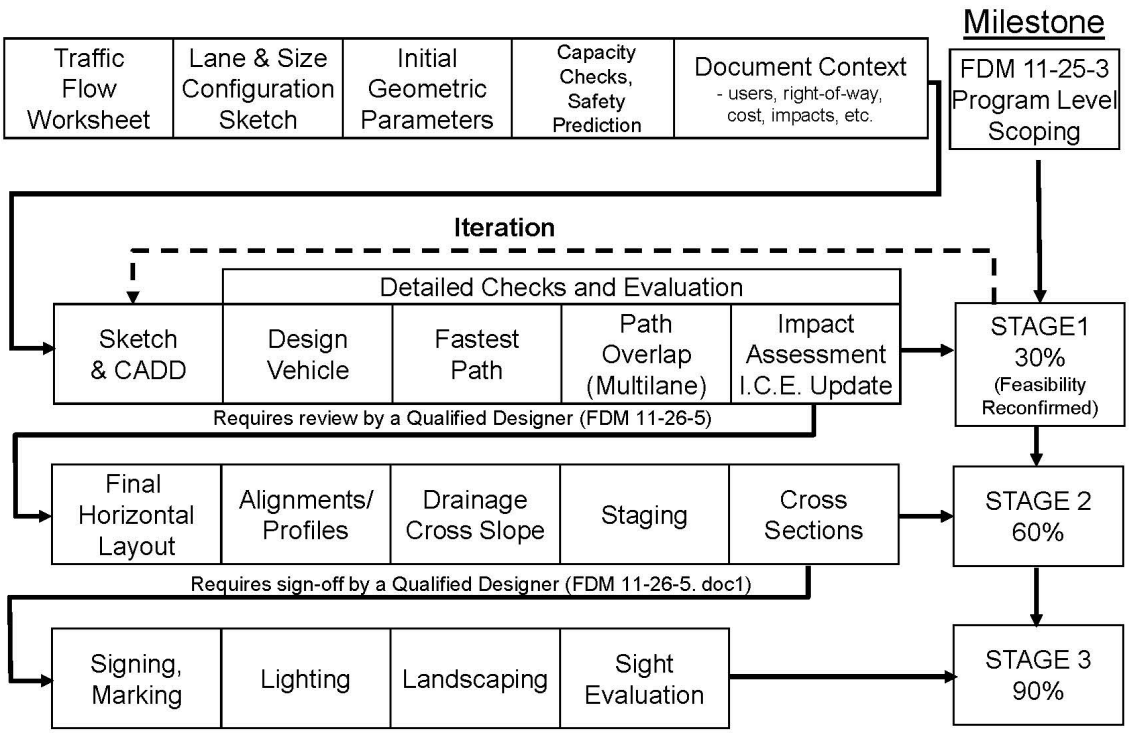


***Figure 30.1* Roundabout Evaluation & Design Process**

For additional information, see NCHRP 672, §6.3.

30.4 General Design Steps & Explanation

The following general design steps will typically apply to most roundabout design practices. However, each roundabout requires a different design and thinking process depending on the unique design constraints, traffic volumes, roadway speeds, existing topography, and geometric alignments of the roadways. Not all aspects of design or the design process are included herein, however, the provided general design steps should be sufficient to get most designers started in an initial conceptual roundabout design.

Step 1 - Document Existing Conditions

Review the most recent site plans and roadway alignment information in an electronic format (e.g. CAD-based software). Review existing roadways with respect to surrounding topography, centerlines, curb faces, edge of pavement, roadway lane markings, existing or proposed bike lanes, nearby crosswalks, environmental constraints, buildings, drainage structures, adjacent access points, shared-use paths, rail crossings, school zones, and right of way constraints. This should include any special design constraints such as specific properties that cannot be encroached or specific lane widths. Review any traffic study, which should include final future design year traffic volumes and assumptions of the proposed intersection or corridor project.

These items should provide adequate background traffic conditions, existing traffic conditions within and outside the project area, as well as the level of detail, design parameters, right-of-way constraints, restricted historical or wetland areas, and location for the proposed roundabout.

Step 2 - Document Future Conditions

The future traffic flows of the existing roadways should be reviewed and possibly discussed with the lead jurisdiction for project understanding and existing operational issues. These operational issues, including potential excessive delay, should be recognized in the design process and geometric criteria. In addition, any potential changes to adjacent sites, access points, or roadway cross-sections that may affect the roundabout design should be provided, reviewed, and incorporated.

Review the future AM & PM peak-hour, and off-peak turning movement volumes (also include mid-day in tourist areas) at the intersection developed from the design year projected traffic volume data. Use the Traffic Flow Worksheet in FDM 11-26 Attachment 20.1 and a simple schematic diagram consisting of the final future peak hour turning movement volumes at the intersection(s). In order to accurately identify the roundabout geometric and capacity needs, the

following are required:

- Traffic Conditions
  - Future turning movement volumes: AM & PM peak, off-peak, and mid-day (in tourist areas)
  - Future percent heavy vehicles (by type and approach) for each peak hour
  - OSOW truck route (OSOW-TR) considerations
  - Design vehicle type by turning movement Refer to FDM 11-25-2 and FDM 11-25 Attachment 2.1 for description of OSOW-MT and OSOW-ST design vehicles and their inventories. Refer to FDM 11-25 Table 2.1 for required intersection design vehicle checks for various trucking route scenarios.
- Constraints
  - Vertical constraints
  - Right-of-way constraints
  - Existing and proposed roadway alignment base map (with travel lanes, proposed curb tie-in, pavement marking, bike lanes, right-of-way, etc.)
- Other Modes
  - Pedestrian volumes (if significantly high)
  - Identify if bike lanes and sidewalks will be needed

Step 3 - Understand the Specific Design Problem(s)

Prior to commencing a design, the designer must first understand the basic intersection problem; is it safety, congestion, or a combination of both and what is the design problem(s) to be solved (right-of-way issues, acute angles, grades, approach legs, roadway alignment, etc.)? After evaluating the traffic volumes, the designer should understand how many lanes may be initially required.

A general roundabout diameter can then be chosen based on the traffic needs, proximity to constraints, design vehicle, and the relative speeds of the roadways (i.e. if high speed approaches present). The designer must be conscious of the design vehicle when choosing a diameter. Refer to FDM 11-25 Table 3.1 as a first step in the evaluation process if no other values have been stated.

Step 4 - Perform Capacity Analysis for Lane Configuration Development (also refer to FDM 11-26-20)

After obtaining all of the pertinent information regarding the roadways, site, and traffic volumes, and a general roundabout diameter has been initially identified, the designer should perform a geometric analysis of the proposed roundabout using roundabout design software. Refer to FDM 11-26 Attachment 20.1 Traffic Flow Worksheet to assist with traffic volume data entry. The capacity analysis results will assist in developing the initial lane geometry and capacity requirements for the roundabout based on the future design volumes.

This will set the design requirements for the conceptual roundabout design. The AM and PM, and sometimes a weekend peak, traffic volumes will need to be analyzed at the intersection. This analysis should ensure that the roundabout will operate appropriately under all peak hour traffic conditions. The results of this analysis will produce key information to include in the roundabout design, some of which are:

Geometry	***Operations***
- Initial roundabout diameter (estimated size) - Entry lane configurations at each approach - Minimum approach widths and entry radii of the roundabout	- Future traffic volume capacity by approach - Delay of each approach and the overall delay of the intersection - Predicted 95th percentile queue lengths for each approach - Future level of service

The allowed movements assigned to each entering lane are key to the overall design. Basic pavement marking layouts should be considered integral to the preliminary design process to ensure that lane continuity is being provided. In some cases, the geometry within the roundabout may be dictated by the number of lanes required or the need to provide spiral transitions (see FDM 11-26-30.5.22 for more information). Lane assignments should be clearly identified on all preliminary designs to retain the lane configuration information through the various design iterations. In some cases, a roundabout designed to accommodate design year

traffic volumes, typically projected 20 years from the construction year, can result in substantially more entering, exiting, and circulating lanes than needed in the earlier years of operation. To maximize the potential safety during those early years of operation, the engineer may wish to consider a phased design solution that initially uses fewer entering and circulating lanes. As an example, the interim design would provide a single-lane entry to serve the near-term traffic volumes with the ability to cost-effectively expand the entries and circulatory roadway to accommodate future traffic volumes. To allow for expansion at a later phase, the ultimate configuration of the roundabout needs to be considered in the initial design. This requires that the ultimate horizontal and vertical design be identified to establish the outer envelope of the roundabout. This method helps to ensure that sufficient right-of-way is preserved and to minimize the degree to which the original roundabout must be rebuilt.

Step 5 - Sketch

Once the minimum design requirements have been established, a modern roundabout design can be sketched by initially identifying the flow of traffic, lane configuration, and approach lane assignment requirements, the circulatory roadway width and the exits of the roundabout. This task includes the placement of the roundabout's circle to roughly determine its location. Special consideration should be taken for any skewed intersection or right-of-way constraints. A general roundabout diameter can then be chosen based on the traffic needs, proximity to constraints, design vehicle, and the relative speeds of the roadways.

Step 6 – Refine the Initial Layout

The hand sketch or initial conceptual layout should be refined. The designer should refine the concept iteratively to suit the site constraints while attending to the design performance criteria of speeds, truck space and site distance. The purpose of this process is to achieve an optimal layout that serves the design objectives without excessive CAD effort. Often designers are wrongly focused on details and do not have the patience to produce multiple iterations of a CAD design.

Step 7 - Formalize the Preliminary Design

Once the general location and roundabout configuration has been developed and all of the design issues have been resolved, a full conceptual design can be initiated.

In multilane designs, the lane pavement marking is applied to establish natural entry and exit paths, i.e. to minimize entry and exit path overlap. Applying the lane pavement marking ensures proper lane widths and widening and confirms the lane designations and possible spiraled lane movements.

Step 8 - Safety and Fastest Path Review

Fastest path design speeds as well as a number of other safety factors and design features, such as the phi angle, must be checked. The fastest paths should be developed and reviewed to see if they are adequate and reasonable. If deficiencies or deviations in any of the design features or safety factors are found, the design must be modified, either with many small changes or by shifting alignments, geometry, or placement of the circle. This is an iterative process which may require an entire redesign.

Step 9 - Design Vehicle Check & Modifications

A CAD-based software program such as AutoTURN or AutoTrack should be used to verify proper accommodations are provided through the roundabout for each approach and every truck turning movement. In addition, the truck apron minimum width is 12-feet and may be wider in some situations to better accommodate OSOW vehicles. All truck movements should have a buffer space between the swept path of trucks and the face of curb equal to 2 feet. Contact the regional Freight Operations Unit for the OSOW vehicle.

Step 10 - Accessorize the Design

When a preliminary design (and pavement marking for multilane roundabouts) has been completed, additional amenities should such as crosswalks, detached sidewalks, bike paths and ramps, truck aprons, disabled access (ADA) ramps, etc. should be added. All efforts should be made to avoid any right-of-way issues.

At the 30% stage of the design process, some form of approval or review consultation should be performed by a qualified designer. Once a roundabout design has been properly designed with respect to horizontal geometry, there are many other geometric and non-geometric design components that must now be completed for a roundabout to function as it was designed. These design components are key to the public driving the roundabout as it was intended without further safety or operational issues. These items are identified in the three stages of the

design process (Figure 30.1).

The 60% and 90% design aspects of roundabout design including horizontal geometry, vertical profiles, signing, pavement marking layout, landscaping, lighting, and construction materials should either be designed by or reviewed by a qualified roundabout designer. Nothing can replace real-world design and field experience.

Continual practice, mentoring from experts, training & education, and quality roundabout review greatly assists the designer in understanding all aspects of the design of modern roundabouts. However, all designers must spend time in the field reviewing roundabout construction and completed roundabouts in order to understand roundabouts and their design completely. After years of daily practice, one can still learn. Small changes in roundabout design elements can influence the operation and safety of a modern roundabout.

30.5 Design Considerations

This section provides guidelines for each geometric element. Further guidelines specific to two-lane entries are provided in the latter part of Chapter 6 of NCHRP 672. Note that two-lane entry roundabout design is significantly more challenging than one-lane entry design. Many of the techniques used in one-lane entry roundabout design do not directly transfer to multilane design. This procedure provides recommended changes to NCHRP 672, Chapter 6. Therefore, designers must become very familiar with Chapter 6 in the NCHRP 672.

30.5.1 Alignment of Approaches and Entries

Adherence to the principles of deflection is crucial to the operation and safety of roundabouts. WisDOT considers this design element to be of the utmost importance. Figure 30.2 shows the typical composition of approach alignment and curves to generate typical speed reduction at entries. It is not good practice to generate entry deflection by sharply curving the approach road to the left close to the roundabout and then to the right at entry.

It is recommended design practice (especially in multilane roundabouts) to provide an offset to the left of the center of the central island. In some situations, it may be appropriate to provide an offset of approximately 20 to 30 feet (or more), left of the center of the roundabout to achieve proper deflection and appropriate entry speeds.

For additional information, see NCHRP 672, §6.2.1 & 6.7.1.

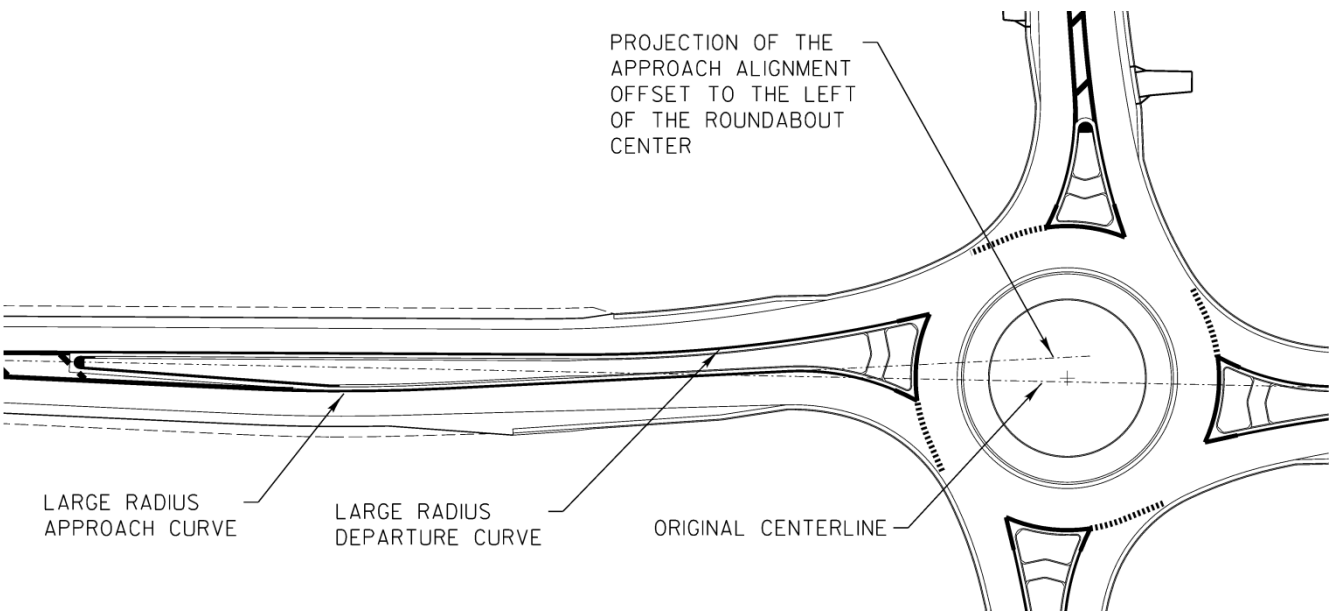


Figure 30.2 Entry Deflection

30.5.2 Assessing Vehicle Paths

Determine the smoothest, fastest path (using a spline curve) possible for a single vehicle, in the absence of other traffic and ignoring all lane line markings, traversing through the entry, around the central island, and out the exit. A step by step process for creating AutoCAD Civil 3D and MicroStation spline curve are provided in FDM 11-26 Attachment 50.1 and 50.2. Usually the critical fastest path is the through movement; but, depending on the angle between arms, in some situations it may be a right turn movement.

Fastest speed path is a critical performance measure in the design of roundabouts. Use NCHRP 672, Exhibit 6-46 for the definition of vehicle path radii. NCHRP 672 Exhibit 6-48 and Exhibit 6-49 illustrate the definition of fastest vehicle path for single-lane and multilane designs. Use Figure 30.3 to determine the radii values for R1 based on the arc and spline definitions. Vehicle speed estimation is in accordance with NCHRP 672, Section

6.7.1.2 Equations 6-1 and 6-2. Equation 6-3 may be used to estimate actual entry speed, but it will not govern the design.

R2 and R4 are determined using the same vehicle path offsets for R1. The R3 exit radius fastest speed path is determined based on the R2 speed plus acceleration over the distance to the point where R3 is measured. Use NCHRP Exhibit 6-50 to determine the radius value for R5 fastest speed path. The vehicle path offsets of 5 feet, as shown in Figure 30.3, are measured from the curb face (not the flange line). In the situation where the approach to the roundabout has centerline pavement marking on the left side with no curb face, then the offset is 3 feet from the centerline pavement marking.

a. The radius should be measured over a distance of 65 to 80 feet. It is the minimum that occurs along the approach entry path near the yield point but not more than 165 feet in advance of it.
b. The beginning point is 3 feet from a pavement marking (if no raised median), or 5 feet from the left curb face (if raised curb median) at a point approximately 165 feet from the yield line. This point is a continuation of a vehicle path spiraling from tangent to a curve, not a point with deflection.
c. Vehicle entry path curvature.

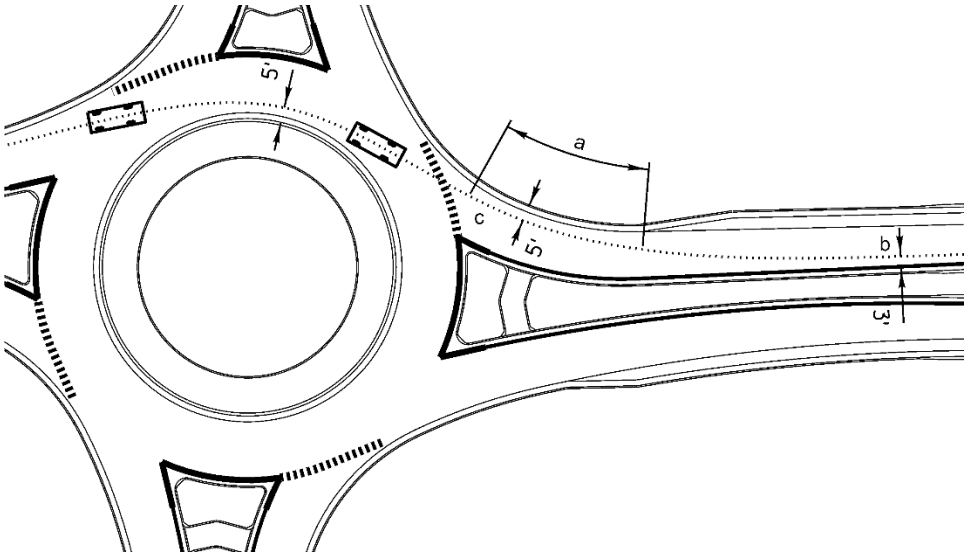


***Figure 30.3* Determination of Entry Path Curvature**
(See NCHRP 672 Exhibit 6-49 for multilane entries and Exhibit 6-50 for right turns)

The radii described in Table 30.2 are used to define the fastest path through a roundabout. They are illustrated in Exhibit 6-12 of NCHRP 672.

***Table 30.2* Roundabout Radii**

Radius	Description	Range of Speeds
Entry Path Radius, R_1	The minimum radius on the fastest through path prior to the yield line. This is not the same as Entry Radius.	Single Lane 20 to 25 mph* Multilane 25 to 30 mph*
Circulating Path Radius, R_2	The minimum radius on the fastest through path around the central island.	15 to 25 mph
Exit Path Radius, R_3	The minimum radius on the fastest through path into the exit.	R_2 + Acceleration over the path to the exit crosswalk*
Left Turn Path Radius, R_4	The minimum radius on the path of the conflicting left-turn movement.	10 to 20 mph
Right Turn Path Radius, R_5	The minimum radius on the fastest path of a right-turning vehicle.	15 to 20 mph*

* Notes: Under conditions where sufficient numbers of pedestrians are present, values of fast path speeds should be lower than maximum values shown in the table. Check the design speed control of sensitive designs that may have high entering or circulating speeds or where the pedestrian activity is anticipated to be medium to high, check for a conservative design by determining the fastest speed paths using a 3.28 ft. (1 m) offset to each of the critical

controlling feature locations (i.e. raised curb face on the approach and exit median, curb face at the central island, or centerline pavement marking between opposing traffic).

For additional information, see NCHRP 672, §6.2.3 & 6.7.1.

30.5.3 Speed Consistency

In addition to achieving the appropriate design speed for the fastest path movements, the relative speeds between consecutive geometric elements should be minimized as well as between conflicting traffic streams. Ideally, the relative differences between all speeds within the roundabout will be no more than 10 to 15 mph. Typically, the R2 values are lower than the R1 values. With either single or multilane entries, R2 values should be lower than the R3 values.

The typical maximum R1 radius is 250 ft. Generally, for urban roundabouts with pedestrian accommodations a lower speed entry is desirable. A typical R1 may range between 150 and 230 feet. Rural roundabouts typically allow slightly higher entry speed than urban roundabouts. The R1 and R2 should be used to control exit speed. Typically, the speed relationships between R1, R2, and R3 as well as between R1 and R4 are of primary interest. Along the through path, the typical relationship is R1> R2< R3, where R1 is also less than R3. Similarly, the relationship along the left-turning path is R1> R4.

For most designs, the R1 - R4 relationship will be the most restrictive for speed differential at each entry. However, the R1 - R2 - R3 relationship should also be reviewed, particularly to ensure the exit speed is not overly restrictive. Design criteria in past years advocated relatively tight exit radii to minimize exit speed; recent best practice suggests a more relaxed exit radius for improved drivability.

30.5.4 Design Guidance for all Trucks

WisDOT is a transport friendly state and accommodates not only for the typical large legal-size trucks, but also the OSOW vehicles that use our highways. The typical design vehicle for the STH system in Wisconsin is the WB-65.

Additionally, intersections of two state trunk highways and state highways that make an abrupt turn at an intersection should accommodate these check vehicles, the WB-92 (formerly WB-67 Long), farm combine, and 80-foot mobile home transport vehicles. If the existing intersection geometrics did not accommodate a Multiple-Trip (OSOW MT) permitted vehicle by staying within the curb face prior to the proposed improvement then it does not have to accommodate that vehicle after the improvement is completed, except as stated below.

The WB-92 (formerly WB-67-Long) is a very challenging vehicle to accommodate at an intersection because of its length and its lack of rear steering. Typically, the right turn movement is most problematic in trying to keep all wheels within the curb lines, especially at single lane entrances to a roundabout but may impact typical intersections as well depending on intersection skew. Check the existing intersection to see which movements can be made with the OSOW-MT vehicles without encroaching beyond the curb/shoulder line of the existing intersection. Once the various movements of the existing intersection have been evaluated and a determination has been made on which future movements are needed a WisDOT decision is needed. Either perpetuate existing turning movements or it may be typical to accommodate all movements, generally preferred, or maybe just certain movements. If a right turn movement is needed the designer will have to balance the entry throat width, circulating roadway width and the possible need for a small truck apron behind the outside curb for off-tracking. It is generally a safer design to keep the roundabout entry lane throat width on the narrow side, usually less than 22 feet. Check movement of the WB-92 vehicle to fit through an intersection or make turns at an intersection without having to remove signals, light poles or sign posts.

Refer to FDM 11-25-2 and FDM 11-25 Attachment 2.2 for additional information on OSOW MT permitted vehicles and Single Trip (OSOW ST) permitted vehicles. See the OSOW maps for routes designated as OSOW-TR available at:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/planning-maps.aspx

1. Slope truck apron at 1% toward the roadway on all roundabouts. In order to ensure that light vehicles encounter sufficient entry deflection at normal roundabouts, a truck apron (i.e. a raised low-profile area around the central island) is necessary. It should be capable of being mounted by the trailers of large goods vehicle, but unattractive to cars and SUVs.
2. The truck apron width is a minimum of 12 feet wide on single lane, as well as, multilane roundabouts. Sometimes additional space is needed for trucks to off-track onto the truck apron that may exceed the 12-foot width. Additionally, provide a 12-inch thick truck apron, as this will provide ample structural integrity while providing adequate tie bar clearances along back of curbs. Apply ties where required per FDM 11-26-30.5.21.2. The 12-inch truck apron also minimizes constructability issues between compaction levels and is expected to improve long-term performance.
3. Widen the truck apron as needed to accommodate the anticipated OSOW turning maneuver. Discuss with the regional Truck Route coordinator.
4. Roundabouts must have the recommended circulatory roadway crown installed, 2/3 inward and 1/3

outward on all roundabouts, not just those on the OSOW-TR. Refer to Figure 30.8 for cross-section clarification.

5. Install a Type A or D 4-inch sloped curb and gutter modified with 8" minimum flange thickness along the outside of the approach where large vehicles may off-track onto the curb, and when necessary install an outside concrete pad.
6. Install a reddish-colored concrete truck apron behind the back of curb along the outside entrance area where off-tracking is anticipated. The slope of the pad should be a maximum of 1%. Evaluate the entrance for pedestrian crossings and placement of the concrete pad to prevent these areas from overlapping. The width of this pad will depend on the amount of off-tracking anticipated. The same reddish colored concrete pad, without stamping, should be installed in the splitter islands where OSOW vehicles may drive to negotiate the roundabout. Consider projected vehicle loadings and constructability issues (tie bar and base construction considerations) when determining concrete truck apron thickness. Provide a 12-inch thick truck apron, as this will provide ample structural integrity while providing adequate tie bar clearances along backs of curbs. The 12-inch truck apron also minimizes constructability issues between compaction levels and is expected to improve long-term performance. Provide tie bars when the adjacent truck apron width is less than 3 feet along its entire length. To limit pavement stress and crack propagation, do not tie the outside truck apron to the back side of curb when the variable-width truck apron is 3 feet wide or greater at any location.

The following items are a reminder for additional roundabout design guidance:

- Keep drainage structures away from the travel path of the possible OSOW vehicle wheel tracking.
- The compaction levels under the concrete pad along the back of curb near the entrance and in the splitter island areas must be equal to the compaction levels under the roadway and truck apron.
- With the wider 12-foot minimum truck apron required by WisDOT for single-lane and multilane entries, it is rare that additional intersection sight distance is needed directly in back of the curb on the inside of the truck apron. If a central island landscape buffer area located adjacent to the back of the most inside curb and gutter is typical, avoid the use of hard surfaces that look like concrete sidewalk.
- 2% cross-slope is the maximum in the roadway area.
- Avoid approach vertical break-over grades over 3% within 200 feet of the entry yield line location.
- Provide a note to the construction engineer that the plans, including the vertical and horizontal design, shall not be adjusted in the field without the design engineer's approval.
- Refer to FDM 11-26-35.1.12 for guidance on removable signs at roundabouts.
- For the roundabouts located on the OSOW Truck Route, their grading plans should be verified with 3D design software for any conflict points. The tractor should be placed 100 feet back from the yield line.
- Produce a swept path diagram showing the vehicle movements and directions for the purpose of supplying the permitting office with diagrams to aid route choice.

30.5.5 Geometric Design Guidance for Legal Trucks

The inscribed circle diameter, the width of the circulatory roadway and the central island diameter are interdependent. Once any two of these are established, the remaining measurement can be determined. However, the circulatory roadway width, entry and exit widths, entry and exit radii, and entry and exit angles also play a significant role in accommodating the design vehicle and providing deflection.

In all cases, the designer will test swept paths and iterate through combinations of circle size and lane widths. A recent roundabout design study identified three cases or categories for accommodating trucks. Case 1, Case 2, and Case 3 categories are determined by a number of factors, primarily whether a truck can stay in lane or not, as explained below.

Roundabouts are designed with a truck apron. Truck drivers that use the inside lane are expected to off-track onto the truck apron. Regardless of the case category the outside lane of a dual lane roundabout is typically wider than the inside lane to better accommodate trucks. Multilane roundabouts can be designed in three different ways to accommodate legal size large trucks. Three categories of design for legal trucks have been identified as Case 1, Case 2, and Case 3:

- Case 1:

  Roundabouts which are designed to allow trucks to encroach into adjacent lanes as they approach, enter, circulate, and exit the intersection. Refer to Figure 30.4 for an example of a Case 1 design.
- Case 2:

  Roundabouts which are designed to accommodate trucks in-lane as they approach and enter the roundabout but may require trucks to encroach into adjacent lanes as they circulate and exit the intersection. Case 2 roundabouts have a painted "gore" area between lanes on the approaches. Refer

to Figure 30.5 for an example of a Case 2 design.

- Case 3:

  Roundabouts which are designed to accommodate trucks in-lane as they approach and traverse the entire intersection. Case 3 roundabouts have a painted “gore” area between lanes on the approaches. Case 3 roundabouts typically are designed to allow trucks to stay in lane for through and left turning movements, while right turning trucks may occupy multiple lanes as they exit. With few Case 3 roundabouts implemented to date, these designs typically require significantly more designer skill than other case types to ensure proper operations, geometrics, speeds, and safety. Refer to Figure 30.6 for an example of a Case 3 design.

Well-designed Case 2 and Case 3 roundabouts do not compromise accepted design principles, as outlined in this chapter. Tables 30.3, Table 30.4, and Table 30.5 show the advantages and disadvantages of Case 1, Case 2, and Case 3 roundabout designs.

Table 30.3 Advantages and Disadvantages for Case 1 Roundabout Designs

Advantages	Disadvantages
Wide variety of approach alignment design methods can be used	May result in increased delays due to trucks occupying both lanes on entries and while circulating
More likely to fit in tight right-of-way locations, including built-up urban environments	Trucks may off-track over outside curbs, resulting in more damage and maintenance
Potentially lower costs in some situations	May result in additional truck-car crashes
Less pavement marking maintenance	

Table 30.4 Advantages and Disadvantages for Case 2 Roundabout Designs

Advantages	Disadvantages
Surveys indicate this entry design is preferred over Case 1 by truck drivers	Fewer approach alignment design methods can be used
Safety benefits at entries due to no truck encroachment	May require geometry with more right-of-way
Potentially less damage to curbs	Potentially higher cost in some situations
Trucks can maneuver more freely at entries	May require more pavement marking maintenance
May have greater entry capacity/less delay	Slightly higher circulating speeds and worse lane discipline possible
Can be used in urban or rural environments	Requires greater designer and contractor skill
May have greater public acceptance	Poor design could result in more crashes
	Possibly lower safety in circulatory roadway due to truck encroachment

***Table 30.5* Advantages and Disadvantages for Case 3 Roundabout Designs**

Advantages	Disadvantages
Surveys indicate this design is preferred by truck drivers and the trucking industry	Fewer approach alignment design methods can be used
Safety benefits at entries and in circulatory roadway due to no truck encroachment	May require larger geometry with more right-of-way
Less damage to curbs	Potentially higher cost in some situations
Trucks can maneuver more freely at entries and in the circulatory roadway	May require more pavement marking maintenance
May have greater entry capacity/less delay	Slightly higher circulating speeds and worse lane discipline possible
Can be used in urban or rural environments	Requires greater designer and contractor skill
Better operations in the circulatory roadway	Poor design could result in more crashes
No truck/trailer encroachment required for turning movements - more lateral clearance	
May have greater public acceptance	

Case 3 design is a priority where practical and feasible and there are approximately 100 large trucks (vehicle classification 3S2) per day using the intersection. In general, it is believed that a well-designed Case 3 roundabout which meets applicable geometric design requirements will provide safe and efficient operations while providing optimal truck accommodations. Where costs or right-of-way impacts are prohibitively expensive or at locations where design truck numbers are very low, other design case types may be more advantageous.

Certain specific locations should warrant additional consideration of a Case 3 design. These would include locations where designated OSOW routes exist, multilane approaches on arterial routes, at interchange ramps, near truck stops, and in industrial/warehouse districts. If a Case 3 is an alternative based on large truck numbers but there are serious adverse impacts, such as environmental, historic, real estate or other impacts then evaluate a Case 2. Consider a step-down approach to the evaluation process and perhaps a Case 1 is all that will fit into the intersection without serious adverse impacts. In the end evaluate the selected roundabout case number option appropriate for the intersection and compare it to the other intersection alternatives such as a signal, or other type.

In the case of three lane entries, off-tracking is assumed to overlap lane lines. If high volumes of large trucks are present and capacity is a concern, a painted gore width of 4 to 6 feet may be placed between the right two lanes.

Table 30.6 depicts typical design parameters for each of the three design cases. Refer to FDM 11-25-1.4, FDM 11-25-2 and FDM 11-26-10.2 for additional information on OSOW routes and vehicles.

***Table 30.6** Typical Design Parameters for Two-Lane Roundabouts**

	Case 1 - No lane discipline entering or circulating	Case 2 – Lane discipline entering only	Case 3 – Lane discipline entering and circulating
ICD[A]	150-190 ft	160-210 ft	180-220 ft
Inner Circulatory Lane Width[B]	11-13 ft		12-14 ft
Outer Circulatory Lane Width[B]	13-15 ft		15-18 ft
Approach Gore Widths	Not used	2-6 ft	4-8 ft
Entry Width[A]	28-32 ft	32-34 ft	32-34 ft
Entry Radius	65 ft or greater		
Controlling Radius	65 ft or greater	65 ft. or greater, 100-130 ft. typical	
Controlling Radius Length	No MAX.—typically 70 ft or less	No MAX.—typically 80 ft or greater	
Entry Angle (measured per FDM 11-26-30.5.2)	16-30 degrees		
Flared Entry Lane Addition (based on 95%ile Queue)	> 100 ft Generally, 100 ft to 300 ft		
Exit Widths[A]	28-32 ft		28-32 ft (where large radius or tangential exit is used)

* Based on site conditions, right-of-way constraints, specific design vehicle, and other factors, designers may choose to implement geometries outside these recommended ranges; however, the overall design should comply with WisDOT general roundabout design practices

[A] Measurements are from the face of curb to face of curb, (includes 2-ft gutter pans on each side)

[B] Measurements are from flange line to lane line

30.5.5.1 Geometric Design Guidance for Case 1 Roundabouts

Case 1 roundabouts are designed with a single solid white paint line dividing the entry lanes. Trucks encroach on adjacent lanes at the approaches and when circulating and exiting the roundabout. Designers should consider implementing features that would result in a clear encroachment by trucks into adjacent lanes rather than a subtle encroachment (such an approach would typically include avoiding wide lanes, long sweeping curves, large ICDs, and large radii).

Additionally, Case 1 designs can allow for the approaching roadways to have more tangential alignments with short, tighter entry radii. In some rare Case 1 design locations, implementing outside curb truck aprons (i.e., a sloped/mountable curb with a concrete/pavement area behind the curb) may be beneficial to repair and prevent rutting behind the entry radius curb, curb damage or damage to signs and landscaping from truck off-tracking. The implementation of outside truck aprons in new designs is discouraged due to potential concerns about pedestrian safety and optimal operations. As such, designers should not typically consider outside truck aprons as a preferable option when sidewalks or shared-use paths are present. The width of this apron should be determined through the use of software that generates swept paths for trucks. Figure 30.4 shows the basic design features of a Case 1 roundabout.

A sub-option for Case 1 designs is to use a short flare from a single lane approach to a two-lane entry. With approximately a 100-foot flare, the design may be acceptable without the gore pavement marking. If the flare is long, e.g. approaching 250 feet to 300 feet, then a Case 2 design with the gore area between lanes would be typical.

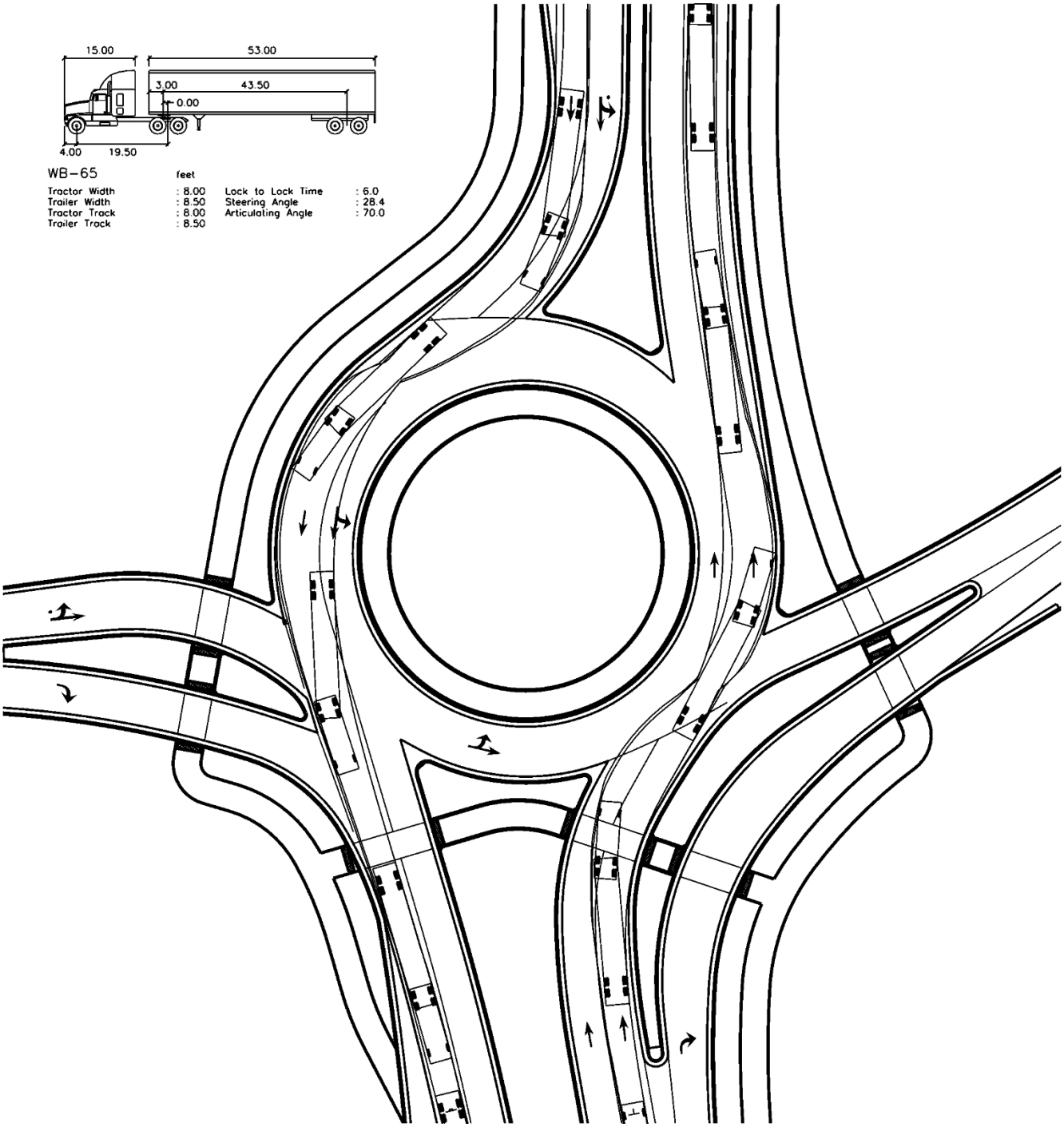


***Figure 30.4** Case 1 Roundabout Design (Single lane line dividing the entry lanes)*

30.5.5.2 Geometric Design Guidance for Case 2 Roundabouts

Once the primary design principles from this guidance have been met (speed control, sight distance, adequate space for a design vehicle), the designer will typically revise the design iteratively to allow trucks to stay in lane at the entry while still maintaining the primary design. Although there are some specific design characteristics which are unique to Case 2 roundabouts, the overall approach, methods, and iterative design process remain the same as multilane roundabouts in general.

Case 2 roundabout ICDs are typically 10-20 feet smaller than for Case 3 roundabouts. Designers must maintain appropriate fastest path entry speeds and speed differentials between entering and circulating traffic. Figure 30.5 shows the basic design features of a Case 2 roundabout.

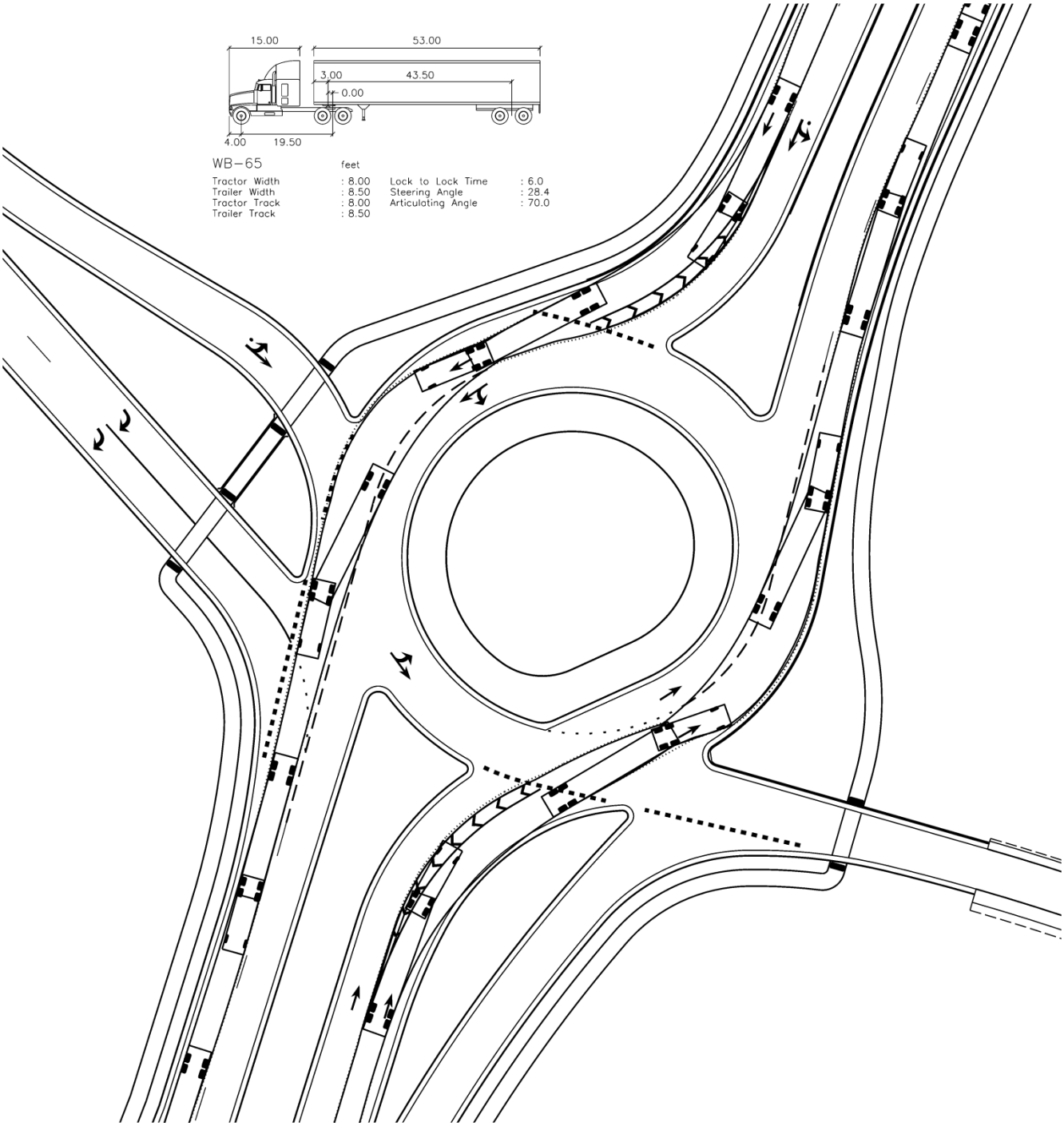


***Figure 30.5* Case 2 Roundabout Design (6-ft gore pavement marking between lanes)**

30.5.5.3 Geometric Design Guidance Common to Case 2 and Case 3 Roundabouts

1. Often have slightly wider entries (typically 2 to 6 feet wider) than a comparable Case 1 roundabout at the same location. For example, a Case 1 roundabout may have an entry width of 28 to 32 feet (including gutter pan width) wherein a typical Case 2 or 3 roundabout could increase the entry width to about 32 to 34 feet (including gutter pan width and gore pavement marking area) to allow trucks to stay in lane in entry.
2. Usually have longer curve lengths than Case 1 roundabouts on the approach geometry and within the entries. Offset left alignments (i.e., alignment directed to the left of the center of the ICD) are generally preferred where possible.
3. Should avoid tight entry radii curves and closely spaced curves in opposite directions. Instead, larger, longer radii with straight tangent sections between curves are common at Case 2 and 3 roundabouts, resulting in gradual sweeping curvature which makes it easier for trucks to stay in lane. Optimal entry radii values will vary based on the ICD, approach alignment, and entry design method. Typically, an

urban Case 2 or 3 design may have a controlling curb radius value of 100 feet or greater, while a larger rural Case 3 design may range as high as 120 feet or more (note: per definition above, controlling radius is not the same as the R_1 radius). Regardless of the actual values (which are site specific), the designer still must maintain other design requirements such as appropriate fast path speeds, while still accommodating for trucks in-lane. Considerable designer skill is typically needed to accomplish these competing objectives.

4. Use of width transitions. With Case 2 and 3 roundabouts relatively long width transitions may be needed to allow trucks to use more roadway width to stay in lane. Designers should ensure that the total length of the combination of the taper and the second full lane width utilized accommodates the design truck as well as queuing and capacity needs. Not including the gore area between entry lanes, the lanes should typically have continual tapers between the normal width upstream location and the entry, (Figure 30.5 and FDM 11-26-35.2.1), and at no point should lane widths become narrower over this distance. The design of the gore area may require variable widths, including narrowing toward the entry as needed.
5. A slightly wider entry width than usually provided at Case 1 roundabouts. The designer should keep the entry width as narrow as possible while still allowing trucks to stay in lane. Total two-lane entry width should typically not exceed 34 feet (from curb face to curb face, including painted gore area) unless special circumstances are present. Lane widths at the entry typically vary from 12 to 14 feet, not including the two-foot gutter or gore area.
6. The relationship between width transitions, entry widths, lane widths, and gore widths should be carefully considered by the designer when determining how to optimally serve trucks and passenger vehicles. As a general principle, widths should be minimized while still accommodating the design truck.
7. Typically, a Case 1 design would have a controlling radius value of 65 feet or greater, while a more common range is 100 to 130 feet for Case 2 and 3 designs.

30.5.5.4 Additional Geometric Design Guidance for Case 3 Roundabouts

The Case 3 design is preferred as the initial consideration at intersections that experience 100 or more large trucks (vehicle classification 3S2). When preparing a Case 3 design, once the primary design principles from this guide have been met (speed control, sight distance, adequate space for a design vehicle), the designer will typically revise the design iteratively to allow trucks to stay in lane at the entry and circulating road while still maintaining the primary design principles. Although there are some specific design characteristics that are unique to Case 3 roundabouts, the overall approach, methods, and iterative design process remain the same as multilane roundabouts in general.

Overall, Case 3 roundabouts embody similar geometric characteristics as Case 1 and 2 roundabouts. However, there are specific geometric elements where Case 3 roundabouts differ from Case 1 and 2 designs.

1. The outside circulating lane is often in the range of 15 to 18 feet (from edge of gutter flange line to lane line). Inside lanes range from 13 to 15 feet (from edge of central island gutter flange line to nearest lane line).
2. Usually include relatively large or flat exit radii which allow trucks to depart from the circulating road with minimal curvature to the right, thus allowing them to stay in lane more easily. Case 3 roundabouts may have larger ICDs in some situations where a double left turn is required. This type of design may be quite complex. Figure 30.6 shows the basic design features of a Case 3 roundabout.

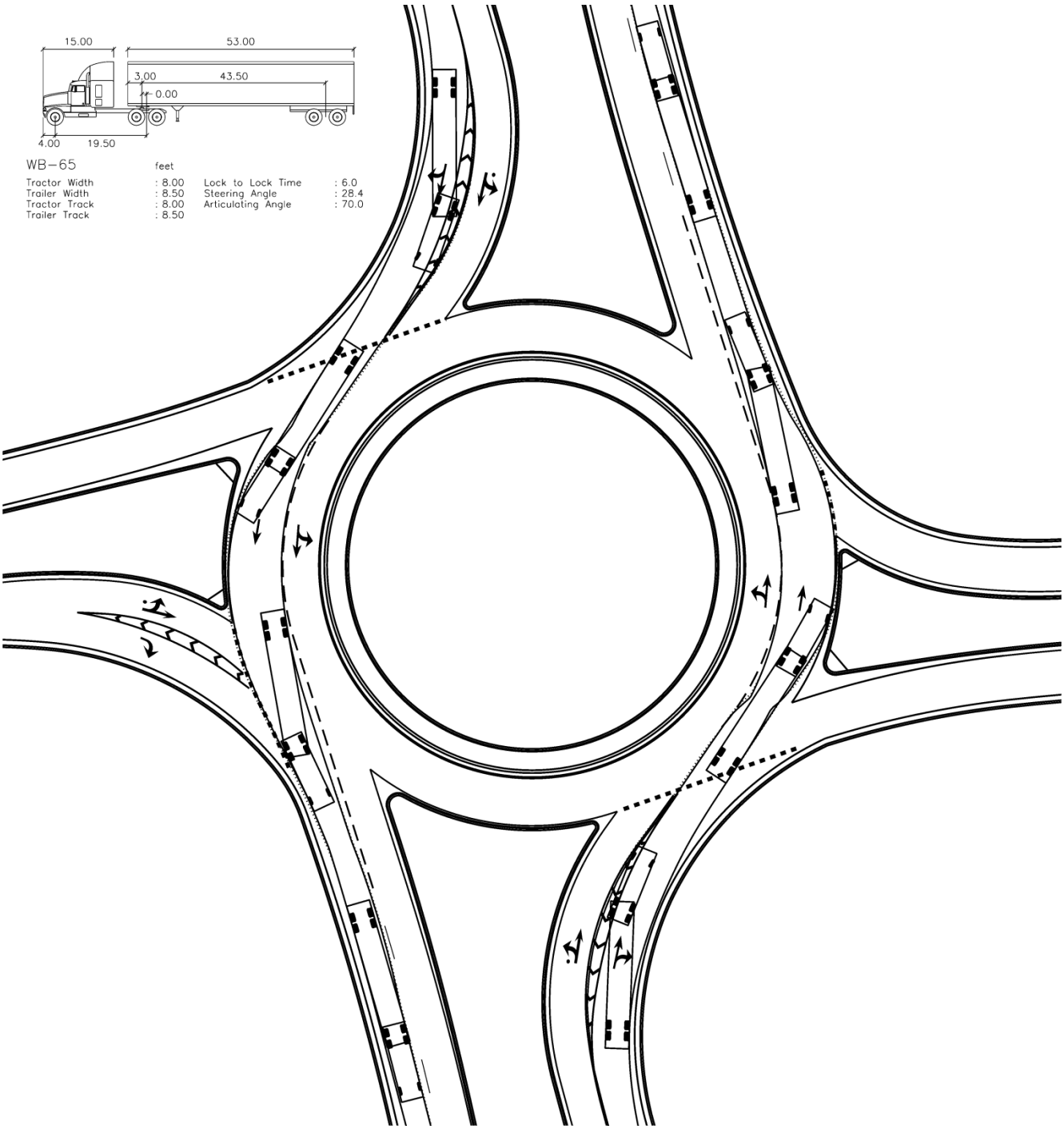


***Figure 30.6* Case 3 Roundabout Design (6-ft to 8-ft gore pavement marking between lanes)**

30.5.6 Vertical Considerations for OSOW Vehicles

Prior to the preliminary design, check with local officials, the public and the State freight engineer in the Bureau of Highway Maintenance to determine if there are any special OSOW vehicles that regularly use the intersection and refer to the WisDOT OSOW vehicle inventory in FDM 11-25 Attachment 2.1.

See the OSOW maps for routes designated as OSOW-TR available at:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/planning-maps.aspx

If a roundabout is located on the OSOW Truck Route or it is thought that OSOW vehicles may use the intersection, conduct a vehicle horizontal turning and a low vertical clearance check with the OSOW vehicle inventory. AutoTurn or AutoTrack software may be used for the horizontal checks. AutoTURN Pro may be used for horizontal analysis and is required to determine if low vertical clearance conflict points are present. Use a low clearance of 5 inches for the DST lowboy evaluation. If clearance issues are found, reconfigure the slopes within the conflict areas and check the surrounding area (i.e. approaches) for additional conflict points. Refer to Figure 30.7 for typical ground clearance problem areas.

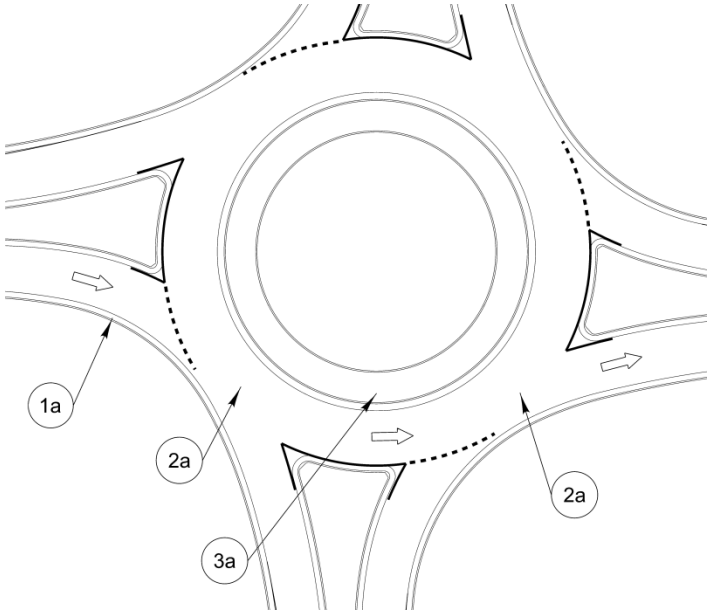


***Figure 30.7* Typical Ground Clearance Problem Areas**

1. Off-tracking at the entry curve/lowboy hitting the outside curb head
    a. Consider a Type A or D 4-inch sloped curb and gutter modified with 8” minimum flange thickness and concrete truck apron behind the back of curb along the outside entrance area. The slope of the truck apron should be a maximum of 1%. Evaluate the entrance for pedestrian crossings and placement of the concrete pad to prevent these areas from overlapping.
2. Entry and exit rollover
    a. Consider flattening the circulatory roadway crown in these areas if needed, while providing approximately 2/3 sloped inward and 1/3 sloped outward.
    b. Avoid break-over grades over 3% within 200 feet of the entry yield line location and exiting the roundabout
3. Truck Apron
    a. Slope truck apron 1% toward the roadway on all roundabouts (not 2% as in the past). Consider a pill shaped central island or other shape where appropriate to accommodate the anticipated OSOW turning maneuver.
        i. See if the vehicle can track more on the circulatory roadway. In rare situations, the designer may consider a 3-inch height R/T type curb and gutter. This will require an evaluation of the inlet casting height/location (out of the vehicle path) and will require a C & G special detail.
    b. Look at the circulatory roadway profile
        i. Keep it as flat/gentle as possible and still maintain drainage (0.75% - 1.0%)
        ii. Locate the crest away from the area(s) of concern

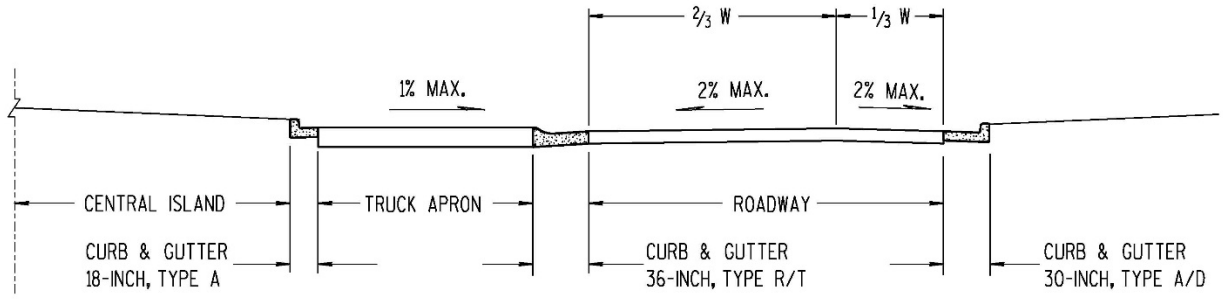


***Figure 30.8* Cross-Section Example**

In some cases, abnormally long vehicles may not be able to negotiate roundabout regardless of geometric adjustments to the truck apron and approaches when making left turns. In some cases, special median crossings may be required, which allow the vehicle to bypass the circle portion of the roundabout by traveling the opposite direction down a right turn bypass. Such maneuvers should be avoided, if possible, due to the extra planning required for escorting a vehicle in such a maneuver. Discuss such alternatives with the regional traffic section and the OSOW-TR coordinator and document route testing produced by turn analysis software for future use by the OSOW Permitting Unit.

30.5.7 Overturning Considerations for Large Vehicles

A further consideration associated with large trucks in roundabouts is the potential for overturning or shifting of loads. There is no simple solution in relation to layout geometry to completely prevent load shifting and roll-overs. Experience suggests that at roundabouts where these problems persist, there are frequently combinations of the following geometric features:

- Long straight high-speed approaches
- Inadequate entry deflection or too much entry deflection
- Low circulating flow combined with excessive visibility to the left
- Significant tightening of the turn radius partway around the roundabout (spirals with arcs that are too short).
- Cross-slope changes on the circulatory roadway or the exit
- Outward sloping cross-slope on the entire width of the circulatory roadway

A problem for some vehicles may be present even if speeds are low because of a combination of grade, geometry, sight distance and driver responsiveness. Research has shown that an articulated large goods vehicle with a center of gravity height of 8 feet above the ground can overturn on a 65-foot radius curve at speeds as low as 15 mph. See Transport Research Laboratory Report LR788.

Layouts designed to mitigate the above noted characteristics will be less prone to load shifting or load shedding. In addition, pay attention during design and construction to ensure that pavement surface tolerances are complied with and that abrupt change in cross-slopes are avoided.

30.5.8 Roadway Width

The width of the roadway at locations with curb and gutter on both sides should accommodate the design vehicle and allow for passing a stalled vehicle. The design width for entries, exits and bypass lanes is shown in Exhibit 3-51, page 220, GDHS 2004 as a 19-foot face-face minimum and 20-foot face-face typical to allow a stalled vehicle to pass.

30.5.8.1 Entry Width

Entry width is measured perpendicularly from the outside curb face to the inside curb face nose P.C. at the splitter island point nearest to the inscribed circle.

Narrow entries tend to promote lower speeds and improved safety. However, a WB-65 may require a 19 to 22-foot-wide entry path for single lane approaches to be able to make a right turn. Design single lane roundabouts to accommodate a WB-65 without encroachment onto the truck apron or the curb and gutters. Wide entries may cause concerns about whether to pavement mark the entry as a multilane or keep as a single lane. Increasing the flare length without changing entry width will increase entry capacity and is crash-neutral (see NCHRP 672 Exhibit 6-25). Increasing both flare width and entry width may produce a substantial increase in capacity but will degrade safety by promoting higher entry speeds. Effective flare length may be as short as 15 feet or as long as

330 feet. Once the effective flare length exceeds 330 feet it will have a minimal benefit to capacity; therefore, adding a full approach lane would be advised.

30.5.8.2 Entry Flare

Flaring an entry from one lane to two or from two to three creates additional entry capacity without extensive mid-block widening. When lane choice options are even, or no preference is given to either lane, it is ideal to split the approach width at a point where the lane width reaches 9.5 feet or 19 feet overall (flange of curb dimensions).

The development of horizontal geometry and pavement marking of a flared entry is balanced and smooth making lane choice options obvious and entry paths clear.

30.5.9 Exit Tapers

Tapering the number of lanes on an exit from two lanes to one lane or from three lanes to two lanes allows for additional roundabout capacity without extensive mid-block widening. The continuous flow nature of roundabouts typically results in less saturated traffic streams exiting the intersection. This is in sharp contrast to a signalized intersection where platoons of traffic are much more concentrated, and consequently typically require more downstream distance to merge. Speeds are also much slower for traffic exiting roundabouts which eliminates the need for long parallel section downstream of the roundabout exit.

Design exit tapers from roundabouts based on the anticipated in lane exiting speed, not the fastest path, typically in the range of 15 to 25 mph. Merging taper rates should be based on the lengths shown in FDM 11-25 Attachment 2.3, typically 20:1 to 30:1. The length of full width lanes beyond the circulating roadway to beginning the merging taper may vary between 100 and 300 feet depending on volume, potential for upstream lane choice, and other factors that may be unique to the site, Consider the farther the full lane widths are extended upstream, the potential for increase in speed and the potential for a longer merge taper. See Figure 30.9.

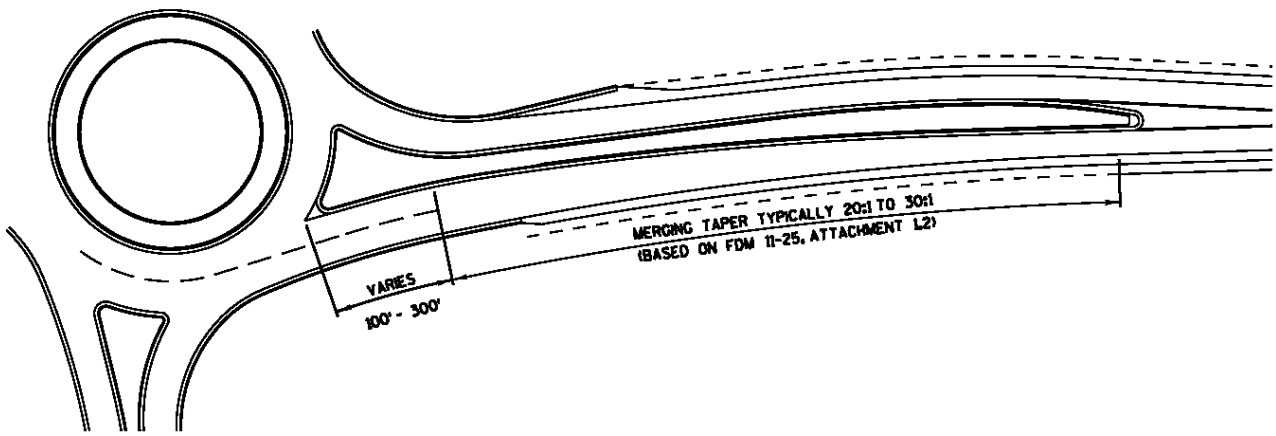


***Figure 30.9** Exit Lane Taper*

30.5.10 Circulatory Roadway Width

Circulatory roadway width is the width between the outer edge of the inscribed diameter at the curb face and the central island curb face. It is typically 1.0 to 1.2 times the width of the widest entry with potential exceptions for Case 2 and Case 3 designs. It does not include the width of any traversable apron, which is defined to be part of the central island. The circulatory roadway width defines the roadway width, curb face to curb face, for vehicle circulation around the central island. The circulatory roadway width does not need to remain constant. A two-lane entry may be appropriate for the major through highway, however, the minor side road may be single lane approaches. The circulating roadway may often have a different width to accommodate the through traffic than for the side road traffic. Alternative lane configurations also produce varying circulatory widths as shown on NCHRP 672 Exhibit 6-27.

30.5.11 Central Island

The central island of a roundabout is always a raised, non-traversable area encircled by the roundabout circulatory roadway. The central island is stepped up from the traversable truck apron to the non-traversable island area. The central island is raised and landscaped to enhance driver recognition of the roundabout upon approach and to limit the ability of the approaching driver to see through to the other side. The inability to see through the roundabout reduces or eliminates headlight glare at night and driver distraction by other vehicles on the circulating roadway.

The center or highest portion of the central island ground surface elevation should be raised a minimum of 3.5 feet and maximum of 6 feet from the circulatory roadway surface. The ground slope in the central island shall

not exceed 6:1.

Concrete, stone, wood or other non-forgiving material used to make a wall within the central island is prohibited. Landscaping the central island and the roundabout area is further addressed in FDM 11-26-40.

The outside 6 feet of the central island should be a low mowed grass surface or low maintenance surface to maintain good visibility to the left upon entry as well as good forward and circulatory visibility on the circulatory roadway.

30.5.12 Entry Curves

The minimum entry radii should be approximately 65 feet. Capacity will increase with increased entry radii, but so may the entry speed. Entry radius is not R1.

NCHRP 672 Exhibit 6-14 illustrates the composition of entry curves to produce natural entry paths. This method is useful but has limitations where large trucks making right turns will require even larger outside radii, particularly on single lane roundabouts with narrow entry widths. In such cases, the larger outside radius may increase entry speeds undesirably. A preferred design technique for single-lane roundabouts is not to make the inside radius/arc tangential to the central island, but to create a flare in the entry such that the large truck path can preserve the outside radius which controls entry speed. The effect gives the entry a flare, typically ranging from 18ft to 24ft. To avoid misleading drivers to expect multilane operation at wider single-lane entries, the left-hand side of the entry may be pavement marked as shown in Figure 30.10 to reinforce single lane operation. Also refer to FDM 11-26-35.2.1, and Attachment 35.1 for further pavement marking procedures.

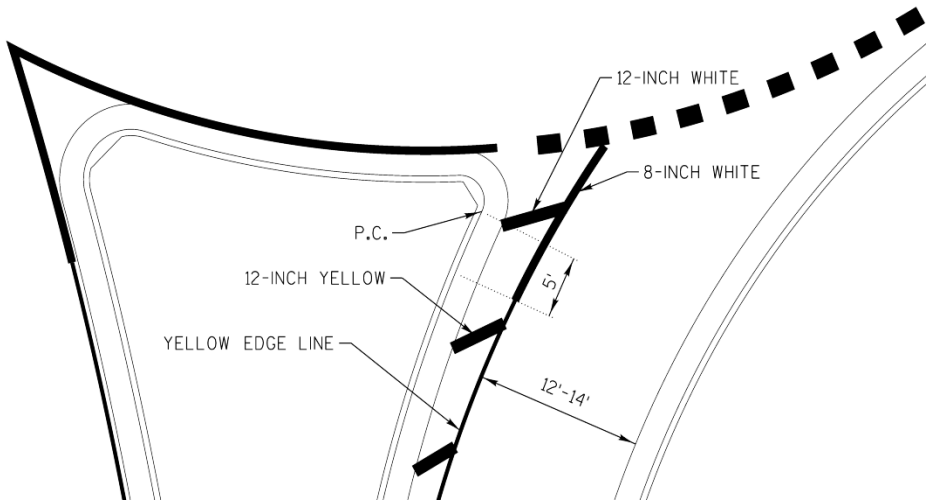


***Figure 30.10* Example of alternative pavement marking design for single entrance lane not in the NCHRP Report 672**

30.5.13 Non-motorized Users

Roundabouts like other intersections need to accommodate bicyclists and pedestrians. The types of facilities provided vary based on the existing urban, suburban and rural conditions as well as future land uses. Evaluate regional and local land use plans including stand-alone bike and pedestrian plans for communities when determining the appropriate bike and pedestrian facilities at a roundabout. See FDM 11-46-1 for guidance on including bike and pedestrian facilities on projects.

Pedestrian accommodations include sidewalks, shared-use paths and roundabout sidepaths.

Bicycle accommodations include bike lanes, wide curb lanes, urban paved shoulders, rural paved shoulders, shared-use paths and roundabout sidepaths. Although a shared roadway is not a bicycle accommodation, shoulders or bike lanes taper down and end just prior to the entrance to a roundabout. Tapers are necessary to help achieve proper speed control for vehicles at entry. Design requirements do not allow bike lanes or shoulders at the yield line or within the circulatory roadway of a roundabout. Bicyclists in Wisconsin have the right to use the roadway in the same manner as motor vehicles. Bicyclists may have concerns when traveling into, through, or around roundabouts depending on traffic volume, vehicle type composition, experience of the bicyclist, lighting or other factors. Therefore, a bicyclist approaching a roundabout may proceed in a travel lane ("take the lane") or exit the roadway by way of a ramp and ride on a roundabout sidepath (or a shared use path, if applicable). See FDM 11-26-30.5.13.1 and Figure 30.11 for guidance on bike exit and entrance ramps). These ramps are where the shoulder or bike lane tapers and a typical 5-foot sidewalk transitions to/from a roundabout sidepath.

A sidewalk transitions to/from a roundabout sidepath as it approaches/departs an isolated roundabout. At

locations with consecutive closely spaced roundabouts, a sidewalk transitions to a roundabout sidepath at the first upstream roundabout, and transitions from a roundabout sidepath at the last downstream roundabout. See FDM 11-20-1, FDM 11-46-5 and FDM 11-46-10 for design guidance on sidewalks.

Shared-use paths are typically community or regional facilities in their own corridors that may extend for miles. Shared-use paths support a wide variety of non-motorized travelers like bicyclists, in-line skaters, roller skaters, wheelchair users, walkers, runners, people with baby strollers or people walking dogs (typically not equestrian users or motorized users - although some state trails in Wisconsin allow snowmobiles). Shared-use paths are designed for bi-directional bicycle travel. Continue a shared-use path around roundabouts (and between consecutive roundabouts if applicable) following shared-use path design criteria. See FDM 11-46-15.6 and the Wisconsin Bicycle Facility Design Handbook for more guidance on shared-use paths. Also, see FDM 11-35-1.6 and FDM 11-35 Attachment 1.1.

Roundabout sidepaths are a variant of shared-use paths that apply specifically to roundabout intersections and between consecutive closely spaced roundabouts. A roundabout sidepath is a sidepath around the perimeter of an isolated roundabout, or a sidepath between two consecutive closely spaced roundabouts and around their perimeters. Consecutive roundabouts are closely spaced if they are 1,000-feet or less from center to center. Roundabout sidepaths are designed with the expectation that bicyclists will travel in a unidirectional manner (i.e., one-way bicycle travel in the same direction as traffic flow on that side of the roadway) and do not connect to shared-use paths. If bicyclists choose to leave the roadway and enter the path, they must yield the right-of-way to pedestrians. If bicyclists stay on the roadway they are expected to position themselves near the middle of the travel lane to circulate around the roundabout.

The roundabout splitter islands provide pedestrian refuge and pedestrian crossings. At roundabouts with high traffic volumes, or where pedestrian or bicyclist volumes are high, consider accommodating both users by enhancing the pedestrian crossings with features such as:

- 6-inch white crosswalk marking next to colored concrete (Wisconsin MUTCD (WMUTCD), 3B.18, 3G.01, 7C.02)
- Colored concrete with 6-inch wide patterned borders with white crosswalk markings, note main walking surface is smooth
- Activated (push button or automatic detection) warning beacons (e.g. Rectangular Rapid Flashing Beacon or pedestrian hybrid beacon)

30.5.13.1 Bike Ramp Entrance and Bike Ramp Exit Design Guidance

End the on-road bicycle accommodations approximately 75 to 150 feet upstream of the yield line and allow the bicyclist an opportunity to leave the roadway by way of a bicycle exit ramp. More distance is needed when a right turn bypass lane is provided. The bike ramp exit should have relatively flat angles as shown so that bicyclists are not directed into the path of pedestrians. The bike ramp entrance should have relatively flat angles as shown so that bicyclists are not directed into the travel lane of motorized vehicles. The bike entrance ramp should not be directed parallel to the bike lane.

The location of bike ramps and driveway aprons need to be spaced as not to conflict with each other. It is not typical for bicyclists and is a last resort to leave or re-enter the roadway by way of a driveway apron.

Design the bike ramps 4 feet wide between the roadway and the multi-use path such that they angle up (25 to 35 degrees) to the path where the bicycles exit the roadway, Figure 30.11. Angle down (25 to 35 degrees) toward the roadway where the bicycles re-enter the roadway, Figure 30.11.

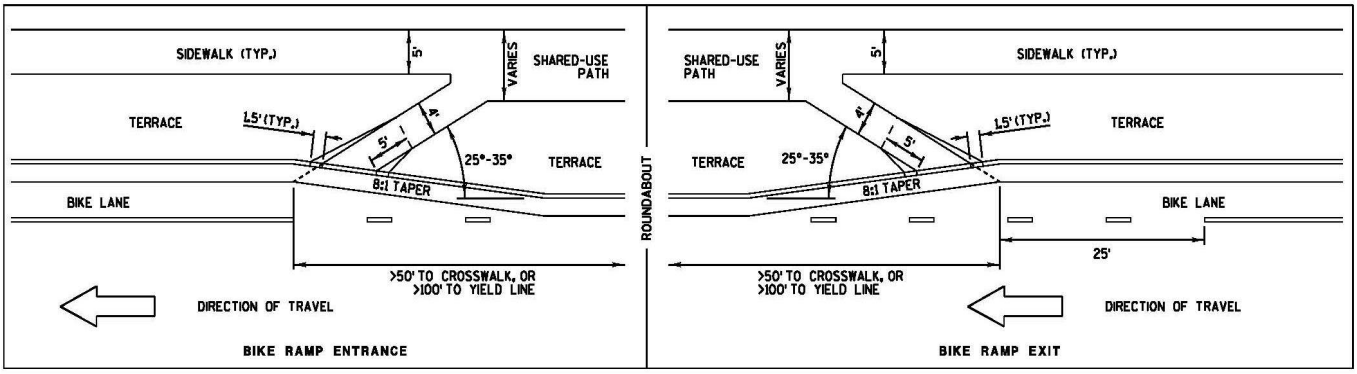


Figure 30.11 ***Bike Ramp Entrance and Exit***

30.5.13.2 Pedestrian Facilities, Shared-Use Paths, and Roundabout Sidepaths

Isolated roundabouts and roundabouts in a series that are closely spaced, which is defined as a distance of

1000' or less between the centers of any two consecutive roundabouts, have design criteria that is different than other at-grade intersections. The following procedures include design guidance for these facilities near and between roundabouts. See FDM 11-46-5 for additional information on Pedestrian Facilities. See FDM 11-46-15 and Wisconsin Bicycle Facility Design Handbook for additional information on typical shared use paths. See FDM 11-46-1 on providing bicycle and pedestrian accommodations on projects.

In most urban and suburban areas sidewalks on both sides of the roadway are common and expected. These sidewalks lead up to and transition into roundabout side path as these facilities approach a roundabout. This typically is a 5 ft sidewalk and a 5 ft terrace, or if there are trees planted in the terrace the minimum terrace width is 6-foot wide minimum.

When an existing or proposed sidewalk approaches either end of a roundabout, provide at least an 8-foot-wide roundabout side path with a terrace when sidepath use is anticipated to be low or medium around and between the roundabout(s). The width of the sidepath (and terrace) remains consistent through the roundabout(s). When the sidepath use is anticipated to be high (frequent passing of users), install a 10-foot-wide sidepath with a terrace. There are many reasons to anticipate high use such as parks close by, elementary and high schools, universities, gas/convenience stores, restaurants, etc.

In an outlying district or rural area, there may be locations with on-road bicycle accommodations but without sidewalks (existing or proposed) (see FDM 11-46-1.3.1.4). In this case, 6-foot wide roundabout sidepaths are appropriate. Work with the regional bike and pedestrian coordinator to determine the appropriate widths.

When a shared-use path approaches the roundabout carry the shared-use path around the roundabout. The typical width is 10 feet with a 5 ft. terrace, or if there are trees planted in the terrace the minimum terrace width is 6-foot wide minimum.

For a series of closely spaced roundabouts, extend the roundabout side path or shared use path from the first bicycle exit ramp to the last bicycle entrance ramp, for the bicyclist to leave the roadway and travel through all roundabouts on the roundabout sidepath. Do not provide entrance ramps for bicyclists to re-enter the roadway between closely spaced roundabouts (1,000 feet or less between roundabout centers). However, provide exit ramps from the roadway to the sidepath prior to the approaching roundabout.

When the distance between any two roundabouts is greater than 1,000 feet, center to center, then the roundabout side path may be discontinued beyond the last roundabout. Provide entrance ramps for bicyclists to re-enter the roadway downstream from each roundabout as well as exit ramps from the roadway to the sidepath. Provide sidewalk(s) between the roundabouts if there is sidewalk on the roundabout approaches (see FDM 11-46).

A roundabout sidepath might not be built during the initial construction if the location meets the criteria under FDM 11-46-1. If a roundabout sidepath around a roundabout is not installed with the initial roundabout construction, it is important to construct the appropriate platform by grading for future facilities (e.g in rural or outlaying area 5-foot terrace and a 6-foot width for the roundabout sidepath around the roundabout) and provide pedestrian crossings in the splitter islands. Maintenance may not be required until the perimeter facilities are installed.

30.5.13.3 Roadway Width, Clear Roadway Width of Bridges, and Underpasses between Closely Spaced Roundabouts

At a minimum, multi-lane roadways with a raised curb median between opposing roadways and between closely spaced roundabouts require a 2-foot median shoulder, two or more 12-foot lanes, and a 4-foot minimum outside shoulder, a 5-foot terrace adjacent to a shared-use path or roundabout sidepath. If there are trees planted in the terrace the minimum terrace width is 6-foot wide.

At a minimum, single lane roadways with a raised curb median between opposing roadways and between closely spaced roundabouts require 19 feet minimum from curb face to curb face. This typically allows for a 2-foot median shoulder, one 12-foot lane and a 5-foot minimum shoulder on the outside, followed by a 5-foot terrace and either a roundabout sidepath or a shared-use path. If there are trees planted in the terrace the minimum terrace width is 6-foot wide. A single lane roadway between opposing roadways and between closely spaced roundabouts without a raised curb median requires a minimum 32 feet from curb face to curb face.

If there is an overpass structure between two closely spaced roundabouts (1,000 feet or less between roundabout centers), and a roundabout sidepath is provided around the outside of the roundabouts, then the roundabout sidepath is at least 2 ft wider on the structure (Figure 30.12). A roundabout sidepath will typically not have a barrier wall separating the path from the roadway. Vehicle travel speeds between closely spaced roundabouts is considered a low speed environment (40 mph or less) and bicycle travel is expected to be unidirectional thus barrier walls between the roadway and path are not required. When there is a barrier proposed between the roadway and a roundabout sidepath, the sidepath is level with the roadway (not a raised sidewalk). See Figure 30.12 and FDM 11-35-1.6 and FDM 11-35 Attachment 1.1 pages 1 and 2. Section B-B shows a section view of a raised curb roundabout sidepath. A barrier between the roadway and roundabout sidepath is unique and maybe a provision requested that requires WisDOT approval, including the regional

bicycle and pedestrian coordinator.

When a shared-use path is provided around the outside of roundabouts, the shared-use path design criteria on structures are followed. See FDM 11-46-15, FDM 11-35 Attachment 1.1 pages 1 and 2. Section B-B shows a section view of a raised curb shared-use path, and Section C-C shows a section view of the barrier wall between the roadway and the path. See FDM 11-35-1.6.3 for required separation distance between outside travel lane and front face of barrier wall to determine the minimum barrier wall height.

The roadway and structure width will depend on the median width, lane width, number of lanes, shoulder width, and path width requirements.

For the STH system, the WisDOT minimum roadway width and clear roadway width of bridge from curb face to curb face, between two closely spaced roundabouts that are less than 1,000 feet apart, is:

- 2 lane divided (each side) - 2’ median shoulder, 12’ lane, 5’ outside shoulder = 19’.
- 2 lane undivided - 4’ shoulder width, + 12’ lane +12’ lane + 4’ shoulder width = 32’, independent of ADT.
- 4 lane divided (each side) - 2’ median shoulder, + 12’ inside lane, + 12’ outside lane, + 4’ shoulder = 30’.
- 4 lane undivided - 4’ shoulder, 12’ outside lane, + 12’ inside lane +12 inside lane, + 12’ outside lane, + 4’ shoulder = 56’.
- 6 lane divided (each side) - 2’ median shoulder, + 2 inside lanes at 12’, + 12’ outside lane, + 4’ shoulder = 42’

The above widths provide a minimum roadway width between closely spaced roundabouts.

To reduce structure width, the designer should consider a narrow-raised median between the splitter islands. A 4-foot raised curb median face to face will provide an 8-foot median measured from flange line to flange line with 2-foot gutters just off the end of the structure. The distance between roundabouts should be sufficient to allow for any curved curb and gutter portion that is formed at the ends of the splitter islands to remain off the structure. The tangent narrow section in the middle between splitter islands could be 4-foot-wide face to face providing there are no signs or other road side elements in that area.

Under structures the roundabout sidepath and terrace widths are consistently provided through and between the roundabouts. If there will be road signs, power poles, light poles or other fixtures installed along the roadside then provide at least a 5-foot-wide terrace between the curb face at the outside of the shoulder and the front of the path. The cross-section under the structure provides at least the median shoulder width, lane width(s), outside shoulder width and path width plus 2 ft. if no obstructions are in the terrace. Follow shared-use path design criteria for under structures.

The above minimum roadway widths between closely spaced roundabouts are not appropriate for rural highway applications or where the distance between consecutive roundabouts is greater than 1000 feet. If existing or proposed sidewalk approaches between consecutive roundabouts are not closely spaced (i.e. greater than 1,000-feet between roundabout centers), provide roundabout sidepath(s) around the roundabout(s) but not between them - provide bike and pedestrian accommodations see FDM 11-46-1.

The roadway between the roundabouts transitions to a cross-section roadway width and clear roadway width of bridges based on the design class of the roadway (see FDM 11-15-1, FDM 11-20-1, FDM 11-35-1.2, and FDM 11-46-1).

If bike or pedestrian facilities are omitted around or between roundabouts, discuss with the regional bicycle and pedestrian coordinator the need to provide an 8-foot roundabout sidepath on or under the structure. Structures have a longer life-span and even if a roundabout sidepath is not immediately included on a structure it is necessary to consider constructing a wider substructure to allow widening of the superstructure in the future to accommodate a roundabout sidepath. In such cases, the pedestrian refuge in the splitter islands should still be constructed.

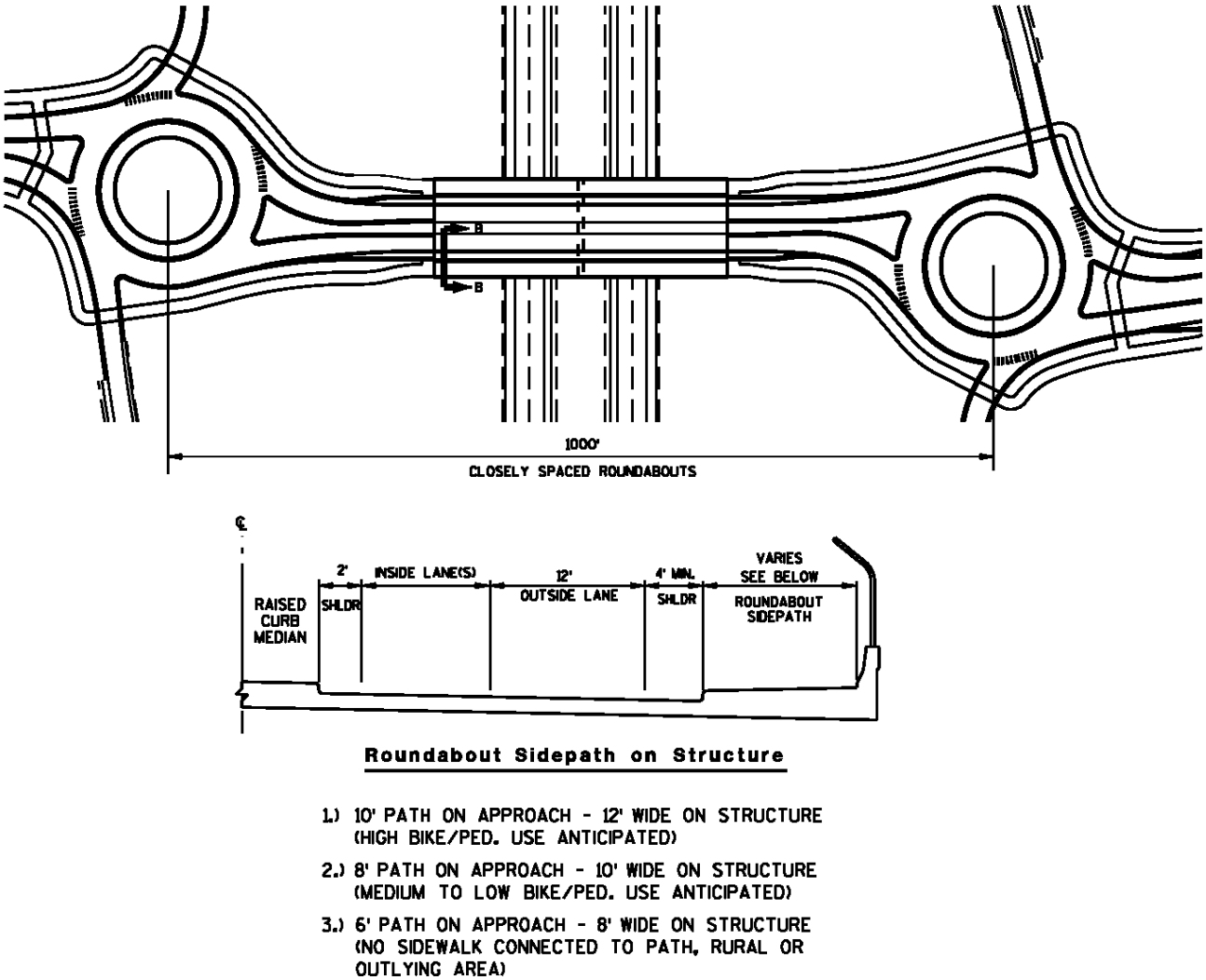


***Figure 30.12** Roundabout Sidepath*

30.5.14 Splitter Islands

For WisDOT roundabout projects crosswalk alignment is not optional as shown on NCHRP 672 Exhibit 6-66. The angled crosswalk produces shorter perpendicular crossing paths and discourages bicyclists from crossing without stopping in the refuge area.

The splitter island lower minimum width within the pedestrian refuge area is 6 feet, typically it is 8 feet, (face of curb to face of curb). The lower minimum crosswalk width in the splitter island is 7 feet, typically it is 10 feet. See NCHRP 672, Exhibit 6-12 except design the curbing to have a continuous gutter through the crosswalk as shown on Figure 30.13.

In general, locate the pedestrian crossing one car length or approximately 20-25 feet upstream from the yield line (WMUTCD, Figure 3C-1). FDM 11-26-30.5 provides additional guidance on pedestrian crossing placement and design. This helps to reduce decision-making problems for drivers and avoids creating a queue of vehicles waiting to enter the roundabout. However, for pedestrian safety the crossing should not be located too far back from the yield line such that entering vehicle speeds are insufficiently reduced or exiting vehicles are accelerating. It may be appropriate to design the pedestrian crossing at two or three car lengths from the yield line on some multilane entries. Make the crossing perpendicular to the direction of traffic on multilane entrances and exits to minimize pedestrian travel and exposure time as shown on Figure 30.13. On single-lane roundabouts it may be appropriate to provide a crosswalk straight through the splitter island (See NCHRP 672, Exhibit 6-66).

Splitter islands can be crowned upward with a slope toward the center of the island area using between a 4 percent slope to as much as a 6:1 slope. This improves visibility of the splitter island for rural conditions. The

maximum overall height above the top of the curb within the splitter island area should be approximately 18 inches from top of curb to the top of any concrete/asphaltic surface. Some islands may become quite wide near the circulating roadway however limit the height to 18 inches. The approach nose separating the entering traffic and the exiting traffic shall be a Concrete Median Sloped Nose, Type 1. This splitter island nose should be 6-foot face-to-face where the R4-7 (KEEP RIGHT) sign is located. The other noses at the edge of the circulatory roadway and the splitter island shall be Concrete Median Sloped Nose, Type 2. Both nose types are shown in SDD 11B2. Where there is a divided highway approaching the roundabout the approach nose is eliminated.

For additional information, see NCHRP 672, §6.4.1.

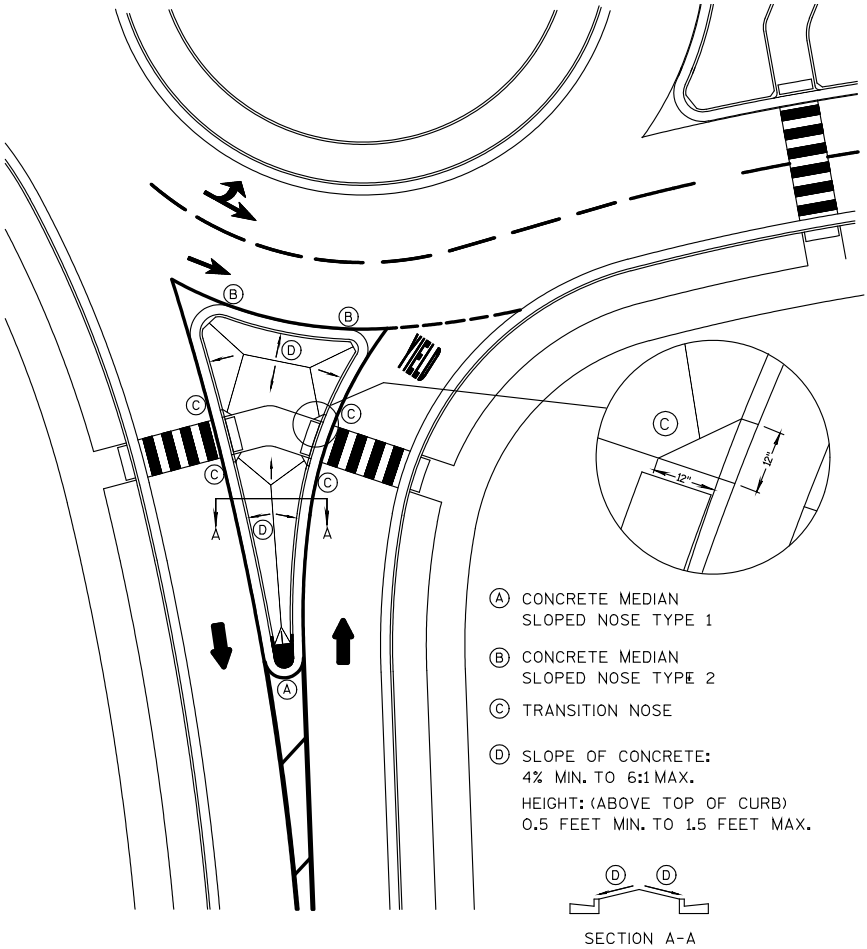


***Figure 30.13** Typical Splitter Island*

30.5.15 Intersection Sight Distance (ISD) and Length of Conflicting Leg of Sight Triangle

See NCHRP Report 672 starting on page 6-63 for guidance on Intersection Sight Distance (ISD) for roundabout approaches. The basis for ISD in NCHRP Report 672 is providing the critical headway time gap (tc) for entering the roundabout. The critical headway time gap (tc) for entering the roundabout is based on the amount of time required for a vehicle to safely enter the conflicting stream. If the perceived available headway time gap is less than tc then most drivers will slow down or stop and wait for an acceptable gap. The critical headway time gap will possibly change over time. WisDOT has revised this time gap per FDM 11-26-20.4.5 however at this time WisDOT will use the critical headway time gap (tc) equal to 5 seconds as stated in NCHRP Report 672 for intersection sight distance. This is less than the 6.5 second required by the 2000 FHWA Roundabout Guide, but greater than the previous FDM requirement of 4.5 seconds. Table 30.7 shows computed distance for various speeds based on a critical headway time gap (tc) = 5.0.

***Table 30.7* Roundabout Intersection Sight Distance**

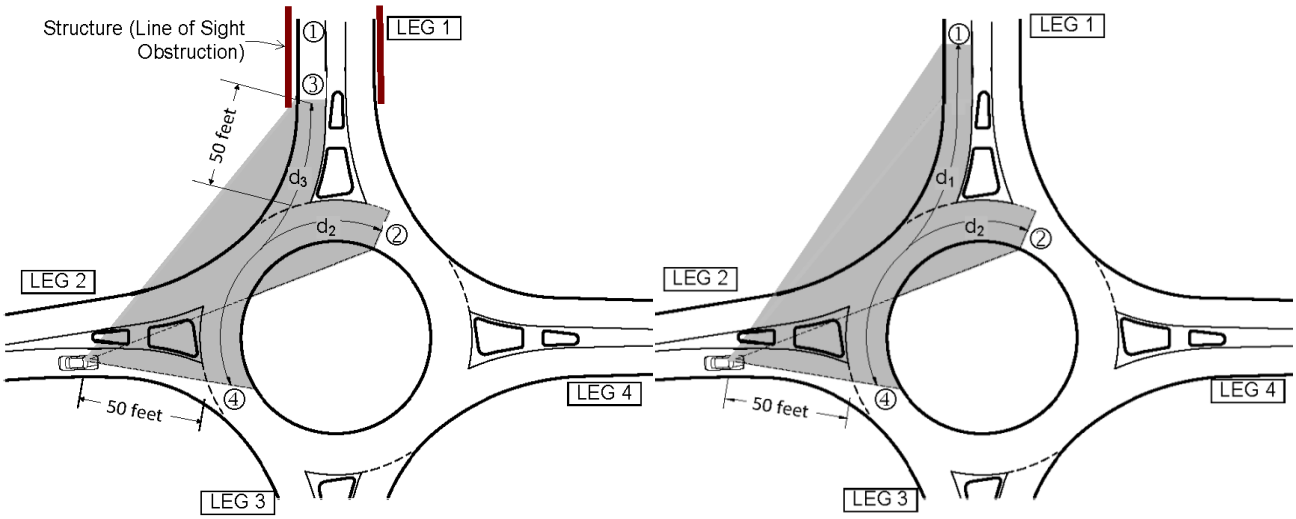
Conflicting Approach Speed (mph)	* Computed Distance (ft) for t_c = 5.0s
10	74
15	110
20	147
25	184
30	221

*distance in feet = speed (mph) multiplied by time (seconds) multiplied by a factor of 1.468.

The "clear sight window" requirements for critical headway time gap (t_c) are shown on Exhibit 6-58 of NCHRP Report 672. Use an eye height above the roadway surface of 3.5 feet for passenger cars and 7.6 feet for trucks in establishing sight lines through a clear sight window. Use an object height above the roadway surface of 3.5 feet.

Figure 30.14a shows "Normal ISD" for a roundabout approach; Figure 30.14b shows "Minimum ISD" for a roundabout approach. Use the following guidance when designing the ISD "clear sight window" for a roundabout approach:

- **[Normal ISD & Minimum ISD - driver's eye position on approach]** Set the initial position of the driver's eye at 50 feet behind the yield line, as depicted on Exhibit 6-58 of NCHRP Report 672, and as shown in Figure 30.14a and b or the vehicle approaching on Leg 2.
- **[Normal ISD & Minimum ISD - to circulating roadway]** Provide ISD based on [t_c=5.0 seconds x "circulating speed X factor"] for the circulating stream distance d_2, as depicted on Exhibit 6-58 of NCHRP Report 672, and shown on Figure 30.14a and b as the distance from point 2 to point 4. For example, if the circulating speed is 20 mph, the distance between point 2 and point 4, per Table 30.7, is 147 feet.
- **[Normal ISD - to adjacent leg to the left]** Provide ISD based on [t_c=5.0 seconds x "fastest path speed X factor"] for the entering stream distance d_1, as depicted on Exhibit 6-58 of NCHRP Report 672, and shown on Figure 30.14a as the distance from point 1 to point 4. For example, if the "fastest path speed" is 25 mph, the distance between point 1 and point 4, per Table 30.7, is 184 feet.
- **[Minimum ISD - to adjacent leg to the left]** It may not be possible to provide "Normal ISD" at some approaches because of a sight obstruction whose removal would cause unacceptable impacts. For these locations, provide ISD to at least 50-feet behind the yield line of the adjacent leg to the left - as shown on Figure 30.14b. The resulting reduced entering stream distance d_3 from point 3 to point 4 is less than [t_c=5.0 seconds x "fastest path speed X factor"]. However, it is unlikely that all vehicles will be traveling at the "fastest path speed" between points 3 and 4 because some drivers will slow down or stop behind the yield line if there is an unacceptable gap.



Legend

d_1 Entering Stream Distance

d_2 Circulating Stream Distance

d_3 Reduced Entering Stream Distance starting at least 50-feet behind the Leg 1 yield line

ISD Clear Sight Window for vehicle on Leg 2

Figure 30.14 Example of Roundabout ISD Clear Sight Window (Leg 2 ISD shown - other legs are similar)

Designer experience and judgment is needed to balance the impacts where ISD is severely restricted or where excess ISD is available. More is not better when it comes to Intersection Sight Distance for roundabouts. Research on sight distance has determined that excessive intersection sight distance results in a higher frequency of crashes because excessive forward visibility at entry or visibility between adjacent entries can result in approach and greater typical entry speeds for intersection geometry.

Consider limiting visibility using selective landscaping. This refers to landscaping or a visual block down the side road or median to restrict visibility between adjacent entries, as well as the forward visibility through the central island. Limiting visibility in this way helps encourage drivers to slow down on the roundabout approach, which provides a safer environment for both drivers and pedestrians.

Forward visibility for the driver entering to have sight of the circulatory roadway ahead of the driver's entering path can also be checked but is generally accounted for by ensuring sight to the left of circulating vehicle upstream (see Figure 30.14b for vehicle along path d_2).

30.5.16 Angles of Visibility

The intersection angle between consecutive entries must not be overly acute in order to allow drivers to comfortably turn their heads to the left to view oncoming traffic from the immediate upstream entry. The intersection angle between consecutive entries, and the angle of visibility to the left for all entries, should conform to the same design guidelines as for conventional intersections. Based on guidance for designing for older drivers and pedestrians, the recommended angle for visibility to the left at entry is 90° ±15°. NCHRP 672 Exhibit 6-62 illustrates an example of a visibility angle for a roundabout entry at a ramp terminal.

Designers should also be aware of the visibility angle for conditions when the entering traffic does not yield, i.e. drivers looking left upstream of the yield line when not needing to yield or stop, a common condition for off-peak traffic conditions. The view to the left is then executed when the driver is well upstream of the roundabout entry unlike what NCHRP 672 Exhibit 6-62 shows. Thus, visibility angles must also be checked for non-yielding driving conditions from a distance upstream of the point of entry. The designer is cautioned not to provide generous sight to the left as this can contribute to failure to yield conflicts and collisions.

For additional information, see NCHRP 672, §6.7.4.

30.5.17 Right Turn Lanes

Right turn lanes should only be used when capacity needs dictate or when other geometric layouts fail to provide acceptable traffic operations or accommodations for the design vehicle. The decision to use right turn lanes should consider pedestrian and right-of-way constraints. Choosing the proper alternative is dictated by the volume of right turns and the available space. See NCHRP 672, §6.8.6 for additional information.

Three alternatives exist to provide for heavy right turn demand:

30.5.17.1 Free Flow Right Turn Lane (Figure 30.15 and NCHRP 672 Exhibit 6-72)

Free flow bypass lanes allow vehicles to bypass the roundabout and then merge into the exiting stream of traffic. A high right-turn demand when coupled with other approaching traffic may indicate the need for a full bypass lane to avoid a wider, faster entry. Roadway right-turn free-flow lanes are not recommended for pedestrians and bicyclists and should be avoided, if possible, in high pedestrian/bike use areas. If free flow right turn lanes are used keep vehicle speeds slow by using a small right turn radius.

30.5.17.2 Partial Bypass Right Turn Lane (Figure 30.15b or c and NCHRP 672 Exhibit 6-73)

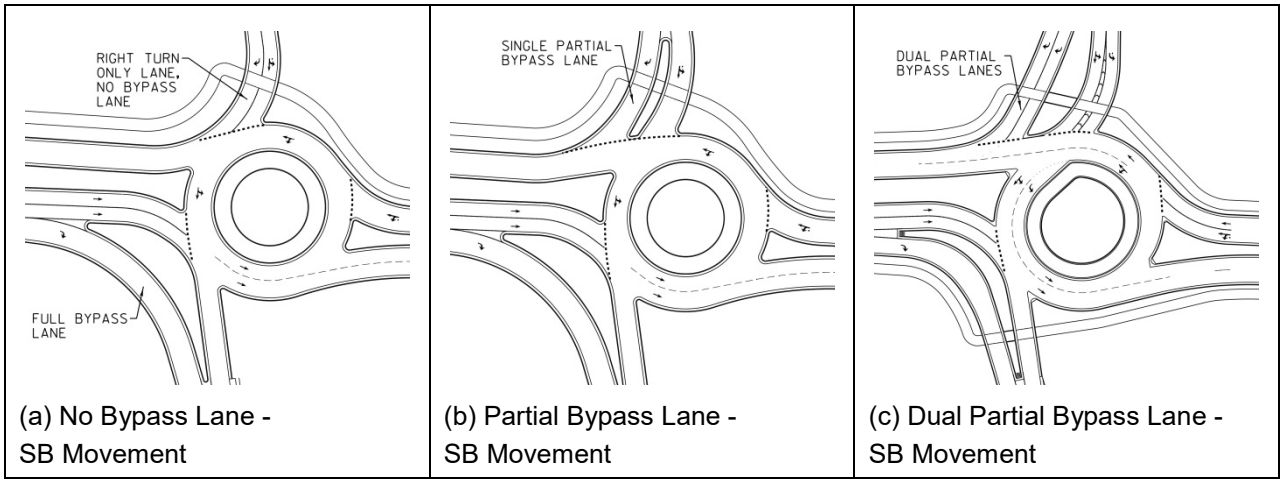
A partial bypass lane with a curbed vane island requires approaching vehicles to yield to traffic leaving the adjacent exit. This alternative ‘snags’ the right turner from making a through movement while preserving good sight to the left for circulating/exiting traffic. Generally, an intersection angle of 70 degrees or higher is typical.

Dual partial right turn bypass lanes with a curbed vane island may also be an appropriate alternative to accommodate heavy right turn demand, especially at interchange ramp terminals. Dual partial bypass lanes maybe problematic for pedestrians and should only be used at locations where there is not a crosswalk near the exit receiving the dual right turning vehicles. Pedestrians may have a hard time seeing a vehicle turning right from the left lane of the dual right turn entry.

When designing dual partial right turns, special attention is required to ensure that vehicles in both right turning lanes have adequate sight of vehicles in the circulatory roadway. Speed of vehicles in the right turn lanes also need to be well controlled. Use a smaller entry radius to help reinforce that vehicles exiting the roundabout have the right of way. This will also minimize the potential for rear end crashes associated with larger right turn radii. Like the guidance provided for a Case 1 design, allow the design vehicle to encroach into adjacent lanes on the entry and exit while making the right turn.

30.5.17.3 Exclusive Right Turn Lane (Figure 30.15a and NCHRP 672 Exhibit 6-74)

Exclusive right turn lanes with or without a painted gore help to keep the overall roundabout layout compact while accommodating the heavy right turning movement. An exclusive right turn lane should be ‘snagged’ from making a through movement while preserving good sight to the left for circulating/exiting traffic.



(a) No Bypass Lane - SB Movement | (b) Partial Bypass Lane - SB Movement | (c) Dual Partial Bypass Lane - SB Movement

Figure 30.15 Right Turn Bypass Lanes
(See also NCHRP 672 Exhibit 6-74)

30.5.18 Vehicle Path Overlap and Methods to Avoid Path Overlap

Designing multilane roundabouts is significantly more complex than single-lane roundabouts due to the additional conflicts present with multiple traffic streams entering, circulating and exiting the roundabout in adjacent lanes. The natural path of a vehicle is the path it will take based on the speed and orientation imposed by the roundabout geometry. While the fastest path assumes a vehicle will intentionally cut across the lane markings to maximize speed, the natural path assumes there are other vehicles present and all vehicles will attempt to stay within the proper lane.

Designers should determine the natural path by assuming the vehicles stay within their lane up to the yield

point. At the yield point, the vehicle will maintain its natural trajectory into the circulatory roadway. The vehicle will then continue into the circulatory roadway and exit with no sudden changes in curvature or speed. If the roundabout geometry tends to lead vehicles into the wrong lane, this can result in operational or safety deficiencies.

Path overlap occurs when the natural paths of vehicles in adjacent lanes overlap or cross one another. It occurs most commonly at entries, where the geometry of the right-hand lane tends to lead vehicles into the left-hand circulatory lane. However, vehicle path overlap can also occur at exits, where the exit geometry or pavement marking of the exit tends to lead vehicles from the left-hand lane into the right-hand exit lane. Figure 30.16 illustrates an example of entry path overlap at a multilane roundabout where the left lane geometry directs the approaching vehicle into the central island, while the right lane geometry directs the approaching vehicle toward the inside circulatory lane, thus creating entry path overlap.

For additional information, see NCHRP 672, §6.2.3 & 6.5.4.

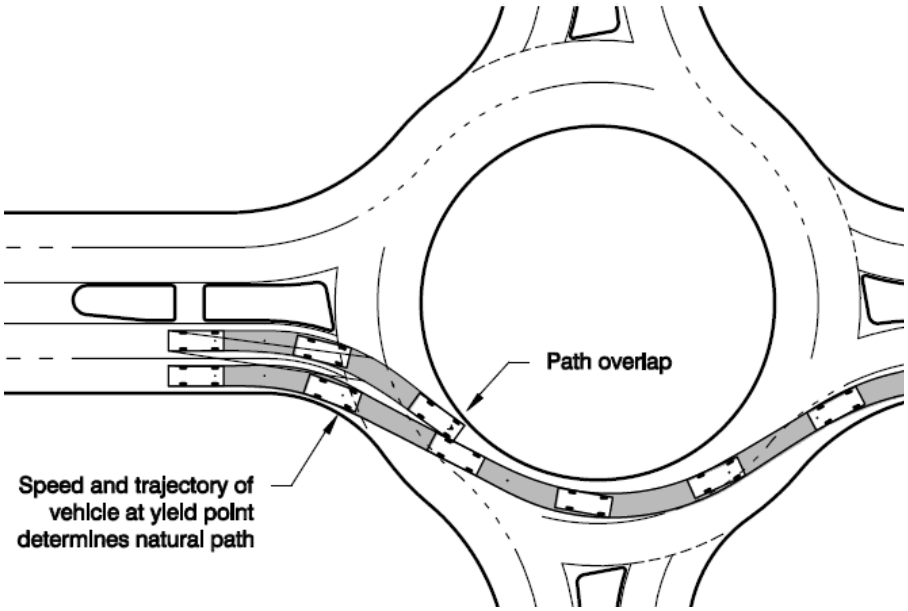


***Figure 30.16* Entry Path Overlap**

30.5.18.1 Method for Checking Path Overlap

Figure 30.17 provides a method for checking entry and exit path overlap. To avoid path, overlap the typical tangent length is 40-ft to 50-ft or two car lengths for the entry path tangent and 40-ft and greater for exit path tangent. The minimum tangent length to avoid entry and exit path overlap is 26-ft or one car length.

As a rule of thumb path overlap can be avoided if there is typically 5 feet between the face of the central island curb and the extension of the face of curb on the splitter island, see Figure 30.17.

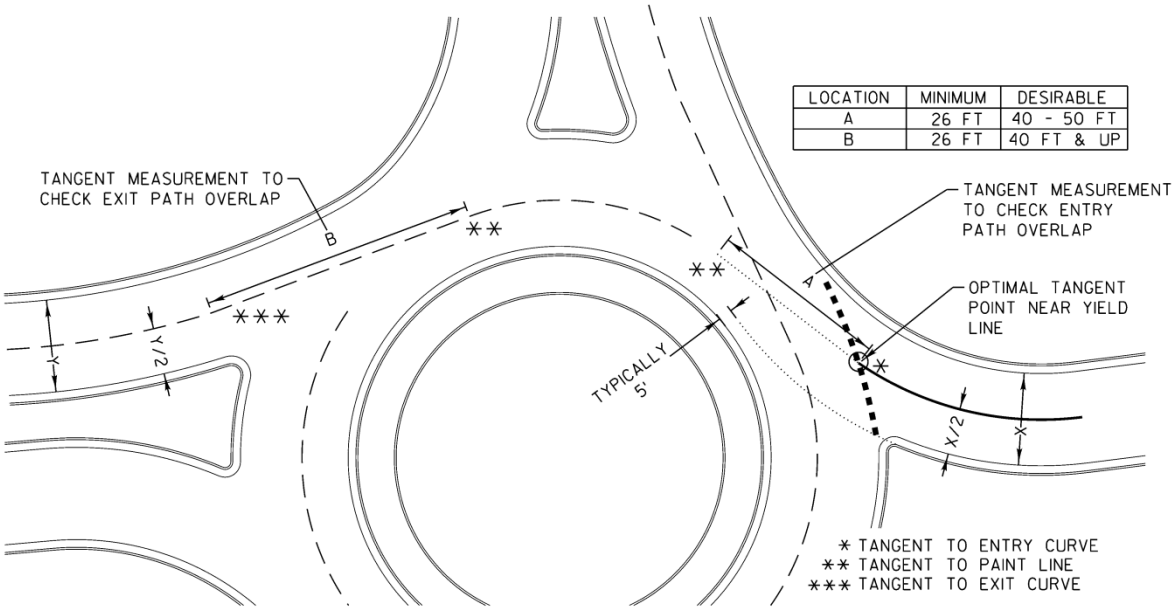


Figure 30.17 Method for checking path overlap

30.5.18.2 Design Method to Avoid Path Overlap

Figure 30.18 shows the preferred method to avoid path overlap in multilane entries. Start with an inner entry curve designed so when the edge of the splitter island curve is extended across the circulatory roadway the line is tangent to the central island as shown. Once the lane geometry is determined to avoid path overlap then design the adjacent lane(s). The small radius entry curve will vary depending on the approach geometry and the fastest speed path but will typically range from 65-110 feet. A large-radius (greater than 150 feet) curve is then fitted between the entry curve and the outside edge of the circulatory roadway.

The primary objective of this design technique is to locate the entry curve at the optimal placement so that the projection of the inside entry lane at the yield point forms a line tangent to the central island. This inner curve design concept is essential for multilane design and is recommended for single lane entries as well. Figure 30.18 illustrates the result of proper entry design.

The location of the entry curve directly affects path overlap. If it is located too close to the circulatory roadway, it can result in path overlap. However, if it is located too far away from the circulatory roadway, it can result in drivers accelerating to the yield point.

For additional information, see NCHRP 672, §6.4.3.

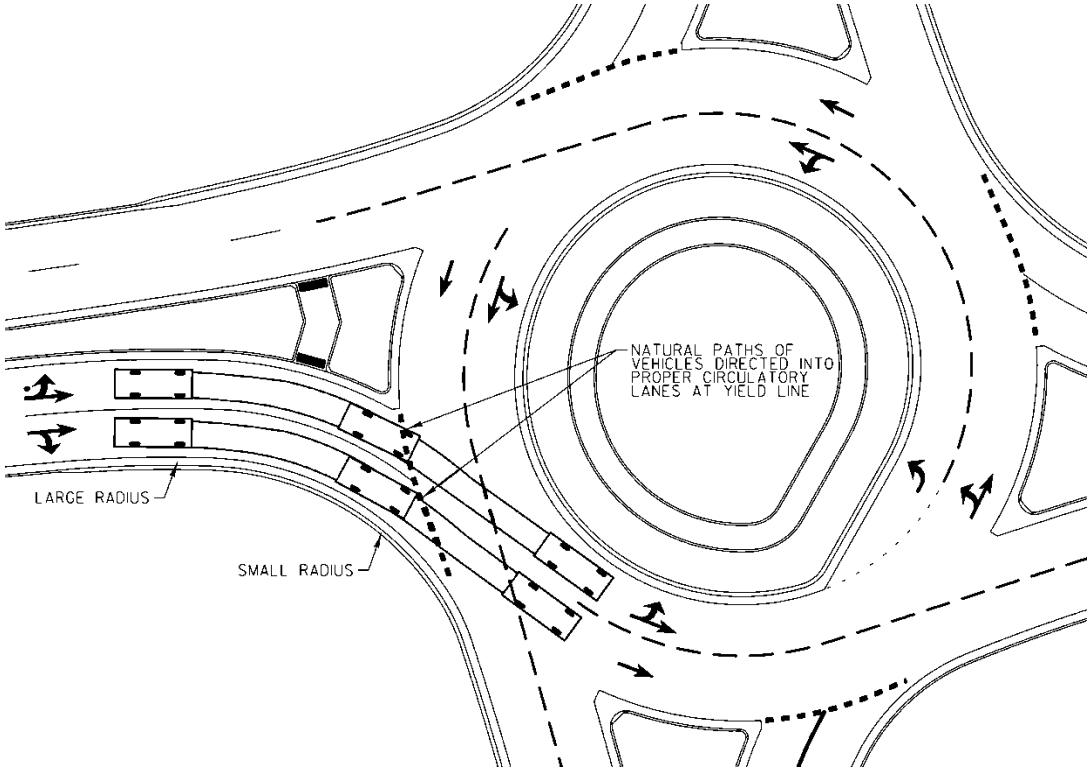


***Figure 30.18** Multilane Entry Design*

30.5.19 Approach Design

The primary safety concern in high-speed context is clarity of the driving situation, that is, to make drivers aware of the roundabout with ample distance to comfortably decelerate to the appropriate speed. Therefore, designs should follow these principles:

- Provide the typical stopping sight distance of the entry point based on approach operating speed.
- Align approach roadways and set vertical profiles to make the central island conspicuous.
- Splitter islands should extend upstream of the yield line to the point at which entering drivers are expected to begin decelerating - a minimum length of 200 feet is recommended.
- Approach curves should be gentle, become successively smaller and should be sized based on the design speed and expected speed change.
- Tangents should be used between reverse curves.
- Use landscaping on extended splitter islands and roadside to create a tunnel effect.
- Provide illumination in transition to the roundabout.
- Use signs and pavement marking effectively to advise of the appropriate speed and path for drivers.

The consequences of an inconspicuous central island or splitter island is mainly loss of control crashes as motorists unfamiliar with the roundabout are not given sufficient visual information to elicit a change in speed and path. See Figure 30.19.

30.5.19.1 Low Volume, Non-STH Side Road Approaches

For an intersection having non-STH side road approaches with low traffic volumes, a reduction in roundabout approach construction length - including the splitter island length - may be appropriate if meeting all these side road conditions:

- Design year AADT is less than 2,000
- Must be single-lane roundabout entry
- Existing side road intersection control is stop-controlled, as motorists are already conditioned to yield to mainline traffic
- Typical stopping sight distance (SSD) is attained or exceeded at all approaches
- Pedestrians are not present at transitional and high-speed approaches (posted speed 45 mph and greater)

If all the above conditions are met, continue evaluating the non-STH roundabout approaches based on post-construction side road posted speeds and other considerations cited below.

Where side road roundabout approaches have posted speeds 45 mph and higher, provide a combination of alignment deflection or offset and non-superelevated curvature that spans the deceleration distance from the entry. This will produce gradual deceleration to avoid forcing all the reduction in speed to be completed through the curvature at the roundabout. The length of roundabout splitter island should be minimum 200 feet as explained in the FHWA Roundabout Guide [4]. Always verify that the side road approach and entry condition, including the roundabout splitter island, provide deflection per the design principles of FDM 11-26-30.5 to safely and effectively slow traffic.

Where side road roundabout approaches have posted speeds 40 mph and lower, use a lower minimum 50-foot raised splitter island (typical 100-foot) length to alert drivers of the upcoming roundabout as described in NCHRP 672 [2]. A splitter island also provides refuge for crossing pedestrians and needs to be long enough to contain the pedestrians. Always verify that the side road approach and entry condition, including the roundabout splitter island, provide deflection per the design principles of FDM 11-26-30.5 to safely and effectively slow traffic.

During preliminary design, consider whether any major development is planned along the side road. Any significant development may result in additional trips and more unfamiliar drivers. Field running speed assessments may be used to ascertain current side road speed conditions and determine prudent splitter length selection. Additionally, assess current access locations along with the real estate, environmental and utility impacts with the selected side road approach lengths. Document all findings in the DSR, including any known future local land development plans and whether access control is planned along the side road.

For non-STH roundabout approaches with medium and high traffic volumes (greater than 2,000 AADT) or with high-speed STH mainline roundabout approaches, apply the high-speed roundabout approach design principles as prescribed under FDM 11-26-30.5.19, FDM 11-26-30.5.20 and Figure 30.19.

30.5.20 Vertical Design

Super elevation of curves on approaches to roundabouts is counterproductive to the objective of transitional speed reduction. Design super elevation on approaches based on the low-speed urban street criteria outlined in FDM 11-10-5.3.2. Speed for the curve being designed is based on its distance from the yield line and the deceleration length determined from AASTHO Figure 2-25.

Example: For a posted speed of 55 mph with deceleration to 0 mph, the distance is approximately 410 feet. Curves prior to 410 feet should be designed for 55 mph; curves within 410 feet should be based on a prorated estimated speed based on distance from the yield line.

30.5.20.1 Approaches/Departures (Intersection Legs)

The most critical vertical design area of the roundabout is the portion of roadway from the approach end of the splitter island to the circulatory roadway. This area requires special attention by the designer to ensure that the user can safely enter the circulatory roadway, especially for OSOW vehicles. This area usually requires pavement warping or cross-slope transitions to provide an appropriate cross-slope transition rate through the entire transition area and within the circulatory roadway.

Entry grade profiles (approximately 2 car lengths from the ICD) are not to exceed 3%, with 2% being the typical maximum. It is typical to match the exit grades and the entry grades. Adjustments to the circulatory roadway cross-slope may be required to meet these criteria but should be balanced with the effects on the circulatory roadway.

30.5.20.2 Circulatory Roadway

Roundabouts typically should be constructed on relatively flat or rolling terrain with an approach grade that is typically less than 3%, but not greater than 5%. Grades approaching 4% and steeper terrain may require greater transitions to provide an appropriate grade through the intersection. The profile grades along the central island should generally not exceed 4%, (typically 3% or less).

- Single-lane Roundabout - crown the roundabout circulating roadway with a 2% cross-slope with approximately 2/3 width sloping toward the central island and 1/3 width sloping outward.
- Multilane Roundabout - Same crown guidance applies where possible. However, when considering factors such as paver screed width, contraction joint location for concrete pavement, pavement marking location, and the total width of the circulatory roadway, it may be a challenge to comply with the 2/3 sloping inward and 1/3 sloping outward. Therefore, another alternative (independent of material type) on dual lane roundabouts is to slope the inside lane, or left lane, toward the central island and slope the outside lane (typically wider lane) to the outside. This alternative will allow the contraction join on concrete pavement to generally coincide with the lane line pavement marking and allow asphalt pavement roundabouts to be similar in design. On triple lane roundabouts, it may be possible to slope the two inside lanes toward the central island and slope the outside lane to the outside.

The crown vertical design feature provides good drivability, keeps water from draining across the circulating roadway which is particularly important in a northern climate with freeze-thaw cycles, and provides a smooth transition in/out of the approaches and departures. This 'crown' also reduces the probability of load shifting or truck over turning.

The preferred truck apron slope is between one and two percent toward the circulatory roadway. Greater than one percent slope should not be used on OSOW routes. However, it may vary between 1 and 2 percent when justified on other routes.

30.5.21 Curbing

30.5.21.1 Approach Curbs

Low speed approaches should incorporate 6-inch vertical face curbs, on both sides of the roadway. The purpose of the vertical face curbs is to control the fastest speed paths at the roundabout entrances and exits. On the OSOW a 4-inch mountable curb and gutter may be used in limited situations to better accommodate truck tires that may have to go over the curb or the splitter island. Refer to FDM 11-26-30.5.4 and FDM 11-26-30.5.6 for suitable curb type along the outside and FDM 11-26-30.5.21.2 for curb type adjacent to the truck apron.

High speed approaches to roundabouts usually occur where there is a rural cross-section. This rural cross-section for undivided highways will have shoulders without curb on the outside. When the highway is divided there will be shoulders on the inside, sometimes with sloped curbs, the outside will have shoulders typically without curb leading up to the roundabout. High speed approach design will require a transition section to the roundabout where the shoulders will narrow, and vertical curb will be introduced. See Figure 30.19 for an example of the high-speed approach layout.

In rural areas, the pavement marked gore and the curbs serve to alert the driver approaching a roundabout of the changing conditions and that a speed reduction is expected. Driver awareness that conditions are changing is accomplished through a combination of roadway curvature, channelization, lighting, landscaping, and signing.

Figure 30.19 shows the layout of the gore area for the beginning of the splitter island and the curb and gutter layout as the driver approaches the yield line. The pavement marked gore area transitions into a raised curb median nose (Type 1) followed by a 4-inch sloping curb and gutter for a short distance. The curb transitions in two ways as it approaches the roundabout. At the nose, the curb face is offset 4 to 6 feet from the driving lane or has a 4 to 6-foot shoulder on the left side of the approach. The shoulder narrows (according to the minimum shifting taper shown in FDM 11-25 Attachment 2.2 as the vehicle is anticipated to decelerate to 40 mph. When the vehicle speed is anticipated to be 40 mph the 4-inch sloped curb and gutter transitions into a 6-inch vertical curb and gutter. Both curb and gutter types should have a 24-inch gutter, therefore the flow line and gutter flange are consistent. Total curb length starting from the yield line should be the deceleration distance required to reduce from the approach speed to the fastest path design speed (R_1).

Example: The posted speed is 55 mph and decelerating to approximately 20 mph produces a total raised curb length distance of approximately 350 feet for the splitter island side of the roadway. Approximately 250 feet of that 350 feet is 4-inch sloped face curb and gutter and approximately 100 feet is 6-inch vertical face curb and gutter (may be 6-inch sloped face on OSOW network, or 4-inch sloped in limited situations). At a posted speed of 40 mph and decelerating to 20 mph produces a total raised curb length of approximately 200 feet and all of the length is 6-inch vertical face curb and gutter (may be 6-inch sloped face on OSOW network, or 4-inch sloped in limited situations). Deceleration distance guidance can be found in the 2011 AASHTO GDHS, Exhibit 2-25, page 2-35. Use the posted speed as the AASHTO design speed. Differing approach conditions may produce different deceleration distances.

For the roundabout approach, the minimum length of vertical face curb on the right side of the travel way should be the greater of; 25 feet prior to the bike ramp or 100 feet prior to the yield line (may be 6-inch sloped face on OSOW-TR or 4-inch sloped). The vertical face curb installation will enforce the fastest speed path geometry.

The curb on the right side at the exit from the roundabout needs to be long enough to control exit speed and generally should be the greater of: 25 feet past the bike ramp or 100 feet past the exit measured from the ICD.

Consider drainage in the area of the curb/gutter by providing a flume or inlet structure.

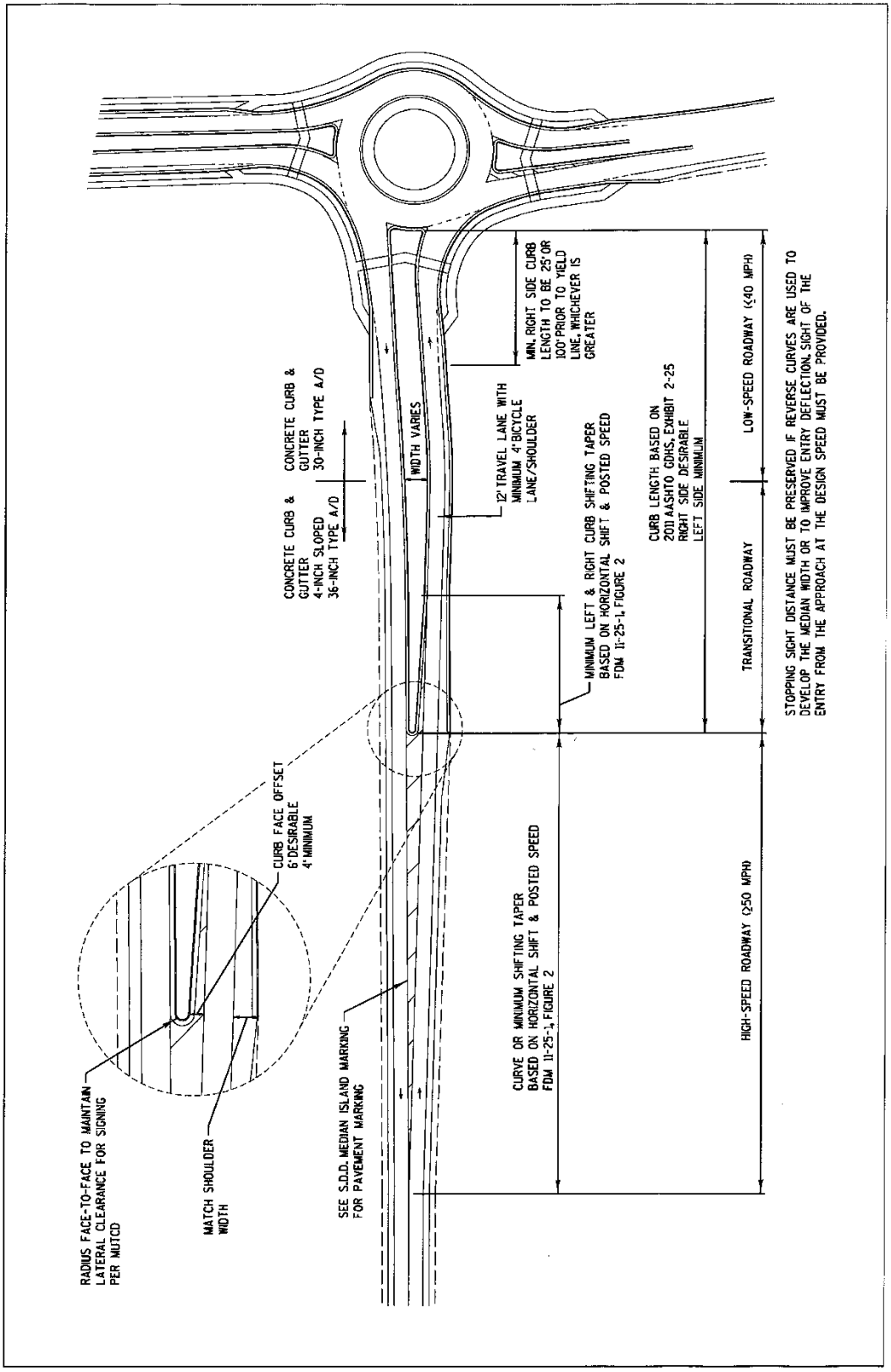


***Figure 30.19** High-Speed Roundabout Approach*

30.5.21.2 Curb and Gutter Separating the Circulatory Roadway from the Truck Apron

Use Type R or T curb and gutter, 4-inch sloped, between the circulating roadway and the truck apron shown in SDD 8D1. Use a Type T inlet casting on the drainage structure, as shown in SDD 8A5. This curb and gutter is gentle to large truck tires but should be unfriendly for SUVs and autos to traverse. When the circulatory roadway is concrete it shall be tied to the gutter flange with tie-bars, but not to the truck apron. When the circulatory

roadway is asphalt, the apron shall be tied to the back of curb with tie-bars. See FDM 14-10-35 for pavement related topics.

30.5.21.3 Curb at the Inside of the Truck Apron or Edge nearest the Central Island

This curb shall be a reverse-slope 18-inch curb and gutter. The adjacent pavement will be a concrete truck apron. There may be situations when this inside curb could be deleted, but this is rare and should be addressed in the DSR.

30.5.22 Spirals

A spiral system involves a series of lane gains and lane drops around the circulatory roadway to lead drivers into the appropriate lane for their desired exit. Spirals guide drivers that enter the roundabout on the inside lane to shift to the outside lane at the appropriate location within the circulatory roadway to exit from the outside lane, unless there are dual lefts then the two inside lanes could be shifted. The spiral is designed to prevent vehicles from becoming trapped on the inside lane and then drivers making a quick lane change to exit all while maximizing the use of the circulating space and reducing potential conflicts between adjacent vehicles. Spirals can also accommodate for heavily biased turning movements. Spirals should only be considered where the circulatory roadway has sufficient width to provide two or more lanes of traffic and where the geometry and traffic volumes are determined to warrant the use of spirals. Circulatory roadway spirals require considerable engineering judgment to design and locate properly, although they are intended to guide drivers, they may be confusing to properly understand and not always intuitive to the driver. Small compact two-lane circles do not function as well with spiral designs because the lengths of arcs are too short to guide drivers to ‘spiral out’. In such cases speed reduction occurs in the circulatory roadway where the spiral often begins. Drivers are more likely to turn tight across the spiral rather than follow it to the next outside lane. Spirals can be very effective on larger circles where the spiraling curves are longer, intuitive to drivers and more easily detectable.

A spiral should be developed from the central island by curb and gutter until a full lane width is available. Observations of previously installed spiral crosshatch pavement markings without a ‘hard surface’ indicate that some drivers ignore the pavement markings, which increases the potential for vehicle conflict in the circulatory roadway.

An example of a curbed spiral is shown in Figure 30.20. This spiral is used to shift the westbound left turn to the outside lane. The spiral is used because the southbound exit is only a single lane exit and the southbound entrance allows dual left turns. To exit without conflict, the westbound left turn needs to be spiraled to the outside lane. Without the spiral, the left turn would be trapped on the inside lane and would do a U-turn or have to crossover lanes.

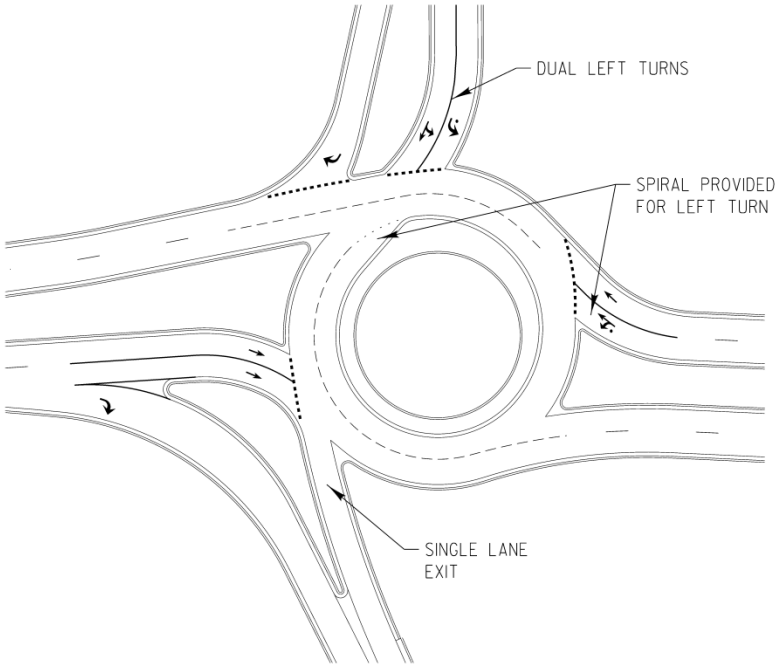


Figure 30.20 Spiral

30.5.23 Entry Angle, phi

Phi is not discussed in detail in NCHRP 672. This angle is not a controlling design parameter but instead a gauge of sight to the left and ease of entry to the right. This affects both capacity and safety at the intersection.

The typical range for the Phi angle is between 20 and 30-degrees with 25-degrees or greater being the optimal, although there are designs that operate safely and efficiently with a Phi angle as low as 16 degrees. Designers may find it difficult to attain Phi angle values in the typical range, but provided that the fast path speeds are relatively low, the Phi angle is not a controlling criterion.

There are three situations or design conditions in which Phi can be measured. They are:

1. Condition 1: Phi = $2\frac{Phi}{2}$ where the distance between the left sides of an entry and the next exit are NOT more than approximately 100 feet. In Condition 1, the acute angle is denoted as 2 PHI in which the actual value must be divided by two to obtain Phi (see Figure 30.21, Method 1).
2. Condition 2: Phi = Phi if the distance between the left sides of an entry and the next exit are more than approximately 100 feet (see Figure 30.22, Method 2).
3. Condition 3: Applicable when an adjacent exit does not exist, or an exit located at such a distance or obtuse angle to render the circulatory roadway a dominating factor of an entry (such as in a “3-leg” intersection). Used at “T” intersections or where the adjacent entrance and exit lane(s) are far apart (see Figure 30.22, Method 2).

The two methods of measuring Phi are described below in Figure 30.21 and Figure 30.22.

Method 1 phi is measured by dividing the entry and exit radii into three segments. The midpoint of the lane for each segment is best fit with a curve that extends to the face of curb of the splitter island extended. Begin line (a-b) and (c-d) at the intersection of the best fit arc and face of curb of the splitter island extended. Line (a-b) and (c-d) are then projected tangent from the best fit arc towards the circulating roadway, the angle formed by the intersection of the two lines is twice the value of Phi see Figure 30.21.

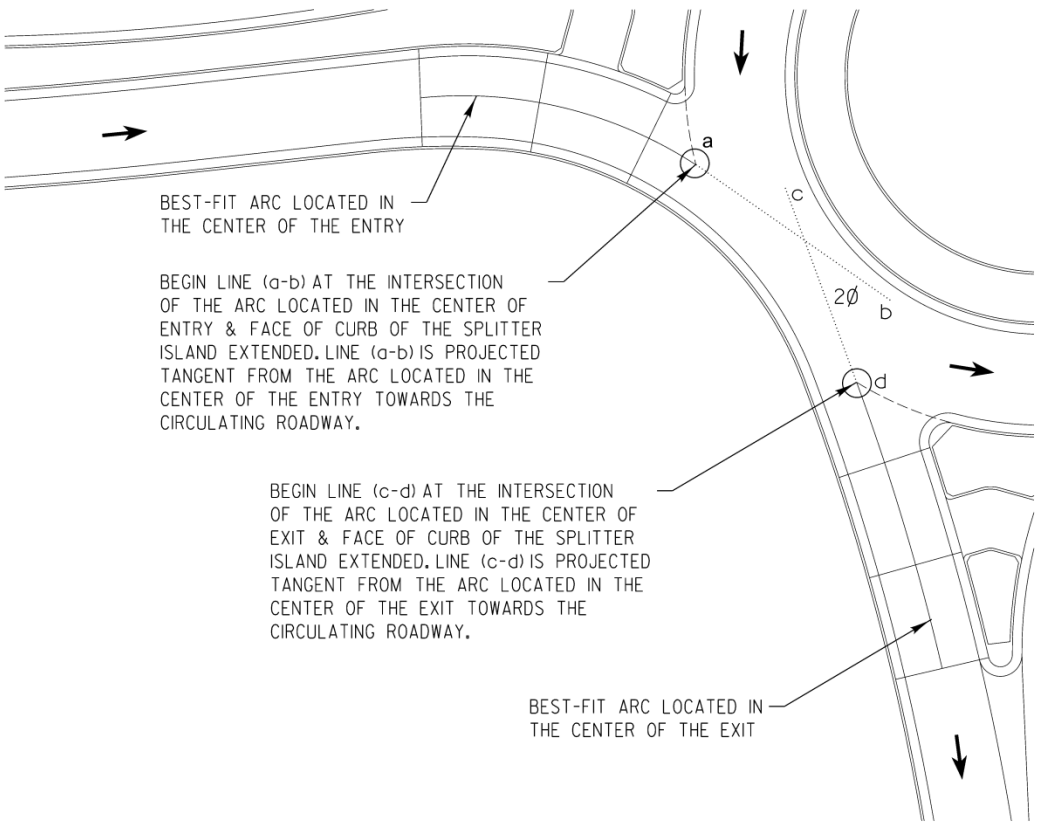


Figure 30.21 Method 1 Phi Measurement

Method 2 Phi is measured by dividing the entry radii into three segments. The midpoint of the lane for each segment is best fit with a curve that extends to the face of curb of the splitter island extended. Begin line (a-b) at the intersection of the best fit arc and face of curb of the splitter island extended. Line (a-b) is then projected tangent from the best fit arc towards the circulating roadway. Begin line (c-d) at the intersection of line (a-b) and the arc located at the center of the circulating roadway. Line (c-d) is then projected tangent from the arc located in the center of the circulating roadway. The angle formed by the intersection of (a-b) and (c-d) is Phi.

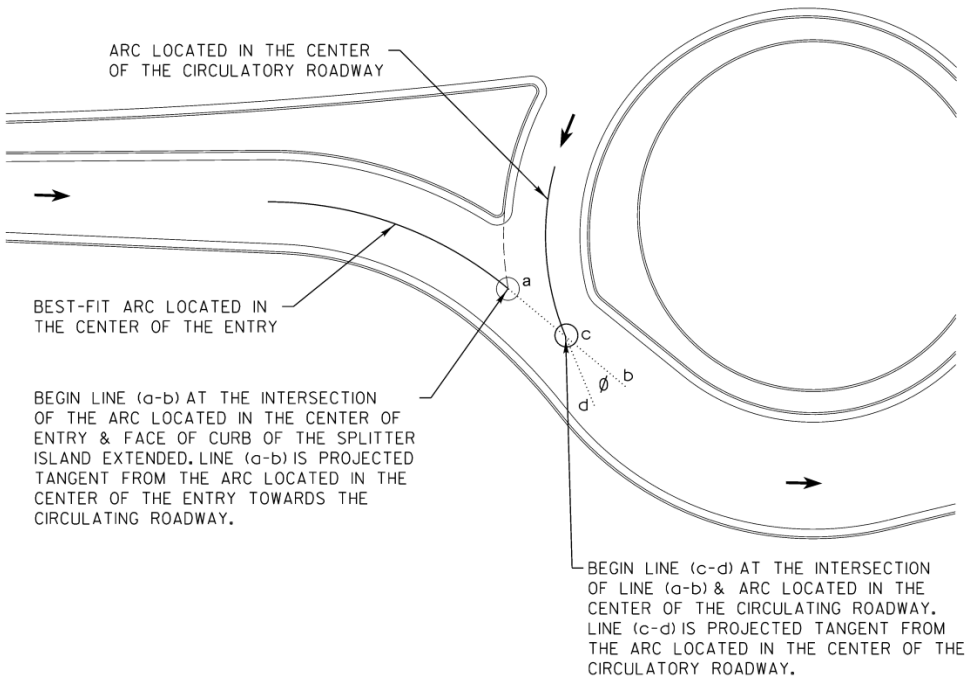


***Figure 30.22* Method 2 Phi Measurement**

30.5.24 Clear Zone

Clear zone guidance for roundabout installations requires consideration of the approach speeds, fastest path speeds, adjacent side slopes leading into and through the roundabout, and average daily traffic on the facility. The guidance for the determination of clear zone is provided in the current AASHTO Roadside Design Manual and FDM 11-15, Attachments 9 and 10.

The vehicle speed approaching an intersection and the speed allowed through an intersection, along with the ADT and side slopes, will determined the required clear zone. A traffic signal-controlled intersection allows vehicles to go through the intersection at the posted speed, does not require the vehicle to reduce speed as it approaches the intersection, and therefore the clear zone is maintained through the intersection. A stop sign controlled intersection located in a high speed rural condition will require less clear zone as the vehicle slows down to stop. As the approaching vehicle reduces speed it may be appropriate and typical to reduce the corresponding clear zone. The designer has the responsibility to balance the need for clear zone and right-of-way acquisition.

The yield condition for a roundabout and the fastest path design speed approaching and traveling through the roundabout are similar to the stop sign controlled intersection. The horizontal geometrics leading to and through the roundabout intersection requires the vehicle to slow down leading to the approach and through the roundabout. The approaching speed transition distance for a roundabout is determined by the posted highway speed and the deceleration needed to enter the roundabout in accordance with the fastest speed path calculation, R_1 value. FDM 11-26-30.5.21.1 and Figure 30.19 show how to determine the roundabout approach layout for high-speed highways. The design speed to use for clear zone around the perimeter of the roundabout is the average of the entry speed (R_1) and the circulating path speed (R_2) values. The maximum average entry speed (R_1) and circulating speed (R_2) for any type of roundabout is approximately 25-30 mph. The average fast path, $\left(\frac{R1 + R2}{2}\right)$, of approximately 25-30mph will produce a clear zone between 7 and 18 feet depending on ADT.

The exit ramps from an interchange are also considered to be low speed in close proximity of the approach to the roundabout. In an urban environment, lateral clearance is typically used rather than clear zone to determine the minimum distance to fixed objects such as power poles, light poles, fire hydrants, trees etc. In a rural environment, it is typical to use a clear zone based on the design speed, ADT and slopes. The side slopes adjacent to a roundabout are generally quite flat to accommodate a small terrace and a shared-use path around the perimeter. When the shared-use path is not installed at the time of the roundabout the area should be graded such that at some time in the future the path could be installed. The side slopes in the approach area having an approach speed of 40mph or less and the perimeter of the roundabout, outside of the shared-use path, should be 4:1 (recoverable slope) but may be steeper depending on meeting the clear zone requirement and local impacts.

Central island clear zone is considered to be within a low speed environment therefore needs to meet the lateral

clearance for urban streets, typically 2 feet back from the face of curb. Having stated this WisDOT believes there are precautions, which are dependent upon the approach speed that need to factor into the central island landscaping design. See FDM 11-26-40, for additional guidance on central island landscaping.

30.5.25 Coloring and Stamping Concrete

The truck apron shall be reddish colored, concrete conforming to Standard Spec 405.

For shared-use paths that are colored use a reddish colored concrete pavement. Colored pavement materials are a community and designer agreed upon preference. Do not stamp pedestrian areas that will result in an uneven surface as this may aggravate back injuries or violate other ADA considerations. Refer to TEOpS 3-2-3, and WMUTCD Section 3B.18, for additional information on marking crosswalks and use of reflective materials. The colored concrete pavement could be used for terrace areas and may be stamped, if not a walking surface, but stamping must be specified in the special provisions. Colored or uncolored concrete in the terrace adjacent to the corner radii where there is the possibility of truck off-tracking shall be 8-inch thickness or thicker (12-inch thick truck aprons per FDM 11-26-30.5.4) depending on anticipated loading.

See FDM 14-10-35 for additional information relating to colored concrete, pavement design, tie bar location, dowel bar location, contraction joint layout, and other pavement guidance.

30.6 Plan Preparation

30.6.1 Plan Preparation Considerations

The overall concept of roundabout plan preparation is similar to other intersection types (see example plan sheets in FDM 11-26-50). The designer should provide the following plan information when designing roundabouts. At a minimum, roundabout plans should include the following plan details:

- Layout details for any alignments utilized for the roundabout
- Layout details for any crosswalks and bike ramps if utilized
- Elevation at low points, high points, island noses, and 25-foot intervals within circulatory roadway
- Provide one 1” = 40’ scale plan sheet for each concrete roundabout in the plans (1” = 20’ scale is preferred if it will fit on one sheet). Plan sheet will be used by the contractor to prepare the concrete transverse joint details. This plan sheet must show all curb and gutter lines, longitudinal joint lines, proposed pavement marking lane lines, surface utilities such as manhole covers, valve box covers, and inlet covers in the concrete circulatory roadway and concrete truck apron.
- Storm sewer plans
- Landscaping and erosion control plans
- Permanent signing plans
- Lighting plans
- Pavement marking, and pavement marking-layout plans

30.6.2 Alignment Plans

When considering the location of alignments, the designer should consider their usefulness in generating cross-sections, profiles, layout details, and ease of use during construction layout. Alignments along both flange lines of the splitter islands are required. The designer should also consider additional alignments for the following locations:

- Along the curb and gutter flange line located between the truck apron and the circulatory roadway
- Along the curb and gutter flange lines at locations where the width is varying from the main alignments (usual from bike ramp to bike ramp)
- Along the curb and gutter flange lines for both sides of right turn bypass lanes
- Along the back of sidewalks or shared use paths where the distance from the back of curb varies
- On OSOW routes: Along the inside of the central island and along the back of additional pavement placed outside the entry/exit curbs

30.6.3 Profile Information

The designer should consider placing profiles on all of the alignments mentioned above. Some general guidelines for creation of the profiles are:

- It is ideal from a drivability and safety perspective to design and construct the circular component of the roundabout in one plane (planar) with one low point and one high point around the circle.
- Once the circulatory roadway profile is established, the approach and exit leg profiles can be adjusted to match the outside edge of the circulatory roadway.
- Varying of cross-slopes may be done on the circulating lane(s), but the variance from 2% should

generally be minimized where possible except where OSOW profile and grading design governs (see FDM 11-26-30.6.1). Varying of cross-slopes may require the approach and exit profiles to be modified.

- The designer should also complete a profile on the outside edges to verify a smooth transition from the approach roadway, roundabout and exit roadway. The designer may have to adjust profiles or cross-slopes on the approach, in the roundabout or on the roundabout exit if there are major kinks in the profile.

30.6.4 Typical Sections

At a minimum, roundabout plans should include typical sections at the following:

- Approaches and exits to the roundabout
- Within the splitter island
- Within the central island

The plans should include a sufficient number of cross-sections through the roundabout to allow for accurate construction of the roundabout.

30.99 References

[1] Roundabout Design Guidelines, Ourston Roundabout Engineering, page 36 and 37

[2] NCHRP 672, Roundabouts: An Informational Guide, Second Edition, December 2010

[3] Joint Roundabout Truck Study, Minnesota DOT and Wisconsin DOT, June 2012

[4] FHWA-RD-00-067, Roundabouts: An Informational Guide. FHWA, June 2000, p. 177

FDM 11-26-35 Signing and Pavement Marking *August 15, 2019*

35.1 Signing

The overall concept for roundabout signing is similar to general intersection signing. Proper regulatory control, advance warning, and directional guidance are required to provide positive guidance to roadway users. Locate signs where roadway users can easily see them when they need the information in advance of the condition. Sign location should be checked so they are not in conflict with vehicle turning movements, the swept path of vehicles with a long overhang, or vehicle navigation on the OSOW Truck Route. Signs should never obscure pedestrians, motorcyclists or bicyclists. Signing needs differ for urban and rural applications and for different categories of roundabouts. On connecting highways coordinate sign selection with the Region Traffic Section and local agency to maintain consistency on the facility.

The signing and pavement marking can get complex on roundabout projects. To assist project managers and contractors, the designer should use a minimum of 40 scale drawings for signing and pavement marking plan sheets.

The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), the Wisconsin Manual on Uniform Traffic Control Devices (WMUTCD), Wisconsin DOT Traffic Engineering, Operations and Safety Manual (TEOpS) and appropriate sign plate details govern the design and placement of signs. To the extent possible, this text follows the principles outlined in the 2009 MUTCD and the WMUTCD.

35.1.1 Regulatory Signs

Several regulatory signs are appropriate for roundabouts and are described below and shown in Figure 35.1.

1. Install a YIELD sign (R1-2) on both the left (in splitter island) and the right side of all approaches, single lane and multilane entrances, to the roundabout. Attention should be given to ensure that the left side YIELD sign and right-side YIELD sign are mounted at the same height. Place a note on the signing plans directing the contractor to make sure the YIELD signs are at the same mounting height (7’ - 3” ± to bottom of YIELD signs. During the first six months of operation of the roundabout, install 18” x 18” orange flags on top of the YIELD signs to emphasize the yield movement. Install a ONE WAY sign, R6-2R, under the left side yield sign on all approaches, single and multilane entrances, to the roundabout to establish the direction of traffic flow within the roundabout. Install a TO TRAFFIC FROM LEFT sign, R1-54, under the right-side yield sign on all approaches, single and multilane entrances, to the roundabout to reinforce the yielding required at a roundabout.
2. A chevron sign (series of 4 chevrons, R6-4b) shall be used in the central island opposite the entrances in combination with the ONE WAY sign (R6-1R). The mounting height to the bottom of the Chevron sign is 48-inches, measured from the surface of the truck apron to the bottom of sign. Specify the four (4) foot mounting height from the surface of the truck apron in the Miscellaneous Quantities.
3. Install a ONE WAY sign, R6-1R, in the central island opposite each entrance and mounted above the chevron sign (R6-4b) to emphasize the direction of travel within the circulatory roadway.
4. Install a KEEP RIGHT sign (R4-7) at the nose of raised curb splitter islands. The mounting height of

the R4-7 ranges from 5-feet to 7-feet to the bottom of the sign. In urban areas where pedestrians or bicyclists are expected to use the crosswalk it is recommended to use the 7-foot mounting. The Down Arrow, W12-1R, may be used but is less typical for consistency and driver expectancy but may be mounted 2-feet to the bottom of the sign. Attention should be given to the location of the KEEP RIGHT sign and light poles on the right side to ensure that conflicts do not occur with larger width vehicles. This is especially critical with single lane entry roundabouts.

Lane use signs such as the R3-8 sign are not used for single-lane entries. For multilane entries consult the Regional Traffic Engineer for sign placement. Roundabout operation will dictate which R3-8 sign is installed.

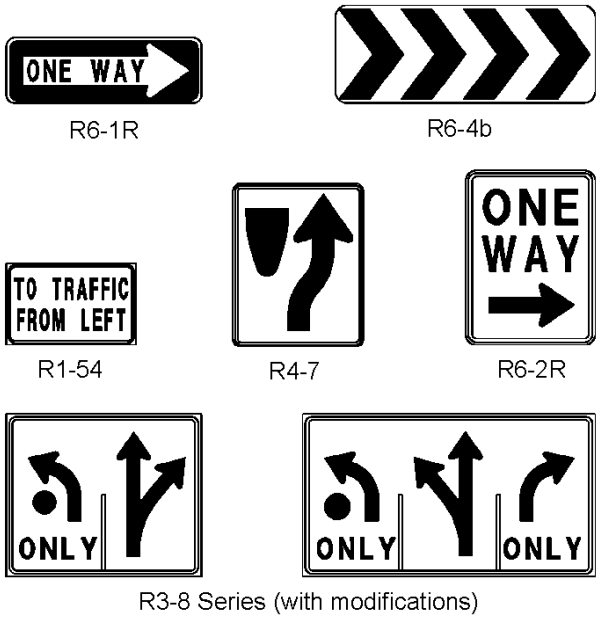


***Figure 35.1* Regulatory Signs**

* The R3-8 sign is modified to show the placement of a dot under the left arrow, which graphically helps depict the presence of a roundabout. Use the dot under the left arrow, only for the left most lane.

35.1.2 Warning Signs

Several warning signs are appropriate for roundabouts and are described below and shown in Figure 35.2. The amount of warning a motorist needs is related to site-specific intersection conditions and the vehicular speeds on approach roadways. The applicable sections of the MUTCD and WMUTCD govern the specific placement of warning signs.

1. Install a circular intersection sign (“chasing arrows”, W2-6) on each approach in advance of the roundabout. Below the W2-6 sign, install an advisory speed plate (W13-1). Rural roundabouts have a typical advisory speed of 20 mph, urban roundabouts have a typical advisory speed of 15 mph. Check with the Regional Traffic Engineer before assigning an advisory speed. The speed given on the advisory speed plate should be no greater than the design speed of the circulatory roadway. Advisory speeds are posted in multiples of 5 mph. For conventional highways with posted approach speeds of 45 mph or greater or 3 or more approach lanes, use size 3 W2-6, and W13-1 signs and double up the placement of the W2-6, and W13-1 signs. For expressways, use size 4 W2-6, and W13-1 signs and double up the placement of the W2-6, and W13-1 signs. Coordinate with the Region Traffic Section on the proper sign sizes and type of roadway (conventional highway or expressway). For closely spaced roundabouts, these signs may be omitted, see FDM 11-26-35.1.6 below for guidance as to when these signs may be omitted.
2. Use a YIELD AHEAD sign (W3-2) on each approach to a roundabout if the approach speed is 45 mph or greater. If the approach speed is less than 45 mph, the YIELD AHEAD (W3-2) would only be needed if the yield sign is not readily visible for a sufficient distance per Table 35.1 (Minimum Visibility Distance). For closely spaced roundabouts, this sign may also be omitted, see FDM 11-26-35.1.6 for guidance as to when these signs should be omitted.
3. The usage of the pedestrian crossing sign assembly is optional per the 2009 MUTCD and is generally used if the visibility of the pedestrian crossing is poor. The designer needs to coordinate the usage of pedestrian crossing signs with the Region Traffic Section. In general, rural roundabouts will not have pedestrian accommodations and therefore would not require signing. For closely spaced roundabouts,

the pedestrian crossing sign assemblies may be omitted, see FDM 11-26-35.1.6 below for guidance as to when these signs may be omitted, when used. If used, the pedestrian crossing sign assembly shall be placed at the actual pedestrian crossing as well as in advance for locations where the posted speed is 45 mph or greater. If there is a school crossing at the roundabout, the school warning sign assembly with arrow (S1-1 and WF16-7L) is required at the crosswalk location. In addition, install the school warning sign, AHEAD plaque and FINES HIGHER plaque (S1-1, WF16-9P and R2-6P) in advance of the school crosswalk assembly. Install the pedestrian crossing sign (W11-2 and W16-7L) or school crossing sign assembly (S1-1 and WF16-7L) just in front of the crosswalk for approaching traffic at entries and exits. School crossing signs are required if there are any school pedestrians. If the crosswalk at a roundabout is not considered to be part of the intersection and is instead considered a marked mid-block crossing, pedestrian crossing signs are required.

The Combination Bike/Pedestrian Crossing sign (W11-15 and W16-7L) may be used in lieu of the pedestrian crossing sign assembly if there are recreational trails crossing the roundabout, where the primary trail users are bicyclists and pedestrians. The TRAIL CROSSING word message sign (W11-15A and W16-7L) may be used in lieu of the pedestrian crossing sign assembly if there are multi-use recreational trails crossing the roundabout. The usage of these signs is optional per the 2009 MUTCD and the designer is encouraged to coordinate the usage of these signs with the Region Traffic Section. Placement criteria for these signs are the same as that of the pedestrian crossing signs mentioned above.

4. A bicycle sign may be needed to designate the exit to the bike path (D11-1a and M7-2, federal sign plate).

Locate pedestrian crossing signs in such a way to not obstruct the approaching driver's view of the YIELD sign or pedestrians standing at the crosswalk.

Flashing beacons may be used above some warning signs as a long-term awareness technique for areas with approach speeds of 45 mph or higher.

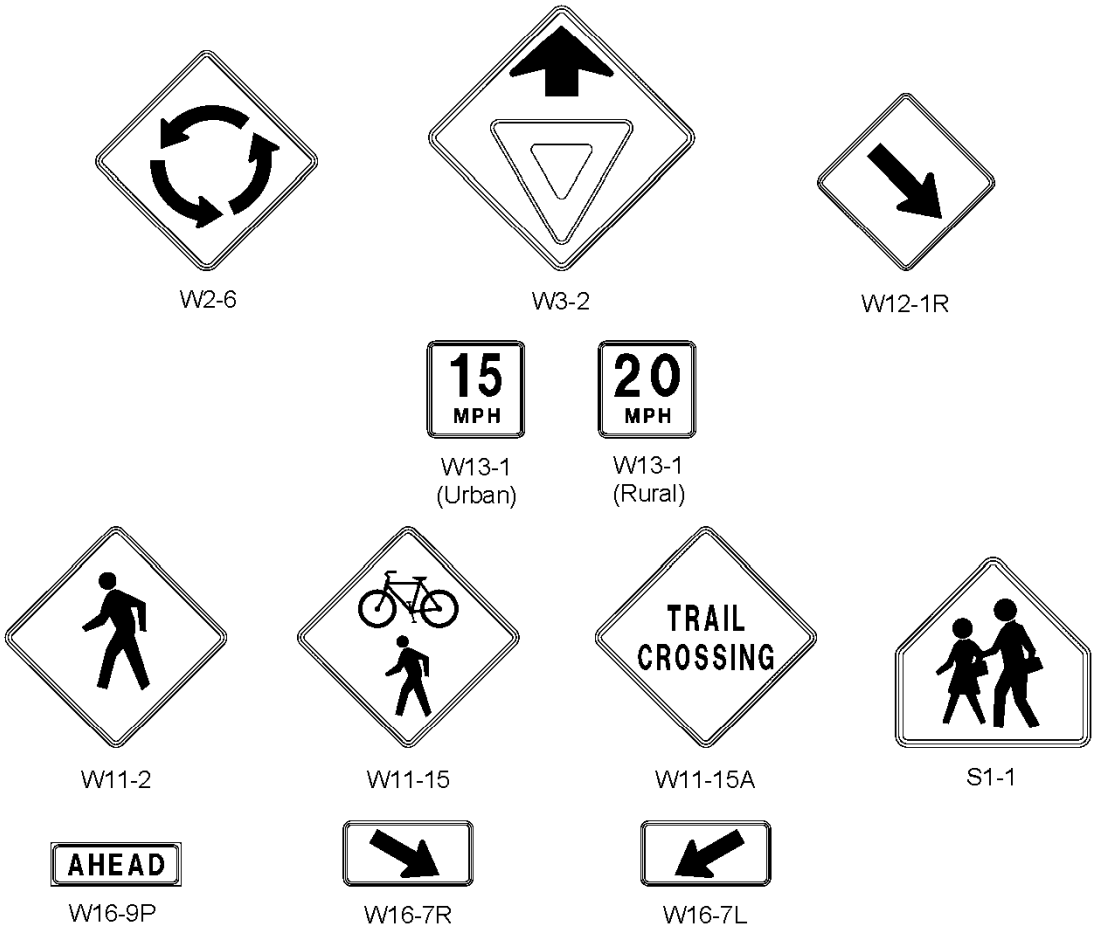


***Figure 35.2* Warning Signs**

35.1.3 Guide Signs

Guide signs provide drivers with needed navigational information. They are particularly needed at roundabouts

since circular travel may disorient unfamiliar drivers. Overhead guide signs should be considered at multilane roundabout approaches to guide motorists into the proper travel lane in order to navigate the roundabout properly and help avoid lane changing within the roundabout. A number of guide signs are appropriate for roundabouts and are described below.

35.1.3.1 Intersection Destination/Direction Signs

Use intersection destination/direction style signs in all single lane approach roundabouts for rural locations and in urban/suburban areas where space allows and is appropriate. The diagrammatic style guide sign is preferred over the text style sign (D1 series sign); examples of both are shown in Figure 35.3. The circular shape in a diagrammatic guide sign provides an important visual cue to all users of the roundabout. Diagrammatic guide signs are preferred because they reinforce the form and shape of the approaching intersection and make it clear to the driver how they are expected to navigate the intersection. If lack of terrace space or longitudinal location spacing are issues, use a text style sign or overhead diagrammatic guide sign.

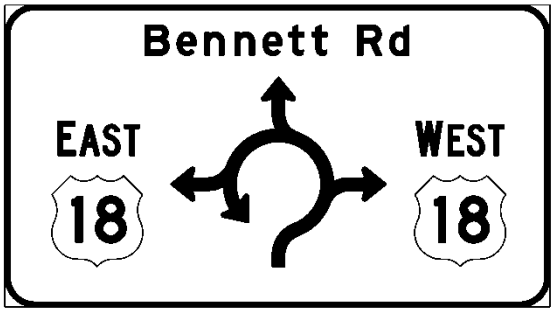
Use 4 1/2” lower case / 6” upper case letters with 18” Interstate, U.S. and State route shields and 15” County route shields for ground mounted signs in urban and rural areas where posted speed is less than 45 mph, and 2 or less approach lanes. Use 6” lower case / 8” upper case letters with 24” Interstate, U.S. and State route shields and 20” County route shields for signs in urban and rural areas if the signs are overhead, posted speeds are 45 mph or greater or there are 3 or more approach lanes. In general, the lettering height rule of thumb is to provide approximately 1-inch in letter height for each 40-foot of distance from the sign. All capital letters are harder to read than the first letter capitalized with the following letters small case. Cardinal directions shall be all capital letters with the first letter slightly larger.

The arrow direction conventions for the text signs follow the same convention as that for conventional intersections as shown in the WMUTCD, 2D.37. The ahead destination is on top, the left destination in the middle and the right destination on the bottom. The curved-stem arrow (D1-1d signs) shown in the WMUTCD, 2D.38 shall not be used.

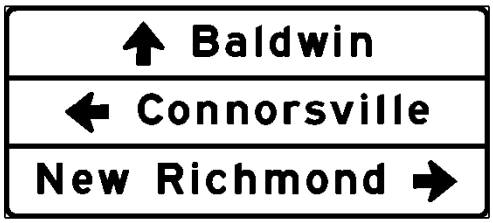
Occasionally, Specific Information Signs (SIS - GAS, FOOD, LODGING, CAMPING or ATTRACTIONS) may need to be included on roundabout approaches. The arrow direction convention and placement of SIS signs follows the WMUTCD, 2J.09.

Sample dimensioned details on the designs of diagrammatic signs, including the arrow and shaft dimensions are shown on the Bureau of Traffic Operations A11-12 sign plate.

Intersection destination signs may not be necessary at local street roundabouts or in urban settings where there are no significant destinations and the majority of users are familiar with the site.



D1-62



D1-3

***Figure 35.3* Destination Signs**

35.1.3.2 Overhead Lane Guide Signs

In general, overhead lane guide signs are encouraged at roundabouts with multiple approach lanes. By giving destination guidance to the motorist in advance, the motorist will be able to be in the correct lane at the roundabout approach and be discouraged from making a lane change within the roundabout. Qualifying criteria for overhead lane guide signs would include two or more approach lanes, higher vehicle ADT’s, lane splits approaching roundabouts, dual turn lanes, if the major route is turning, closely spaced roundabouts, narrow terrace widths, unfamiliarity of drivers, and lane drops within the roundabout. Since these are lane use guide signs, they would have an up arrow. A sign is placed over each travel lane (see multilane layout example in Attachment 35.3) and the arrow is typically placed over the center of the lane. Coordinate sign designs with the Region Traffic Operations section and the Bureau of Traffic Operations Traffic Design unit. If overhead guide signs are used on an approach, then the circular diagrammatic guide sign may not be needed. The circular diagrammatic guide sign is good for showing destinations and directions, however it does not depict proper lane assignments like the overhead lane guide signs do.

There may be situations in urban, multilane roundabout approaches where the overhead lane guide signs (Type I) may not be feasible, (space constraints). Options for the overhead guide signs are shown in Attachment 35.2 to 35.5. Region Traffic Section approval is required to use these options.

The 2009 MUTCD allows the usage of combination lane-use / destination overhead guide signs (D15-1 and D15-2). The advantage of these types of overhead signs is that they show both the route/destination with the regulatory lane-use arrows, thus eliminating the need for additional installations of the ground mounted regulatory lane control signs. It should be noted that these signs shall not be used for lanes that have optional movements. They shall be used only for lanes that have an exclusive ahead, left or right turn movement. If the roundabout approach has a lane that has an optional movement, then all signs on the approach should be the Overhead Lane guide signs with separately mounted regulatory lane control signs. If the roundabout is part of a closely-spaced corridor of roundabouts, (i.e., ramp terminals), the design of all Overhead Lane guide signs in each direction shall match. If designs are mixed along the same direction, motorists may become confused by the change in location of lane control information. Refer to Attachment 35.3 for further design guidance in addition to consulting the Regional Traffic Engineer.

Use 8” lower case / 10.67” upper case letters with 24” Interstate, U.S. and State route shields and 20” County route shields for all overhead signs. For situations with overhead structure loading limitations or on approaches with posted speeds of 35 mph or less, 6” lower case / 8” upper case letters with 18” Interstate, U.S. and State route shields and 15” County route shields may be used. Use a dot with the left arrow to designate the roundabout. The dot shall only be used to depict the left-most lane of the approach. Use an ONLY plaque over thru lanes that become turn lanes. The ONLY plaque is optional elsewhere. Consult the Regional Traffic Engineer for further design guidance.

Sample details of overhead lane guide signs are shown in Figure 35.4. Additional dimensioned details on the designs of diagrammatic signs, including the arrow and shaft dimensions are shown on the Bureau of Traffic Operations A11-13 sign plate.

Generally, use overhead sign supports, not sign bridge trusses. See FDM 11-55-20 for overhead sign support design guidance.

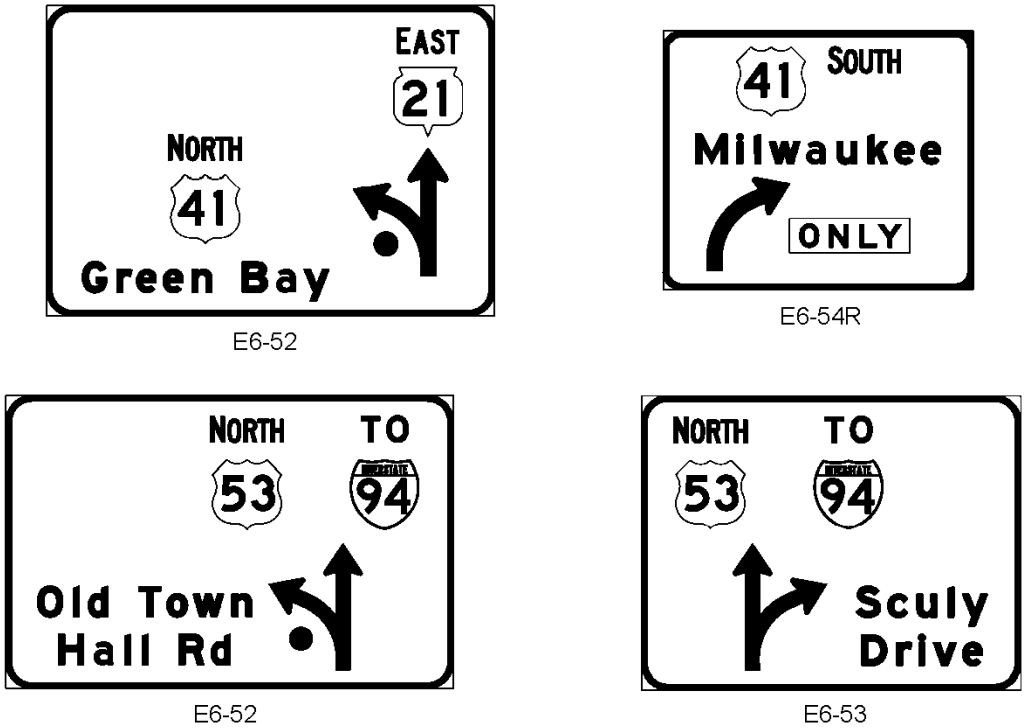


***Figure 35.4** Overhead Lane Guide Signs*

35.1.3.3 Exit Guide Signs - In Splitter Island

Exit guide signs reduce the potential for disorientation. Use them to designate the destinations of each exit from the roundabout. These signs are conventional intersection direction signs (D1 series signs). Exit guide signs with route shields should have the shield incorporated into the sign with cardinal direction and arrow. If the same route marker is used in more than one direction, the route shield should be accompanied with the cardinal direction. The arrow is slanted up and to the right. At freeway ramp situations utilize the route continuation with exit on the exit guide sign. Letter heights for signs are 4 1/2” lower case / 6” upper case with 12” route shields.

Signs are placed in the splitter island facing the circulating traffic. The mounting height is to be a minimum of 60-inches from the ground to the bottom of the sign. Specify the revised mounting height in the special provisions.

Sample details of exit guide signs are shown in Figure 35.5. Additional dimensioned details on the designs of the exit guide signs are shown on the Bureau of Traffic Operations A11-14 sign plate.

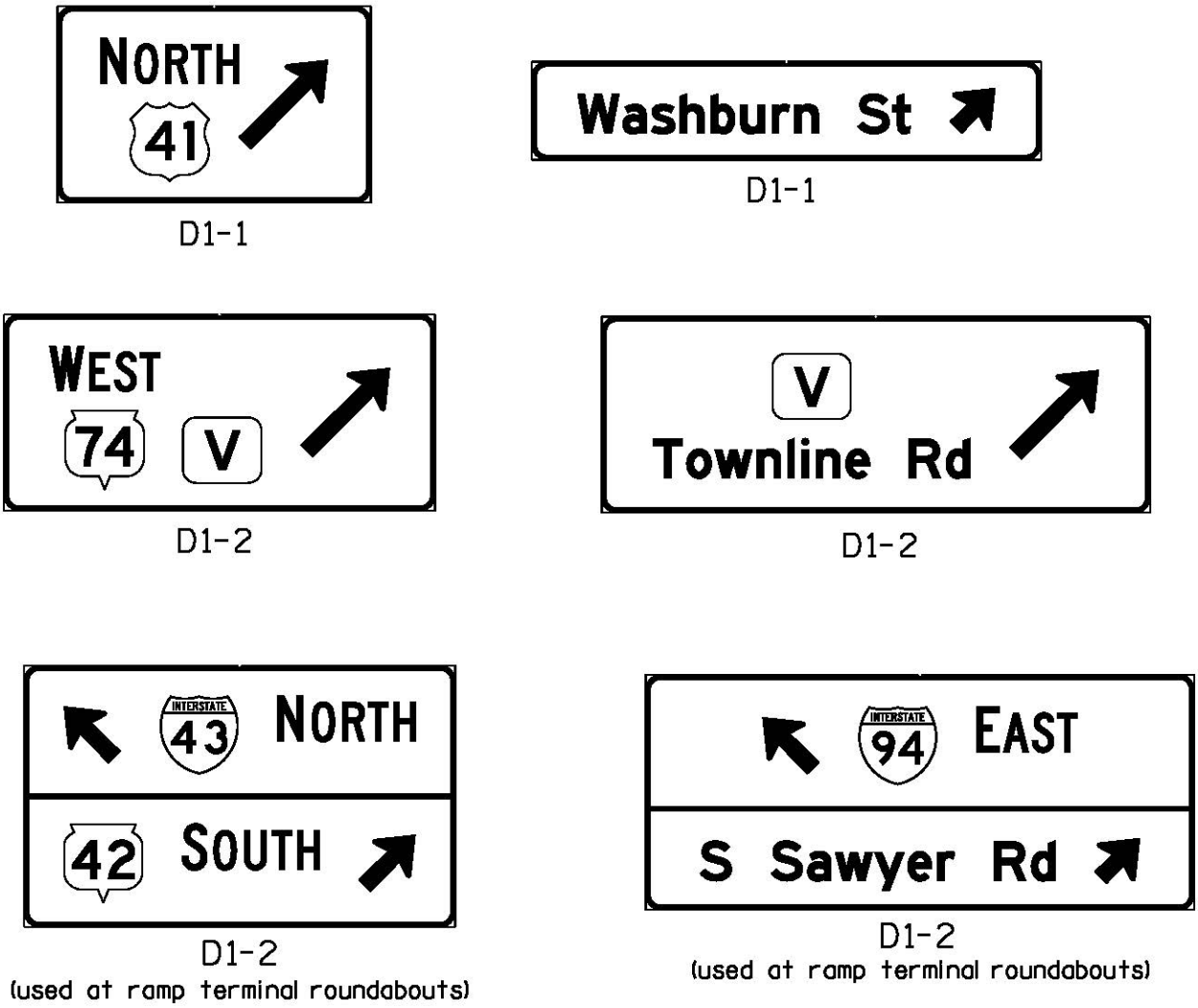


***Figure 35.5** Exit Signs*

35.1.3.4 Junction Assemblies

As with traditional intersections, consider using junction assembly consisting of either a “JCT” (M2-1) auxiliary sign with the appropriate route markers or a junction (J1-1) assembly in advance of the roundabout.

35.1.3.5 Route Confirmation Signs

For roundabouts involving the intersection of one or more numbered routes, install confirmation assemblies (J4’s) directly after the roundabout exit to reassure drivers that they have selected the correct exit at the roundabout. Locate confirmation assemblies no more than 500 feet beyond the intersection in urban or rural areas. If possible, locate the assembly’s close enough to the intersection so drivers in the circulatory roadway can see them.

35.1.4 Urban Signing Considerations

Urban intersections tend to exhibit lower speeds. Consequently, the designer can, on a case-specific basis, consider using fewer and smaller signs in urban settings than in rural settings. However, include some indication of street names in the form of exit guide signs or typical street name signs. Also review proposed signing to ensure that sign clutter will not reduce its effectiveness. Avoid sign clutter by prioritizing signing and eliminating or relocating lower priority signs.

There are sometimes situations with multilane approach urban roundabouts where the right-of-way is tight and

there is no physical room for typical overhead sign structures. There may be aesthetic considerations for multilane approach urban roundabouts where large overhead guide signs may not fit in. Scaled-down versions of overhead guide signs or J-assemblies may be utilized for these situations that may show route assembly panels instead of large guide signs as shown in Attachment 35.3.

35.1.5 Rural and Suburban Signing Considerations

Route guidance emphasizes destinations and numbered routes rather than street names. The exit guide sign needs to be visible (but discrete) from within the roundabout and much smaller than the typical rural shields and lettering size. Six-inch upper case and 4-1/2-inch lower case lettering height is the maximum needed.

35.1.6 Closely-spaced Multiple Roundabouts

Often multiple roundabouts may be installed in close proximity to each other (roundabouts 1,000 feet apart center to center, or less). This can often happen at interchange ramp terminals and roundabouts beyond ramp terminals at frontage roads. Multiple roundabouts in close proximity to each other can cause signing challenges due to longitudinal space constraints between the roundabouts. As a result, some signing may be eliminated between the roundabouts. Visibility distance is based on stopping sight distance of vehicles. The roundabout warning assembly signs (W2-6, W2-6P and W13-1), pedestrian warning signs (W11-2, W11-15, W11-15A, W16-9P and W16-7L/R) and YIELD AHEAD (W3-2) may be eliminated between roundabouts if the visibility distance between the roundabouts exceed the minimum visibility distance shown in Table 35.1. Other signs may be eliminated with consultation with the Region Traffic Section. The roundabout warning assembly signs and YIELD AHEAD would continue to be placed at the approaches to the first roundabouts in the series.

Table 35.1 Minimum Visibility Distance*

Posted or 85th Percentile Speed	Minimum Visibility Distance
25 mph	280 ft
30 mph	335 ft
35 mph	390 ft
40 mph	445 ft
45 mph	500 ft
50 mph	555 ft
55 mph	610 ft

* Minimum Visibility Distances are from Section 2C.36 of the WMUTCD

35.1.7 Roundabouts in Close Proximity to Railroad Crossings

Railroad crossings in close proximity to roundabouts can present additional signing challenges due to safety concerns involving railroad crossings and the installations of additional signs in spaces already containing numerous signs. Because each railroad crossing is unique, roundabout designers need to contact the Bureau of Traffic Operations Traffic Design unit and the appropriate Region Traffic Operations section for the proper signing and marking layout if the railroad crossing is 1000 feet or less from the roundabout.

35.1.8 Wrong Way Movements in Roundabouts

There is a potential for wrong way movements at roundabouts, especially roundabouts that are new in an area. The typical signing applications include the usage of a chevron sign (series of 4 chevrons, W1-8a) in the central island with a One Way sign (R6-1R sign) mounted above it. In addition, a One Way sign is mounted below the left side YIELD sign. If wrong way movement problems persist, there are some signing options that can be employed:

- Oversize ONE WAY (R6-1R) sign in the central island, above the chevron sign
- DO NOT ENTER (R5-1) signs mounted in the circular island to face potential wrong way traffic
- DO NOT ENTER (R5-1) and NO RIGHT TURN (R3-1) signs is required for roundabouts at ramps per TEOpS 2-15-12 mounted on the outside radius of roundabout as shown in the detail in 2-15-12

35.1.9 Wide Turning Trucks in Roundabouts

As large trucks maneuver a multilane roundabout, often times they need to encroach into the adjacent travel lanes. In many multilane roundabouts, this happens by design. Occasionally there may be issues resulting from

large trucks encroaching into the adjacent travel lanes as they make the turn. For these problem areas, it may be necessary to warn the motorist that the large trucks will encroach into the adjacent travel lanes in the roundabout circle. The WATCH FOR WIDE TURNING TRUCKS (W8-73) sign may be installed on the roundabout approaches for multilane roundabouts exhibiting these problems

35.1.10 Short Term Awareness Techniques

Some of the following bullet items are listed as short-term awareness techniques and others are mitigation considerations after field problems have been identified. In either situation contact the Region Traffic Engineer for guidance. Do not expect traffic control devices to accomplish what the geometric design cannot.

- Provide portable changeable message signs.
- Install orange flags on top of the YIELD signs during the first six months of operation.

35.1.11 Maintenance of Signs

For roundabouts on the STH System with county highway approaches or local road approaches, it is recommended that early in the design process, a Maintenance Agreement needs to be developed. By having the Maintenance Agreement developed early in the design process, the county or local unit of government will clearly have knowledge of what they are to maintain.

Some particular items that should be included in the Maintenance Agreement would include:

- Specific signs that WisDOT would maintain and what the locals/county would maintain. This would also include signposts.
- Specific overhead sign supports (if any), that WisDOT would maintain, and what the locals would maintain.
- Recommended inspection frequencies for overhead sign supports that the locals would maintain.

Further guidance on the maintenance of signs for roundabouts is included in the Traffic Engineering, Operations and Safety Manual, policy TEOpS 2-15-52.

35.1.12 Sign Installation for OSOW Vehicle Routes

Give careful attention to signs that are installed for roundabouts on OSOW vehicle routes. Periodically signs and posts may need be temporarily removed to accommodate the vehicles as they pass through the roundabout and turns properly. The designer should review the OSOW truck route maps in FDM 11-25-1.4 and contact the Region freight coordinator to confirm if the roundabout is located on an OSOW vehicle route. Confirm the proposed post usage type on these routes with the Region Traffic Operations.

For roundabouts on OSOW routes, install tubular steel sign post assemblies or a comparable system (approved by the Project Engineer) for the following signs:

1. Left side YIELD (R1-2) - ONE WAY (R6-2R) sign assembly
2. Right side YIELD (R1-2) - TO TRAFFIC FROM LEFT (R1-54) sign assembly
3. Exit Guide signs (D1 series) in the splitter islands
4. PEDESTRIAN CROSSING (W11-2m W16-7R or similar) sign assemblies at the intersection crosswalks
5. Roundabout chevron bank (R6-4b) and ONE WAY (R6-1R) sign assembly in the circular island
6. Any signs located on the median island separating a right turn lane from the through lane(s)
7. Any additional signs on the outer portion of the roundabout circle, if directly impacted by OSOW vehicles.
8. Additonal consideration should be given to sleeving, all signs on single lane roundabout approaches with clear width less than 20'.

Install tubular steel sign post assemblies in accordance with Standard Spec 634.3.2 and standard sign plat A4-9. Refer to the sign plate manual at:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/signplate/signplate.aspx

To help prevent bending of the anchor tube and potential puncturing of vehicle tires, place the top of the 2 1/4" x 2 1/4" anchor level with the top of the 18" diameter PVC box-out (which is at ground level). The box-out is typically filled with gravel or dirt which will require about 2" of it to be removed in order to access the corner bolt when removing/reinstalling the post. The designer will need to ensure that notes are placed on the permanent signing plan to notify contractors of the required height of the top of the anchor system.

35.2 Pavement Marking

Pavement marking is needed on single and multilane roundabouts. The more complex the roundabout and the higher the volume, the greater the need for proper pavement marking. Pavement marking must be closely evaluated when designing a roundabout. Pavement marking is part of a "whole system" to consider, meaning

that various design concepts from geometric design, to signing, and pavement marking should complement each other.

Typical pavement marking for roundabouts consists of delineating the entries, exits, bike lane accommodations (only on approaches and exits), and marking the circulatory roadway. Single lane roundabouts need no lane arrows or circulatory roadway pavement marking, except for edge line marking. Attachment 35.1 shows various combinations of common roundabout lane configurations, including full and partial right-turn bypass situations. In order for roundabout markings to be effective and sustainable, they must:

- Be integrated with and preferably designed at the same time as the roundabout geometry
- Be configured to guide proper usage of the roundabout
- Help the motorist identify the correct lane as early as possible using lane arrows on multilane approaches and circulatory roadways
- Be designed and implemented collaboratively between Regional Traffic Operations and project development staff with expertise in roundabouts and knowledge of maintenance considerations

Based on findings from the Department's pavement making evaluation, mark all roundabouts and their approaches with epoxy pavement marking. Epoxy pavement marking replaces preformed thermoplastic and grooved tape applications.

Refer to TEOpS 3-10-1 of the Traffic Engineering, Operations and Safety Manual (TEOpS) for further guidance with roundabout pavement marking applications, including pavement marking preparation and installation at existing roundabouts.

Markings not covered in this policy shall follow practices established by standard detail drawings or require the approval of the Regional Traffic Engineer in collaboration with others who have knowledge of the design of roundabouts. On connecting highways, (local jurisdiction), coordinate pavement marking with the Regional Traffic Engineer and the local agency to maintain consistency on the facility.

It is just as important to make sure field layout and pavement marking application on the circulatory pavement is located and positioned correctly. A pavement marking layout detail showing the exact locations is required on all multilane roundabouts. Consider wheel tracking when developing the pavement marking layout detail.

Proper pavement marking within the circulatory roadway will help prevent left turns from the outer lane and thus reduce exit crashes. Complex lane configurations should be reviewed by an experienced roundabout designer and the Regional Traffic Engineer.

35.2.1 Approach Markings

1. Centerline marking on the approach to the splitter island may require a minimum of 500-foot segment no passing barrier line as shown in SDD 15C18 “Median Island Marking”. Refer to Attachment 35.1 item *O*.
2. Lane lines on the approach shall be 4 inches wide. The markings are at the typical spacing of 12.5-ft segment, 37.5-ft gap, unless an even segment of 12-ft segment, 12-ft gap is needed. Start when flare widens to 9.5 feet for each lane. Match the width of line extended. Refer to items *T* and *X* in Attachment 35.1.
3. A lane line on the approach *may be either 4 inches or 8 inches wide* when it separates two through lanes. The line shall be solid for a length of 50 feet in advance of the Point of Curve (P.C.) or as far as possible in advance of the P.C. to allow minimum marked lane widths of 9.5 feet, whichever is shorter. Refer to items *B* and *I* and its various marking width applications in Attachment 35.1.
4. When an approach lane is a turn only lane, the channelizing line *may be either 4 inches or 8-inches wide and solid*. A R3-8 series Lane Control sign *shall* be placed for this type of approach. Refer to FDM 11-26-35.1.1. The line shall be solid for a length of 50 feet in advance of the P.C., or as far as possible in advance of the P.C. to allow minimum marked lane widths of 9.5 feet, whichever is shorter. Refer to item *B* and its various marking width applications in Attachment 35.1.
5. When the left approach lane is a dropped lane/exclusive turn lane, the approach dotted marking *shall be 4-inches wide with 3-ft segment, 9-ft gap.* Consult with the Regional Traffic Engineer on the start of this marking. Refer to item *D* in Attachment 35.1.
6. The painted median splitter island marking on the approach *shall be double yellow with 12-inch yellow diagonal marking.* Do not place diagonal marking if the island is less than 6-ft wide. When the island nose width is greater than 6 feet, the diagonals shall be spaced every 25-ft if the median gore is longer than 50-ft; spaced every 10-ft if the median gore length is 50-ft or less. Refer to items *J* and *K* in Attachment 35.1.
7. Lane separation markings (truck gores) *shall be outlined by 8-inch white lines*. Refer to item *U* in Attachment 35.1. When the separation is greater than 6-ft, *12-inch white chevrons shall be placed and spaced every 25-ft if the truck gore length is longer than 50-ft; spaced every 10-ft if the truck gore*

length is 50-ft or less. Do not install chevrons when the truck gore is 6 feet wide or less. The point of the chevron shall 'point' upstream. Refer to item *U* for chevron application in Attachment 35.1.

8. The edge line marking on the circle end of the splitter island will be white. Refer to Attachment 35.1 which shows the breakpoint from 8-inch white to 4-Inch yellow markings 5 feet in advance of the curb/splitter island P.C (items M and N of the *Special Case* in Attachment 35.1). Refer to TEOpS 3-10-1 and consult the Regional Traffic Engineer for further placement guidance of the yellow edge line upstream of the roundabout.

   When the yellow edge line marking is used to narrow the width of an entry or exit, 12-inch yellow diagonal markings should be placed. When used, the diagonals shall be spaced at 10-foot spacing. Place diagonal markings only if distance between curb flange and edgeline is greater than 3 feet. Refer to item W of the Special Case in Attachment 35.1. Also see FDM 11-26-30.5.12 for its application with wide entry flares only.

9. When two or more lanes approach a roundabout, lane use arrows shall be marked in each lane to denote proper lane usage. Full complement of signing *shall be installed* as shown in Figure 35.1, Regulatory Signs. Refer to item *V* in Attachment 35.1. *Lane use arrows should not be used on single-lane approaches.* Left turn arrows *with the oval (Type 2R or Type 3R) shall only be placed in the left most lane.* Refer to SDD 15C7-d for typical detail of a dot with left pavement marking arrow. *The fish-hook arrow shall not be used.*

   In addition to approach lane lines, appropriate lane arrows encourage balanced lane use, which improves capacity and safety. Left turn arrows are important on multilane approaches, since traffic otherwise has a bias towards the right-most lane. Place arrows to show the movements for each lane, and to indicate permitted dual right or left turns. Place the arrows at or just before the point where the channelizing or lane line begins or when the road widens to allow minimum lane widths of 9.5 feet. This is intended as a visual cue to the motorist to select an appropriate lane for entering the roundabout. Refer to SDD 15C8-e and Regional Traffic Engineer for guidance for multiple sets of arrows.

10. Crosswalk markings should be placed such that vehicles approaching the roundabout are not likely to stop on the crosswalk. A distance of 20 to 25 feet per stored vehicle back from the yield point is typically appropriate. Refer to Attachment 35.1 as well as crosswalk policy in TEOpS 3-2-3 or selection guidance of appropriate crosswalk markings.

11. The word, "YIELD" placed prior to the dotted edge line extension is encouraged as an educational tool initially as part of a project. It should typically be used on multilane approaches when necessary as a tool for enforcement or where there are unusual geometrics, visibility problems, or crashes caused by motorists failing to yield. An example is an approach with a high volume of through traffic that was not required to stop or yield prior to the construction of the roundabout, especially where there is no side road leg 90 degrees to the right. When used on a multilane approach, the "YIELD" word should be placed in each approach lane. After initial placement, this marking should only be maintained as necessary based upon crash data. Refer to item *S* in Attachment 35.1 and SDD 15C7-b, Yield Markings.

12. Dotted Edge Line Extensions *shall be 18-inch-wide dotted white at 2-ft segment, 2-ft gap.* Place markings to avoid conflict between the entering vehicle and internal roundabout traffic, this is the point where entering traffic must yield. Refer to item *A* in Attachment 35.1.

Approach and entry pavement markings consist of lane line, channelization marking, dotted edge line extension marking (yield line) and symbol markings. Consider high durability markings on the approaches. Refer to TEOpS 3-10-1 for approved pavement marking materials and their locations at a roundabout. Consult with the Regional Traffic Engineer before determining final pavement marking materials.

35.2.2 Circulatory Roadway Marking

13. Lane lines within the roundabout *shall be 4-inch or 8-inch width, with a 6-ft segment, 3-ft gap marking cycle*. These lines shall be the same width as the lines they extend. Lane lines in the circle can have a spiral effect and together with proper lane assignment guide motorists through the roundabout to the appropriate exit eliminating the need to change lanes. Refer to item *C* in Attachment 35.1 along with guidance in selecting either the 4-inch or 8-inch width. For longevity, place the markings to avoid wheel paths of the intersecting traffic.

14. When used, dotted line markings shall be the same width as the lane lines and 1-ft segment, 3-ft gap marking cycle. Refer to item E in Attachment 35.1.

15. When two lanes are allowed to proceed around the circle, Lane use arrows *shall* be marked in each lane within the roundabout adjacent to each splitter island to denote proper lane usage. Arrows placed within the circulatory roadway *shall not* include the oval. Refer to item *Q* in Attachment 35.1.

35.2.3 Exit Marking

16. Avoid chevron makings at the exit point adjacent to the splitter island and at the exit or on the approach. This former special case application has been discovered to provide limited benefits in speed control and directional guidance versus curb and gutter.
17. *Do not paint the noses of the splitter island yellow* (where the splitter island meets the circulatory roadway, unless there is a documented crash problem). Yellow nose paint is intended to separate opposing directions of traffic such as the approach nose.

35.2.4 Bicycle Marking

18. When required, bike lane markings should be placed as per Figure 35.6.

Bike lane marking within the circulatory roadway is not permitted on any roundabouts. Refer to Figure 35.6 for Bike Lane markings on roundabout approaches.

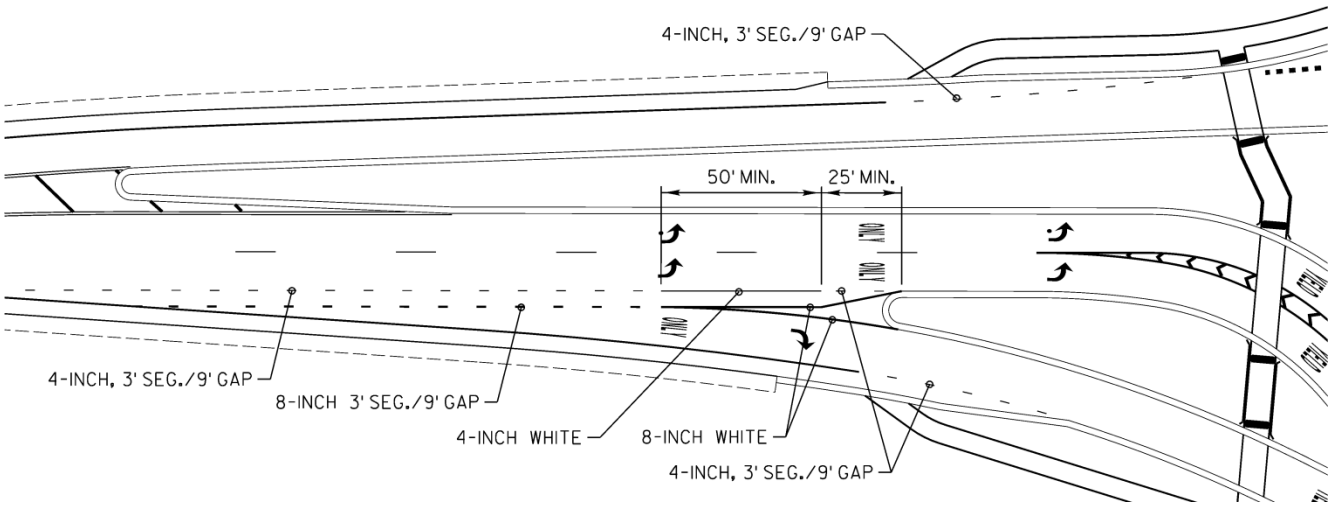


***Figure 35.6* Bike Lane Roundabout Marking**

35.2.5 Maintenance of Pavement Marking

For roundabouts on the STH System with county highway approaches or local road approaches, it is recommended that early in the design process no later than the time of the design study report, a Maintenance Agreement be developed. By having the Maintenance Agreement developed early in the design process, the county or local unit of government will clearly have knowledge of what they are to maintain.

LIST OF ATTACHMENTS

Attachment 35.1	Example Pavement Markings for Typical Designs
Attachment 35.2	Sample Signing Layout for Single-Lane Roundabout
Attachment 35.3	Sample Signing Layout for a Multilane Roundabout
Attachment 35.4	Sample Signing Plan for Roundabout Ramp Terminals
Attachment 35.5	Sample Signing Plan for Roundabout Ramp Terminals

FDM 11-26-40 Landscaping and Maintenance *August 15, 2019*

Illumination can be found in chapter 11 of the Traffic Engineering, Operations and Safety Manual (TEOpS 11-1).

40.1 Central Island Landscaping

Landscape elements are vital to the proper operation of a roundabout and needs to be in place when the roundabout is opened to traffic. The purposes of landscape elements in the roundabout are to:

- Make the central island conspicuous to drivers as they approach the roundabout
- Clearly indicate to drivers that they cannot pass straight through the intersection. Restrict the ability to view traffic from across the roundabout through mounding of the earth and plantings. This will lead to slower entering speeds, which increases safety.
- Require motorists to focus toward on-coming traffic from the left
- Help break headlight glare
- Discourage pedestrian traffic through the central island

- Help blind or low vision pedestrians locate sidewalks and crosswalks
- Improve and complement the aesthetics of the area

When designing landscaping for a roundabout it is important to:

- Minimize driver distraction and provide central island crashworthiness
- Consider maintenance requirements early in the program stages of development
- Develop a formal municipal agreement describing the landscaping and maintenance requirements for roundabouts elements early in the scoping process and prior to design of the facility.
- Maintain adequate sight distances
- Avoid obscuring the view to signs
- Minimize fixed objects such as trees, poles, or guard rail
- Apply the guidance below relative to approach speeds and the permissible use of fixed objects such as trees, poles, non-hazard walls, non-hazard rocks/boulders, or guard rail

The Department takes a proactive approach toward minimizing driver distraction. Avoid items in the central island that may be considered an attractive nuisance and may encourage passersby to go to the central island for pictures, or other objects that might distract drivers from the driving task. Decorative features that may attract pedestrians within the central island or lead to distracted driving include (not all inclusive):

- Decorative statutes
- Water fountains/features
- Artwork
- Decorative walls
- City logos or community welcome signs
- Commemorative plaques or monuments
- Banners and flags
- Roundabout sponsorship signing
- Street furniture (decorative and non-decorative)
- Combination of these above features

Any decorative features planned to be added to the central island should be of vegetative nature or natural-looking and close to ground level. Refer to FDM 11-26-40.2.1 for reference to Department-approved plant materials.

Crashworthiness is a key element of roundabout central island landscaping design. While central island crashes are rare, they are often the most severe crashes. Optimize the crashworthiness of the central island design while balancing a community's desire to implement aesthetic treatments. Further discussion regarding allowable central island aesthetic treatments for low speed environments is cited below. Designers need to be mindful when considering non-hazardous aesthetic treatments. Consider an object's potential adverse influence to an errant vehicle, including vehicle abrupt deceleration, underside fuel tank or oil pan tears, launching and rollovers and their effects to occupants and pedestrians.

The Department's typical approach to central island landscaping is mounding the earth and providing plantings. Refer to Figure 40.1 for the general layout of the central island. Design the slope of the central island with a minimum grade of 4% and a maximum of 6:1 sloping upward toward the center of the circle. The earth surface in the central island area forms an earth mound that is a minimum of 3.5-feet to a maximum of 6-feet in height, measured from the circulating roadway surface at the curb flange. As an absolute minimum, keep the outside 6 feet of the central island free from landscape features to provide a minimum level of roadside safety, snow storage, and unobstructed sight distance. In some situations, this central island area may need to maintain a low profile beyond 6-feet to allow OSOW vehicle loads to pass over the central island without the axles passing over the central island, (i.e. 165-foot girder, wind turbine parts).

The combination of the earth mound and plantings in the central island shall provide a visual blocking such that drivers will not be able to see through the roundabout central island. The central island area is considered a low speed environment, however errant vehicles occasionally end up in the central island or crossing the central island. The inner portion of the central island is typically most vulnerable to drivers/vehicles that for some reason leave the roadway and drive headlong into the central island. If a driver is driving too fast to negotiate a curved approach to a roundabout, or otherwise distracted and is not aware of the upcoming roundabout, the impact angle entering the central island typically will be much greater than 25 degrees and outside the realm of roadside design. The consequence of hitting a fixed object at an angle greater than 25 degrees is severe.

The approach highway speed is an indicator of the probability of an errant vehicle entering the central island. The following items are prohibited within the central island regardless of approach speed:

- Hazardous material - such as concrete, stone, boulders or wood walls
- Fixed objects - including trees having a mature diameter greater than 4-inches

Where all approach legs to a roundabout have a posted speed of 35 mph or less there may be objects that appear to be hazardous such as walls or rocks, but they are to be constructed with materials and in a manner that is not hazardous to errant vehicles. It is important to minimize the consequences of an errant vehicle that may impact these features.

Minimize the consequence of hitting a wall by following these guidelines:

1. Do not allow any walls in the central island with cast in-place or reinforced concrete or natural boulders.
2. When all roundabout approach legs have posted speeds of 35 mph or less, walls may be constructed with light-weight, Styrofoam type, artificial bricks/blocks typically used in landscaping and boulders with chicken wire and stucco. No mortar or reinforcing between the bricks/blocks. Minimize the wall thickness while maintaining stability.
3. If light-weight walls are desired for aesthetic reasons then construct at a height 20-inch or lower. This will tend to keep flying debris at a lower level as not to penetrate a windshield, or impact other vehicles.
4. Do not allow fill material in back of the light-weight brick/block wall for approximately 2 feet. Then at ground level begin to slope the earth up and away from the non-hazardous wall at a 6:1 slope or flatter.

Communities desiring to include decorative, lightweight fiberglass boulders with the central island landscaping design may use these boulders for low-speed urban environments up to 35 mph posted roundabout approach speeds by following these additional guidelines:

1. Decorative boulder wall thickness is 1/8” or less
2. Decorative boulders are not anchored to concrete base or pad
3. Use decorative boulders sparingly and strategically locate them as to minimize potential striking by errant vehicle
4. Keep larger diameter decorative boulders (max 24”) toward the top of the central island berm

Diamond interchange exit ramps departing from high speed freeways and expressways will be considered as having a posted ramp termini approach speed exceeding 35 mph. On a case-by-case basis, designers may consider slower ramp termini approach speeds of 35 mph or less for exit ramps with sharper ramp curvature (e.g. loop ramp) that reduce operational speeds prior to the ramp termini.

Early in the design process, consult within the region and with Bureau of Project Development for input on local community’s landscaping plans and possible decorative solutions. Options may be realized with various material treatments and applications on a case-by-case basis.

Landscape design elements requested by municipalities/communities that exceed costs of typical Department guidelines will need to be funded by the municipality. Refer to Program Management Manual for specific cost share policies. A maintenance agreement with the municipality will be required. Address any roundabout utility needs requested by the municipality, such as water and electrical costs and maintenance, in the agreement.

40.2 Landscape Design

Landscape design is an important aspect of roundabout operation. Before starting the landscape design first determine the maintaining authority and comply with the intersection sight distance as described in FDM 11-26-30.5.15. More flexibility is allowed on projects that are not maintained by WisDOT.

Low-to-the-ground landscape plantings in the splitter islands and approaches can both benefit public safety and enhance the visual quality of the intersection and the community. In general, unless the splitter islands are very long or wide they should not contain trees, planters, or light poles.

Landscape plantings on the approaches to the roundabout can enhance safety by making the intersection more conspicuous and by countering the perception of a high-speed through traffic movement. Avoid landscaping within 50 feet in advance of the yield point. Plantings in the splitter islands (where appropriate) and on the right and left side of the approaches (except within 50 feet of the yield point) can help to create a funneling effect and induce a decrease in speeds approaching the roundabout. Low profile landscaping in the corner radii can help to channelize pedestrians to the crosswalk areas and discourage pedestrian crossings to the central island.

40.2.1 Owned, Operated, and Maintained by WisDOT

The goal for State-owned and maintained roundabouts is to achieve a landscape design that enhances the safety around the central island and splitter islands with little or no landscape maintenance required over time. Landscape design elements should minimize areas of mulch and the planted vegetation that requires maintenance.

Low maintenance planting plans for roundabout landscapes are required. Vegetation approved for use by the department requires minimum maintenance and has been demonstrated to tolerate highway site conditions.

The central island earth berm may be planted with trees and shrubs, a prairie grass mixture that doesn't require mowing, or both. Plant materials approved for use by the Department, including trees and shrubs listed in FDM 27-25 Attachment 1.3 are approved for use on roundabouts owned, operated and maintained by the Department. Certain native grasses are also approved at roundabouts and are included in the grasses portion of the "Table of Native Seed Mixtures" in Standard Spec 630.

Locations of plant materials shall be selected for salt tolerance and be located to allow for sufficient snow storage in the winter. Snow removal operations typically radiate out from the central island. Plant materials shall not be placed to impede snow removal practices.

The uses of pre-emergent herbicides are recommended for use in plant bed and "hardscape" areas. Follow label instructions provided on the product container for use and application procedures.

Contact the Highway Maintenance and Roadside Management Section in the Bureau of Highway Operations for additional landscape design guidance.

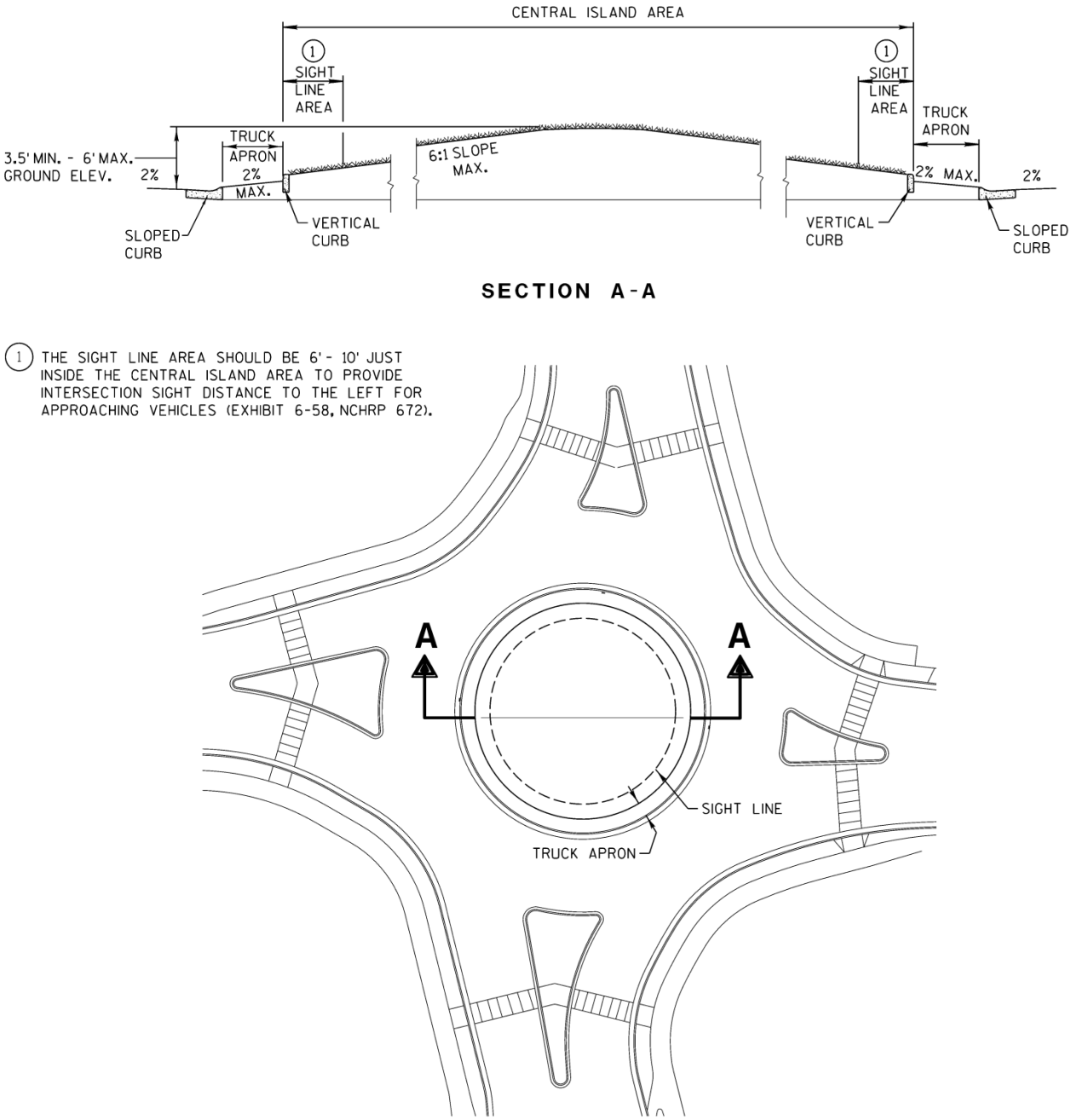


***Figure 40.1* Low-Maintenance Central Island Landscaping**

40.2.2 Owned by WisDOT but Maintained by Others

Landscape design requests in excess of FDM 11-26-40.2.1.1 will be considered only upon receipt of a formal, signed project agreement prior to design of the facility and are the sole responsibility of the requesting municipality. These agreements are to be obtained in the planning stages of the project.

40.2.3 Local Roads and Connecting Streets

Landscape design costs in excess of department's design criteria described in FDM 11-26-40.2.1.1 on local roads and connecting streets are the sole responsibility of the municipality.

40.3 Landscape Maintenance

Maintenance responsibilities for roundabouts will vary by ownership. Roundabouts are located on the local road system, on connecting state highways, and state highways.

40.3.1 Owned, Operated, and Maintained by WisDOT

All maintenance costs and operations of roundabout landscaping owned, operated and maintained by the department are the responsibility of the department, except as provided below. Landscape design elements and guidance have been outlined to minimize maintenance and operational costs to the department. Plants shown on the approved list have been selected to best meet these needs, FDM 27-25 Attachment 1.3. FDM 11-26-30 and Figure 40.1 provide detailed layout dimensions of the area to be planted within the central island area.

Only those landscape maintenance operations necessary to maintain the safe operation of the department roundabout will be undertaken.

40.3.2 Owned by WisDOT but Maintained by Others

Municipalities often request special landscaping. Landscape requests in excess of requirements contained in FDM 11-26-40.2.1.1 are the responsibility of the requesting municipality. Such requests will be considered only upon receipt of a formal, signed municipal agreement approved by the department prior to the design of those roundabouts. This procedure shall be completed early in the planning stages of project development.

40.3.3 Local Roads and Connecting Streets

Maintenance and operating costs of roundabouts located on local roads and connecting streets are the responsibility of the local government.

40.4 Shared-Use Path Maintenance

For urban, suburban, outlaying and rural locations for roundabouts, a roundabout sidepath or shared-use path is provided accordingly; see FDM 11-26-30.5.13. Facilities may be omitted if conditions are met as described in FDM 11-46-1. Appropriate cost share policies apply and maintenance agreements with the local unit of government are required, unless refusal to maintain omission conditions are met see FDM 11-46-1. If conditions are met to omit facilities, grading for future facilities apply as detailed in FDM 11-26-30.5.13 and cut-through crossing are to be provided in splitter islands. The cost of the path installation and maintenance after the original roadway improvement is the responsibility of the local unit of government. There have been situations where land uses change, the local government leaders change, attitudes about such improvements change, or that pedestrian or bicycle volumes increase over time, and later there is a strong desire to install the path.

FDM 11-26-45 Work Zone Traffic Control

March 28, 2014

45.1 Work Zone Traffic Control

Roundabouts pose unique challenges when maintenance work is performed in or around these facilities. Each roundabout is unique so develop the traffic control plan to meet the specific conditions of the location, traffic volumes, duration, and work operation. Consider detour and staging as alternatives since they may provide better service for traffic movement.

During the design of temporary traffic control in roundabout work zone it is essential that the intended travel path for motorists, bicyclists, and pedestrians is clearly identifiable. Ensure turning radii can accommodate tractor-trailer vehicles. SDD 15D21 and SDD 15D31 show example device spacing at turning radii and curve transitions. Accomplish this through the temporary traffic control part 6 of WMUTCD

https://wisconsindot.gov/dtsdManuals/traffic-ops/manuals-and-standards/wmutcd/mutcd-ch06.pdf

compliant traffic control channelizing devices, signing, delineation, and temporary pavement markings. There are occasions when guidance may be provided by law enforcement personnel or using flagging operation depending on the complexity of the work in the roundabout. Schedule work during off-peak hours to minimize traffic within the roundabout if feasible. A roundabout is not designed to hold stopped or waiting traffic during roadwork. Flagging or a detour may be required if it is likely that work may block traffic from using the circular roadway of a roundabout. Notify emergency services and law enforcement if work is anticipated to cause delays.

SDD 15D37 provides general guidance on the signing and device requirements for maintenance work in and around a roundabout location.

Work in a roundabout may involve any of the situations listed below.

- If work is within the roundabout, initial advance warning (ROAD WORK AHEAD) signs are required for each approach leg.
- If work occurs within the roundabout island and all work vehicles are out of the travel lanes and center island apron, a single “ROAD WORK AHEAD” sign is required per approach.
- If any of the roadway approaches cannot access the intersection due to workspace, a detour may be required. For short closures of less than 15 minutes or less, traffic may be held in place.
- If the center island apron will be impacted by the work or equipment, treat it as a shoulder closure for the duration of the work but consider diverting semi-trailer truck traffic due to large vehicle wheel tracking.
- If work occurs in an approach leg, a minimum of two flaggers should be used to control traffic. High approach volumes may require additional flaggers in the remaining legs. Use the “ROAD WORK AHEAD, BE PREPARED TO STOP” and the Flagger symbol signs in advance of each leg.
- If travel width of at least 10’ can be maintained for shoulder work on an approach lane, the lane can remain open to traffic. Close the workspace with shoulder taper and tangent cones/drums. An initial advance sign and a “SHOULDER (SIDEWALK) CLOSED” sign are required unless the work lasts less than 15 minutes.
- If work is in a multi-lane roundabout, and work can be done without closing both travel lanes, flaggers may not be needed. Appropriate signs for the lane closure at each entry are required. Merge traffic into one lane prior to entry into the roundabout. See the details in SDD 15D12 and part 6 of the WMUTCD

  https://wisconsindot.gov/dtsdManuals/traffic-ops/manuals-and-standards/wmutcd/mutcd-ch06.pdf

  for merging details.
- If the splitter islands are raised, cones may not be needed along the approaches. In these situations, the flagger may have to move ahead on the splitter island so that traffic can maneuver into the roundabout.

When establishing the limits of the work zone ensure maximum possible sight distance to the flagger station, based on the posted speed limit. Motorists should have a clear line of sight from the flagger symbol sign to the flagger.

If sidewalks are impacted, provide a detour or temporary walkway that is a smooth, continuous hard surface (firm, stable and slip resistant) throughout the entire length of the temporary walkway. The following examples are typical work activities expected to occur in/around a roundabout.

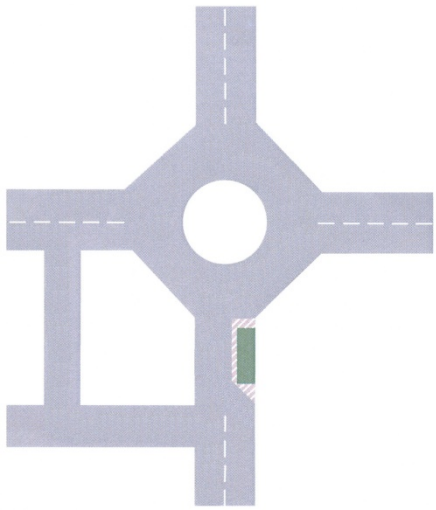


***Figure 45.1* Work Zone at Entrance to Roundabout**

Case A - Work Zone at the Entrance to a Roundabout

Two-way traffic should be maintained if possible. If not, entering traffic should be stopped using a flagger or a detour route provided.

In the case of a work zone illustrated in Figure 45.1, use channelizing devices to direct traffic to the proper travel path and restrict traffic to one lane going towards the roundabout. Advance warning signs “ROAD WORK AHEAD, NARROW LANES (if lanes are less than 10’), barricade with Lane Closed signs should be used. If no suitable detours are available, it may be necessary to adopt an alternating one-way layout.

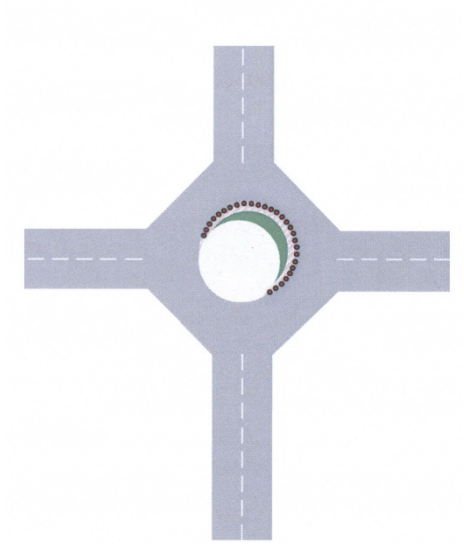


Figure 45.2 Work Zone in the Circulatory Area of a Roundabout

Case B - Work Zone in the Circulatory Area of a Roundabout

If possible maintain all movements. Separate the work area from traffic using channelizing devices and advance warning sign such as “ROAD WORK AHEAD.”

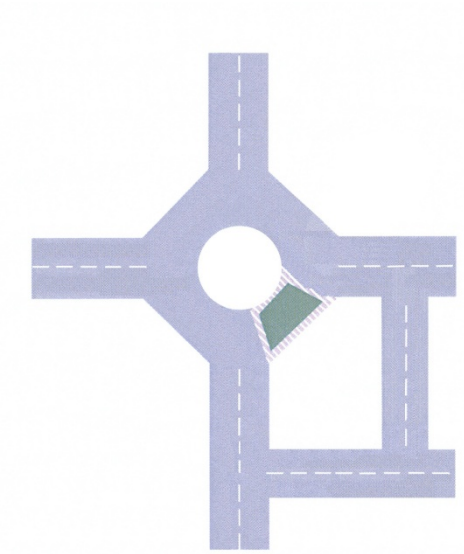


Figure 45.3 Work Zone Completely Obstructing the Circulatory Area of a Roundabout

Case C - Work Zone Completely Obstructing the Circulatory Area of a Roundabout

Refer to Figure 45.3 and the traffic control, 2-lane roundabout information in SDD 15D37.

At night, flagger stations should be illuminated except in emergencies. Portable changeable Message Signs should be considered as part of the traffic control plan to provide clear guidance to motorists on all approaches of the roundabout.

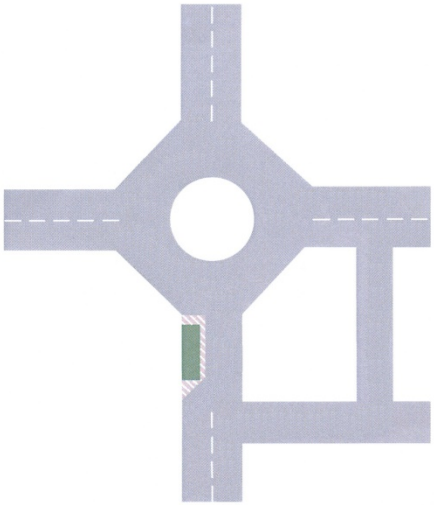


Figure 45.4 Work Zone at the Exit from a Roundabout

Case D - Work Zone at the Exit from a Roundabout

Channelize traffic around the work area using appropriate channelizing devices. Provide buffers space if roadway width allows. Two-way traffic past the work area should be maintained if possible, otherwise the road should be operated as an exit only from the roundabout, and a signed detour route provided.

45.1.1 Pavement Markings

Because of the confusion of a work area and the change in traffic patterns, pavement markings must clearly show the intended travel path. Misleading pavement markings shall be removed or covered in accordance with the Wisconsin Standard Specifications. As new pavement courses are placed consider specifying in the plans that splitter island delineation and broken white lines on the outside edge of the circulatory roadway be marked the same day the pavement course is placed according to Wisconsin Standard Specifications. When pavement markings are not practical, or misleading markings cannot be adequately deactivated, use closely spaced channelizing devices to define both edges of the travel path. When possible, pavement markings used within the work zones should be the same layout type and dimension as those to be used in the final layout. Additional pavement markings may be necessary to avoid confusion from changing traffic patterns used in staging.

45.1.2 Signing

Construction signing for a roundabout should conform to the WMUTCD and the Standard Detail Drawings. Provide all necessary signing for the efficient movement of traffic through the work area, including pre-construction signing advising the public of the planned construction, and any regulatory and warning signs necessary for the movement of traffic outside of the immediate work area. The permanent roundabout signing may be installed, where practicable, during the first construction stage so that it is available when the roundabout is operable, but these signs must be covered until they are needed. Consider using portable changeable message signs when traffic patterns change.

45.1.3 Lighting

Illuminate the temporary construction area through the intersection where possible. Consider adjacent lighting conditions, traffic volumes during the evening when the roundabout is illuminated, and mixture of use such as pedestrians and trucks.

45.1.4 Construction Staging

The Transportation Management Plan, FDM 11-50-5, will consider detouring traffic away from the intersection during construction of the project. A detour will significantly reduce the construction time and cost, increase the safety of the construction personnel and will provide for an overall better finished product

It is typical to complete construction as soon as possible to minimize the time the public is faced with an unfinished layout or where the traffic priority may not be obvious. If possible, all work, including the installation of splitter islands and pavement marking, should be done before the roundabout is open to traffic.

If it is not possible to detour all approaches, detour as many approaches as possible. Carefully consider construction staging during the design of the roundabout if it must be built under traffic. Minimize the number of stages if at all possible. Staging should accommodate the design vehicle and maintain sightlines.

Prior to the work that would change the traffic patterns to that of a roundabout, certain peripheral items may be

completed including permanent signing (covered), lighting, and some pavement markings that reflect actual conditions. These items, if installed prior to the construction of the central island and splitter islands, would expedite the opening of the roundabout and provide additional safety during construction.

As is the case with any construction project, install appropriate traffic control devices as detailed in the project plans and the Standard Specifications. This traffic control shall remain in place as long as it applies and be removed when it no longer applies to the condition. Maintain consistent traffic control; do not change between stop and yield control multiple times during construction.

Stage the construction as follows unless a different staging plan is approved during design:

- Install and cover proposed signing
- Remove or mask pavement markings that do not conform to the intended travel path
- Construct outside widening if applicable
- Reconstruct approaches if applicable
- Construct splitter islands and delineate the central island. Uncover the signs at this point and operate the intersection as a roundabout
- Finish construction of the central island

If it is necessary to leave a roundabout in an uncompleted state overnight, construct the splitter islands before the central island. Any portion of the roundabout that is not completed must be marked, delineated, and signed in such a way as to clearly outline the intended travel path. Remove or mask pavement markings that do not conform to the intended travel path. Consider adding temporary lighting if the roundabout will be used by traffic in an unfinished state overnight or install the permanent lighting that is in operational condition.

45.1.5 Public Education

The Transportation Management Plan, FDM 11-50-5, will advise the public whenever there is a change in traffic patterns. Education and driver awareness campaigns are especially important for a roundabout because a roundabout will be new to most motorists. The Regional Communication Manager coordination through both design and construction is typically vital to the success of a project. Provide brochures on how to drive, walk and bicycle through a roundabout. The following are some specific suggestions to help alleviate initial driver confusion:

- Hold public information meetings prior to construction
- Prepare news releases/handouts detailing what the motorist can expect before, during, and after construction
- Consider the creation of a project website, flash animation graphics, traffic simulation recording (such as Paramics, etc.) or the use of social media before and during construction
- Install portable changeable message signs or fixed message during construction and before construction begins. Advise drivers of anticipated changes in traffic patterns for about one week prior to the implementation of the new pattern.
- Use Wisconsin 511, news media (and Highway Advisory Radio, if available) to broadcast current status of traffic patterns and changes during construction. Also, if appropriate, establish a web site, to post up-to-date traffic and construction information.

45.99 References

1. Federal Highway Administration (2009), Manual on Uniform Traffic Control Devices, (MUTCD), U.S. Department of Transportation, Washington, D.C.
2. Washington State Department of Transportation, Work Zone Traffic Control Guidelines, M54-44.04, February 2012, http://www.wsdot.wa.gov/publications/manuals/fulltext/M54-44/Workzone.pdf.
3. American Traffic Safety Services Association (ATSSA), Temporary Traffic Control for Building and Maintaining Single and Multi-Lane Roundabouts, November 2012
4. Oregon Department of Transportation, “Temporary Traffic Control Handbook for Operations of Three Days or Less,” December 2011.
5. Maryland Department of Transportation, State Highway Administration; “Work Zone Traffic Control, Roundabout Flagging Operation Greater than 40 MHP/Over24 hrs.”

FDM 11-26-50 Design Aides

June 24, 2016

50.1 Example Plan Sheets

Several example plan sheets of the above information have been provided as an aide to the designer when completing roundabout plans. The plan sheets provided are examples and should only be used as guidance. FDM 11-26 File 1 is a .pdf of the various plan sheets. The PDF attached has bookmarks for the various plan

sheets as noted above to assist you in viewing the sheets.

- Project Overview
- Typical Section
- Construction Details
- Pavement Elevation (Concrete)
- Pavement Elevation (Asphalt)
- Erosion Control
- Storm Sewer
- Landscaping
- Permanent Signing
- Lighting
- Pavement Marking
- Construction Staging
- Plan and Profile
- Cross-Sections

50.2 Creating Roundabout Fastest Paths (B-spline Curves) and Using AutoTurn software

Spline curves can be created in both AutoCAD and MicroStation. In AutoCAD, they are called polylines and in MicroStation they are called B-spline curves.

Instructions for creating roundabout fasted paths B-spline in AutoCAD 3D is in Attachment 50.1, and for creating roundabout fasted paths B-spline in Microstation Version 8 is in Attachment 50.2.

Instructions for using AutoTurn software in AutoCAD Civil 3D and MicroStation is in Attachment 50.3.

50.3 OSOW Vehicle Inventory Evaluation Overview

Use AutoTurn, AutoTurn Pro 3D or Autodesk Vehicle Tracking (AVT) software for OSOW horizontal evaluation with the exception of the Wind Tower 80M MID and Wind Tower 205'. For these vehicles, only use AutoTurn or AutoTurn Pro 3D. Use AutoTurn Pro 3D or Autodesk Vehicle Tracking for low clearance evaluation (DST lowboy). Refer to these links for videos and assistance in using these tools.

This is the link to the AutoTurn Pro 3D tutorial videos:

http://www.c3dkb.dot.wi.gov/Content/c3d/dsn-chk/swept-pth/swept-pth-grnd-clrnc.htm

Refer to FDM 11-25 Attachment 2.1 for OSOW vehicle inventories. Additionally, refer to FDM 11-25-2.1.1.3 for OSOW vehicle inventory evaluations overview for further guidance in evaluating the OSOW vehicle tracking.

LIST OF ATTACHMENTS

Attachment 50.1	Creating Roundabout Fastest Paths (Spline Curves) in AutoCAD Civil 3D
Attachment 50.2	Creating Roundabout Fastest Paths (Spline Curves) in Microstation Version 8i
Attachment 50.3	Guide for Using AutoTURN in AutoCAD Civil 3D and MicroStation Version 8i

ROUNDABOUT CRITICAL DESIGN PARAMETERS DOCUMENT (follow link for a working copy of this template: FDM 11-26 A5.1 File 1)

Project ID
Title
Limits
Route
County

ROUNDABOUT CRITICAL DESIGN PARAMETERS

DESIGN PARAMETERS	LEG 1	LEG 2	LEG 3	LEG 4	LEG 5	LEG 6
Approach Width, FT						
Entry Width, FT						
Entry Angle, PHI Φ, DEG						
Inscribed Circle Diameter, FT						
Exit Width, FT						
Circulating Roadway Width Upstream of Entry, FT						

FASTEST SPEED PATH												
R_1, Radius/Speed, FT/MPH												
R_2, Radius/Speed, FT/MPH												
R_3, Radius/Speed, FT/MPH												
R_4, Radius/Speed, FT/MPH												
R_5, Radius/Speed, FT/MPH												
Bypass R_5, Radius/Speed, FT/MPH												

MINIMUM SIGHT PARAMETERS												
Approach Design Speed, MPH												
Horizontal Stopping Sight Distance, FT												
Circulating Intersection Sight Distance, FT/MPH												
Entering Intersection Sight Distance, FT/MPH												

Design Vehicle:

Truck Apron Width:

OSOW Accommodations:

Circulating Roadway Cross-Slope:

Access Control:

Parking Control:

Bicycle & Pedestrian Accommodations:

Designer:
Reviewer:

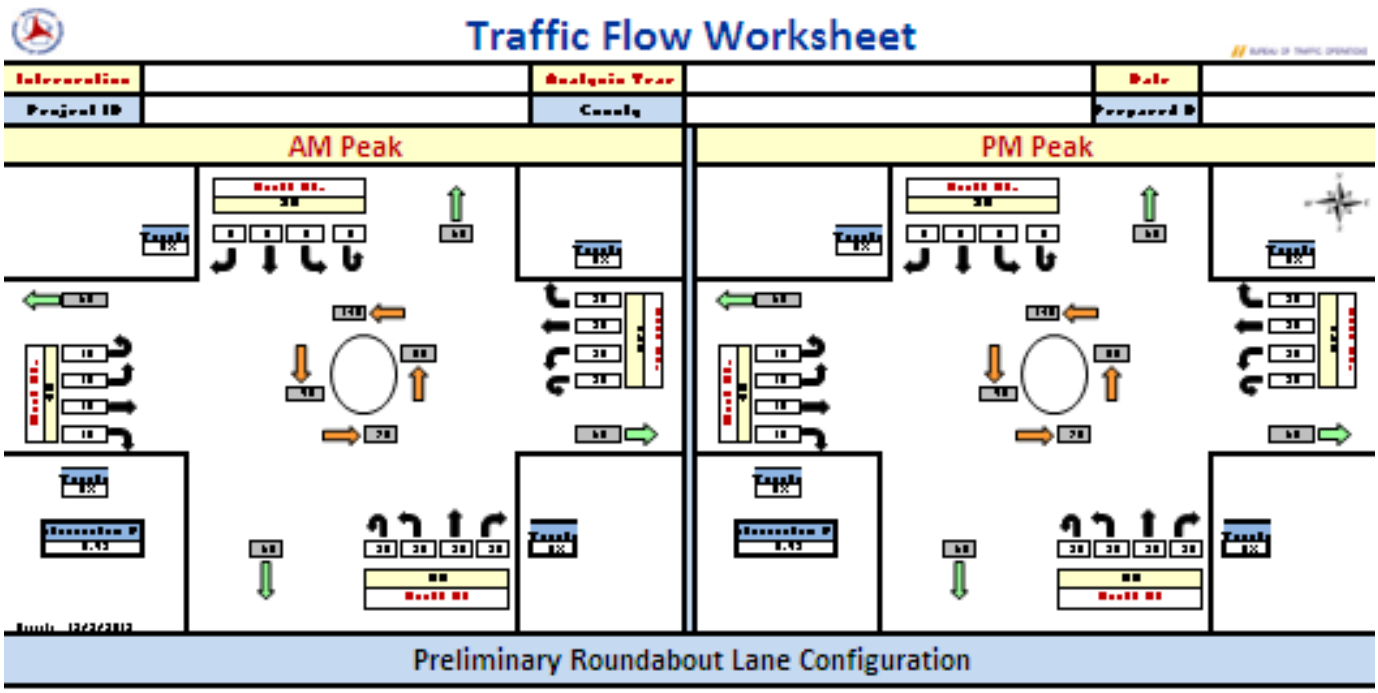
SIGNATURE: _____ DATE:

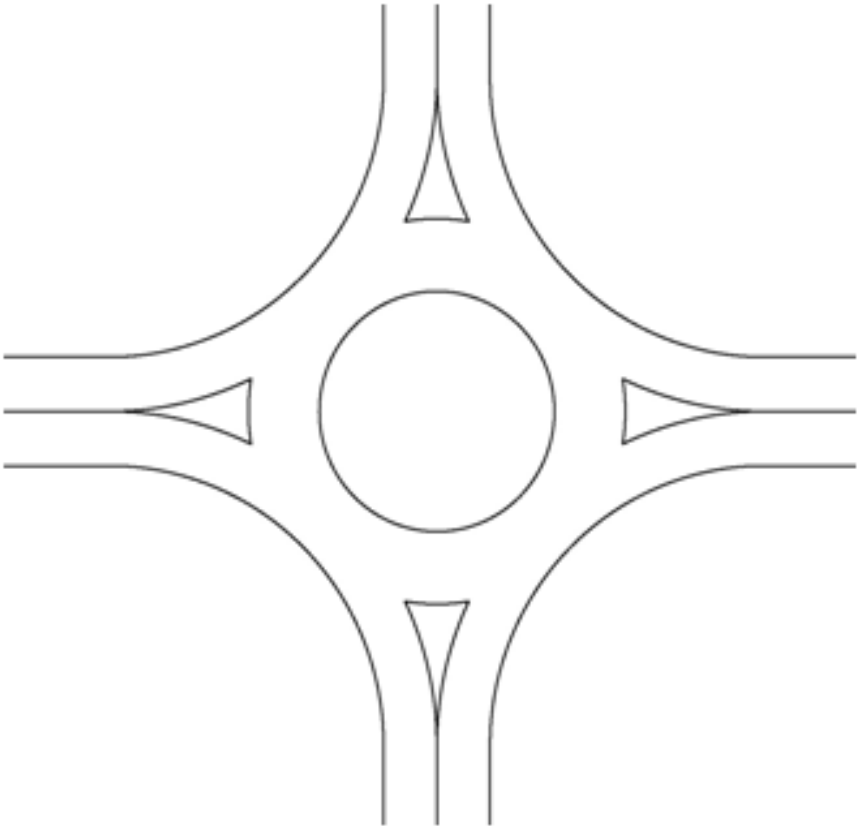
NAME:

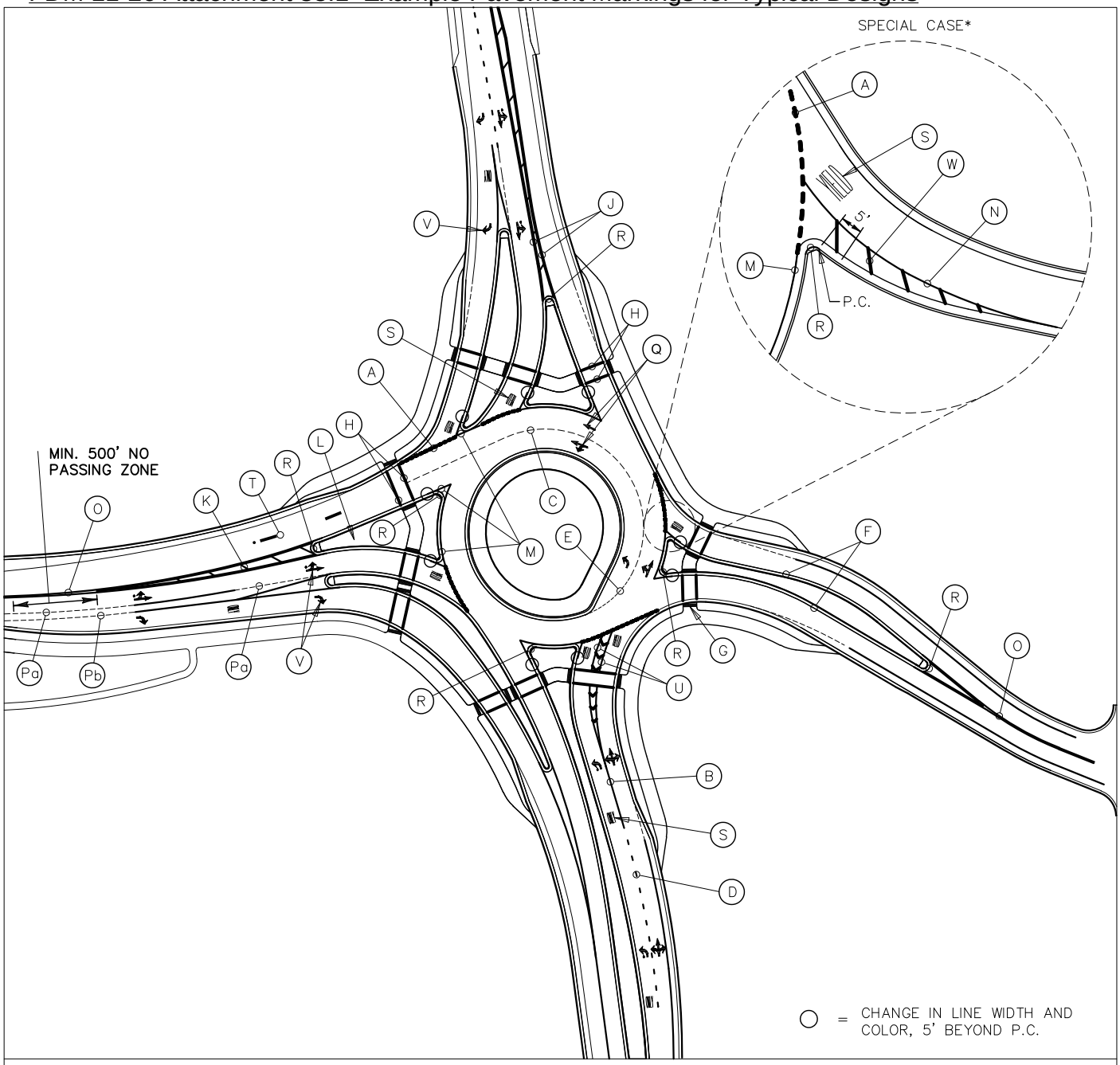
The reviewer's signature on this document indicates that the design has been reviewed and is in general compliance with good roundabout principals. The critical design elements have been addressed. The project design engineer in responsible charge of final plan development will stamp the plans when applicable.

D

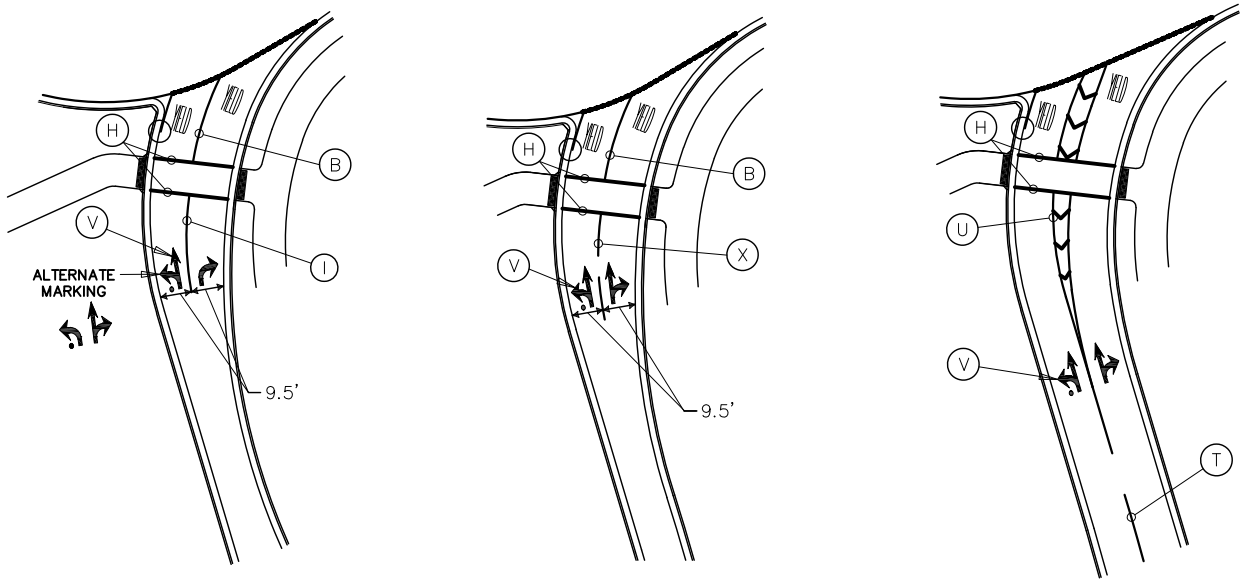
ROUNDABOUT TRAFFIC CONTROL WORKSHEET (follow link for a working copy of this template: FDM 11-26 A20.1 File 1)







*** ALTERNATE APPROACH MARKING



Refer to following pages for Pavement Marking Key.

KEY:

A. Dotted Edge Line Extension, 18-Inch White, (2-ft segment, 2-ft gap)

B. Approach Channelizing Line, 4-Inch White (standard); 8-Inch White may be selected to optimize operations. Contact the Region Traffic Engineer for final marking selection.

C. Circulatory Lane Line, 4-Inch White (standard); 8 Inch White may be selected to optimize operations. Contact the Region Traffic Engineer for final marking selection, (6-ft segment, 3-ft gap).

D. Approach Lane Line, 4-Inch White: 3-ft segment, 9-ft gap for advanced warning of an exclusive turn lane. Begin marking where flare widens to 12 feet for each lane or a minimum of 150 feet before the solid line if no flare is present.

E. Dotted Lane Line, 4-Inch White (standard)**, (1-ft segment, 3-ft gap); 8-Inch White** (1-ft segment, 3-ft gap) may be selected to optimize operations. Contact the Region Traffic Engineer for final marking selection.

F. Splitter Island Left Edge Line, 4-Inch Yellow.

G. Truncated Domes, aligned to ramp direction, not crosswalk direction.

H. Crosswalk, refer to crosswalk selection guidance under TEOpS 3-2-3 for selecting the appropriate crosswalk type.

I. Begin solid approach channelizing line where flare widens to 9.5-ft or 50-ft in advance of approach PC, whichever is shorter. This may be extended for certain exclusive lane configurations.

J. Double Yellow 4-Inch

K. Median Diagonal Marking, 12-Inch Yellow (apply within entire median gore area if distance at island nose is greater than 6-ft wide),

   a. 25-ft C-C spacing, if median gore length greater than 50-Ft long.

   b. 10-ft C-C spacing if median gore length less than 50-ft long.

L. Splitter Island

M. Gore Line, 8-Inch White to 5-ft beyond PC of nose

N. * Left Edge Line, 4-Inch Yellow

O. Center line Yellow Marking 4-Inch Double, or 4-Inch 500-ft segment and 12.5 segment, 37.5-Ft.

P. P_a. Bike Lane Marking, 4-Inch; 3-ft segment, 9-ft gap.

   P_b. Bike Lane Marking, 8-Inch; 3-ft segment, 9-ft gap.

Q. Circulatory Lane Use Arrows, White: No ovals shall be used on any arrows.

R. Island Nose, Yellow

S. Word, White

T. Lane line, 4-Inch White, (12.5-ft segment, 37.5-ft gap)

U. Truck Gore Separation, 8-Inch White. When the separation is greater than 6-ft, 12-inch white chevrons shall be placed every 25-ft if the gore length is longer than 50-ft and spaced every 10-ft if the gore length is 50-ft or less.

V. Approach Lane: Use Arrows, White. Arrows with the oval shall only be used on the left-most turn lane.

W. * Diagonals, 12-Inch Yellow, 10-Ft spacing. Place only if distance between curb flange and edgeline is greater than 3 feet.

Y. Approach Lane Line, 4-Inch White; 12-ft segment, 12-ft gap, even segment gap ratio for symmetrical lane assignment. Begin marking where flare widens to 9.5 feet for each lane.

* SPECIAL CASE:

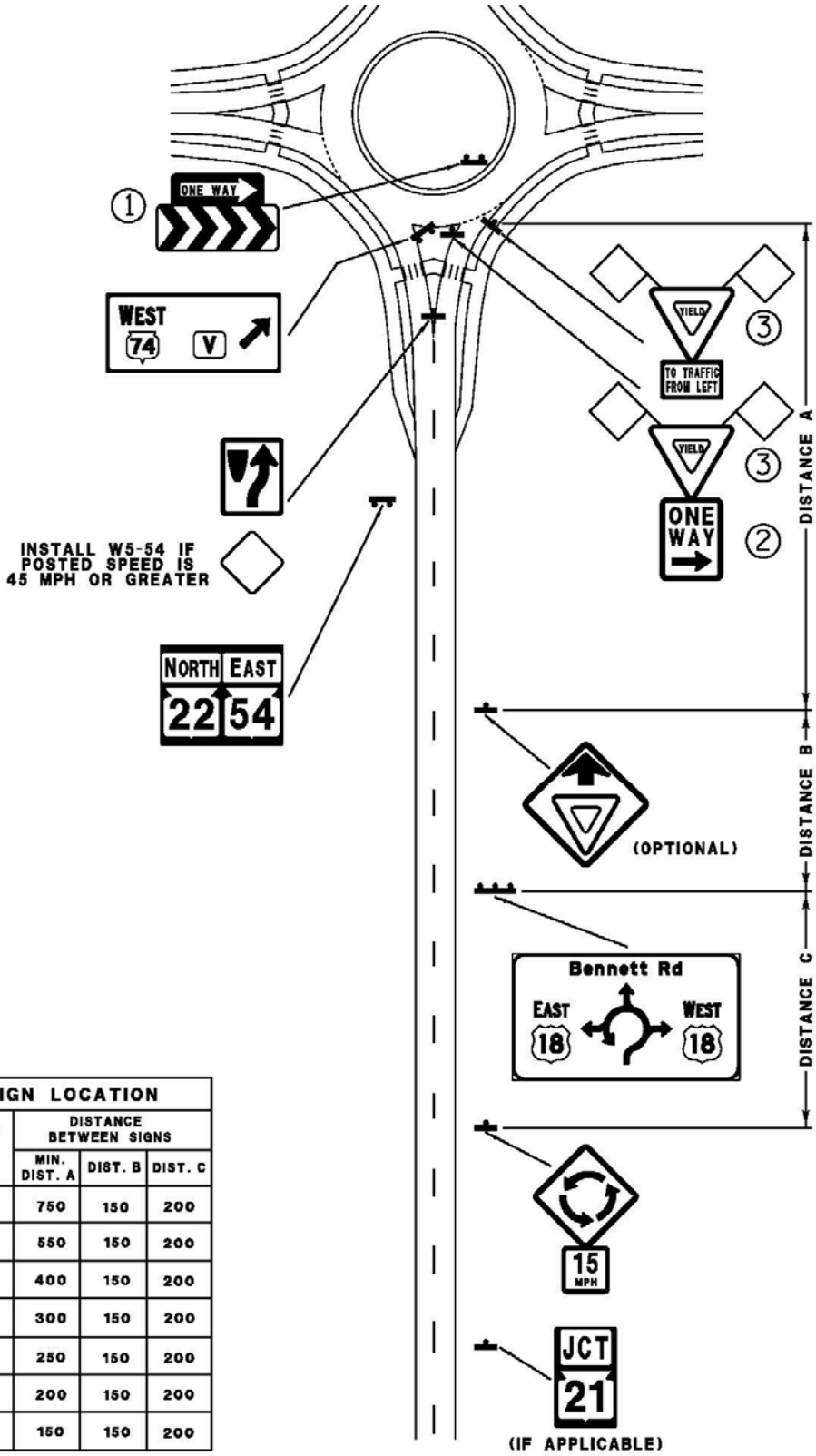
- This alternative pavement marking application should be used when additional space is needed to accommodate truck movements while still restricting the pavement width for smaller

vehicles. It is expected that larger vehicles will have to drive over the markings to complete their maneuver. Use only with wide entry flares. Refer to FDM 11-26-30.5.12 for further guidance.

- The point of the chevron should always ‘point’ upstream.

** Match width of marking extended.

Refer to the TEOpS 3-2 Manual for further information on markings.



SIGN LOCATION			
POSTED SPEED MPH	DISTANCE BETWEEN SIGNS		
	MIN. DIST. A	DIST. B	DIST. C
55	750	150	200
50	550	150	200
45	400	150	200
40	300	150	200
35	250	150	200
30	200	150	200
25	150	150	200

SIGNS WITH ROUTE SHIELDS ARE EXAMPLE APPLICATIONS.

SUBSTITUTE APPROPRIATE ROUTE SHIELDS AND NUMBERS OR LETTERS AS NECESSARY.

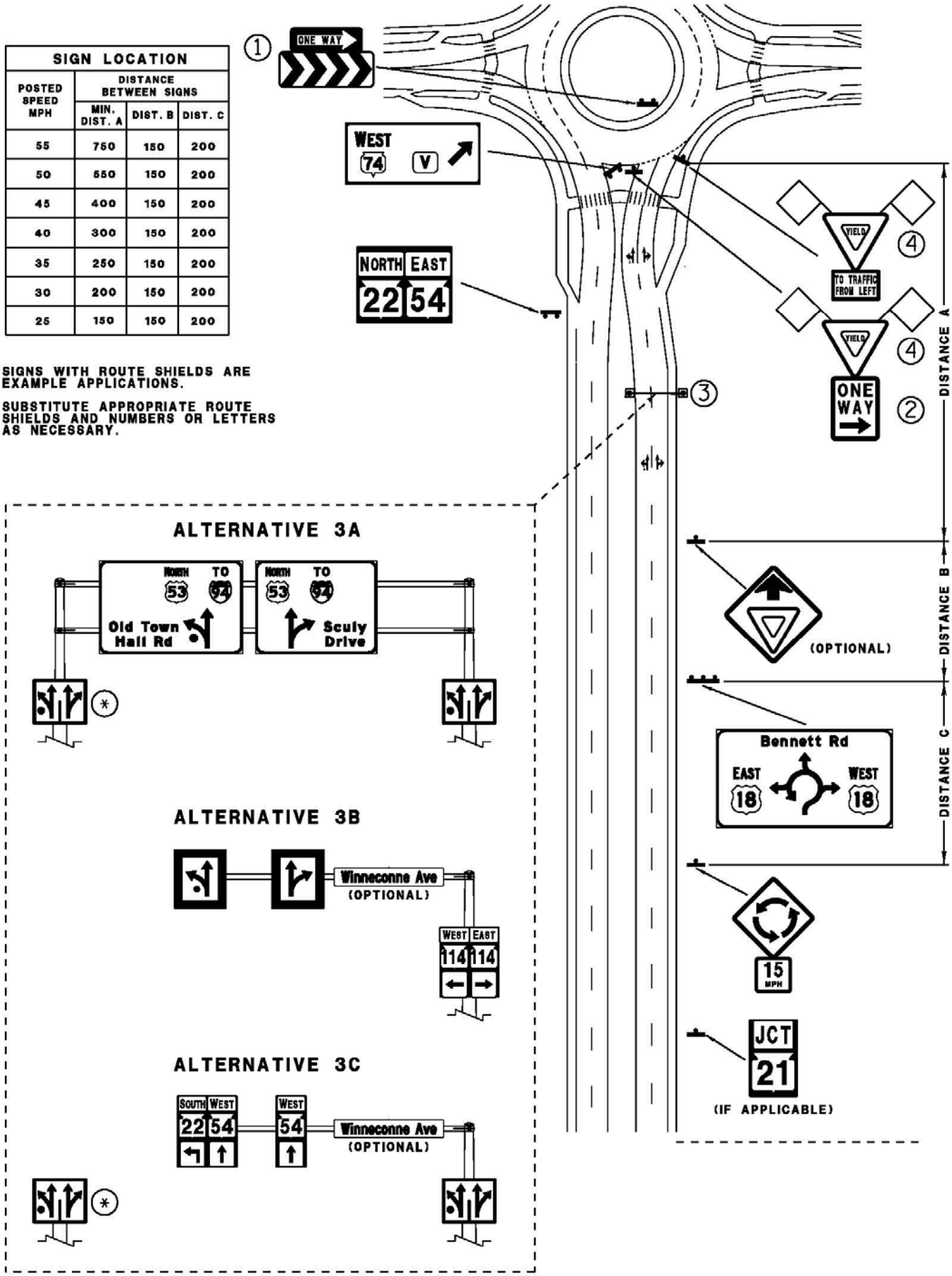
NOTES:

1. Place a ONE WAY (R6-1R) sign above the roundabout chevron bank (R6-4b) in the central island.
2. Place a ONE WAY (R6-2R) sign below the left side YIELD (R1-2) sign. All YIELD signs shall be mounted at the same height (7'- 3"± to the bottom of the YIELD sign).
3. Install 18" x 18" orange flags on top of the YIELD signs for the first six months of operation of the roundabout to emphasize the yield movement.
4. In general, the typical spacing between signs may be reduced to 100 feet in urban areas. Typical rural sign spacing is 200 feet.

SIGN LOCATION			
POSTED SPEED MPH	DISTANCE BETWEEN SIGNS		
	MIN. DIST. A	DIST. B	DIST. C
55	750	150	200
50	550	150	200
45	400	150	200
40	300	150	200
35	250	150	200
30	200	150	200
25	150	150	200

SIGNS WITH ROUTE SHIELDS ARE EXAMPLE APPLICATIONS.

SUBSTITUTE APPROPRIATE ROUTE SHIELDS AND NUMBERS OR LETTERS AS NECESSARY.

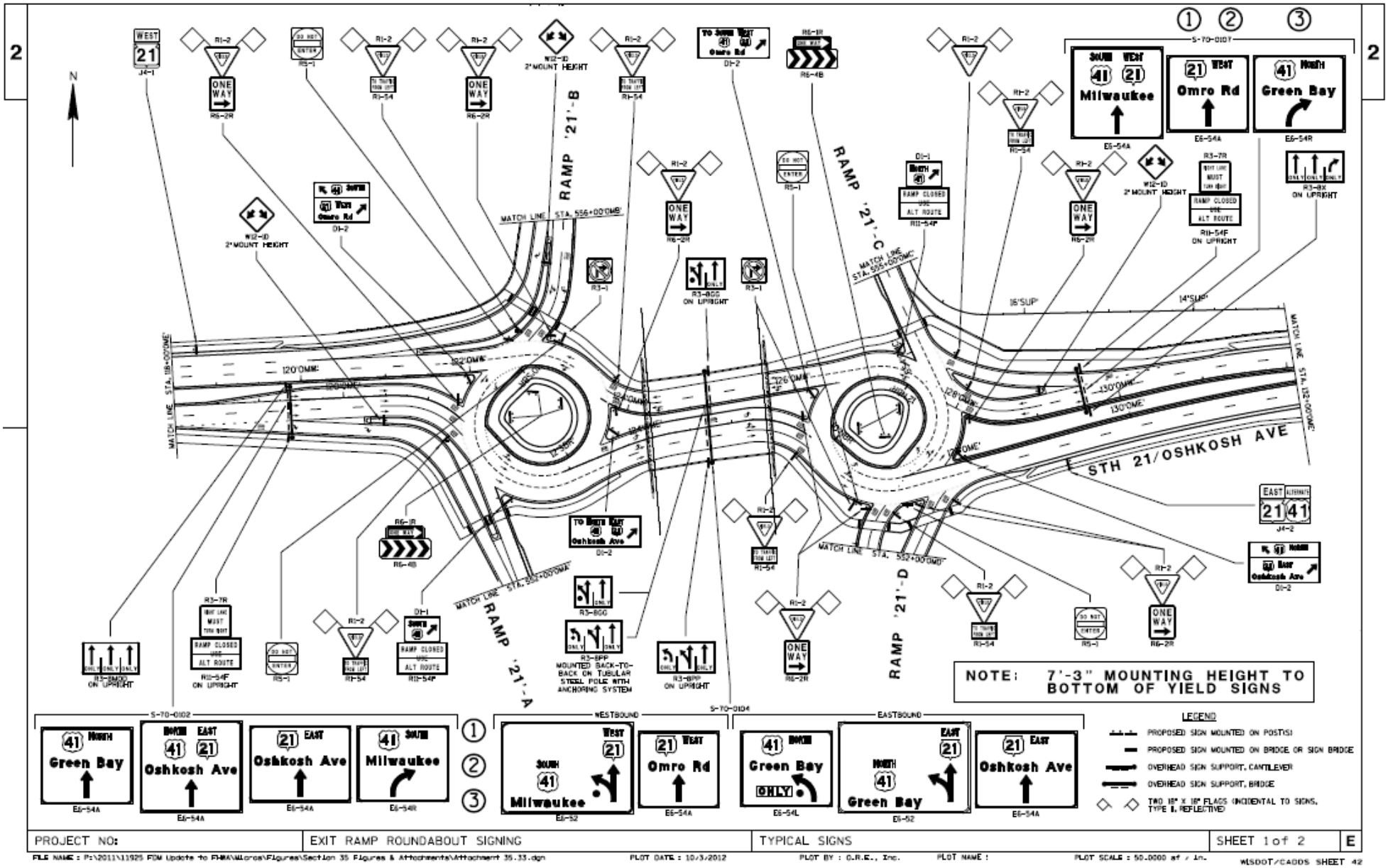


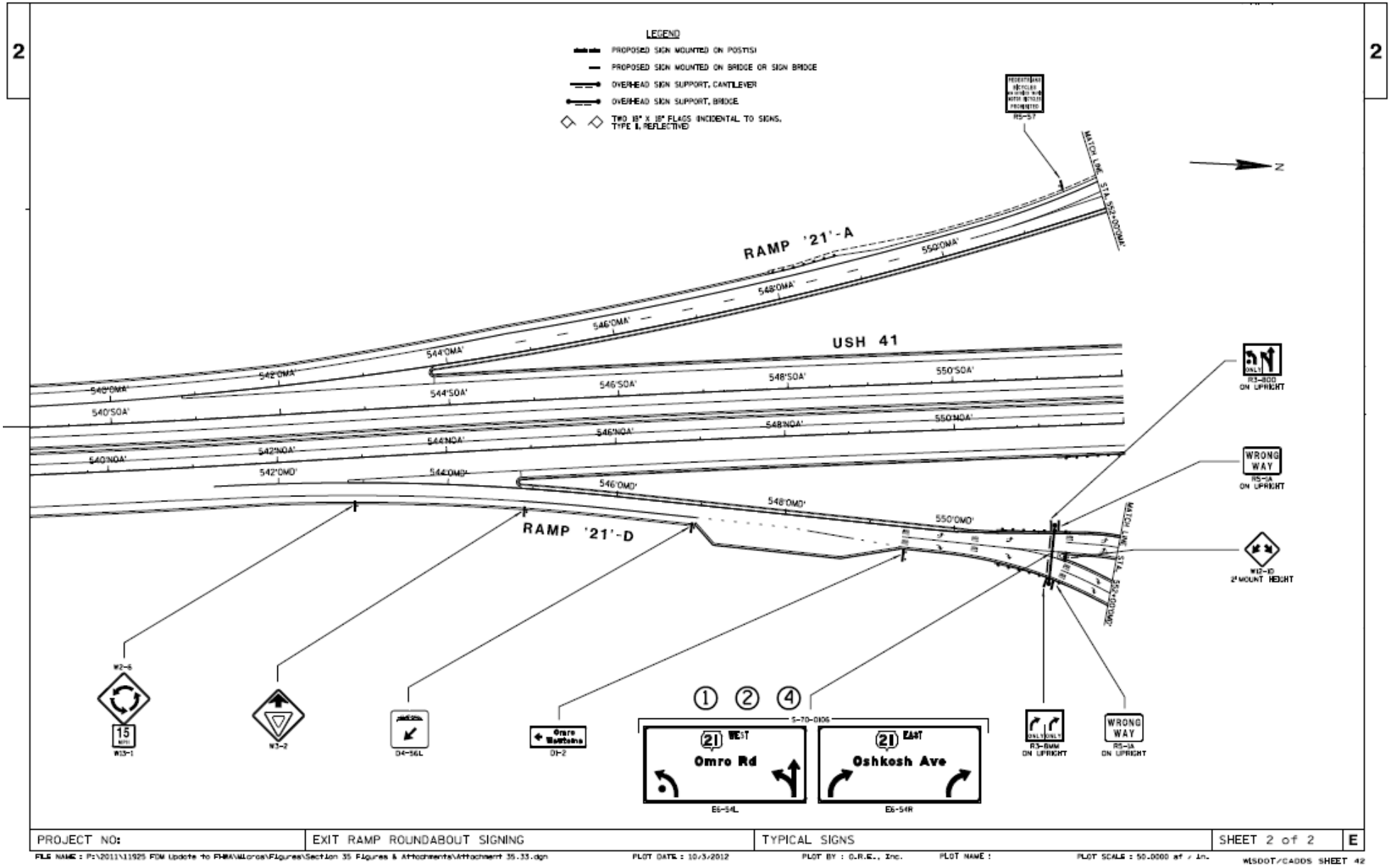
NOTES:

1. Place a ONE WAY (R6-1R) sign above the roundabout chevron bank (R6-4b) in the central island.
2. Place a ONE WAY (R6-2R) sign below the left side YIELD (R1-2) sign. All YIELD signs shall be mounted at the same height (7'-3"± to the bottom of the YIELD sign).
3. Lane use and destination guidance is required on multilane approaches. Approach speed and available lateral space will dictate which style of signing should be installed. Placement of the will depend on the approach speed, sight lines, and lane configuration. Consult the Regional Traffic Engineer for additional guidance.
    a. When green and white (Type I) overhead guide signs are used, a ground mounted lane use sign (R3-8 series) shall be placed as well.
    b. When Type I overhead guide signs are not feasible, overhead lane control signs (R3-5 or R3-6 series) should be used. Route directional sign assemblies (J-series) should be mounted to the structure upright or ground-mounted adjacent to the overhead structure. An advanced street name sign shall also be installed on the cross-arm for additional directional guidance. The route directional assemblies may be directionally split (left turns on the left side, right turns on the right) when multiple routes are concurrent. Use care when splitting these assemblies that the placement matches the adjacent lane designations. Consult the Regional Traffic Engineer for further guidance.
    c. When Type I overhead guide signs are not feasible and lateral space will not allow ground-mounted route directional assemblies (J-series) to be placed, J-series assemblies may be mounted overhead. Ground-mounted lane use signs shall be placed as well. Consult the Regional Traffic Engineer before implementing this type of installation.

* An additional lane use sign may be placed on the left side as well for additional emphasis. The additional sign should be placed when volumes are high, for approaches of three or more lanes, or any time when the sign may have a greater chance of being blocked by passing vehicles. Consult the Regional Traffic Engineer for additional guidance.

4. Install 18" x 18" orange flags on top of the YIELD signs for the first six months of operation of the roundabout to emphasize the yield movement.
5. In general, the typical spacing between signs may be reduced to 100 feet in urban areas. Typical rural sign spacing is 200 feet.


RAMP '21'-A
RAMP '21'-B
RAMP '21'-C
RAMP '21'-D
STH 21/OSHKOSH AVE
NOTE: 7'-3" MOUNTING HEIGHT TO BOTTOM OF YIELD SIGNS
LEGEND
PROPOSED SIGN MOUNTED ON POST(S)
PROPOSED SIGN MOUNTED ON BRIDGE OR SIGN BRIDGE
OVERHEAD SIGN SUPPORT, CANTILEVER
OVERHEAD SIGN SUPPORT, BRIDGE
TWO 18" X 18" FLAGS (INCIDENTAL TO SIGNS, TYPE II, REFLECTIVE)
PROJECT NO:
EXIT RAMP ROUNDABOUT SIGNING
TYPICAL SIGNS
SHEET 1 of 2
E


2
LEGEND
PROPOSED SIGN MOUNTED ON POST(S)
PROPOSED SIGN MOUNTED ON BRIDGE OR SIGN BRIDGE
OVERHEAD SIGN SUPPORT, CANTILEVER
OVERHEAD SIGN SUPPORT, BRIDGE
TWO 18" X 18" FLAGS INCIDENTAL TO SIGNS, TYPE I, REFLECTIVE
R5-57
MATCH LINE STA. 552+00.00(M)
RAMP '21'-A
USH 41
RAMP '21'-D
R3-800 ON UPRIGHT
WRONG WAY
R5-1A ON UPRIGHT
W12-10 2' MOUNT HEIGHT
W2-6
15
W13-1
W3-2
D4-56L
D1-2
S-70-0106
21 WEST
Omro Rd
E6-54L
21 EAST
Oshkosh Ave
E6-54R
R3-8WM ON UPRIGHT
WRONG WAY
R5-1A ON UPRIGHT
PROJECT NO:
EXIT RAMP ROUNDABOUT SIGNING
TYPICAL SIGNS
SHEET 2 of 2
E
FILE NAME : P:\2011\11925 FDM Update to FHWA\Micros\Figures\Section 35 Figures & Attachments\Attachment 35.33.dgn
PLOT DATE : 10/3/2012
PLOT BY : O.R.E., Inc.
PLOT NAME :
PLOT SCALE : 50.0000 ft / in.
WISDOT/CADDS SHEET 42

NOTES:

1. The D15 series of overhead guide signs (Bureau of Traffic Operations A11-17 sign plate) may be used in lieu of the E6 series (BTO A11-13 sign plate) overhead guide signs. D15 series guide signs shall not be used on any approach that has an option lane. A mix of E6 and D15 series signs shall not be used on the same approach. Mixing of the signs may confuse unfamiliar drivers.

   When roundabouts follow in close succession, as in the case of ramp terminals, all overhead signs in the same direction within the corridor shall match. Consult with the Regional Traffic Engineer regarding the final design of corridor overhead signing. Since D15 signs combine regulatory lane assignment and directional guidance, drivers may become distracted and confused if the location of information changes (on the sign or location of the sign).

2. When practical, combine overhead signs to reduce the amount of repetitious information the driver must process. Consult the Regional Traffic Engineer regarding the final design of overhead signing.

3. The ONLY plaque shall be used when a through lane becomes a dedicated turn lane. The ONLY plaque shall be placed on the inside of the curved arrow stem.

4. All lane arrows, pavement marking, regulatory sign, and overhead guide signs shall match for each lane of the approach. The return to the freeway through movement should be indicated by an arrow on the guide sign. Route shields and associated cardinals for the return movement are optional, however, may require significant space and contribute to message clutter when concurrent highways are involved. Consult with the Regional Traffic Engineer regarding the final design of off-ramp overhead signing.

5. Arrow stems should be centered over the center of the lane as space allows.

Creating Roundabout Fastest Paths (Spline Curves) in AutoCAD Civil 3D

Step 1: Copy Curb Offsets

Create the curb offsets as shown in FDM 11-26-30, Figure 30.2 using the "offset" command.

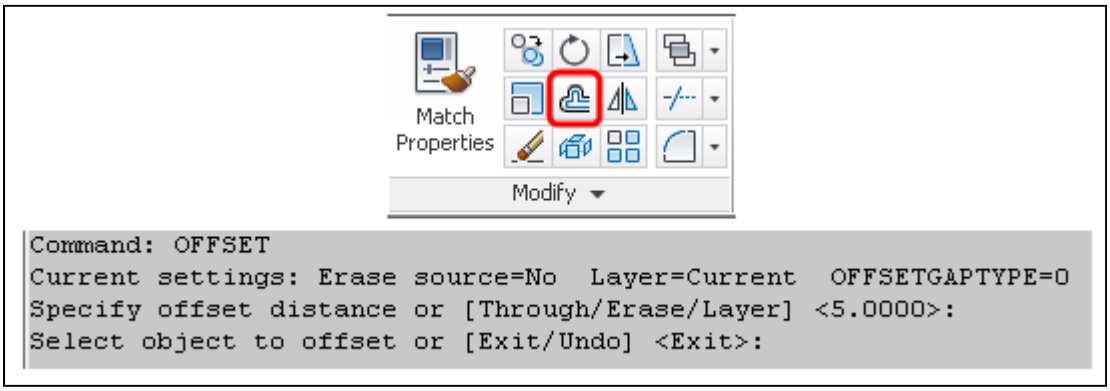


Figure 1 Offset

A. 5' from left side face of curb (or 3' from painted C/L or flange line of curb & gutter) on each approach.

B. 5' from face of curb on driver's right side at each entry and exit.

C. 5' from central island face of curb. Face of curb for the Type R and T is 6-inches from the back of curb.

D. Not less than 165' from roundabout Inscribed Circle Diameter (ICD). Typically, this distance may be 165' but could be more depending on how a driver would approach the yield line at high speed. *"To determine the speed of a roundabout, the fastest path allowed by the geometry is drawn. This is the most realistic, smoothest path possible for a single vehicle, in the absence of other traffic and ignoring all lane markings, traversing through the entry, around the central island and out the exit" (R1).*

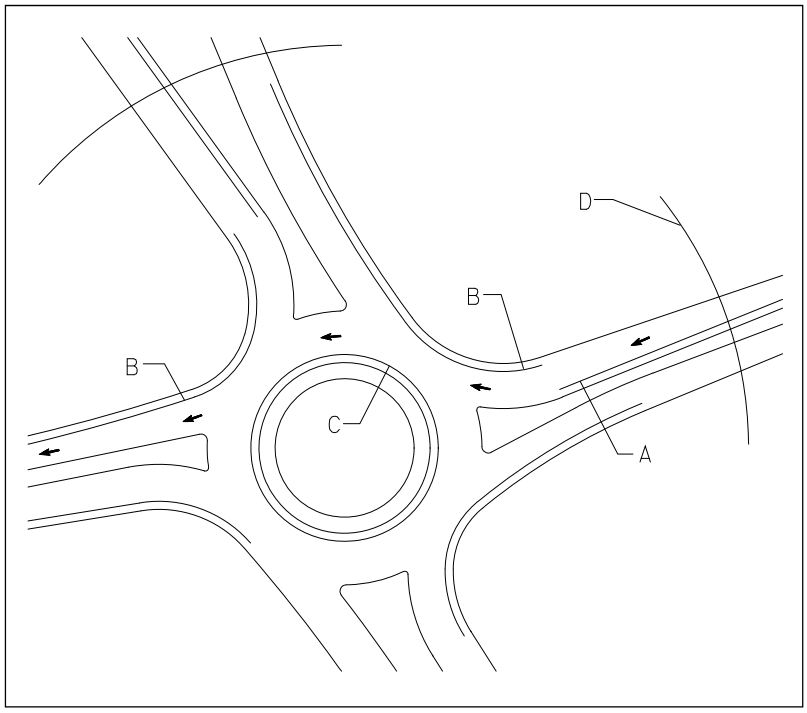
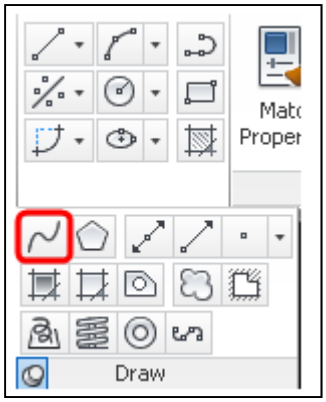


Figure 2 Offsets for Fastest Path

Step 2: Draw Spline Curve

Create the spline curves as shown in FDM 11-26-30, Figure 30.2 using the "spline" command and choosing either "Fit" method or "Control Vertices (CV)" method.




```
Command: SPLINE
Current settings: Method=Fit   Knots=Chord
Specify first point or [Method/Knots/Object]:
```

Or

```
Command: SPLINE
Current settings: Method=CV   Degree=3
Specify first point or [Method/Degree/Object]:
```

Figure 3 Place B-spline Curve

Draw the spline curve for the through movement as shown below, using the “near” object snaps for all points:

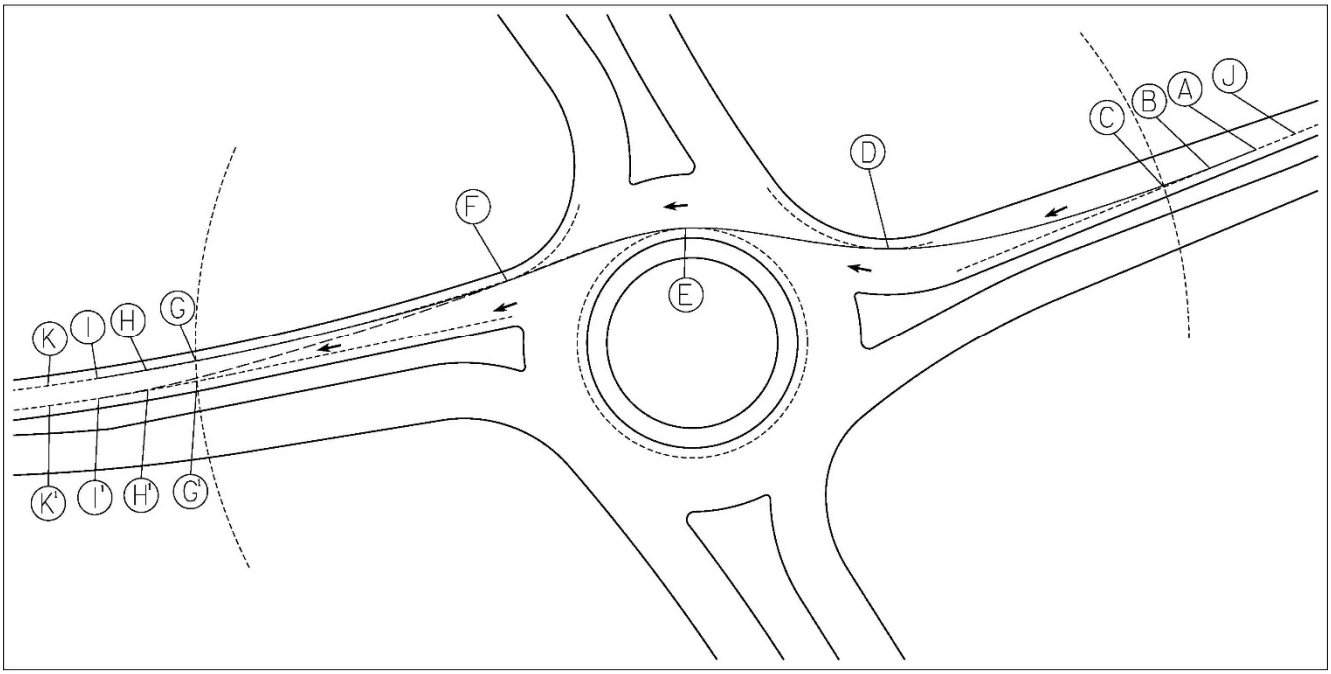


Figure 4 Spline Curve through movement

Clicking sequence:

1. Choose points A through C on the first 5’ curb offset from splitter island. Choose 3 points that are approximately 25 feet apart that will approximate the path of an approaching vehicle. It is advisable to choose two points outside of the 165’ line and one on the 165’ line.
2. Choose a location so the spline is near point D on the 5’ curb offset from entry curve.
3. Choose a location so the spline is near point E on the 5’ curb offset from central island.
4. Choose a location so the spline is near point F on the 5’ curb offset from exit curve.
5. Choose points G through I, or G^1 through I^1 on the 5’ offset from the right side exit curb and the 165’ arc. There may be times when it is appropriate to check the left side instead of the right side. The side is dependent on the anticipated driving path of the vehicle and the roadway alignment.
6. Press Enter to exit the command.

7. For the “Fit” method, select the spline and hover over the point A. Select Tangent Direction from the drop-down menu that appears. Choose point J on the 5’ curb offset just upstream from the end of the spline. This will force the spline to be tangent to the splitter island curb.
8. For the “Fit” method, select the spline and hover over the point I or I[1]. Select Tangent Direction from the drop-down menu that appears. Choose point K on the 5’ curb offset just downstream from the end of the spline. This will force the spline to be tangent to the splitter island curb.

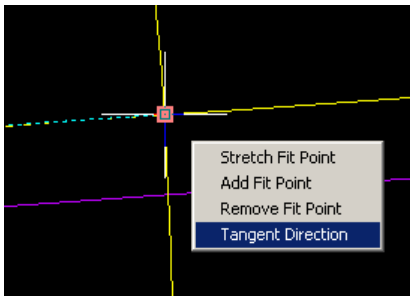


Figure 5 Tangent Direction

Step 3: Modify Spline Curve

Visually inspect the spline created in Step 2 above to see if it violates the 5’ curb offsets. Zoom into the areas of points B through D and visually inspect whether the spline curve violates the curb offsets.

In most cases, the spline may slightly violate the 5’ curb offset. Use engineering judgment to determine if the spline will need to be modified.

Modify the spline:

If the spline is between the curb offset and the curb or outside of the curb offset, it will need to be modified.

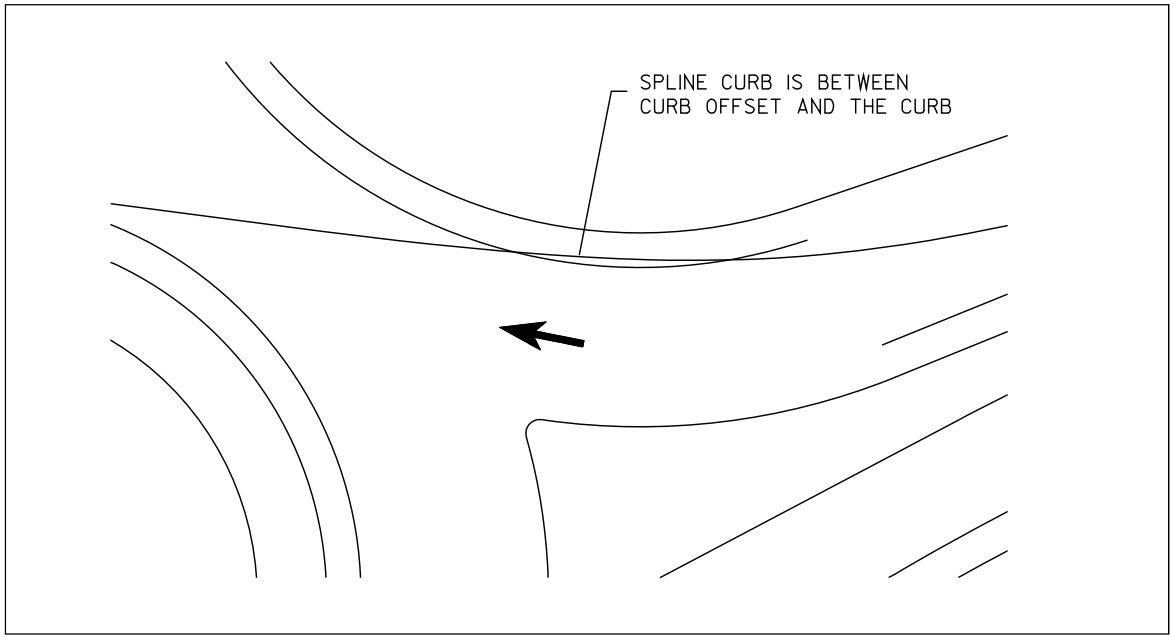


Figure 6 Spline curve between curb offset and the curb

Select the spline curve and click on the “Fit” point or “CV” point that needs adjustment. Pull it to a desired location so the spline is on top of the curb offset. This may need to be done a few times before the spline is on top of all the curb offsets. Evaluate the spline as a whole to see if it “looks” like it is the path that a vehicle would use. Oftentimes, the beginning or end of the spline may need to be pulled further away from the roundabout itself.

Step 4: Measure R-values

1. Once an acceptable spline is created, fit arcs to the spline to measure the R-values using the “arc”

command.

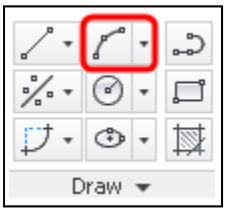


Figure 7 Place Arc

2. Using “Nearest” object snaps, fit an arc onto the spline at a point that appears to be the tightest portion of the spline. This should occur prior to the yield line and not more than 165’ from the yield line.
3. Check the length of the arc. Per FDM 11-26, Figure 30.2 if the arc is not 65 to 80 feet long, recreate it to try to get an arc that is 65 to 80 feet long.
4. Measure the radius of the arc.
5. Repeat to find R-values for R-1, R-2, and R-3.
6. To find R-4, simply measure the radius of the 5’ curb offset from the central island.
7. To find R-5, create a spline that is tangential to the three curb offsets that define the R5 path (the 5’ splitter island offset on the entry, the 5’ offset on the inside of the right turn, and the 5’ splitter island offset on the exit). Check that the arc does not cross any curb offsets, especially when the geometry of the right turn movement is created with multiple arcs. Below is a diagram of a typical R5 spline.

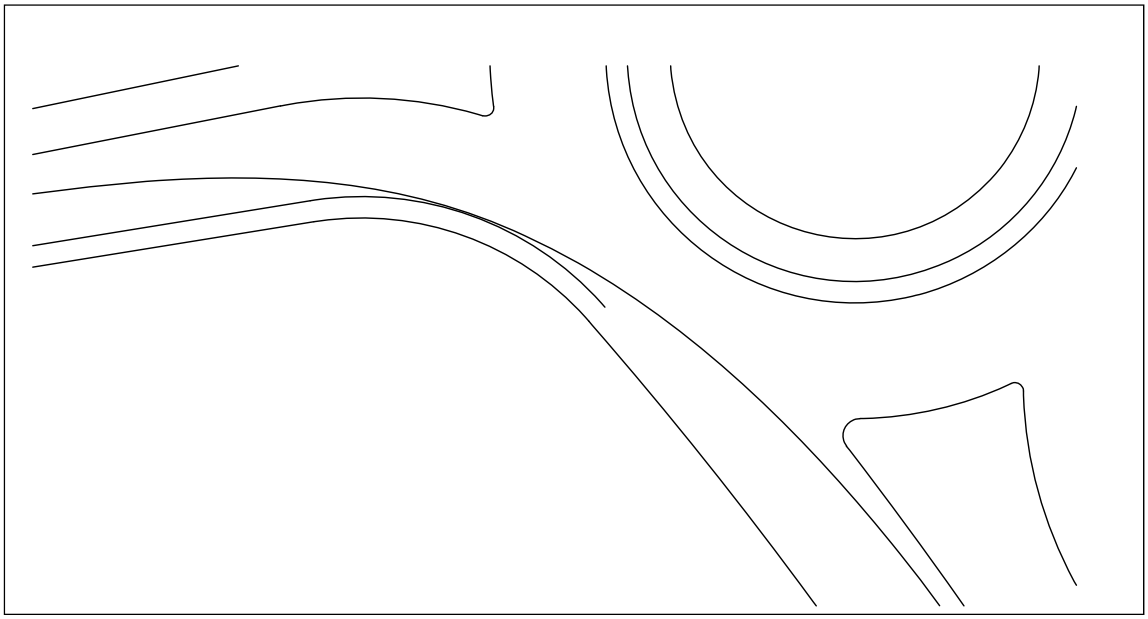


Figure 8 Example R5 Spline

Creating Roundabout Fastest Paths (Spline Curves) in Microstation Version 8i

Step 1: Copy Curb Offsets

Create the curb offsets as shown in FDM 11-26-30, Figure 1 using the move/copy parallel function.

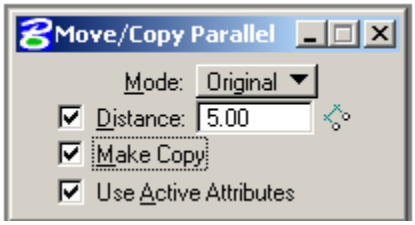


Figure 1 Move/Copy Parallel

A. 5' from left side face of curb (or 3' from painted C/L or flange line of curb & gutter) on each approach.

B. 5' from face of curb on driver's right side at each entry and exit.

C. 5' from central island face of curb. Face of curb for the Type R and T is 6-inches from the back of curb.

D. Not less than 165' from roundabout Inscribed Circle Diameter (ICD). Typically this distance may be 165' but could be more depending on how a driver would approach the yield line at high speed. *"To determine the speed of a roundabout, the fastest path allowed by the geometry is drawn. This is the most realistic, smoothest path possible for a single vehicle, in the absence of other traffic and ignoring all lane markings, traversing through the entry, around the central island and out the exit" (R1).*

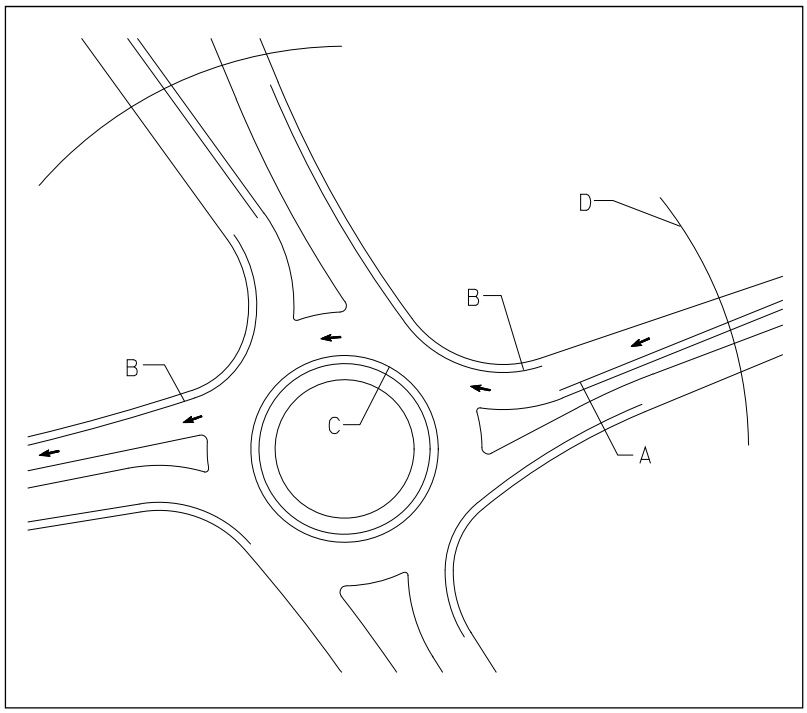


Figure 2 Offsets for Fastest Path

Step 2: Draw Spline Curve

There are a couple different ways to set up spline functions as shown below:

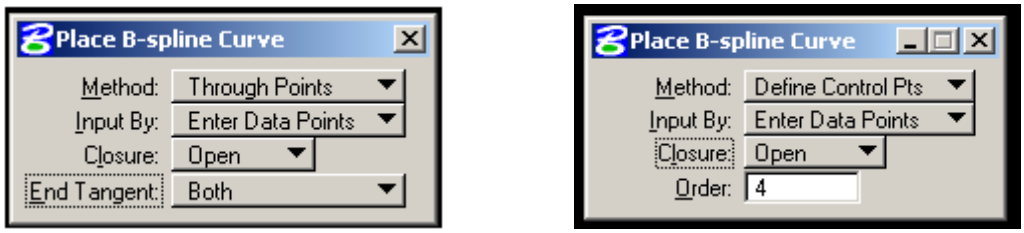


Figure 3 Place B-spline Curve

Draw the spline curve for the through movement as shown below, using “near” snaps for all points picked:

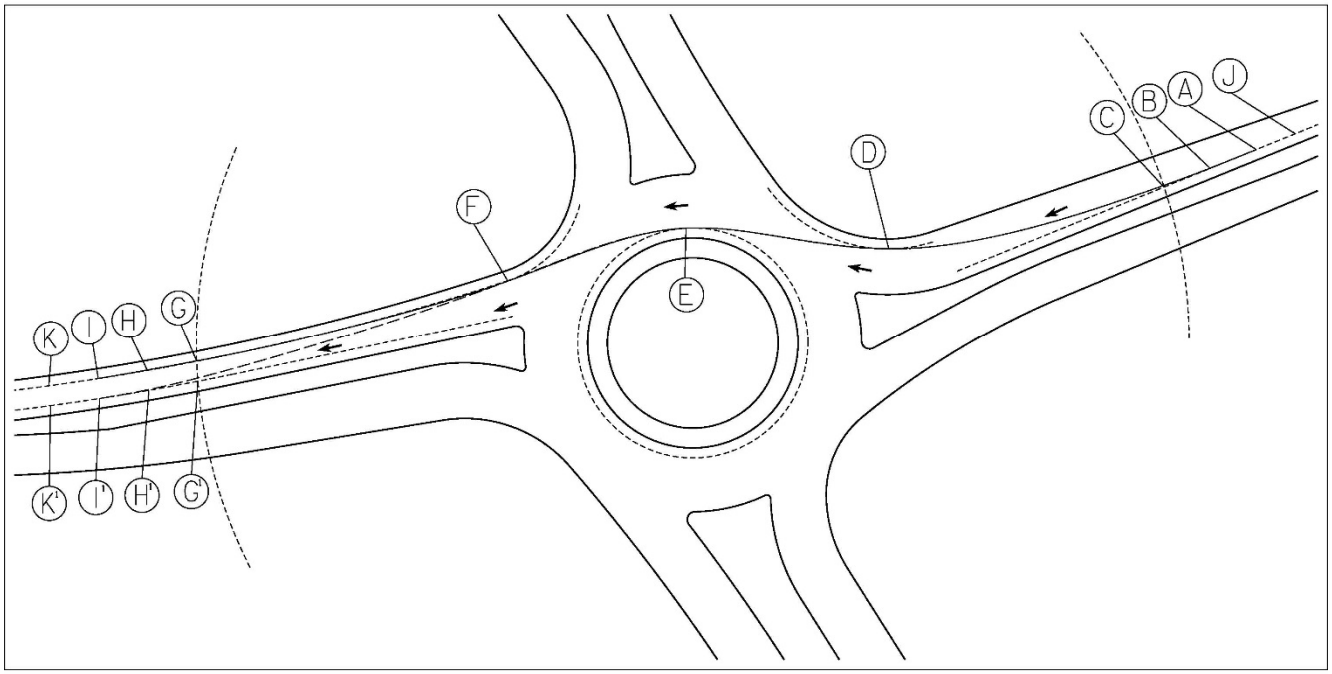


Figure 4 Spline Curve through movement

Clicking sequence:

1. Choose points A through C on the first 5’ curb offset from splitter island (tentative snap, then left click to accept). Choose 3 points that are approximately 25 feet apart that will approximate the path of an approaching vehicle. It is advisable to choose two points outside of the 165’ line and one on the 165’ line.
2. Choose point D on the 5’ curb offset from entry curve (tentative snap, then left click to accept).
3. Choose point E on the 5’ curb offset from central island (tentative snap, then left click to accept).
4. Choose point F on the 5’ curb offset from exit curve (tentative snap, then left click to accept).
5. Choose points G through I, or G^1 through I^1,on the 5’ offset from the right side exit curb (tentative snap, then left click to accept). There may be times when it is appropriate to check the left side instead of the right side. The side is dependent on the anticipated driving path of the vehicle and the roadway alignment. Choose 3 points that are approximately 5 feet apart that will approximate the path of an exiting vehicle. Two points should be outside the 165’ line and one point inside of the 165’ line.
6. Right click to end the spline curve. MicroStation will then “jump” back to the start of the curve.
7. Snap to a point just upstream from the start of the spline at point J (tentative snap, then left click to accept). This forces the beginning of the spline to be tangent to the splitter island curb.
8. Microstation will then “jump” to the end of the curve.
9. Snap to a point just downstream from the end of the spline at point K (tentative snap, then left click to accept). This forces the end of the spline to be tangent to the splitter island curb.

Step 3: Modify Spline Curve

Check the spline created in Step 2 above to see if it violates the 5' curb offsets. This can be done two different ways. One with the "Measure Distance" tool using the "Minimum Between" function. Measure the distance between the face of curb and the spline curve at points A through I shown above.

Figure 5 Measure Distance

The second is to zoom into the areas of points A through I and visually inspect whether the spline curve violates the curb offsets.

In most cases, the spline may slightly violate the 5' curb offset. Use engineering judgment to determine if the spline will need to be modified. As shown, the spline should be modified.

Modify the spline:

If the spline is between the curb offset and the curb or outside of the curb offset, it will need to be modified.

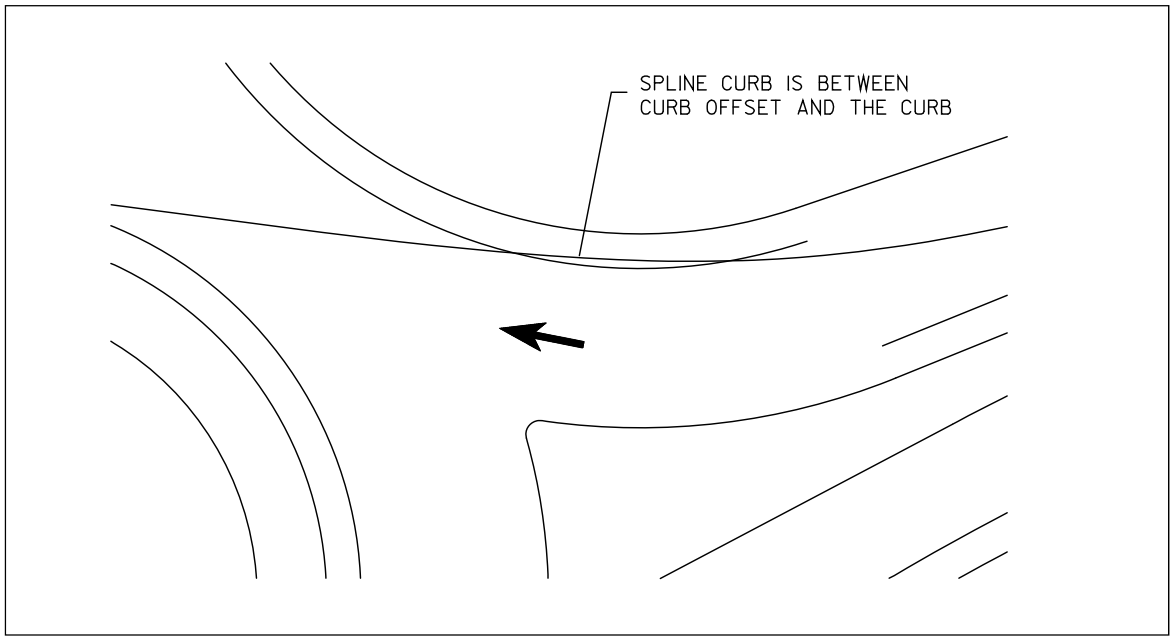


Figure 6 Spline curve between curb offset and the curb

Using the tool 'Modify Element' shown below grab the spline curve and pull it to a desired location on top of the curb offset. This may need to be done a few times before the spline is on top of all the curb offsets.

Figure 7 Modify Element

Evaluate the spline as a whole to see if it "looks" like it is the path that a vehicle would use. Oftentimes, the beginning or end of the spline may need to be pulled further away from the roundabout itself.

Step 4: Measure R-values

1. Once an acceptable spline is created, fit arcs to the spline to measure the R-values using the "Place Arc" tool with the "Edge" method.

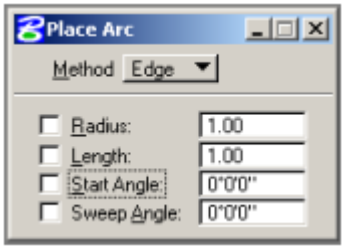


Figure 8 Place Arc

2. Using "Near" snaps, fit an arc onto the spline at a point that appears to be the tightest portion of the spline. This should occur prior to the yield line and not more than 165' from the yield line.
3. Check the length of the arc. Per FDM 11-26, Figure 30.2 if the arc is not 65 to 80 feet long, recreate it to try to get an arc that is 65 to 80 feet long.
4. Measure the radius of the arc.
5. Repeat to find R-values for R-1, R-2, and R-3.
6. To find R-4, simply measure the radius of the 5' curb offset from the central island.
7. To find R-5, create a spline that is tangential to the three curb offsets that define the R5 path (the 5' splitter island offset on the entry, the 5' offset on the inside of the right turn, and the 5' splitter island offset on the exit). Check that the arc does not cross any curb offsets, especially when the geometry of the right turn movement is created with multiple arcs. Below is a diagram of a typical R5 spline.

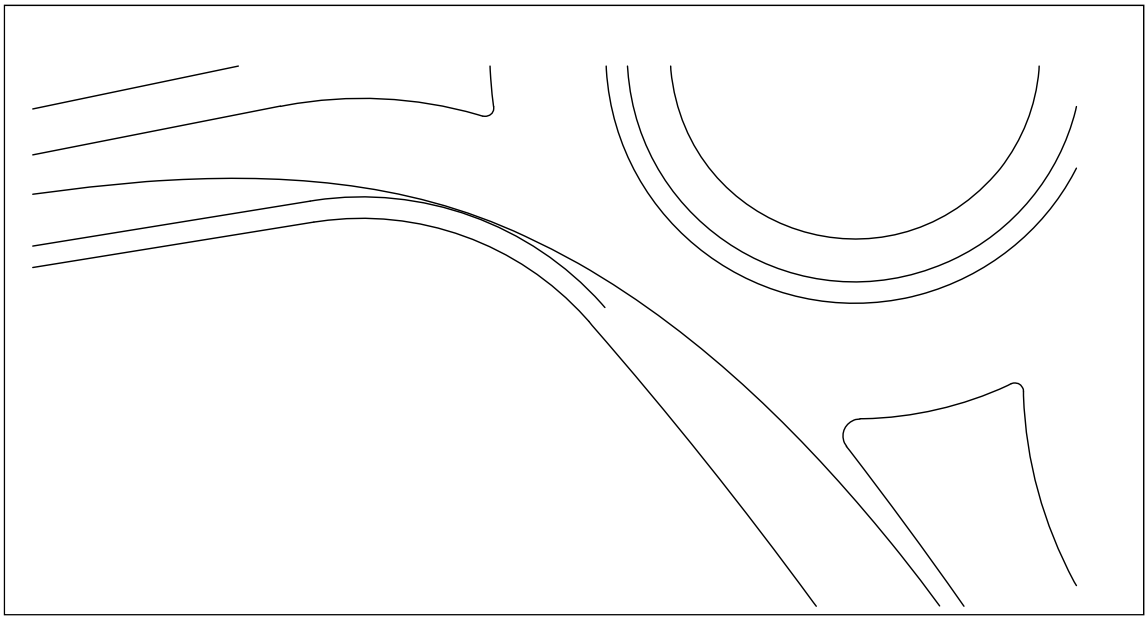


Figure 9 Example R5 Spline

Guide for Using AutoTURN[1]

Below is a step-by-step demonstration of driving a truck through a roundabout

- Once AutoTURN has been loaded, the ribbon below should appear on the screen in AutoCAD Civil 3D as shown in Figure 1a. In Microstion, a tool bar should appear as shown in Figure 1b. A few operational devices have been labeled in the graphic below.

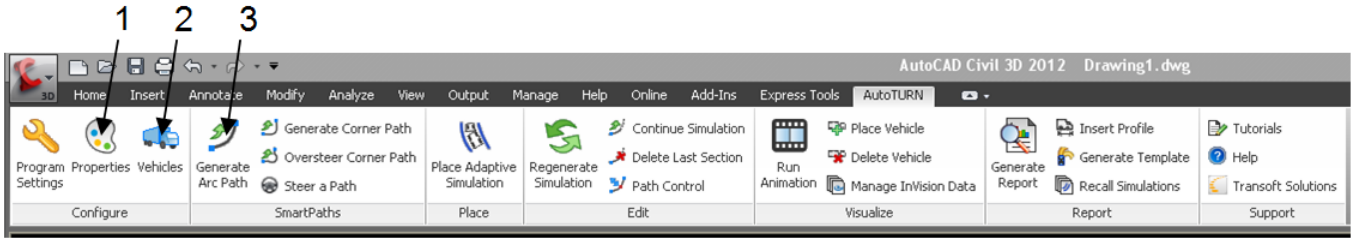


Figure 1a AutoTURN ribbon in AutoCAD Civil 3D

Figure 1b AutoTURN toolbar in Microstation

- Select device labeled 1, the AutoTURN: Simulation Properties box should show up. Select Envelopes from the select category box and the screen should be similar to the one below.

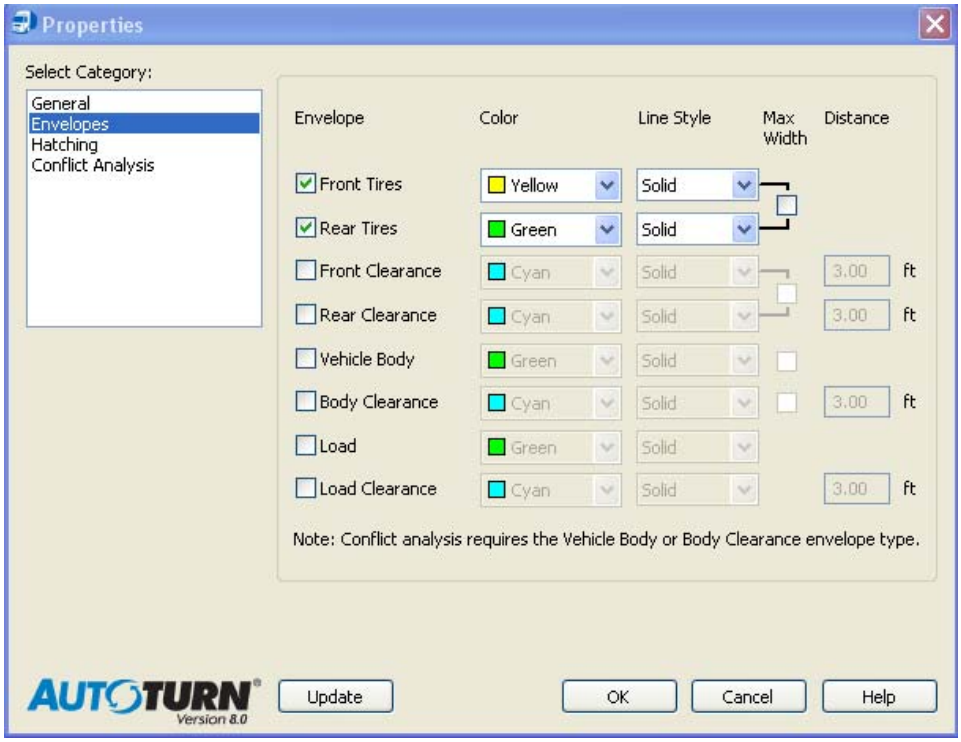


Figure 2 AutoTURN Simulation Properties

- Once in this screen, toggle on the boxes for front tires and rear tires. This will give an accurate envelope for the outside paths of the tires. Other envelopes can be toggled on/off as needed.
- Select device labeled 2
  - Use this device to choose the correct group and correct design vehicle
  - Below is an example of the WB-65 design vehicle. Note the difference in size from the WisDOT

WB-65 design vehicle. AASHTO requires 43.50 ft from king pin to rear axle, WisDOT only requires 43.00 ft. Leave as 43.50 ft to be slightly conservative.

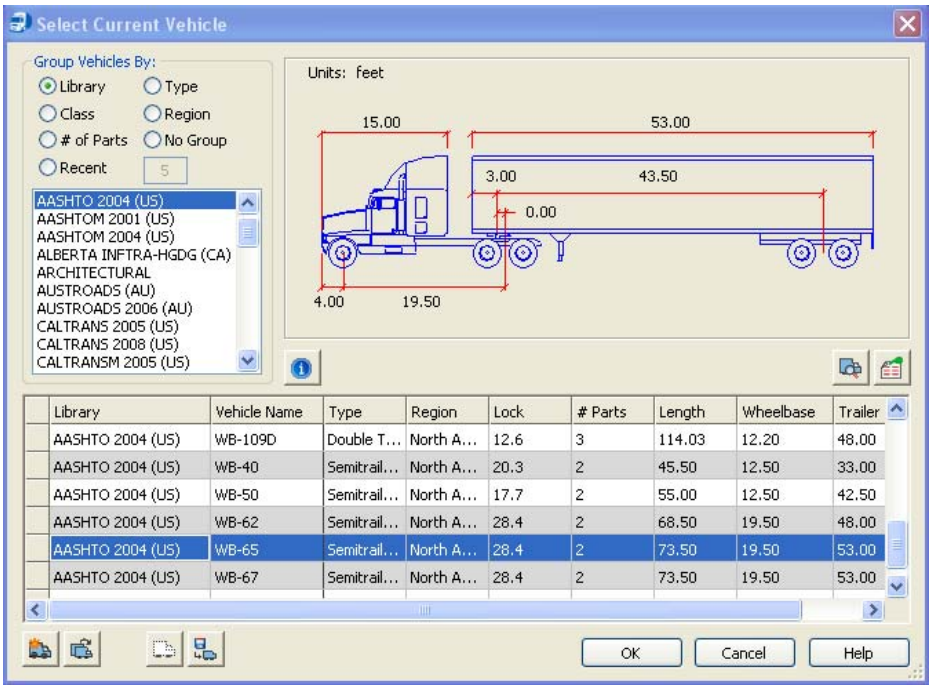


Figure 3 AutoTURN Select Current Vehicle

- Once the correct vehicle is highlighted, select device labeled 3.
    - A top-view of the design vehicle should show up on the display. That view should look similar to the graphic below.

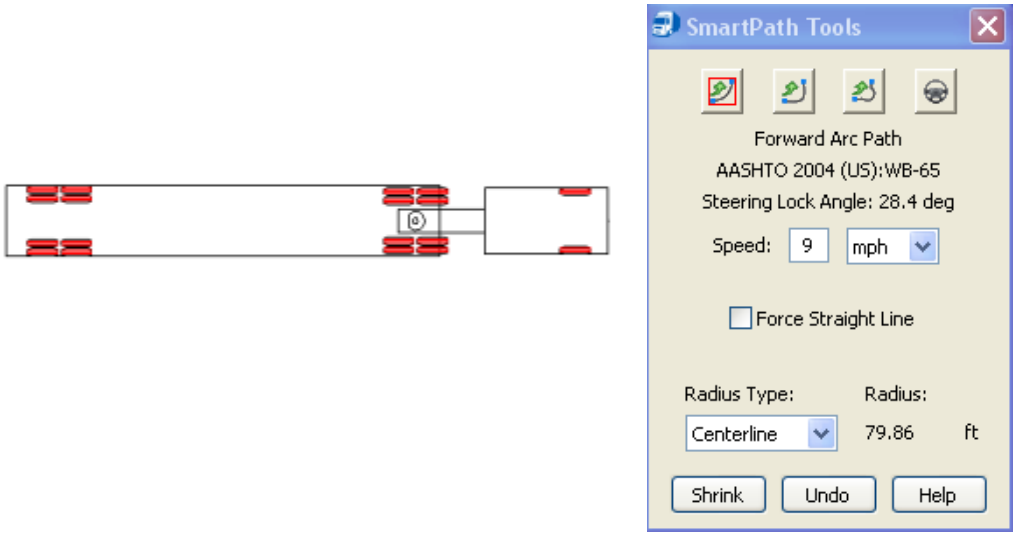


Figure 4 Selected Design Vehicle

- With the design vehicle loaded, select the correct placement for the start of the arc path. The starting point should be prior to the roundabout entrance at a proper angle a truck would be driving if it were approaching a roundabout.
- The box to the right will pop up, use this box to input a reasonable speed (6mph minimum and 9mph desirable) for a driving truck. There may be rare situations where the speed will be below the minimum. AutoTURN sets the steering lock angle.
- Begin to the steer the vehicle through the entrance making sure the truck tires do not go onto the gutter pan at any point.

- Continue to steer the vehicle through the circular roadway of the roundabout avoiding the gutter pans. The truck apron should only be used by the rear trailer tires for through and left turn movements. The vehicles front tires should not use the truck apron for any movement.
- Continue steering the vehicle until it exits the circular roadway at the correct exit.
- A completed right turn movement is shown in the two graphics below.

Multilane roundabouts can be designed in two different ways to accommodate large trucks. One way to design a multilane roundabout is to assume a truck will use two lanes to enter, circulate and exit the roundabout, as shown be below.

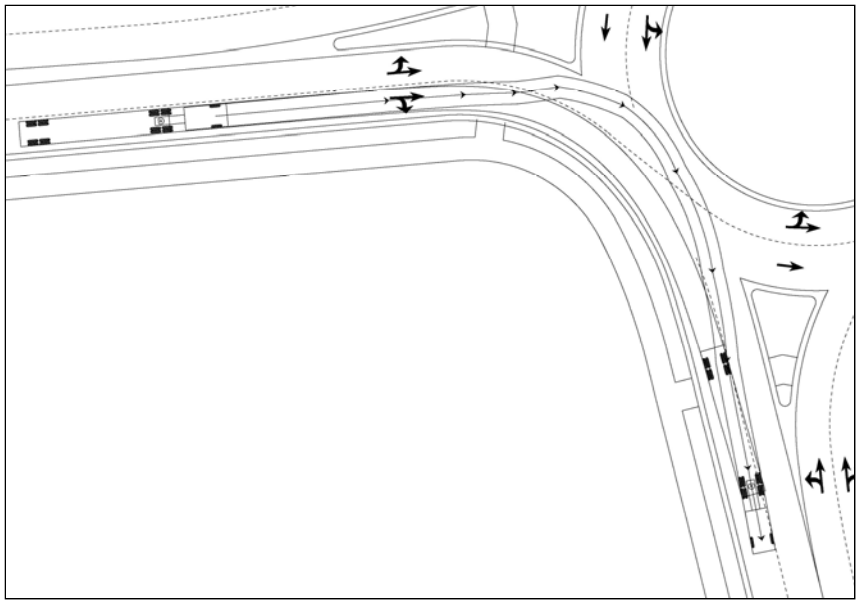


Figure 5 AutoTURN Right turn Movement

Alternatively, a roundabout can be designed so that trucks can remain in one lane as they traverse the intersection. This approach is less commonly used since overall geometry must be larger, possibly resulting in increased ROW needs, higher cost, and a potential for increases in certain types of crashes. An example of this design is shown below. This example utilizes a truck hatching area to allow the truck to make the right turn without encroaching on the adjacent left lane.

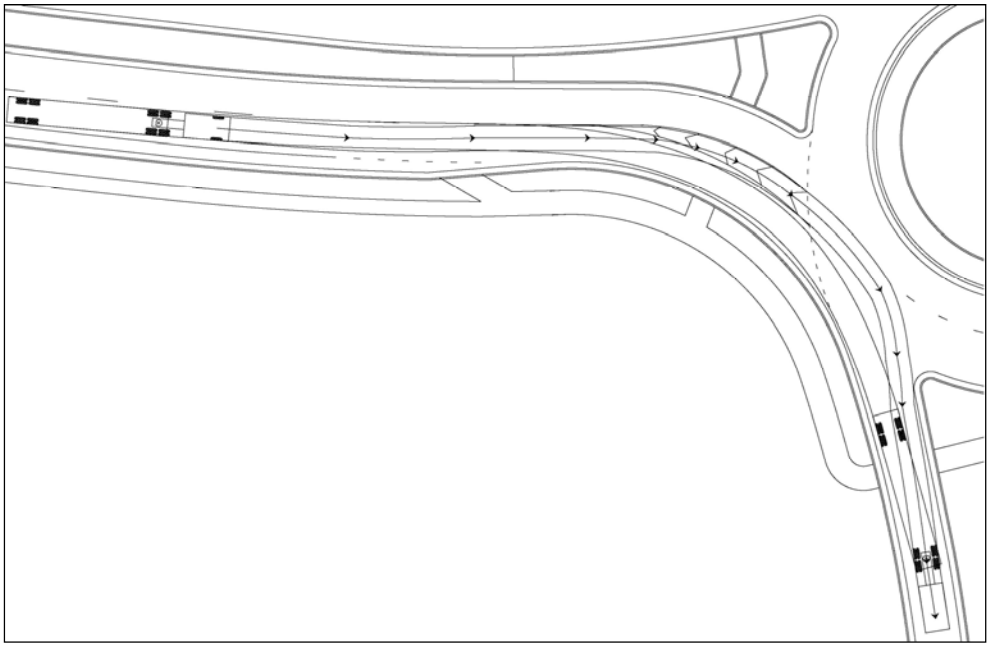


Figure 6 AutoTURN Right turn Movement w/truck hatching

AutoTURN is also a tool utilized for evaluating the size of a truck apron needed at roundabouts. As shown below, when a left turn movement is utilized in AutoTURN the rear wheel path of the truck movement provides guidance for determining the central island truck apron width.

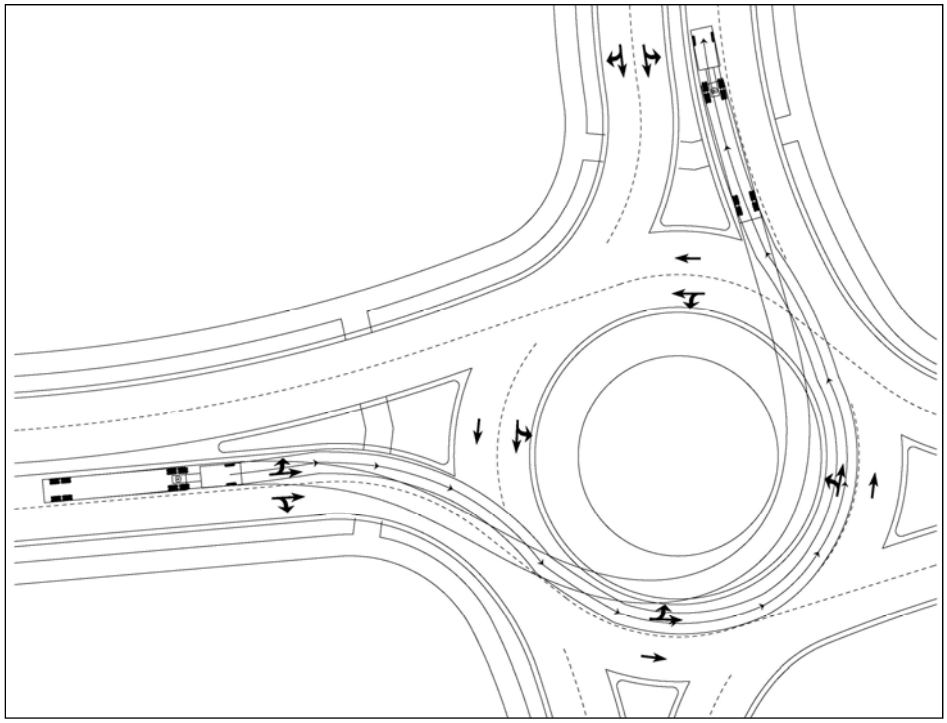


Figure 7 AutoTURN Left turn Movement

1 AutoTURN Version 8.0 shown. Other versions of AutoTURN and AutoTURN Pro 3D are similar.

FDM 11-30-1 Design Elements

August 15, 2019

1.1 Warranting Guidelines

The criteria to evaluate the need for a rural highway interchange are under study at this time. However, in the interim, it may be necessary to provide a gauge on when to consider construction of an interchange. A Corridors 2030 report provides a general "rule of thumb" that interchanges warrant consideration when the design year mainline and side road combined AADT > 12,000 and the side road traffic AADT > 2,000. The design process will make final determination. Other factors to consider may be economic development, safety, and potential for signals in the near future.

This is interim guidance for rural highways that may apply to four-lane divided expressways or current two-lane facilities where it may be appropriate to reconstruct a short section to four lane divided design criteria. This does not apply to interstate routes.

1.2 General Design

The rest of this procedure deals primarily with interchange ramps, ramp terminals, and cross road details. For information relating to the structures, refer to FDM 11-35-1.

Guidance concerning sight triangles, exit and entrance ramp tapers, ramp curvatures, and other elements of interchange design are included within this section. For additional information, refer to Chapter X, page 747, GDHS 2001.

Preliminary studies should be made for each highway to establish category of treatment, grade relationship (crossroad over or under), and layout of interchange where required. Layouts of interchanges should include turning diagrams showing design hour volumes.

1.3 Interchange Type and Selection

There are several basic interchange configurations to accommodate turning movements at a grade separation. Refer to pages 747 to 756 2001 GDHS for general interchange and grade separation warranting criteria.

The configuration used at a particular site is determined by a number of factors.

- The number or intersection legs,
- Capacity,
- Route continuity,
- Topography,
- Design controls,
- Uniformity of exit patterns,
- Single exits in advance of the separation structure,
- With or without weaving,
- Right-of-way availability
- Potential for stage construction,
- Compatibility with the environment
- Proper signing and intersection treatment at the crossroad.

Interchange configurations are covered in two categories, "system interchanges" and "service interchanges." The term "system interchange" is used to identify interchanges that connect two or more freeways, where as the term "service interchange" applies to interchanges that connect a freeway to lesser facilities. System interchange connections should be high speed and free-flow to provide all directional movements. Connections between freeways and other controlled access facilities are analyzed and, where practical, provide all movements unstopped. Refer to pages 808 to 827, GDHS 2001 for general design considerations and specifically Exhibit 10-43 for interchanges that are adaptable on freeways as related to classifications of intersecting facilities in rural, suburban, and urban environments.

At service interchanges the crossroad should pass over the freeway or access controlled highway. There are many reasons for this; the exit ramp is constructed as an upgrade that assists vehicles to decelerate as they

approach the intersection, the entrance is constructed on a downgrade that assists vehicles to accelerate as they enter the freeway.

In most cases building the cross road over the mainline offers these added benefits:

- Less earthwork required,
- Lower structure costs
- Lower maintenance costs
- Lower delay costs when the cross road structure is rehabilitated

The side road intersection is typically controlled by stop signs, roundabouts, or signals and will sometimes determine the type of interchange. Signal and roundabout control should be analyzed as equal alternatives until such time when the analysis of capacity, user delay, crashes and available space dictates which treatment is more appropriate for the location. For more information on at-grade intersections refer to FDM 11-25-1.

While interchanges are custom designed to fit specific site conditions, it is desirable that the overall pattern of exits along the freeway have some degree of uniformity. Furthermore, from the standpoint of driver expectancy, it is desirable that all interchanges have one point of exit located in advance of the crossroad wherever practical. Urban freeway design is more challenging than rural and should:

1. Maintain a basic number of continuous lanes,
2. Provide lane balance at ramp exits and entrances,
3. Provide appropriate ramp spacing, one mile or greater between the gore areas,
4. Maintain route continuity,
5. Use auxiliary lanes as appropriate

Route continuity and system configuration may also drive the interchange type. Typical urban freeway operational problems that result in high crash locations include; weave sections, limiting geometry (horizontal and vertical), and left side ramps. Left side entrance and exits should rarely be used. A FHWA publication [1] suggests that crashes may be reduced 25-70 percent with the use of right-off, right-on ramps as compared to left side ramps.

Signing and operations are major considerations in the design of the interchanges. The need to simplify interchange design from the standpoint of signing and driver understanding is critical.

To prevent wrong-way movements, confusion, driver frustration and misdirection, all freeway interchanges with non-access-controlled highways should provide ramps to serve all basic directions. When drivers exit the freeway system they should be able to enter again at the same interchange or within a short distance on a frontage road. Do not design at-grade braided ramps[1] at any interchanges. Remove existing at-grade braided ramps on reconstruction projects and relocate the frontage road separate from the ramp.

Provide direct entrance and exit ramps without driveway, side road or other access to ramps. Access within interchange ramps or access within proximity to ramps on expressways is counter to driver expectancy. See FDM 11-5 Attachment 5.2 for additional information on nearest access from ramp entrance and exit as well as nearest crossroad access outside the ramp/crossroad termini.

The accommodation of pedestrians and bicyclists also should be considered in the selection of an interchange configuration.

The most favored interchange type for Department applications is the conventional diamond interchange. The more common interchange configurations are addressed in the following text. For additional information on interchanges see pages 774-827, GDHS 2001.

1.3.1 Diamond Interchanges

Diamond interchanges are the simplest, generally the least expensive and the most common type of interchange. The conventional and the tight diamond are the preferred WisDOT interchange type for most situations. The more common types of diamond interchanges are:

1. Conventional diamond, used in rural conditions or urban conditions where space allows; See GDHS 2001Exhibit 10-16a, page 783
2. Tight diamond[2], primarily used in urban areas where space is limited;

[1] Braided ramps are entrance or exit ramps that connect a controlled access highway to a nearby parallel frontage road.
[2] A tight diamond is a diamond interchange whose ramps are pulled in closer by using retaining walls.

3. Split diamond, used where local conditions justify separating the ramps by using one-way frontage road pairs; See GHS 2001Exhibit 10-17a.
4. Single-point urban diamond (SPUI), used where all four turning movements are controlled by a single traffic signal and opposing left turns operate to the left of each other, and again where space is limited; See GDHS 2001 Exhibit 10-23. The single-point is quite costly to construct. Single-point diamond interchanges should be designed such that the mainline passes under the at-grade-intersection. There are two primary reasons for this: (1) by constructing the mainline at the lower level columns may be located in the center of the structure thus reducing the clear span of the structure and substantially reducing girder depth, earth work and the cost, (2) The at-grade-intersection should be located on the top level where it is exposed to an even lighted surface, thus not requiring the driver to go from sunlight into shade and back into sunlight. The eye needs time to adjust to changing light conditions. Turning on a curved path through the intersection with a changing light condition may be unsafe and problematic particularly for older drivers. There are multilevel and other diamond interchange configurations that may be appropriate for certain situations that are explained further in the pages 782 to 791, GDHS 2001.

The capacity of a diamond interchange is limited by the capacity of the at-grade terminals of the ramps at the crossroad. The entrance ramp capacity may be limited by the traffic volume on the mainline. Traffic operations may be improved, and interchange life expectancy extended by using a roundabout at the ramp/crossroad termini. The approximate limit of left turning traffic to any intersection approach is with double left turn lanes and that is limited to approximately 600 left turning vehicles for the DHV. Left turn demand greater than 600 DHV should consider a roundabout or directional ramp design to reduce user delay and crashes. A roundabout will usually break up traffic platoons and allow ramp entrance traffic to enter the system in a dispersed manner which may preclude the need for ramp metering. Proper analysis and evaluation of the projected intersection traffic volumes and turning movements will guide the designer to the correct intersection treatment (i.e. stop, roundabout, or signal control).

1.3.2 Three-Leg Designs

An interchange with three legs consists of one or more highway grade separations and one-way roadways for all traffic movements. They are sometimes referred to as “T” and “Y” interchanges. The more common types of three-leg interchanges are:

1. Trumpet - A. (page 776, GDHS 2001)
2. Trumpet - B. The more direct alignment favoring the heavier volume of the left turn movements and the tight loop favoring the lesser volume.
3. Directional-Y (page 777, GDHS 2001). Direct alignment is provided to both left turn movements where volume is anticipated to be high. A review of capacity of tight loop ramps is presented in the Four-Leg Design section.

1.3.3 Four-Leg Designs

Interchanges with loops in all four quadrants are referred to as “full cloverleafs” and all others with loops in one or more quadrants are referred to as “partial cloverleafs” or “par-clo.” The common types of cloverleafs are:

1. Full cloverleaf without collector-distributor (C-D) road, requires substantial space, may reduce capacity on high volume highways when collector-distributor roads are not used (page 783, GDHS 2001).
2. Full cloverleaf with C-D road requires substantial space. The C-D road should be considered when the sum of the traffic on two adjoining cloverleaf loops approaches 1,000 vph. C-D roads allow weaving and slower moving loop ramp traffic to adjust and select the appropriate lane while still separated from the mainline traffic (page 793, GDHS 2001).
3. Par-clo is commonly used where the right-of-way is restricted (e.g., with loops on one side of the mainline because of a stream or railroad). For other par-clo configurations see page 795 GDHS 2001.
4. Semi-directional interchange, with loops and ramp to accommodate high-volume left turn traffic in one direction (page 799, GDHS 2001).
5. Directional interchange, allows for all high speed direct movements from one facility to another. There are many other three and four-leg interchange designs that are covered further in the pages 776 to 827, GDHS 2001.

The volume on a tight loop ramp (25-30 mph design speed) is limited to approximately 12,000 ADT or about 1,200 DHV. A loop ramp should be restricted to one lane unless there is ramp metering or other extenuating circumstances. The entrance to loop ramps should be designed with consistent radii, without compound curves

entering the loop from a high-speed condition. Compound curve design is acceptable when leaving the loop and entering the acceleration lane. Two-lane tight loop ramps are difficult to design without encountering potential operational issues and should only be utilized when absolutely necessary. In lieu of designing a loop ramp with design year volume greater than 12,000 ADT, consider a directional ramp or roundabout at the termini.

For more assistance contact your BHD project development engineer.

1.4 Ramps

The relationship of speed to curvature for ramps is shown in Attachment 1.2 and Attachment 1.3, "Details for Entrance Terminals at Interchanges" and "Details for Exit Terminals at Interchanges., respectively. The values shown for curve radius and curve length were derived from Exhibit 10-70, page 851 and Exhibit 10 73, page 855, GDHS 2001, and are adequate for main line design speeds through 75 mph.

Details for cross road designs, assuming a stopped condition, are shown in Attachment 1.4, Attachment 1.5, and Attachment 1.6.

The lengths of the exit ramps on diamond-type interchanges are typically in the range of 900 to 1,200 feet from the crossroad terminal to the gore. The length will vary depending on needed crossroad terminal storage, deceleration length, type of exit (taper or parallel), grade and profile.

Entrance ramp design lengths depend on grade and acceleration length. A long vertical curve is needed if the ramp profile is opposite in direction to that of the through highway, because of the large algebraic difference in grade. Additional length may also be needed to warp the ramp profile to attain superelevation, or to provide drainage.

The distance between ramp terminals as measured along the crossroad will vary depending on site-specific conditions. The spacing for a conventional diamond is 800 feet or more; for a compressed diamond, typically about 400 to 800 feet; and for a tight diamond, typically about 250 to 400 feet. Urban designs will generally have closer spacing than rural designs because of higher right-of-way costs. Using greater spacing will provide more flexibility for future interchange upgrades. The ramp description information is from ITE 2005, Freeway and Interchange Geometric Design Handbook. Some of the values have been adjusted to eliminate gaps in the description.

Design the ramp terminal intersections to accommodate safe and efficient operations. Provide enough separation between the ramp terminal intersection and the interchange structure (at least 100 feet) and design the crossroad profile, so that the structure does not obstruct intersection sight distance. See FDM 11-10-5 and FDM 11-30-5 for additional guidance.

Stop signs on the exit ramp terminals at the crossroad are the minimum control for diamond type interchanges and are generally used for rural or lower volume intersections. If additional control is warranted, evaluate roundabouts, signals and, where appropriate, 4-way stop control as alternatives. A proper evaluation will determine the appropriate and desired intersection control. Roundabouts at interchange ramp terminals with the crossroad will generally provide a longer useful life without the use of loop ramps or fly-over directional ramps, improve intersection safety, and decrease intersection delay.

It may be appropriate to extend a left turn bay back through the previous ramp terminal intersection at signalized ramp terminal intersections. This extended turn bay will provide greater storage for queued traffic to reduce the possibility of the turning traffic queue extending into the through traffic lanes, or the opportunity for vehicles to enter the turn bay when the through traffic queues are long. The extended left turn bay may result in undesirable operations and safety concerns when aggressive drivers anticipate “jumping” in front of other vehicles in the queue. The desired option is to provide adequate storage between the ramp terminals; however, it may not be cost effective to provide a wide distance between ramp terminals in an urban area. Extending the left turn bay in urbanized areas where signals exist or where signals may be proposed in the future may be preferred to using valuable right-of-way to accommodate wide ramp terminals.

Traffic signal progression must be considered if two or more intersections are signalized along the corridor. Contact the Region Traffic Unit for further guidance.

1.4.1 Speed Change Lanes

Speed change lanes (acceleration and deceleration) are needed at both entrance and exit terminals to the main line roadways of interchanges. These lanes should be of sufficient length to allow a driver to make the necessary change between the speed on the highway and the lower speed on the turning roadway or ramp.

Parallel-type entrance ramps are recommended for new interchange construction or for the reconstruction or reconfiguring of existing interchanges. Merge tapers at the downstream end of parallel-type entrance ramps are to have a minimum taper rate of 30:1.

Parallel-type ramps are not to be confused with the auxiliary lanes, which serve a different function than parallel-type ramps. Refer to FDM 11-25-35 and pages 818-821, 2001 GDHS.

Except in special situations, use the details shown in Attachment 1.1 and Attachment 1.2 of this procedure to design single-lane parallel-type entrance and taper-type exit terminals to the main line roadway. Special situations include, but are not limited to, multi-lane entrance or exit ramps, and overlapping entrance and exit tapers (as in a full cloverleaf interchange). Refer to pages 860-867, 2001 GDHS, for guidance in special designs.

1.4.2 Right Hand Ramps vs. Left Hand Ramps

Use right hand entrance and exit ramps in the design of new interchanges. Left hand entrance and exit ramps are contrary to driver expectation (refer to page 845, GDHS 2001). An FHWA publication [1] suggests that crashes may be reduced as much as 25-70 percent with the use of right-off, right-on ramps as compared to left hand ramps.

If possible, replace existing left-hand entrance/exit ramps with right hand ramps when reconstructing an interchange. If this is impracticable because of unacceptable economic, agricultural, wetland or historical impacts then document and justify this in the Design Study Report. This justification shall include a crash data analysis showing that the existing left-hand ramp is not a safety hazard.

Major forks or major freeway splits are not considered ramps and therefore may diverge left or right. Examples of major splits/forks that enter or exit on the left-hand side are IH 94 EB/IH 90 EB near Tomah, and IH 894 WB/IH 43 in Milwaukee.

1.4.3 Parallel-Type Entrance Ramps vs. Taper-Type Entrance Ramps

When designing new interchanges or reconstructing interchanges. Use parallel-type entrance ramps in rural or urban applications. Refer to Exhibits 10-69/70/71, pages 849-853, GDHS 2001 for more information.

Taper-type entrance ramps have been used predominantly for interchange design in the past. However, studies [2] have shown that parallel entrance ramps are generally safer than tapered. With tapered entrance the driver has less time and poorer angles in which to use side/rear-view mirrors to monitor surrounding traffic prior to merging. Taper-type entrance ramps can also cause confusion in mainline horizontal curve situations when the driver cannot identify mainline alignment. See Attachment 1.1 for parallel-type entrance ramp design.

A curve with a radius of 1000 ft or more and a length of 200 ft should be provided in advance of the parallel ramp. If the approach curve is short drivers tend to drive directly onto the mainline without using the acceleration lane, which is undesirable.

As the parallel ramp becomes longer the driver's perception is that they are in a continuing lane. When the parallel entrance ramp design exceeds 800 ft, pavement marking, arrows, may be necessary to reinforce the lane drop. Consult the Region Traffic Section for the need, placement and spacing of the Type 5 arrows.

If it is necessary to provide an acceleration lane longer than computed by applying the adjustment factors in Attachment 1.1 then consult with the Region Traffic Section about the use of auxiliary lanes or lane additions.

The length (L) of the parallel entrance ramp is measured from the point where the left edge of the traveled way of the ramp pavement is 3 ft from the right edge of the traveled way of the mainline, refer to Attachment 1.1 and SDD 13C17, to the point where the downstream taper begins. The length (L) is given in Attachment 1.1 for the ramp according to the entering speed (design speed of ramp)[3], and the design speed of the mainline. Refer to Chapter 10, pages 849-853, GDHS 2001. Provide a down stream merge taper of 360 ft in all applications of parallel entrance ramps.

Review the DHV traffic on the mainline. If it is anticipated that the freeway will frequently approach capacity or the percent of trucks on the ramp exceeds 10%, then a minimum length (L) of 1200 ft plus the 360 ft merge taper is typical.

The grade of the mainline parallel ramp area will have an effect on the length of the acceleration lane needed to achieve merging speed. Attachment 1.1 gives multipliers to be used where the grades are + 2.2% to +4% and when the ramp truck volume exceeds 10%.

Consider the following factors when designing parallel entrance ramp terminals.

1. The entering speed of the vehicle - directly related to the radius and design speed of the last curve on the ramp.

[3] The design speed of a ramp is based on the most restrictive curve radius leading into the parallel portion of the ramp. See values for R_1, R_2 and R_3 in Attachment 1.2.

2. Type of mainline roadway (freeway, expressway, interstate)
3. Design speed of the main line.
4. Percent trucks using the ramp.
5. The grade of the main line.

Example 1

Given: A freeway with a design speed of 70 mph,
A parallel on-ramp with approach curves R_1=1095 ft and R_2 & R_3 = tangent
Mainline grade is 0.5%,
No capacity problems on either the ramp or the mainline.

Find: The length (L) of the parallel entrance ramp.

From the table in Attachment 1.2, this combination of R_1, R_2 and R_3 will permit a ramp design speed of 55 mph.

From the table in Attachment 1.1 this combination of ramp and mainline design speeds requires a ramp length of 600 ft. To this must be added the 360 ft merge taper.

Example 2

Given: Same situation as Example 1 except now the mainline grade is +3%.

Find: The length (L) of the parallel entrance ramp.

Start with the same basic length as determined in Example 1 but now apply the adjustment factor for mainline upgrades from +2.2% to +4%. In this case the factor is 1.85.

600 x 1.85 = 1110 ft. To this must be added the 360 ft merge taper.

With a length of 1110 ft, consult with the Region Traffic Section about the need, placement and number of any Type 5 arrows needed to reinforce the lane drop.

1.4.4 Ramp Speeds

Ramp design speed will vary by type of interchange design. This section also addresses a freeway split which by definition is not a ramp. The various scenarios are provided as follows:

1. Freeway Splits
2. Freeway-to-Freeway directional ramp
3. Freeway-to-Service Road off and on ramps

Provide the highest practicable design speed for the ramps as well as attempt to reach the AASHTO suggested upper ranges for the given situation.

Exhibit 10-56, page 830, AASHTO 2001, provides guide values for ramp design speed as related to various mainline highway design speeds (i.e. those in the upper range (85%) of the mainline ramp terminal should be designed to be within 85% of the mainline design speed, middle range within 70%, and lower range within 50%). Guidance is provided for each scenario, including the freeway split.

1. Freeway Splits – Each freeway shall have the same design speed. Freeway split example: Tomah Interchange where I-90 continues westward and I-94 diverges northward.
2. Freeway to Freeway directional ramps – Design directional ramps to be in the upper range, or within 85% of the mainline design speed (within 10mph of mainline highway design speed for 60mph and greater). Freeway to freeway directional ramp example: Portage Interchange where I-39 South connects to I-94 Westbound.
3. Freeway to Service Road off and on ramps – Design diamond interchanges to be in the upper range, or within 85% of the mainline design speed (within 10 mph of mainline highway design speed for 60mph and greater). Design Tight loop ramps (cloverleaf or partial cloverleaf) in the lower range, or within 50% of the mainline design speed. The minimum design speed on ramps or turning roadways associated with interchanges is normally 30 mph. A minimum design speed of 25 mph may be used on loop ramps when the mainline design speed is 50 mph or less. Because of the increased lengths and large areas required, the maximum design speed on loop ramps should be limited to 30 mph. Provide proper deceleration distance to transition from the mainline design speed to the ramp design speed while maintaining proper stopping sight distance.

The design speed of ramps approaching their junction with crossroads should be adjusted to fit the conditions existing or desired at these terminals. The details for a stop condition at a crossroad are shown in Attachment 1.5 and Attachment 1.6. For cross road terminal treatments that merge with an arterial, such as at a cloverleaf where the design speed on the arterial is less than 65 mph, the length of the taper should be provided in accordance with Exhibit 10-70, page 851, or Exhibit 10-73, page 855, GDHS 2001.

1.4.5 Ramp Alignment

Ramp alignment details and transition lengths for curves on entrance and exit terminals are shown in Attachment 1.1, Attachment 1.2, and Attachment 1.3. Exit ramp tapers should be located along tangent sections of the main line. Ramp tapers that are located adjacent to a main line section that is on a curve are undesirable because of the confusion created as to which alignment is the main line. Ramp terminals on a curve are addressed on pages 856-860, GDHS 2001. Transition curvature of turning roadways on ramps should be designed with adequate length to facilitate any speed change to the design speed of the succeeding curve. Lengths of transition are also shown in Exhibit 3-45, page 204, GDHS 201.

1.4.6 Ramp Sight Distance

For minimum stopping sight distance along ramps or the turning roadway, refer to Exhibit 3-1, page 112, GDHS 2001. Entrance ramps and merging areas should be visible to approaching main line traffic for a minimum distance equivalent to the design stopping sight distance. The design of the ramp and merging area should take into account the effect of grades, especially where there is a substantial volume of heavy truck traffic (see Exhibit 10-71, page 852, GDHS 2001). Exit ramp tapers should diverge from the main line roadway in such a way that the vertical curvature will not restrict visibility along the ramp to a value less than the stopping sight distance for the ramp design speed. Ramps that "drop out of sight" create a definite problem in driver recognition of queuing and should be avoided. At least 200 feet (60 m) of ramp pavement beyond the gore should be visible from the main line at the point where the exit taper begins.

1.5 Intersection Sight Distance

The sight distance at a ramp terminal must be adequate to allow safe turning movements. For ramp terminals that merge with a crossroad, such as at a cloverleaf, the sight distance requirements for the main line apply except that the design speed may be lower (refer to "Ramp Speeds" in this procedure).

1.6 Grades and Profile

The effect of grades on the length of speed change lanes is shown in Attachment 1.1 and Attachment 1.2. Grades on ramps should not exceed five percent. The maximum acceptable grade is eight percent provided the length of such grade is relatively short.

Profiles for ramps usually consist of a combination of crest and sag vertical curves. The vertical curves should be designed simultaneously with the horizontal alignment to avoid hidden curves for a driver leaving the through highway and turning onto a ramp.

1.7 Superelevation and Cross Slope

The maximum superelevation rate for ramps and ramp terminals is 6 percent. The one exception is existing ramp roadways with cross slopes based on an 8 percent maximum superelevation. In these cases, the existing 8 percent rate may be retained when such roadways are perpetuated or rehabilitated. Guidance on development of superelevation at turning roadways and terminals is included in GDHS, 2001 Chapter 9, Intersections, Superelevation For Curves At Intersections and, Chapter 10, Grade Separations and Interchanges, Ramps.

The maximum algebraic difference in pavement cross slope at turning roadways should not exceed 5 percent. Where necessary, the divergence angle between the ramp and through lanes should be increased to limit the rollover rate to 5 percent.

1.8 References

[1] US Department of Transportation, Federal Highway Administration. Safety Effectiveness of Highway Design Features, Volumes 1 to VI. Washington DC, 1992. Volume IV specifically discusses interchanges.

[2] Transportation Research Record 1385, Ramp Exit/Entrance Design

LIST OF ATTACHMENTS

Attachment 1.1 Single Lane Entrance Terminal

Attachment 1.2 Typical Entrance and Exit Ramp Terminal Details

Attachment 1.3	Single Lane Exit Terminal
Attachment 1.4	Typical Details of Ramp - Mainline Intersections
Attachment 1.5	Details of Ramp - Mainline Intersections with Special Turn Lanes
Attachment 1.6	Layout for Turning Volumes

FDM 11-30-5 Cross Section, Ramp and Crossroad *August 15, 2019*

5.1 Interchange Ramp Roadway Widths

Ramp widths for single-lane, one-way operation with up to 12% trucks should be 15 feet when the ramp is not curbed, plus shoulders (see FDM 11-15 Attachment 1.5 for typical section), and 22 feet, face to face of curbs, when the ramp is curbed on both sides. The width of ramps designed for two-lane operation or for truck volumes in excess of 12% shall be in accordance with Table X-3, page 976, GDHS. Single-lane ramps should be designed with a uni-directional slope (straight line without crown) over the entire width. Two-lane ramps on tangent should have a normal center line crown. Ramp pavement widths at crossroad terminals shall be as shown in FDM 11-30 Attachment 1.4, FDM 11-30 Attachment 1.5, and FDM 11-30 Attachment 1.6. Multi-lane exit and entrance ramps are discussed on pages 860-867, GDHS 2001.

Where the radius of the turning roadway is less than 430 feet, a barrier curb with a 5 foot turf shoulder should be provided on the low side or inside of the curve and an 8 foot shoulder, on the high side or outside of the curve. The turf shoulder should be sloped at the rate of 4 percent and normally away from the curb.

5.2 Interchange Ramp Median (Two-Way Operations)

Two-way ramps on which one or both lanes are designed for 50 mph or greater should be provided with a median barrier when the median width is 30 feet or less. Two-way ramps on which both lanes are designed for less than 50 mph may be designed with a flush or curbed median. The minimum width of median should be 6 feet between curb faces to permit room for signing.

5.3 Intersecting Road

A crossroad should normally be divided through an interchange area to help safeguard against wrong-way entry onto ramps and to accommodate left-turning lanes when stop or signal control are used. The typical section shown in FDM 11-30 Attachment 1.4, is the minimum design for two lane crossroads when the intersection treatment is stop or signal controlled. When roundabouts are provided at the ramp/crossroad termini, additional width for turn lanes or storage for turning vehicles is not part of the design. Therefore, when roundabouts are used at the termini, it is not important to divide the highway other than to provide the splitter island at the approach to the roundabout.

Another consideration at the crossroad termini is sight distance. The sight distance for a roundabout design is approximately half the sight distance required for a stop or signal controlled condition. For more information on roundabout design refer to FDM 11-25-3.

FDM 11-30-10 Collector Distributor Roads *May 19, 1997*

10.1 Collector-Distributor Roads

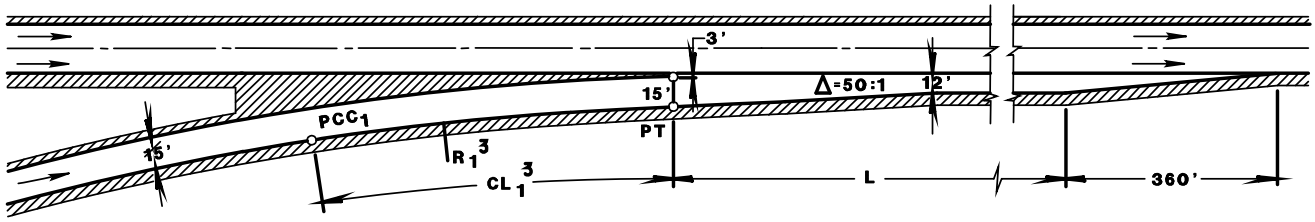
If the spacing between successive interchanges or between successive ramps of high-volume cloverleaf or directional interchanges is less than about one-half mile (800 m), it may be necessary to provide collector-distributor (C-D) roads for weaving vehicles. The C-D road should be separated from the freeway so weaving maneuvers are not made in the through lanes of the main line roadway. C-D roads are particularly adaptable to cloverleaf type interchanges where vehicles are entering and leaving simultaneously on adjacent loop ramps. The auxiliary lane has the dual function of operating as a deceleration/acceleration lane and as a weaving area. The need for C-D roads (capacity, weaving analysis, speeds, etc.) should be analyzed as part of interchange selection (see FDM 11-30-1).

If traffic volumes are high, the ramp to the C-D road should be preceded by an adjacent lane parallel to the main line, through roadway, similar to a parallel type off-ramp. Leaving vehicles can decelerate on a lane away from the through traffic lanes.

Where two high-volume entrance ramps are connected via a C-D road, an added lane downstream from the entrance may also be necessary.

In addition to handling high volumes of weaving and merging traffic, collector-distributor road systems enable cloverleaf type interchanges to be compressed in size, thus saving right-of-way. This is accomplished by

providing speed changes on the C-D roadways, which permits the use of shorter radius ramp loops.



PARALLEL ENTRANCE RAMP

Entering Speed (Design Speed) of Ramp (mph)	Main Line Design Speed		Adjustment Factor for Upgrade on Mainline
	70 mph	**55 mph to 65 mph**	
	L feet	**L feet**	**+2.2% to + 4% [1]**
30	1350	1120	1.60
35	1230	1000	1.65
40	1000 [1]	800	1.70
45	820 [2]	600	1.75
50	600 [2]	600	1.80
55	600 [2]	600	1.85

[1] For mainline upgrades less than +2.2 %, no adjustment is necessary. For mainline grades exceeding + 4%, see Exhibit 10-71 on page 852 of GDHS 2001. Also discuss this with your Project Oversight Engineer in the BPD Project Services Section.

[2] An acceleration lane length of a least 1200 feet, plus taper, is desirable whenever it is anticipated that the ramps and freeway will frequently carry traffic volumes approximately equal to the design capacity of the merging area (2001 AASHTO Page 853.)

[3] Ramp geometrics are adequate for mainline design speeds through 70 MPH. See Attachment 1.2 for R_1 and CL_1 Values.

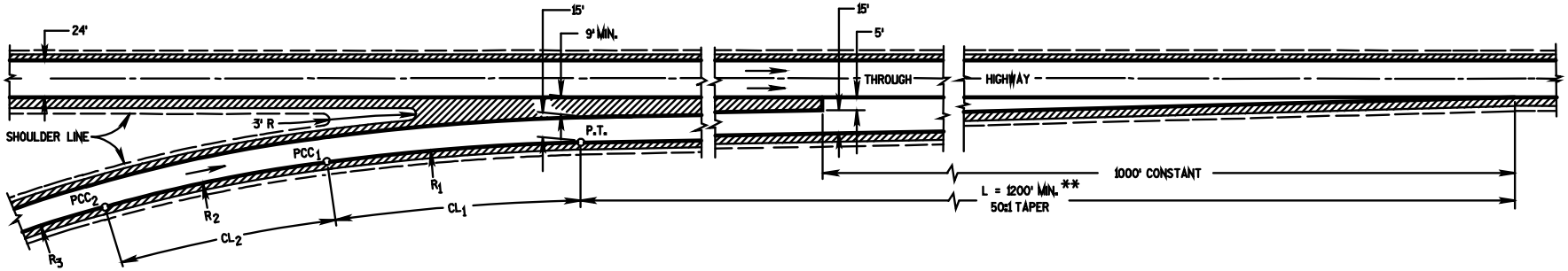
<u>Minimum Shoulder Treatments</u>

Mainline

Left – 6' total / 3' paved [4' for interstate] (10' for 6 lane facility & greater.)
Right – 10' total / 8' paved (12' when the directional DHV for trucks exceeds 250)

Ramps

Left – 4' total / 3' paved
Right – 8' total / 5' paved



SINGLE LANE ENTRANCE TERMINAL

Ramp Design Speed PCC 2	Min. Radius			Curve Length	
(mph)	R_3	R_2	R_1	CL_2	CL_1
60	TANGENT ALIGNMENT		Min. 1350'		Min.200
55			Min. 1095'		Min.200
50			Min. 850'		Min.200
45	660'		850'		150'
40	510'		850'		150'
35	380'	660'	850'	150	150'
30	273'	510'	850'	150	150'
	*250'	* Minimum Desirable			

Minimum Shoulder Treatments

Mainline

Left - 6' total / 3' paved [4' for interstate] 10' for 6-lane facility & greater

Right - 10' total / 8' paved (12' when directional DHV for trucks exceeds 250)

Ramps

Left - 4' total / 3'paved

Right - 8'total / 5' paved

NOTES:

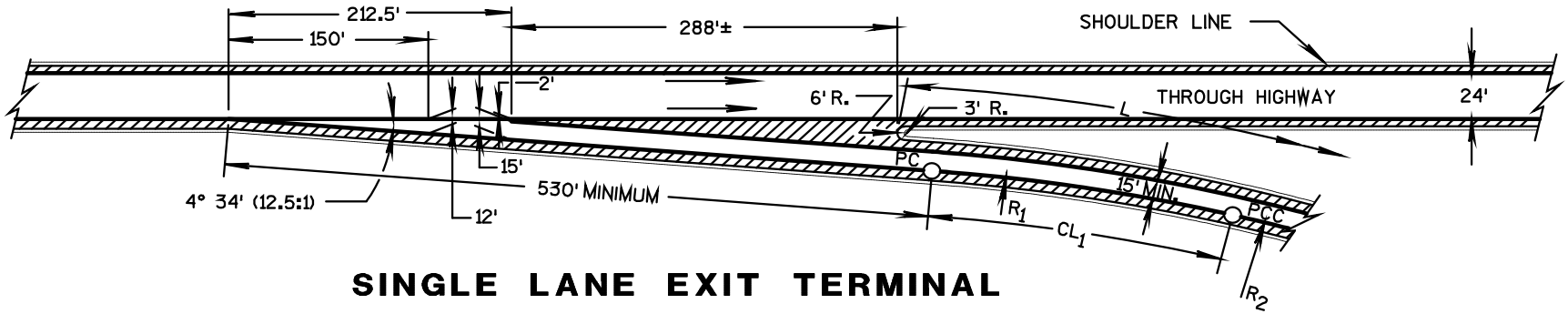
Ramp design speeds at PCC_2 are based on governing radii R_3 or R_1. Assuming SE = 6% refer to Exhibit 3-14 page 145, GDHS 2001.

Minimum acceleration lane, taper length (L), based on Exhibit 10-70, page 851 GDHS 2001.

For acceleration lanes having grades in excess of ±2% refer to Exhibit 10-71 page 852, GDHS 2001, for length adjustment.

**When design speed at PCC_2 is 40 MPH or less, adjust acceleration length (L) as follows: 1250' (40 MPH), 1300' (35 MPH), and 1400' (30 MPH) (50 km/h).

Ramp geometrics are adequate for mainline design speeds through 65 MPH.



SINGLE LANE EXIT TERMINAL

Ramp Design Speed	Min. Radius		Ramp Design Speed	Curve Length
PC	R_1	R_2	PCC	Min. CL_1
60 mph	1350’	850’	50 mph	200’
55 mph	1095’	660’	45 mph	200’
50 mph	850’	510’	40 mph	150’
45 mph	660’	380’	35 mph	150’
40 mph	510’	273’	30 mph	150’

L = 900’

LEGEND

Paved Shoulder

L Minimum ramp distance from gore to the intersection of the ramp with the crossroad.

R_2 Radius of the major internal segment of the loop.

NOTES:

The length of the deceleration lane is based on ramp grades of 0 to 2%. Refer to Exhibit 10-73 page 855 GDHS 2001, for length adjustment factors to be used when ramp grades exceed ± 2%.

If the ramp speed and radii relationships listed in the table cannot be attained due to area R/W restrictions, consideration should be given to collector-distributor roads.

The radii of the horizontal curves are rounded and based on a maximum superelevation rate of 6% and the speeds shown.

Ramp geometrics are adequate for mainline design speeds through 70 MPH.

Minimum Shoulder Treatments

Mainline

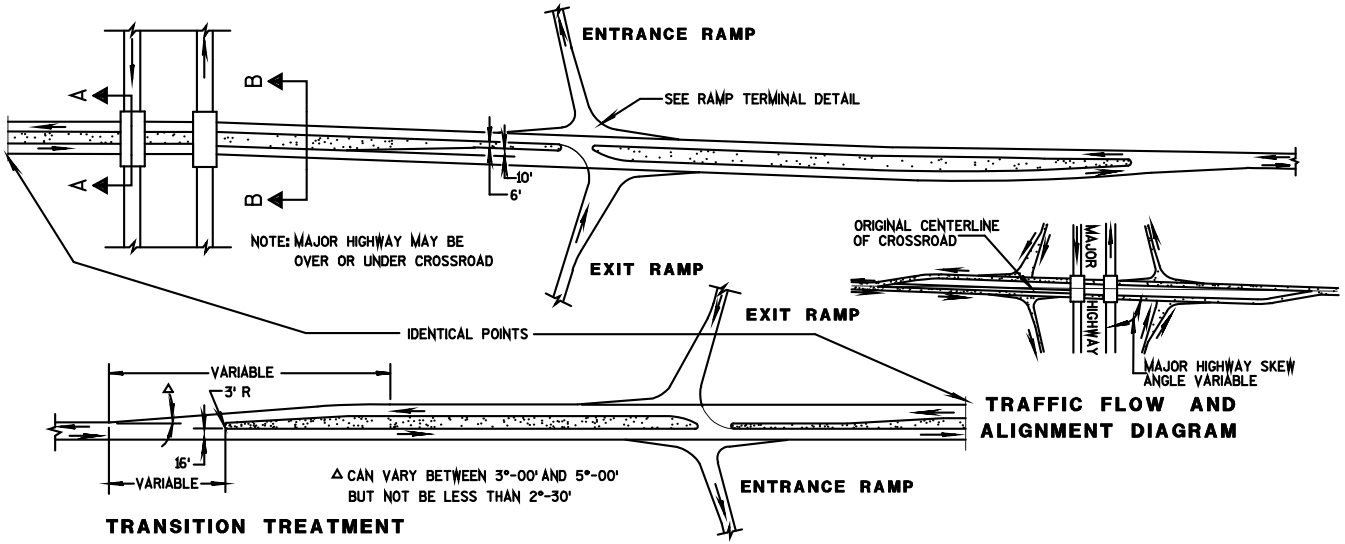
Left – 6’ total / 3’ paved [4’ for interstate] (10’ for 6 lane facility & greater.)

Right – 10’ total / 8’ paved (12’ when the directional DHV for trucks exceeds 250)

Ramps

Left - 4’ total / 3’ paved

Right - 8’ total / 5’ paved



TRANSITION TREATMENT

CONCRETE CURB
MOUNTABLE TYPE

CONCRETE CURB & GUTTER
MOUNTABLE TYPE
SECTION A-A

CONCRETE CURB
MOUNTABLE TYPE

CONCRETE CURB & GUTTER
MOUNTABLE TYPE
SECTION B-B

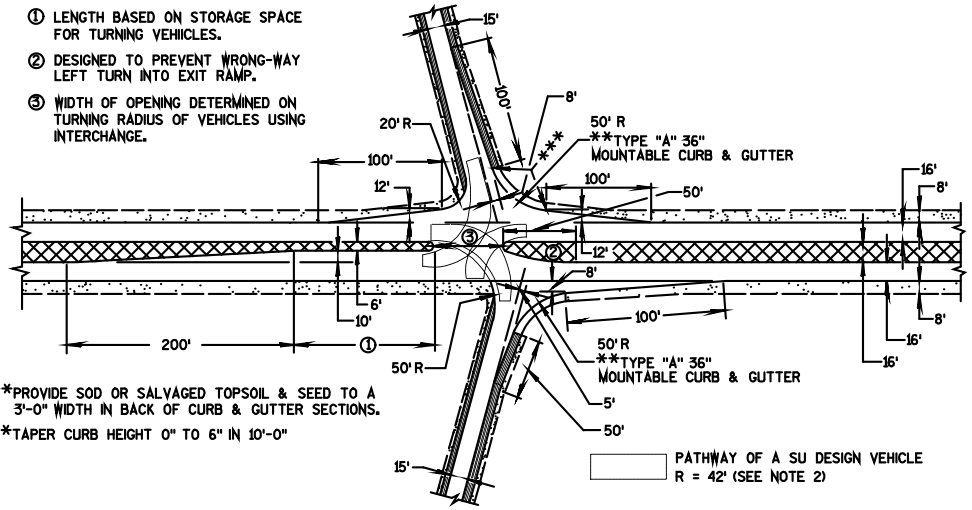
TYPICAL SECTIONS

NOTES:

① LENGTH BASED ON STORAGE SPACE FOR TURNING VEHICLES.

② DESIGNED TO PREVENT WRONG-WAY LEFT TURN INTO EXIT RAMP.

③ WIDTH OF OPENING DETERMINED ON TURNING RADIUS OF VEHICLES USING INTERCHANGE.



**PROVIDE SOD OR SALVAGED TOPSOIL & SEED TO A 3'-0" WIDTH IN BACK OF CURB & GUTTER SECTIONS.

***TAPER CURB HEIGHT 0" TO 6" IN 10'-0"

TYPICAL ENTRANCE AND EXIT RAMP TERMINAL DETAIL

PATHWAY OF A SU DESIGN VEHICLE R = 42' (SEE NOTE 2)

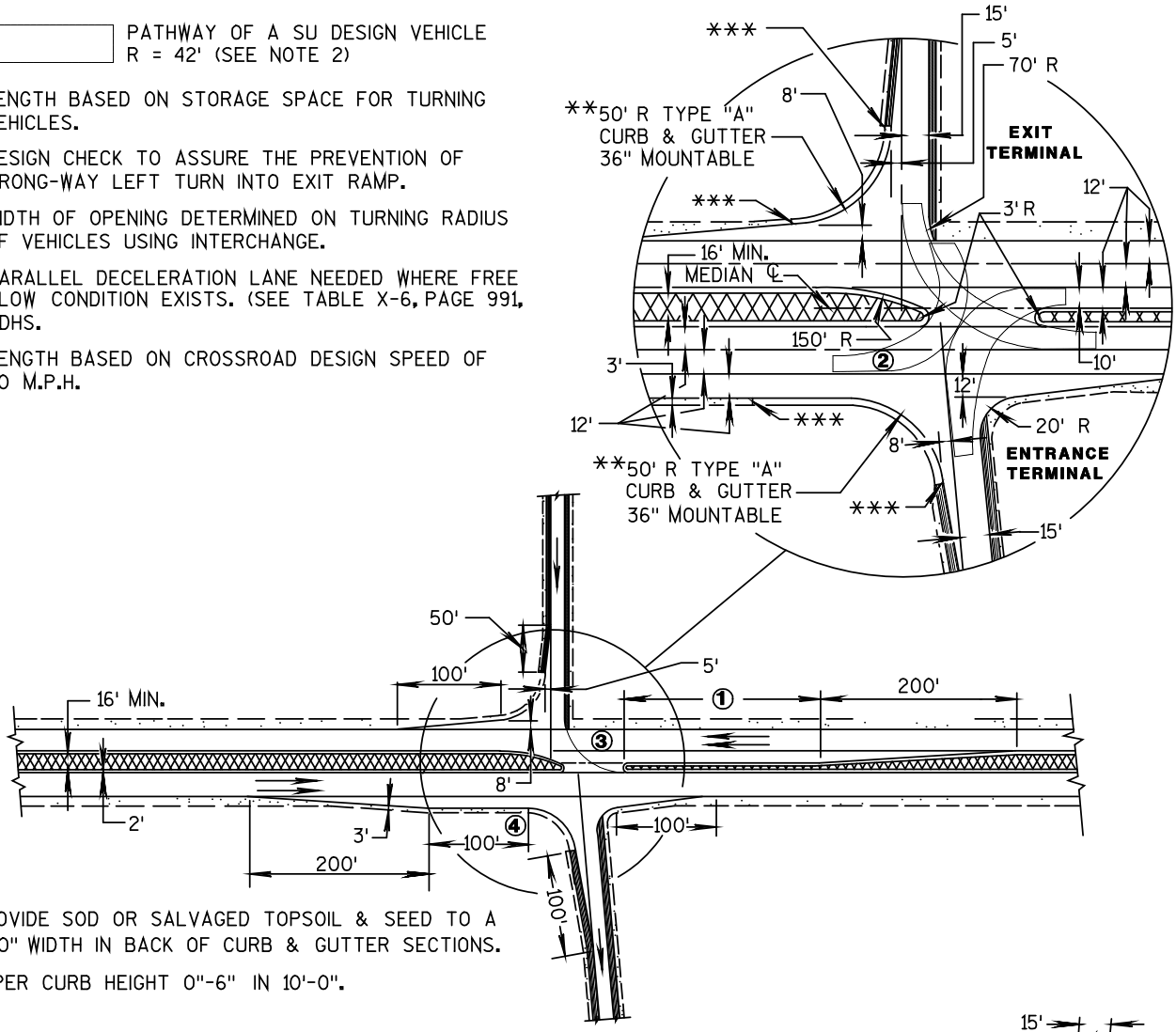
① LENGTH BASED ON STORAGE SPACE FOR TURNING VEHICLES.

② DESIGN CHECK TO ASSURE THE PREVENTION OF WRONG-WAY LEFT TURN INTO EXIT RAMP.

③ WIDTH OF OPENING DETERMINED ON TURNING RADIUS OF VEHICLES USING INTERCHANGE.

④ PARALLEL DECELERATION LANE NEEDED WHERE FREE FLOW CONDITION EXISTS. (SEE TABLE X-6, PAGE 991, GDHS.

⑤ LENGTH BASED ON CROSSROAD DESIGN SPEED OF 50 M.P.H.



** PROVIDE SOD OR SALVAGED TOPSOIL & SEED TO A 3'-0" WIDTH IN BACK OF CURB & GUTTER SECTIONS.

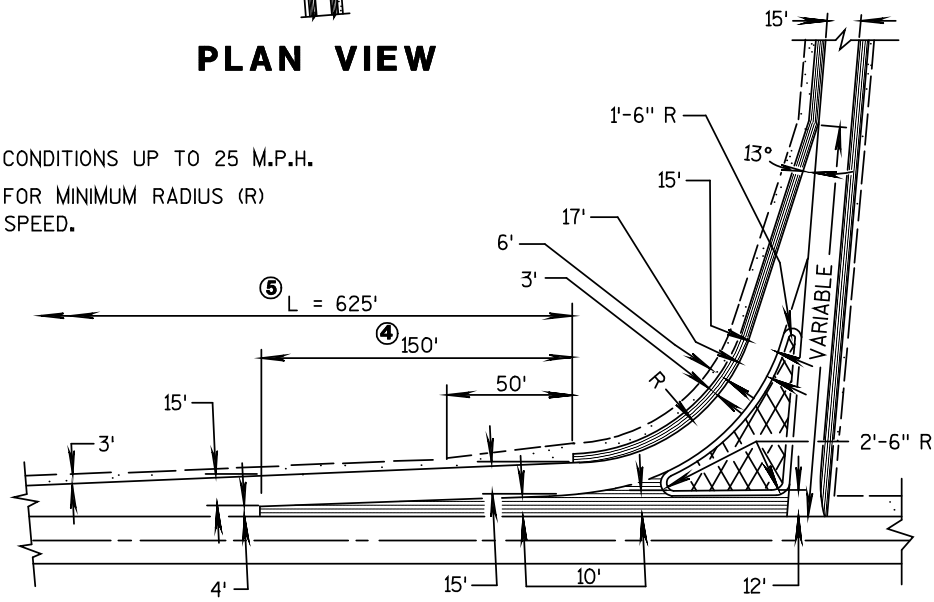
*** TAPER CURB HEIGHT 0"-6" IN 10'-0".

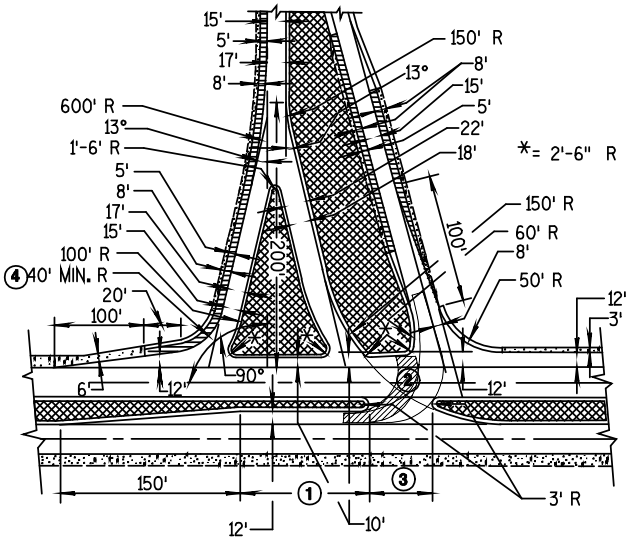
PLAN VIEW

NOTES:

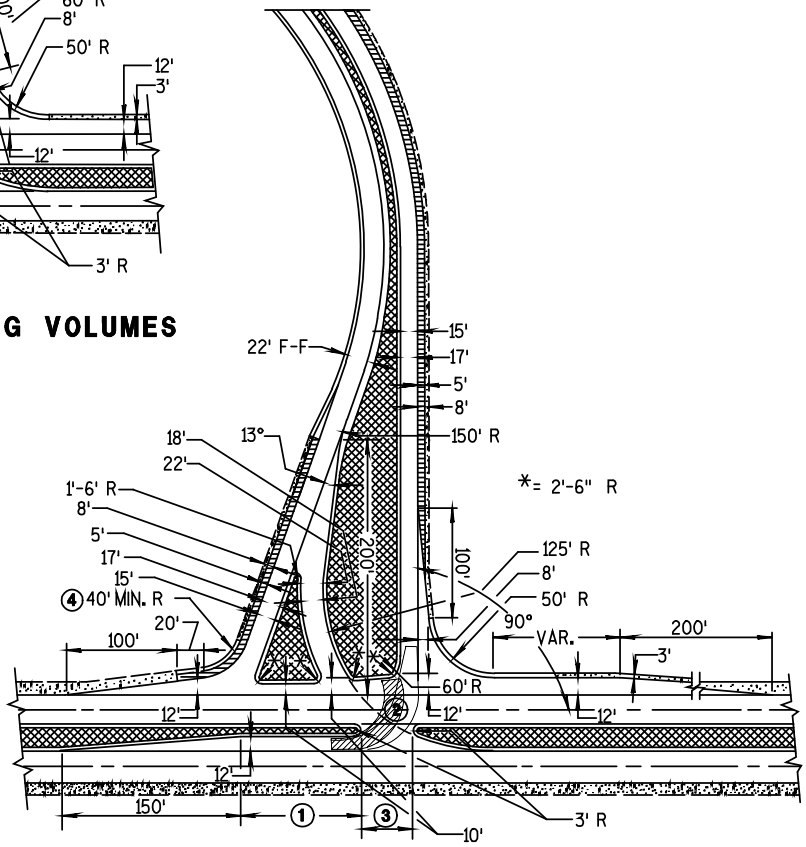
USE THIS DETAIL FOR FREE FLOW CONDITIONS UP TO 25 M.P.H.

SEE TABLE III-17, PAGE 197, GDHS FOR MINIMUM RADIUS (R) NECESSARY FOR DESIRED TURNING SPEED.



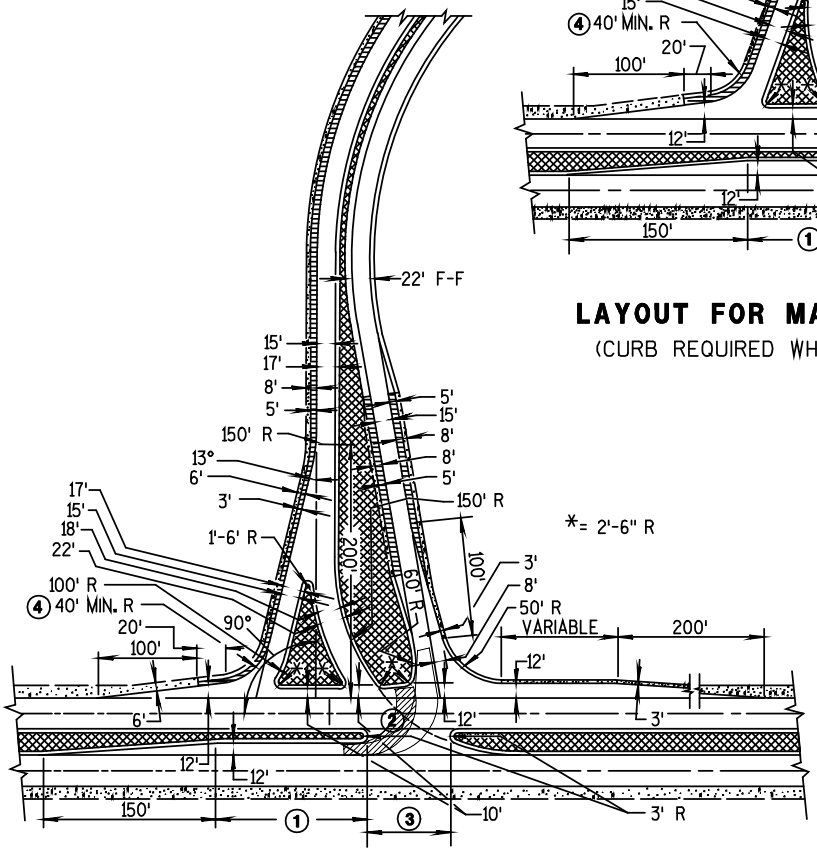


LAYOUT FOR EQUAL TURNING VOLUMES



LAYOUT FOR MAJOR RIGHT TURNING VOLUMES

(CURB REQUIRED WHEN RAMP RADIUS IS LESS THAN 430')



LAYOUT FOR MAJOR LEFT TURNING VOLUMES

(CURB REQUIRED WHEN RAMP RADIUS IS LESS THAN 430')

PAVED SHOULDER

UNPAVED SHOULDER

PATHWAY OF A SU DESIGN VEHICLE R=42' (SEE NOTE 2)

① LENGTH BASED ON STORAGE SPACE FOR TURNING VEHICLES.

② DESIGN CHECK TO ASSURE THE PREVENTION OF WRONG WAY LEFT TURN INTO EXIT RAMP.

③ WIDTH OF OPENING DETERMINED ON TURNING RADIUS OF VEHICLES USING INTERCHANGE.

④ VARIABLE DEPENDING ON THE AMOUNT OF FREE FLOW MOVEMENT DESIRED.

EITHER CURB OR CURB & GUTTER (MOUNTABLE OR BARRIER) MAY BE USED FOR THE ISLAND AND THE CROSSROAD MEDIAN.

FDM 11-35-1 Widths, Clearances, Sidewalks and Protective Screening

August 17, 2020

1.1 Structure Survey Reports

A structure survey report is required for all new, replacement, and rehabilitation bridge, retaining wall, box culvert extension and sign structure projects, or any other work performed on structures (refer to Chapter 6 of the WisDOT Bridge Manual Chapter 6 (https://wisconsindot.gov/dtsdManuals/strct/manuals/bridge/ch6.pdf). This report, including the appropriate soils information, must be received by Central Office Bureau of Structures according to the schedule. Variations to this schedule must be approved by the DTSD, Chief Structural Design Engineer. Reference should be made to the Bridge Design Manual for guidance in making this report and the selection of bridge types.

1.2 Clear Roadway Width of Bridges

Clear roadway width of bridges (aka "Bridge Width", "structure width" and "clear roadway width of structures") is a non-controlling criterion. Clear roadway width of bridges as defined in FDM 11-15-1 is "the most restrictive lower minimum distance between curbs or rails on a structure roadway. This measurement is exclusive of flared areas for ramps.

STH design criteria for clear roadway width of bridges are in FDM 11-15 Attachments 1.1 - 1.3.

CTH design criteria for clear roadway width of bridges are in FDM 11-15 Attachments 1.17 - 1.19.

Variances from these design criteria may be justified for long-span, high-cost structures and structures widened on the Corridors 2030 **(C2030)** Backbone system to accommodate traffic demand in work zones. See FDM 11-35-10 for warranting criteria and guidance on the appropriate use of 3-lane rural structures on the C2030 Backbone system. See FDM 4-1 Attachment 5.1 for a map showing the C2030 Backbone and Connector facilities. See FDM 11-45-30 for additional guidance if separated multi use paths are being considered as part of the structure.

1.2.1 Interstate [1]

On the Interstate System, the preferred design is full width shoulders across all bridges. However, the width of long bridges may be reduced to the width of the traveled way plus 4 feet offset on each side to the toe of the bridge parapets. Interstate long bridges are defined as those having an overall length in excess of 200 feet.

1.2.2 Town Roads

Town Road design criteria for clear roadway width of bridges are in FDM 11-15 Attachment 1.4 in the "Modernization Design Criteria for Town Roads (New Construction Only)".

1.2.3 Urban Roadways

Urban Roadway design criteria for clear roadway width of bridges is the wider of:

- The full roadway width necessary to carry the design traffic* (see '*' note on next page), or
- The width needed to meet rating code 4 for item 68 as shown in FHWA's Bridge Coding Guide[1], as shown in Table 1.1.

[1] *(3) Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges.* FHWA-PD-96-001. Office of Engineering, Bridge Division, Bridge Management Branch, 1995. http://www.fhwa.dot.gov/bridge/mtguide.pdf, pp.48-50, Tables 2A, 2B, 2C, 2D

***Table 1.1** Clear Roadway Width of Bridges Needed to Meet Rating Code 4 for Item 68 as Shown in FHWA'S Bridge Coding Guide*

Roadway configuration	Coding Guide min. width*
2 lane divided	18' @ 2 sides
2 lane undivided	Depends on ADT & Length (L) 0-100 ADT = 18' 101-400 ADT = 20' 401-1000 ADT = 22 1001-2000 ADT = 24 2001-5000 ADT = 28' >5,000 ADT, L<200' = 32' >5,000 ADT, L >200' = 28'
4 lane divided	30' @ 2 sides
4 lane undivided	51'
6 lane divided	40' @ 2 sides

** Note: The full roadway width necessary to carry the design traffic includes:*

- *The traveled way (defined by AASHTO as the portion of roadway for the movement of vehicles, exclusive of shoulders),*
- *Shoulder or bike accommodation, and*
- *Gutter pan.*

Examples:

1. An urban 4-lane undivided roadway with 4 x 11-foot lanes and 2-foot gutters has a roadway width of 48-feet. The lower minimum clear roadway width of bridge needed to meet rating code 4 is 51-feet. Therefore, design the bridge clear roadway width = lower minimum width needed to meet rating coded 4 = 51-feet.
2. An urban 4-lane undivided roadway with 4 x 12-foot lanes and 2-foot gutters has a roadway width of 52-feet. The lower minimum clear roadway width of bridge needed to meet rating code 4 is 51-feet. Therefore, design the bridge clear roadway width = approach roadway = 52-feet.

In situations where bridge approaches with curb and gutter adjoin structures with concrete parapets, the horizontal offset (shy distance) shall be aligned and maintained consistent throughout the transition between the curb face and the parapet toe. This offset in urban areas is generally the width of the gutter pan, or the combination of the gutter pan plus the shoulder or bike lane width. This offset in rural areas is generally the shoulder width. Refer to Attachment 1.1 through 1.4 for detail drawings.

1.2.4 Between Consecutive Roundabouts

The design criteria for clear roadway width of bridges between consecutive roundabouts are in FDM 11-26-30.5.13.3.

1.3 Lateral Underclearances to Structures [2,3]

Lateral underclearance to Structure is non-controlling criteria. Requirements are shown in Attachment 1.5 and Attachment 1.6. An approved Design Justification (DJ) is required if the provided lateral underclearance to structure is < distance ①, as shown on Attachment 1.5 and Attachment 1.6. It is possible that approved DJs to other design criteria will also be needed.

Lateral Underclearance to Structure (also known as "Lateral Clearance under Structures", or "Lateral Clearance at Bridge Underpass," is defined as "the distance from the edge of the through roadway (excluding shoulders) to the nearest substructure unit (pier, abutment, etc.), to a rigid barrier (concrete bridge rail, etc.), to a retaining wall, or to a toe of slope steeper than 3:1." There are different requirements for structures to the left and

structures to the right. Lateral underclearance to structures requirements to the right applies to both sides of undivided bi-directional roadways, the right side of 1-way streets and ramps, and the outside lanes of divided highways. Lateral underclearance to structures requirements to the left applies to the left side of 1-way streets and ramps, and the median side of divided highways. Also, see FDM 11-15-1 for additional discussion of Horizontal Clearance.

Provide the full approach traveled way width(s) and shoulder widths through new and replacement structures and, if possible, through existing structures. For expressways, freeways and ramps it is recommended to carry the entire roadway section under the structure without change. Entire roadway section includes the median, traveled way and shoulders. For urban streets, it is also recommended that the entire roadway width of the approach be carried under the structure without change. However, the economic impacts should be analyzed in each individual case. In some cases, right of way restrictions may necessitate a reduction in the median width under the structure. This reduced width would not be as objectionable on urban streets as on freeways because of the lower speeds.

Another consideration is sight distance thru the structure. Make sure that the lines of sight needed for sight distance along the roadway are not obstructed. Also, make sure that the lines of sight needed for intersection sight distance for nearby intersections are not obstructed. See FDM 11-10-5 for sight distance requirements.

1.3.1 Barrier considerations

Roadside barrier under structures is provided for 2 purposes – either (1) to protect vehicles on the roadway from roadside hazards - such as substructure units or (2) to protect the structure from damage by vehicles impacting the structure. Roadside barrier used for vehicle protection may not be adequate for structure protection. Roadside barrier used for structure protection will be adequate for vehicle protection. If roadside barrier is used, then provide the appropriate type, height, length-of-need, transitions, and terminals in advance of and beyond the structure.

1.3.1.1 Vehicle Protection Barrier

Evaluate the need for vehicle protection barrier using the methods described in FDM 11-45. A vehicle protection barrier must have sufficient height and a sufficient offset between the barrier and the substructure unit (distance ③ on Attachment 1.5 and Attachment 1.6) to lessen the possibility of a vehicle impacting the structure, either because of barrier deflection or from leaning over the top of the barrier. Height and offset requirements are shown in Attachment 1.5 and Attachment 1.6.

1.3.1.2 Structure Protection Barrier

Confer and coordinate with the Bureau of Structures (BOS) on the need for structure protection barrier and document in the DSR. Structural design criteria specify the criteria for which structure protection barrier is required.

Confer and coordinate with the Bureau of Structures (BOS) and the Bureau of Project Development (BPD) on the design requirements for a structure protection barrier. A structure protection barrier must have sufficient strength, length, height and a sufficient offset between the barrier and the substructure unit (distance ③ on Attachment 1.5 and Attachment 1.6) to lessen the possibility of a vehicle impacting and damaging the structure, including impacts from leaning over the top of the barrier. Height and offset requirements are shown in Attachment 1.5 and Attachment 1.6. Provide suitable end treatment, such as transition to W-beam or a crash cushion.

A safer and more cost-effective alternative to a structure protection barrier may be to retrofit or strengthen the existing substructure element(s) to resist the load requirement – for example, a suitably designed concrete beam (crash wall) between the columns [4]. This approach would be especially appropriate where the use of a structure protection barrier would adversely affect adjacent pedestrian facilities, utilities, sight distances on adjacent roadways, etc. Of course, these locations would still need to be evaluated for vehicle protection barriers.

1.3.2 Lower Minimum Lateral Underclearance to Structure for Railroads

Lower Minimum Lateral Underclearance to Structure for railroads is defined as the distance from the centerline (between rails) to the nearest substructure unit (pier, abutment, etc.), to a rigid barrier (concrete bridge rail, etc.), to a retaining wall, or to the toe of a slope steeper than 3:1. Requirements are shown in the Bridge Manual. Also, see FDM Chapter 17.

1.4 Parapets on Structures

Parapets on structures without approaching concrete barrier should generally be the 42-inch parapet with the Steel Thrie Beam Structure Approach and end treatment. There may be other bridge rails used as well, but

typically end treatments will be applied. See FDM 11-45 for guidance on appropriate end treatments.

Parapets on structures should match the height and shape of the approaching barrier in the highway area. If the highway median approach concrete barrier is 51-inch, provide a 51-inch parapet on the structure as well.

1.5 Vertical Clearances [1-3]

See Attachment 1.8 and Attachment 1.9.

Additional under-clearance for pedestrian and sign bridge structures on roadways is provided because these types of structures are assumed to be non-redundant structures (i.e. trusses, two girder bridges) and have main structural members which are substantially lighter than the main structural members of vehicle overpass structures, and thus are more susceptible to collapsing from the impact of an over-height vehicle. This additional clearance is not required for railroads because railroads have exclusive control for heights moving down their lines, and therefore do not have the risks associated with highway traffic.

Vertical clearance over railroad tracks may sometimes be less than 23 feet -0 inches. See Note 7 on Page 1 of Attachment 1.8.

1.5.1 OSOW High Clearance Routes

The Department has adopted OSOW High Clearance Routes with the objective of minimizing overhead constraints for OSOW vehicles along these routes. Refer to FDM 11-10-5.4.3 for further vertical clearance guidance along the high clearance routes.

Provide a lower minimum 20'-0" vertical clearance for new and replacement sign structures along the OSOW High Clearance Routes.

Coordinate early in the design process with the Bureau of Highway Maintenance and Bureau of Structures in determining the appropriate vertical clearance along an OSOW high route for new bridges, replacement bridges and bridges with superstructure replacement. The Department's goal is to provide a lower minimum vertical clearance of 20'-0" for bridges along these routes. Do not reduce existing vertical clearance less than or equal to 20'-0" along these routes. Consult the general notes of Attachment 1.8 and Attachment 1.9 for vertical clearance design criteria.

1.6 Sidewalks, Bicycle Accommodations, Shared Use Paths and Roundabout Sidepaths

Where a bridge is being replaced or receiving a major rehabilitation, such as re-decking, on a highway without full control of access, and bicycle operation is permitted at each approach, the bridge should be built to safely accommodate bicycle traffic. Likewise, provide sidewalk on or under a bridge within urban, suburban and transition areas where sidewalks exist or are very likely to be connected to the bridge once the bridge is in service. US DOT Policy on Accommodating Pedestrians and Bicycles states that bicycle and pedestrian ways shall be established in new construction and reconstruction projects in all urbanized areas unless the cost of establishing those facilities exceeds 20% of the cost of the larger project.

See FDM 11-46 for guidance on accommodating pedestrians and bicyclists.

1.6.1 Sidewalks

Sidewalks on bridges shall be designed a lower minimum of 6 feet wide. The typical sidewalk approach to the bridge will be 5 feet wide. Just prior to the bridge it is important to transition the sidewalk width to 6 feet. The transition area will include the sidewalk plus a nominal width for the curb head (1 foot is typical) to provide a lower minimum 6-foot wide sidewalk across the bridge, curb face to the parapet toe, or vertical face. In situations where high pedestrian usage across the bridge is anticipated, a wider sidewalk may be justified. This may occur in urban areas that are fully developed, or developing with retail stores or office buildings. Apply the same sidewalk width principals described above. The approach sidewalk width plus a nominal width for the curb head (1 foot is typical) will yield a final width of sidewalk for the bridge crossing. The 1-foot of typical additional width will provide for the curb head and will serve as a 1 foot recommended shy distance from the curb face to the pedestrian.

Sidewalks under new, replacement and existing structures with at least a 3-foot terrace between the face of curb and the sidewalk shall have a lower minimum width of 5 feet. Sidewalks under new, replacement and existing structures where terrace is less than 3-feet between the face of the curb and the sidewalk is adjacent to the back of curb shall have a lower minimum width of 6 feet from face of curb to the back of sidewalk. If a parapet or barrier separation device is used between the roadway and the sidewalk then the lower minimum width of sidewalk under new, replacement and existing structures shall be 6 feet. A wider sidewalk may be justified where high pedestrian usage is anticipated.

If conditions require that a sidewalk under an existing structure remain in place with less than the lower

minimum width then provide justification in the DSR based on an evaluation of current use, width, safety, and ADA requirements.

Raised curb and sidewalk are sometimes provided on a structure in anticipation of future sidewalk being connected to it. If the barrier is located on the outside edge of the sidewalk, then the sidewalk and curb must be extended beyond the barrier terminal for a distance of at least 30-feet - see Attachment 1.1. The purpose is to maintain the functionality of the barrier and barrier terminal. Terminate the sidewalk and raised curb by installing a temporary asphaltic height transition, or ramp, on the roadway approach from the top surface of the sidewalk down to the level of the adjacent ground surface to eliminate the blunt end effect of the sidewalk. This transition height is typically 6 to 8 inches and shall extend approximately 10 feet in advance of the end of the sidewalk. This guidance applies to all posted speeds and all project locations. Consider using white, 4-inch, cross hatch pavement marking to delineate the ramp area.

Existing conditions on Perpetuation and Rehabilitation projects may require that a raised sidewalk remain in place with less than the lower minimum width. The current use, width, safety and ADA requirements shall be evaluated on a project specific basis. Provide justification in the DSR for sidewalks left in place with less than the lower minimum width.

Note: sidewalks on or under bridges need an agreement with local governments to establish maintenance responsibility.

A structure shall include a parapet or barrier wall to separate the roadway from a sidewalk based on Table 1.2 for the proposed posted speed. Barrier requirements for shared use paths are discussed below in the Shared Use Paths section.

Table 1.2 Barrier Wall Separation Required Between Roadway and Sidewalk [5]

For new, reconstructed, or rehabilitated structures with a posted speed >= 45 mph	For other existing structures with a posted speed >= 45 mph	For any structure with a posted speed <= 40 mph
Yes	No, unless requested by community and agreed to by the Department. [1]	No, unless requested by community and agreed to by the Department [1]

[1] The designer and community may decide that a parapet/barrier wall separation is a desirable safety solution, especially for posted speeds of 35 mph and greater. Bear in mind that installing a parapet or barrier on a structure is considered structure rehabilitation. Consider the adjacent roadway character, shy distance between traveled way and raised curb sidewalk, pedestrian volume, length of structure

1. *Part of reasonable justification to provide separation is if the adjacent roadway character is rural.*
2. *Another reasonable justification to provide separation is if there is a narrow shoulder or gutter (< 1.8-ft) located between the travel lane and the sidewalk.*
3. *High, seasonal or year around, pedestrian volume may suggest that separation is desirable.*
4. *A long structure may be more likely to include separation than a short structure.*

Justification to include parapet/barrier wall separation in the Design Study Report is not required, but is encouraged.

The lower minimum height for a barrier wall/parapet separating the sidewalk from the roadway is 32-inches for posted speeds of 40 mph or greater (see Attachment 1.1, Section C-C). A lower barrier meeting NCHRP 350 TL2 may be considered for posted speeds of 35 mph or less.

The lower minimum height for a barrier wall/parapet on the outside of the sidewalk is 42-inches (see Attachment 1.1, Section B-B to visualize the raised curb sidewalk option). Keep in mind that certain areas require Protective Screening, to discourage people from dropping or throwing objects onto vehicles passing under the structure. See FDM 11-35-1.8 for guidance on Protective Screening.

Also, see FDM 11-45-30.3.5, “Transitions to Rigid Barriers”.

1.6.2 Bicycle Accommodations

The majority of bicycle accommodations in rural areas will be provided through paved shoulders and in urban areas through bike lanes. If a bridge or approaching highway has either pavement-marked bike lanes, or is signed as a bicycle route, and the bicycle accommodation is immediately adjacent to the bridge railing, the railing height should be a lower minimum of 42-inches. If the bridge/highway is not marked or signed as a bicycle facility then use the typical 32-inch barrier height on the bridge (i.e. even if the bridge/highway has a paved shoulder wider than typical paved width shoulder and is not marked or signed as a bicycle facility use the

typical barrier height). Refer to FDM 11-46-15 for additional information on bicycle accommodations.

1.6.3 Shared Use Path

In some situations, a two-way shared use path will be provided. Two-way shared use paths, like sidewalks, need agreement for maintenance and right-of-way considerations from the local unit of government and the DTSD, Chief Structural Design Engineer. Two-way shared use paths should only be used when they connect to, or are planned to connect to, two-way shared use paths on both ends of the bridge for a significant distance beyond the approaches.

Two-way shared use paths are required to be separated from the traveled way for all posted speeds with a 42-inch barrier wall, except that a 32-inch barrier wall may be considered if:

- There is 5 feet or more separation (i.e. shoulder or bike accommodation) between the outside edge of the traveled lane and the face of barrier, or
- There is a shared use path on a short bridge (less than 75 feet).

There is another unique option for a shared use path that allows the elimination of the barrier wall if the posted speed is 40 mph or less. That option is to provide a 16- foot wide raised curb shared use path across the structure. This option provides the 5- foot space separation and the shared use path as a combined raised curb section (see Attachment 1.1, Section B-B to visualize the raised curb option).

If a parapet/barrier separation device is used then a shared use path on or under a structure is required to be 2 feet wider than the width of the path approaching the structure (this is commonly 12 feet wide). For paths on the structure this width is measured from the barrier wall back face to the face of the outer protection, be it fencing, railing or parapet (see Attachment 1.1, Section C-C to visualize the separated path option). For paths under a structure, this width is measured from the barrier wall back face to the face of the nearest substructure unit.

The outside protection is recommended to be a 54-inch height when adjacent to a shared use path. The lower minimum height of the outside protection is 42 inches. The higher height protection should be provided on any curved sections of paths leading up to or away from a bridge or underpass. Providing higher protection on long and high bridges will also provide an additional level of comfort for users. The consequences of going over the outside protection can be considered in determining the height. For example, a short drop-off or a grassy sideslope with a modest grade of incline on the other side of the protection would support the lower minimum height, as would a short bridge crossing or an extra wide path where users can shy away from the railing or fence.

Chain link fence is available in nominal heights of 4-feet, 5-feet, 6-feet etc. Therefore, if using chain link fence use 5-foot height or higher. Keep in mind that certain areas require Protective Screening, to discourage people from dropping or throwing objects onto vehicles passing under the structure. See FDM 11-35-1.8 for guidance on Protective Screening.

When a height transition between different height barrier walls or between beam guard and a higher wall is needed, the transition ratio is 20:1. When transitioning from Steel Thrie Beam Structure Approach, 31-inch height, to a 42-inch barrier wall height approximately 18 feet of wall length is needed for the height transition. As a result of this transition up to full barrier wall height and back down on the other end of the barrier wall to the beam guard height, the overall/total barrier wall length should be 75 feet or longer to justify a 42-inch barrier wall separation device. See FDM 11-46-15 for additional guidance on bicycle facilities.

Also, see FDM 11-45-30.3.5, “Transitions to Rigid Barriers.”

Under structures, provide at least the median shoulder width, travel lane width(s), outside shoulder width and shared-path width. If there will be road signs, power poles, light poles or other fixtures installed along the roadside then provide at least a 5-foot-wide terrace between the face of curb at the outside of the shoulder and the front of the path.

Note: Increasing bridge width to facilitate snow removal can rarely be economically justified.

1.6.3.1 Roundabout Sidepath

A “roundabout sidepath” is a sidepath around the perimeter of an isolated roundabout or a sidepath between two closely spaced roundabouts and around their perimeters. See FDM 11-26-30.5.13 and FDM 11-46-15.6 for additional guidance on closely spaced roundabouts and roundabout sidepaths.

Typically, the barrier wall/parapet is on the outside of a roundabout sidepath and not between the roadway and a roundabout sidepath (see Attachment 1.1, Section B-B). However, at locations with high, seasonal or year around, pedestrian or bicycle use, the barrier wall/parapet may be between the roundabout sidepath and the roadway if the Department and the community jointly agree that this is a desirable safety solution. For this case,

place a fence on the outside of the roundabout sidepath - see Attachment 1.1, Section C-C. For locations where a barrier wall/parapet is between the roadway and the roundabout sidepath, the lower minimum height of barrier wall/parapet is 42-inches, except that a 32-inch barrier may be considered if:

- There is 5 feet or more separation between the outside edge of travel lane and the face of barrier, or
- There is a roundabout sidepath on a short bridge (less than 75 feet).

A roundabout sidepath on a structure is required to be 2 feet wider than the width of the roundabout sidepath approaching the structure. This width is from the face of curb to the face of the barrier wall/parapet (or, if the parapet/barrier is between the roundabout sidepath and the roadway, from the back face of the barrier wall/parapet to the fence).

As with shared-use paths, the recommended height of the outside protection is 54-inch when adjacent to a roundabout sidepath. The lower minimum height of the outside protection is 42 inches. Provide the taller protection on any curved sections of a roundabout sidepath leading up to or away from a bridge or underpass. Providing taller protection on long and high bridges also provides an additional level of comfort for users. Consider the consequences of going over the outside protection in determining the height. For example, a short drop-off or a grassy sideslope with a modest grade of incline on the other side of the protection would support the lower minimum height, as would a short bridge crossing or an extra wide roundabout sidepath where users can shy away from the railing or fence.

Keep in mind that certain areas require Protective Screening to discourage people from dropping or throwing objects onto vehicles passing under the structure. See FDM 11-35-1.8 for guidance on Protective Screening.

Also, see FDM 11-45-30.3.5, “Transitions to Rigid Barriers.”

Under structures, provide at least the median shoulder width, travel lane width(s), outside shoulder width and roundabout sidepath width. If there will be road signs, power poles, light poles or other fixtures installed along the roadside then provide at least a 5-foot-wide terrace between the face of curb at the outside of the shoulder and the front of the path.

1.7 Touchdown Points on Local Program Bridge Projects

Refer to FDM 3-20-1 for a discussion of the process for determining local program bridge approach length eligible for federal funding.

1.8 Protective Screening

Protective screening is a special type of fence built on the sides of an overpass to discourage people from dropping or throwing objects onto vehicles passing under the structure. Protective screening shall be provided on overpasses based on the following chart.

Table 1.3 Protective Screening Requirements

Structure Type	With Sidewalk, Shared-Use, or Roundabout Sidepath	Without Sidewalk, Shared-Use Path, or Roundabout Sidepath
New	Yes	When Warranted
Existing	When Warranted	When Warranted

Example situations that warrant consideration of protective screening are:

1. If there have been instances of objects being dropped or thrown from an existing overpass.
2. For new overpasses, if there have been such instances at other existing overpasses in the area.
3. On overpasses near a school, playground, residential area or any other location where the overpass may be used by children who are not accompanied by adults.
4. On railroad bridges over highways in urban areas. If screening is used then use one -inch chain link mesh screening at these locations.

In addition, all pedestrian overpasses should have protective screening on both sides.

Protective screening is not always warranted. An example of when it may not be warranted is on an overpass without sidewalks where pedestrians do not have safe or convenient access to either side because of high traffic volumes or the number of traffic lanes that must be crossed.

If protective screening is warranted, the lower minimum design should require screening on the side of the

structure with sidewalk. Designers may call for protective screening on sides without sidewalk if those sides are readily accessible to pedestrians.

Designers should ensure that where protective screening is called for, it does not interfere with sight distances between the overpass and any ramps connecting it with the road below. This is especially important on cloverleaf and partial cloverleaf type interchanges.

Protective screening is considered part of the design of the overpass structure. Designers should refer to the Bridge Manual for further guidance on protective screening.

1.9 References

[1] AASHTO. A Policy on Design Standards Interstate System. Washington, DC: AASHTO, 2005.

[2] AASHTO. A Policy on Geometric Design of Highways and Streets 2001. (2nd printing) 4th ed. Washington, DC: American Association of State Highway and Transportation Officials, 2001.

[3] FHWA. Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges. FHWA-PD-96-001, Office of Engineering, Bridge Division, Bridge Management Branch. Washington, DC, Dec. 1995. http://www.fhwa.dot.gov/bridge/mtguide.pdf. Accessed 12-5-2012. Ref Type: Report

[4] Sicking DL. barrier requirements for pier and abutment protection to be included in FDM Procedure 11-35-1 - comment from Dean Sicking of MWRSF. Emerson E, editor. 6-18-2007.
Ref Type: Internet Communication

[5] TRB, Plaxico CA, Ray MH, Weir JA, Orengo F, Tiso P et al. Recommended Guidelines for Curb and Curb-Barrier Installations. NCHRP Report [537], C1-C2; i-vi, 1-96; A-I; C3 (106 total). 2005.
Ref Type: Journal (Full)

LIST OF ATTACHMENTS

Attachment 1.1	Structure Roadway Widths and Approach Details
Attachment 1.2	4 - Lane Divided Highway Structure Widths (w/Acceleration Lanes)
Attachment 1.3	4 - Lane Divided Highway Structure Widths (w/Deceleration Lanes)
Attachment 1.4	2, 4, and 6 - Lane Structure Widths (Special Situations)
Attachment 1.5	Lateral Underclearance to Structure for Rural Highways, Expressways, and Freeways
Attachment 1.6	Lateral Underclearance to Structure for Urban Streets
Attachment 1.7	Examples of Lateral Underclearance to Structure
Attachment 1.8	Lower Minimum Vertical Clearance for New Bridges and Replacement Bridges
Attachment 1.9	Lower Minimum Vertical Clearance for Bridges to Remain

FDM 11-35-5 Temporary Bridges *May 15, 2019*

Temporary bridges may be warranted to minimize user delays. Early in the design process, confer and coordinate with the Bureau of Structures (BOS) and the Bureau of Project Development (BPD) on the need for temporary bridges and for design requirements. See Chapter 8 of the WisDOT Bridge Manual for hydraulic design criteria for temporary structures (http://wisconsindot.gov/dtsdManuals/strct/manuals/bridge/ch8.pdf). Typically, temporary bridges are either designed by the department or the contractor. For contractor-designed bridges, the contractor is responsible for the design, construction, inspection, maintenance, and removal, while the department provides clearance requirements. For department-designed bridges, the contractor is typically responsible for the construction, inspection, maintenance, and removal, while the department provides the design.

Lower minimum clearance requirements shall be considered when using temporary bridges. This is especially important for vertical clearance checks with contractor-designed bridges. During the design process, the designer will need to assume a superstructure depth to check vertical clearances. Keep in mind that contractor-designed temporary bridges are the responsibility of the contractor and assuming a less than practical superstructure depth may result in high costs or construction issues.

Note: The region and structural engineer should verify estimated superstructure depths are reasonable. Contact BOS early in the design process for questions regarding estimated superstructure depths.

FDM 11-35-10 Three Lane Bridge Criteria

August 15, 2019

10.1 General

This guidance is limited to 4-lane divided Corridors 2030 (C2030) Backbone rural facilities. See FDM 4-1-5. It is not intended to address structure widening on C2030 Backbone facilities in urban areas, or rural facilities wider than 4-lanes. However, information contained in this procedure may assist in the thought process of potential solutions for urban, high capacity, high volume roadways.

For guidance on determining the work zone capacity and user delay reference FDM 11-50.

This guidance is intended to assist in the evaluation of:

1. When to provide a wider bridge, with overall clear width of 56-feet.[2]
2. Methods to widen an existing bridge from 2-lanes to 3-lanes, while maintaining 2-lanes of traffic on the bridge as it is being widened.

View these guidelines as warrants to consider a wider bridge, not as absolute “must build” design criteria.

10.2 Bridge Widening Warrants

The widening decision depends on the following factors.

- Projected traffic volumes for the year when the adjoining highway will be reconstructed or rehabilitated (not when the bridge will be overlaid or re-decked)
- The proposed project improvement type for the adjoining highway
- The hours during which highway construction will cause lane restrictions.

Bridge widening is warranted if the projected AADT reached 25,000. This AADT on a highway with average peaking characteristics would produce a DHV of approximately 1,700 vph.

Bridge widening may be warranted under the following conditions.

- If the projected AADT is between 20,000 and 25,000 and high seasonal peaking characteristics are present. This AADT on a highway with average peaking characteristics would produce a DHV of 1,400 vph and 1,700 vph respectively.
- If the projected AADT is less than 20,000 and high summer weekend traffic is present. In this situation, an hourly traffic demand and capacity analysis in the project areas is required to justify the need for a 3-lane bridge.

Also, consider whether the proposed construction would allow lanes to be re-opened during peak traffic hours.

Within the 75-year life cycle of a bridge on a Corridors 2030 Backbone route, there is typically a deck overlay that takes place 25-30 years after the original construction. The bridge is re-decked about 20-25 years after the overlay. After the bridge is re-decked, it is anticipated to last another 25-30 years, or the remainder of the structure’s useful life. The decision whether to widen in conjunction with the bridge rehabilitation or wait until the next highway rehabilitation project depends on the type of bridge work needed (i.e., replacement, re-decking, or overlay) and the timing of the next anticipated pavement reconstruction project.

10.2.1 Bridge Replacement or Re-Decking.

Bridge widening is warranted if reconstruction of the adjoining highway is anticipated within 20 years, and if the projected traffic volumes meet the warrants described above.

10.2.2 Bridge Deck Overlay

Typically, bridge widening isn’t done when a bridge is programmed for an overlay. However, bridge widening is warranted at the time of the overlay if highway reconstruction or rehabilitation is scheduled within 10 years and the work will require lane closures and will cause the traffic demand to exceed the capacity of the existing

---

[2] The 56-foot clear width bridge is based on three 12-foot lanes with 10-foot shoulders on each side. The final bridge width may vary from the typical 56-feet in some situations. This variation may be necessary to accommodate construction staging and other project specific requirements. The 56-foot clear width will allow for a work zone to have four 11-foot lanes, a barrier wall separating the 2 lanes of traffic in each direction, and approximately 2.5-foot shy distance on each side of the center barrier wall and 2.5-foot shy distance from the outside parapet walls. The shy distance may vary as well depending on construction staging.

facility.

10.3 Bridge Rehabilitation and Widening Practices

After the decision to widen has been made, there are 3 other decisions to make. The first is whether to widen both bridges at a location. Although widening both bridges is preferable because it allows future work zones to be separated from traffic by the median, it may be uneconomical or undesirable for other reasons. However, even if only one bridge is widened, construction traffic control can still be staged to maintain 2 lanes of traffic in each direction.

The second decision is whether to replace the entire existing deck, or to attach the widening to it. Refer to the Bridge Manual Chapter 40, Bridge Rehabilitation, particularly Section 40.8, “Widenings”. This section, in part, states that:

> *“Deck widenings, except on the Interstate, are attached to the existing decks if they are structurally sound and the remaining width is more than 50 percent of the total new width. If the existing deck is over 20 percent surface delaminated or spalled, the existing deck shall be replaced. For all deck widenings on Interstate Highway bridges, consideration shall be given to replacing the entire deck in order that total deck life is equal and costs are likely to be less when considering future traffic control. Evaluate the cost of traffic control for deck widenings on other highway bridges. The total deck should be replaced in these cases where the lifecycle cost difference is minimal if future maintenance costs are substantially reduced.”*

The third decision is whether to widen to the inside (median side), to the outside, or to both sides. This is decided on a case-by-case basis, but factors which may affect this decision include:

- Whether the widening construction is to be done under traffic,
- Environmental impacts,
- Right-of-way acquisition,
- Whether there are plans for capacity expansion on the approach roadway,
- Cross section geometry, including: clear roadway width of the bridge, median width, crown line, ditch depth, fill height, maximum side slopes, and clear zone,
- Vertical clearance (particularly if there is superelevation), usually below the bridge, but possibly above the bridge for multi-level sites,
- Drainage.

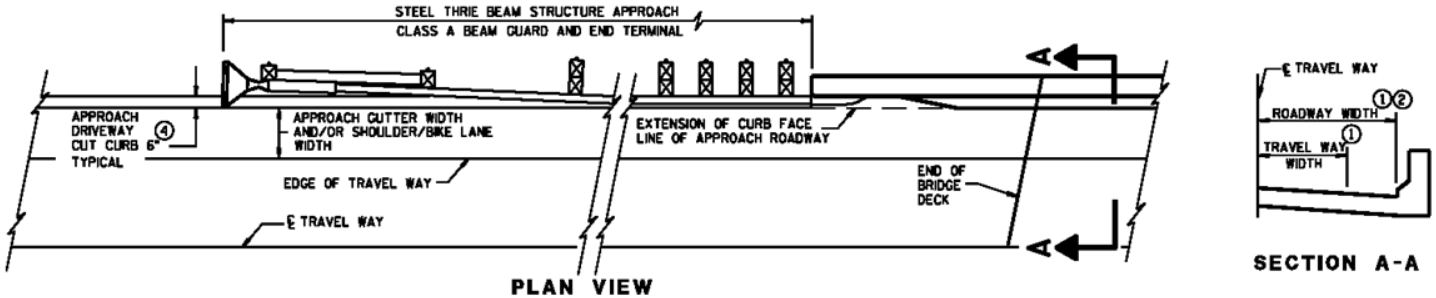
If the widened portion of the bridge isn’t to be used, other than for construction traffic handling, provide edgeline pavement marking similar to the adjoining highway. Shield the parapet wall with either an acceptable crash cushion, or with thrie beam and an energy-absorbing terminal.

10.4 Other Factors To Consider

When planning a bridge or a highway rehabilitation project, consider using a public awareness campaign to reduce the anticipated traffic and provide alternative detour routes where possible. In certain situations, this may eliminate the need for a wider bridge.

For bridges that are to be widened adjacent to live traffic lanes, consider requiring deck pours to be done during period of low traffic volume. This will reduce the vibrations that can cause an insufficient bond between the concrete and the reinforcing steel. Although important, this concern is generally considered to be less significant than the major user delay that will result if traffic is restricted and long queues develop.

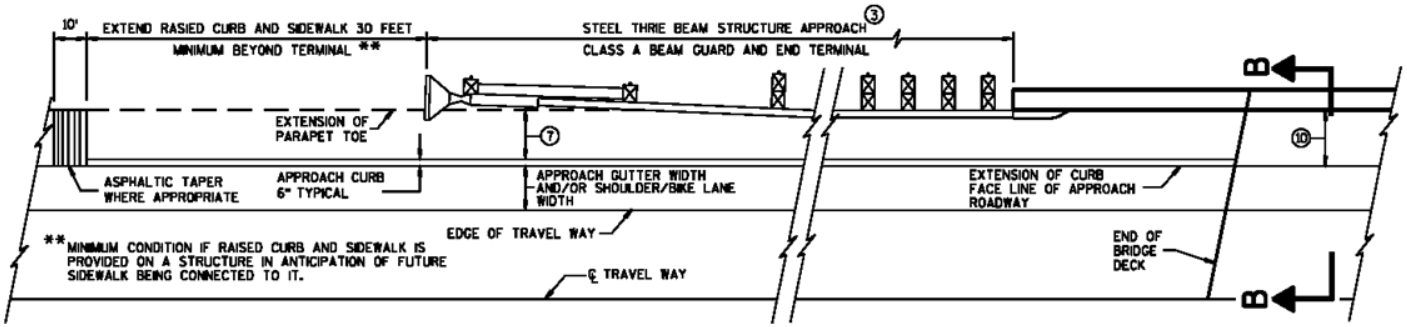
Consider funding availability and impacts on other projects in the program. This is especially true when making decisions on deck overly projects, and basing the decision on the timing of projected highway reconstruction projects that fall beyond the current 6-year program. Given the limited Backbone Program budget and the history of project cost increases and critical additions to the Backbone Program, it is possible that projects anticipated in 8-10 years may be delayed beyond this period. In these cases, consider waiting to do the widening until just before the reconstruction occurs.

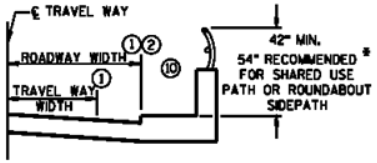


SECTION A-A

PLAN VIEW

BARRIER ON OUTSIDE EDGE OF ROADWAY (NO SIDEWALK, SHARED USE PATH, OR ROUNDABOUT SIDEPATH)

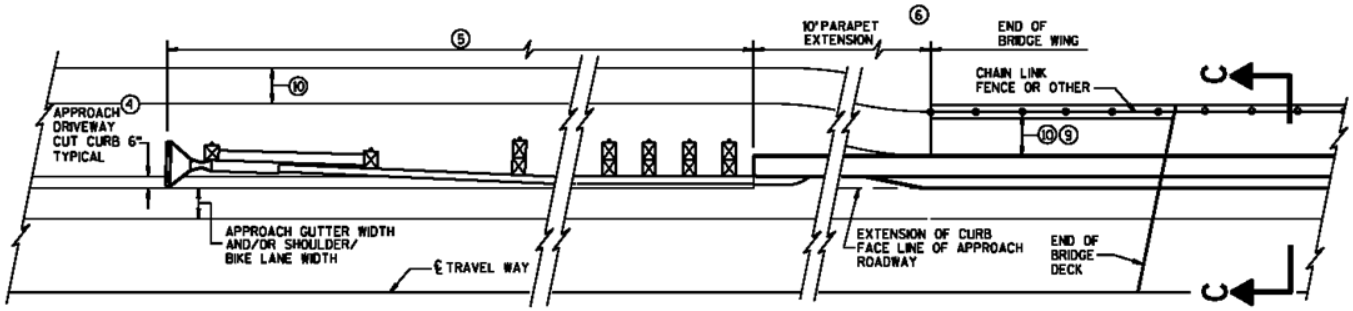


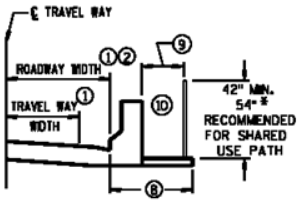


SECTION B-B

PLAN VIEW

BARRIER ON OUTSIDE EDGE OF SIDEWALK, SHARED USE PATH, OR ROUNDABOUT SIDEPATH - CURB ON OUTSIDE EDGE OF ROADWAY





SECTION C-C

* FOR CHAIN LINK FENCE, USE 5-FOOT MIN.

PLAN VIEW

BARRIER ON OUTSIDE EDGE OF ROADWAY WITH SEPARATED SIDEWALK, SHARED USE PATH, OR ROUNDABOUT SIDEPATH

See notes on p. 2 of this Attachment

Notes

① Refer to FDM 11-35-1.2 for guidance on “Clear Roadway Width of Bridges”

② Total width of approach pavement. Roadway width includes gutter-pan, shoulder width or both.

③ Use roadside barrier / end treatment if raised curb sidewalk is provided on a structure in anticipation of future sidewalk being connected to it. Extend the raised curb sidewalk at least 30 feet beyond the end of the barrier terminal. Terminate with a temporary asphaltic height transition ramp where appropriate. (See additional guidance in text in FDM 11-35-1.6.1, "sidewalks").

④ Urbanized areas with curb and gutter shall have a flat driveway cut type Curb 100 feet in advance of the energy absorbing terminal and continue to the third post, (see FDM 11-45-30.4.1.6, Curb and Gutter near EAT), transitional and rural areas may not have curb & gutter.

⑤ Barrier wall end protection is required. Use steel thrie beam structure Approach, Class A beam guard with end terminal or crash cushion.

⑥ If sidewalk/shared-use path/roundabout side path is behind the parapet

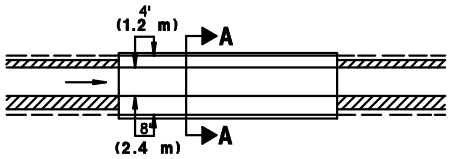
⑦ If a roadside barrier / end treatment is provided on the outside edge of a sidewalk/shared-use path/roundabout side path, then the sidewalk/shared-use path/roundabout side path may veer away from the back of the curb to create a terrace once it is past the terminal or crash cushion.

⑧ Distance from parapet toe to outside edge of sidewalk/shared-use path/roundabout side path

⑨ Sidewalk = 6-foot lower minimum if distance ⑧ <= 11 feet.
Sidewalk/roundabout side path = 10-foot lower minimum if distance ⑧> 11 feet (to allow bridge inspection Truck on sidewalk/roundabout side path.
Shared use path = 12 foot typical (required width = width of shared-use path + 2 feet).

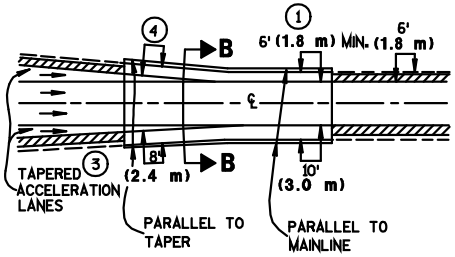
⑩ Sidewalk, shared-use path or roundabout side path

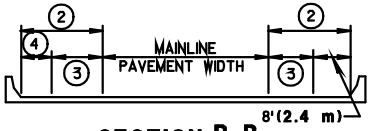
4-LANE DIVIDED HIGHWAY STRUCTURE WIDTHS



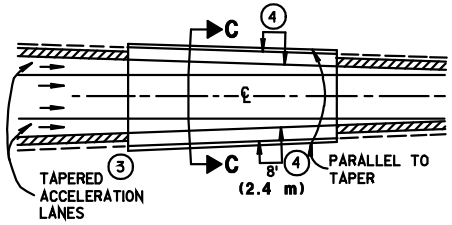
SECTION A-A

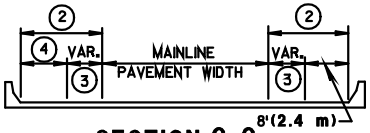
STANDARD RAMP STRUCTURE



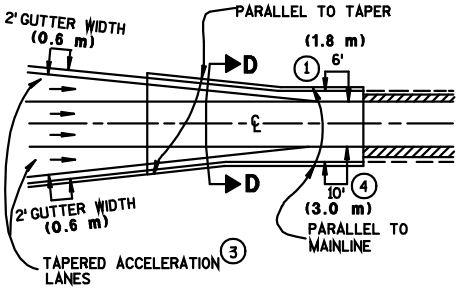


SECTION B-B

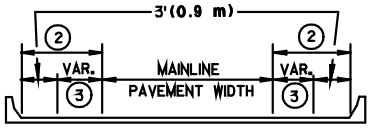




SECTION C-C



NOTE: CONTINUOUS APPROACH CURB



SECTION D-D

STRUCTURES WITH ACCELERATION LANES

(LEFT OR RIGHT RAMP ENTRANCES)

NOTES:

TAPERS AND LANES ARE SHOWN OPPOSITE EACH OTHER FOR PICTORIAL PURPOSES.

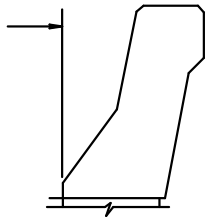
TOTAL STRUCTURE WIDTH IS A COMBINATION OF MAINLINE AND RAMP PAVEMENT WIDTHS PLUS MAINLINE OR RAMP SHOULDER WIDTHS. AN EXCEPTION IS THE WIDTH ASSOCIATED WITH AN APPROACHING CONTINUOUS CURB (SEE APPLICABLE DRAWING).

DASHED LINE INDICATES EDGE OF SHOULDER.

SHADOWED AREA BETWEEN EDGE OF APPROACH PAVEMENT AND EDGE OF SHOULDER REPRESENTS PAVED SHOULDER.

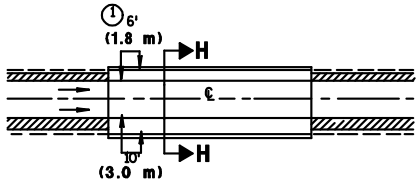
THE FACE OF THE STRUCTURE CURB SHALL BE A STRAIGHT LINE CONTINUATION OF THE SHOULDER LINE EXCEPT AS INDICATED.

1. USE 10' (3.0 m) WHERE MAINLINE MEDIAN SHOULDER WIDTH IS 10' (3.0 m).
2. EQUAL TO OR GREATER THAN APPROPRIATE MAINLINE ROAD SHOULDER WIDTH.
3. RAMP PAVEMENT TAPER WIDTH.
4. EQUAL TO THE APPROPRIATE DIRECTIONAL ROADWAY SHOULDER WIDTH.



POINT OF MEASUREMENT

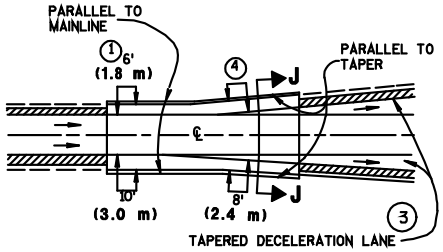
4-LANE DIVIDED HIGHWAY STRUCTURE WIDTHS



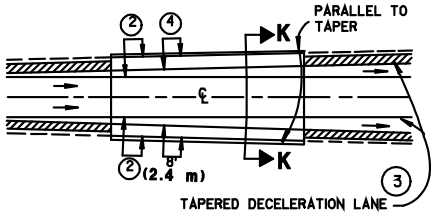
SECTION H-H

STANDARD "MAINLINE OVERPASS" STRUCTURE

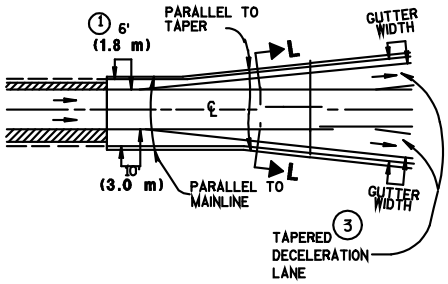
DIVIDED HIGHWAY (FOR DIVIDED HIGHWAYS WITH A MEDIAN WIDTH GREATER THAN 30'(9.0 m)PLUS MEDIAN SHOULDER WIDTHS)



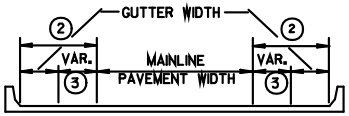
SECTION J-J



SECTION K-K



NOTE: CONTINUOUS APPROACH CURB



SECTION L-L

STRUCTURES WITH DECELERATION LANES

(LEFT OR RIGHT RAMP EXITS)

NOTES:

TAPERS OR LANES ARE SHOWN OPPOSITE EACH OTHER FOR PICTORIAL PURPOSES.

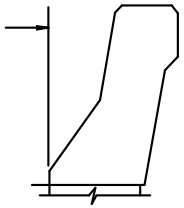
TOTAL STRUCTURE WIDTH IS A COMBINATION OF MAINLINE AND RAMP PAVEMENT WIDTHS PLUS FULL MAINLINE OR RAMP SHOULDER WIDTHS. AN EXCEPTION IS THE WIDTH ASSOCIATED WITH AN APPROACHING CONTINUOUS CURB (SEE APPLICABLE DRAWING).

DASHED LINE INDICATES EDGE OF SHOULDER.

SHADOWED AREA BETWEEN EDGE OF APPROACH PAVEMENT AND EDGE OF SHOULDER REPRESENTS PAVED SHOULDER.

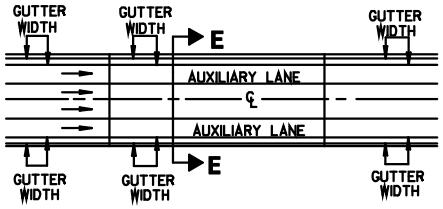
THE FACE OF THE STRUCTURE CURB SHALL BE A STRAIGHT LINE CONTINUATION OF THE SHOULDER LINE EXCEPT AS INDICATED.

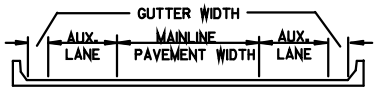
1. USE 10'(3.0 m) WHERE MAINLINE MEDIAN SHOULDER WIDTH IS 10'.(3.0 m)
2. EQUAL TO OR GREATER THAN APPROPRIATE MAINLINE ROAD SHOULDER WIDTH.
3. RAMP PAVEMENT TAPER WIDTH.
4. EQUAL TO THE APPROPRIATE DIRECTIONAL ROADWAY SHOULDER WIDTH.



POINT OF MEASUREMENT

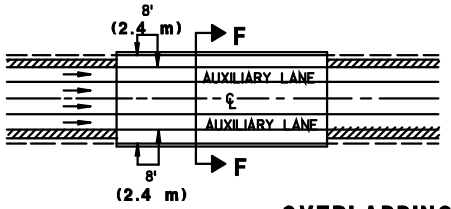
2, 4 AND 6 - LANE DIVIDED HIGHWAY STRUCTURE WIDTHS

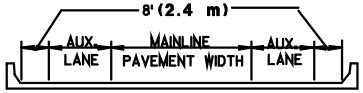




SECTION E-E

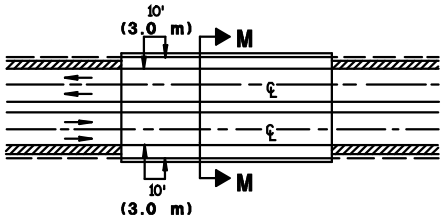
NOTE: CONTINUOUS APPROACH CURB

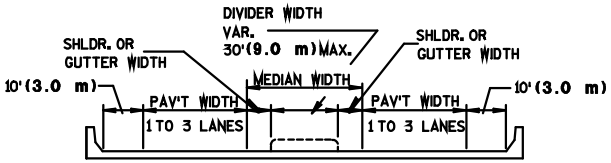




SECTION F-F

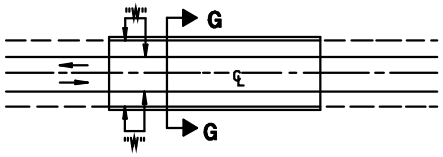
OVERLAPPING ACCELERATION-DECELERATION LANE (AUXILIARY LANE) STRUCTURE





SECTION M-M

COMBINED DUAL - LANE STRUCTURE



SECTION G-G

2 - LANE STRUCTURE WIDTHS

NOTES:

TAPERS OR LANES ARE SHOWN OPPOSITE EACH OTHER FOR PICTORIAL PURPOSES.

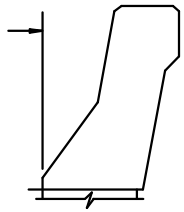
TOTAL STRUCTURE WIDTH IS A COMBINATION OF MAINLINE AND RAMP PAVEMENT WIDTHS PLUS FULL MAINLINE OR RAMP SHOULDER WIDTHS. AN EXCEPTION IS THE WIDTH ASSOCIATED WITH AN APPROACHING CONTINUOUS CURB (SEE APPLICABLE DRAWING).

DASHED LINE INDICATES EDGE OF SHOULDER.

SHADOWED AREA BETWEEN EDGE OF APPROACH PAVEMENT AND EDGE OF SHOULDER REPRESENTS PAVED SHOULDER.

THE FACE OF THE STRUCTURE CURB SHALL BE A STRAIGHT LINE CONTINUATION OF THE SHOULDER LINE EXCEPT AS INDICATED.

DESIGN CLASS	"W"
A 1	6' (1.8 m)
A 2	10' (3.0 m)
2-LANE INTERCHANGE STRUCTURES OVER-PASSING DESIGN CLASS A 2 HIGHWAYS	8' (2.4 m) MIN.

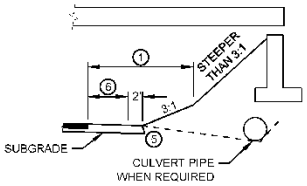


POINT OF MEASUREMENT

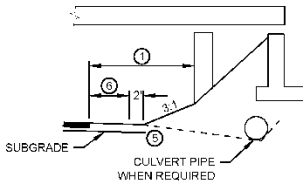
NOTE: FOR COUNTY TRUNK AND TOWN ROAD STRUCTURES SEE APPROPRIATE STANDARDS FOR STRUCTURE WIDTHS.

LATERAL UNDERCLEARANCES TO STRUCTURE FOR BRIDGES ON RURAL HIGHWAYS, EXPRESSWAYS, AND FREEWAYS, INCLUDING URBAN ROADWAYS WITH RURAL CROSS-SECTIONS

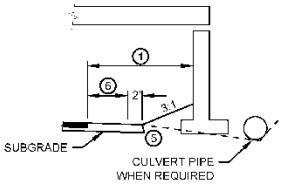
WITHOUT TRAFFIC BARRIER (DESIRABLE) PREFERRED SECTION *



(a) To a critical slope

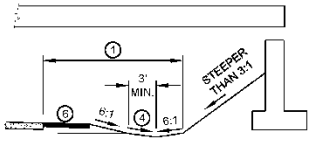


(b) To a pier or column

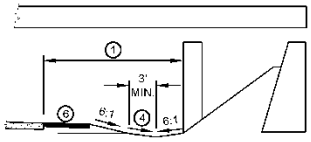


(c) To an abutment or wall that is not suitable as a barrier

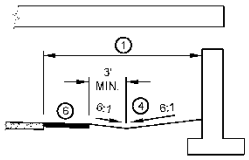
WITHOUT TRAFFIC BARRIER (DESIRABLE) ALTERNATE SECTION *



(d) To a critical slope



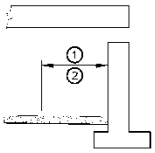
(e) To a pier or column



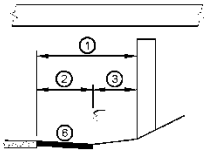
(f) To an abutment or wall that is not suitable as a barrier

* Consider using the "Alternate Section" on the high side of superevelvated sections to help reduce the potential for snowmelt water to drain across the roadway.

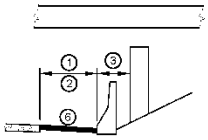
WITH TRAFFIC BARRIER (MINIMUM)



(g) To retaining wall, abutment or pier that is suitable as a barrier. Also applies to vertical fillet concrete barrier wall between columns.



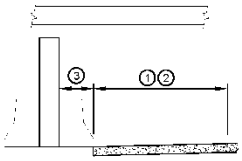
(h) To a pier or column or wall that is not suitable as a barrier and which is shielded by a beamguard



SAFETY SHAPE OR SINGLE SLOPE CONCRETE BARRIER

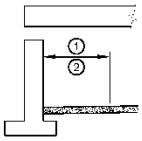
(i) To a pier or column or wall that is not suitable as a barrier and which is shielded by a concrete barrier.

MEDIAN SIDE EXAMPLE

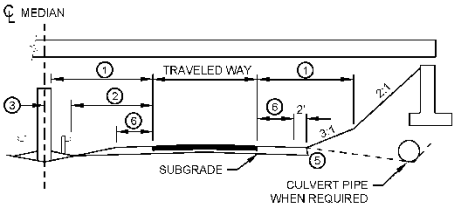


SAFETY SHAPE OR SINGLE SLOPE CONCRETE BARRIER

(j) To a pier or column that is not suitable as a barrier, and which is shielded by a concrete barrier.



(k) To a pier that is suitable as a barrier. Also applies to vertical fillet concrete barrier wall between columns.



(l) To a pier or column or wall that is not suitable as a barrier and which is shielded by a beamguard.

LEGEND

①	Lateral underclearance to structure as defined in text.
②	Lateral distance from edge of thru lane to beam guard face or to concrete barrier face at the toe.
③	Lateral distance from beamguard face or from concrete barrier face at the toe to face of fixed object (abutment, column, pier, or wall).
④	Ditch dimensions are determined by drainage requirements. Alternate traversable ditch cross-sections may be used. See FDM 11-15, Attachment 1.11
⑤	Perforated pipe underdrain may be required when free draining native soils are not present.
⑥	Shoulder width per FDM 11-15, Attachment 1.1 - 1.5 and 1.16 - 1.18

[A] Lateral Underclearance to structure for RURAL HIGHWAYS, EXPRESSWAYS, and FREEWAYS, including URBAN ROADWAYS with rural cross-sections

[B] Barrier type used	Distance	Mainline		Ramp	
		Left	**Right**	**Left**	**Right**
None (a-f)	①	**Lower MIN. =** The GREATEST of [C]Clear Zone Width OR [D] Lateral Clearance OR 4 feet	**Lower MIN. =** The GREATEST of [C]Clear Zone Width OR [D] Lateral Clearance OR 6 feet for 2-lane highway OR 10 feet for multi - lane divided	**Lower MIN. =** The GREATEST of [C] Clear Zone Width OR [D] Lateral Clearance OR 2 feet	**Lower MIN. =** The GREATEST of [C]Clear Zone Width OR [D]Lateral Clearance OR 4 feet
Beam guard (h, I)	①	= Dist. ② + Dist. ③	= Dist. ② + Dist. ③, Not < 6 feet for 2-lane highways Not <10 feet for multi-lane divided	= Dist. ② + Dist. ③	= Dist. ② + Dist. ③
	②	**Lower MIN. =** [D] Lateral Clearance			
	③ Vehicle protection	**Lower MIN.** = 4'-6"			
[E] Safety shape concrete barrier; Single slope concrete barrier (i, j)	①	= Dist. ②	= Dist. ②	= Dist. ②	= Dist. ②
	②	**Lower MIN. =** The GREATER of [D]Lateral Clearance OR 4 feet	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 6 feet for 2-lane highway OR 10 feet for multi -lane divided	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 2 feet	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 4 feet
	③ Vehicle protection	{Safety-shape concrete barrier with height >=32-inch } **Lower MIN. =** 2'-6" {Single-slope concrete barrier with height >=32-inch } **Lower MIN. = Working width (see** FDM 11-45-30**)**			
	③ Structure protection	{Either safety-shape or single-slope concrete barrier with height >=42-inch and <54-inch } **Lower MIN.** = 10'-0" {Either safety-shape or single-slope concrete barrier with height >=54-inch} **Lower MIN. =** 2'6"			
[E] Vertical wall concrete barrier (g, k)	①	= Dist. ②	= Dist. ②	= Dist. ②	= Dist. ②
	②	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 4 feet	**Lower MIN. =** The GREATER of [D]Lateral Clearance OR 6 feet for 2-lane highway OR 10 feet for multi -lane divided	**Lower MIN. =** The GREATER of [D]Lateral Clearance OR 2 feet	**Lower MIN. =** The GREATER of [D]Lateral Clearance OR 4 feet
	③ Vehicle protection	Existing structures: {vertical fillet concrete barrier wall between columns with height >=51-inch} **MIN**. = **MAX**. = 0"			
[E] solid shaft style piers; full retaining abutments (g, k)	①	= Dist. ②	= Dist. ②	= Dist. ②	= Dist. ②
	②	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 4 feet	**Lower MIN. =** The GREATER of [D]Lateral Clearance OR 6 feet for 2-lane highway OR 10 feet for multi -lane divided	**Lower MIN. =** The GREATER of [D]Lateral Clearance OR 2 feet	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 4 feet

Letters in parentheses (a) thru (I) refer to examples shown on page 1 of this attachment; distance numbers ① thru ③ refer to the legend on page 1.

Notes:

A Lateral Underclearance to Structure is non-controlling criteria.

Lateral Underclearance to Structures requirements to the right applies to both sides of undivided bi-directional roadways, the right side of 1-way streets and ramps, and the outside lanes of divided highways. Lateral Underclearance to Structures requirements to the left applies to the left side of 1-way streets and ramps, and the median side of divided highways.

B See text under section "Barrier Considerations" for discussion of and criteria for Vehicle Protection Barriers and Structure Protection Barriers.

For new and replacement structures, it is desirable to construct new and replacement structures so that a barrier is not needed on the **right (outside)**. Explain in the DSR if barrier is required on the **right (outside)**.

If barrier is used, then provide appropriate length of need, transitions and terminals in advance of and beyond the structure.

For new and replacement structures it may be necessary to provide solid shaft style piers or full retaining abutments at locations where it is not possible to provide a lower minimum distance ③. These need to meet structural load requirements, and to be geometrically, structurally, and texturally suitable as a barrier wall.

For existing structures, it is most important to provide the full approach traveled way and shoulder width through the structure. Provide the maximum distance ③ possible without encroaching onto the required shoulder width and lateral clearance.

C Clear Zone Width per Table "Clear Zone Distance Table (In Feet from Edge of Traveled Way)" on FDM 11-15 Attachment 1.9.

For the "PREFERRED SECTION", use the maximum distances shown in the "BACKSLOPES" columns for a 1V:3H slope (for example, with a design speed of 60 mph, ADT = 6500, and slope = 3H: 1V, the required distance would be 22-feet).

For the "ALTERNATE SECTION", use 30-feet or the maximum distances shown in the 1V:6H "FORESLOPES" column, whichever is less (for example, with a design speed of 60 mph, ADT = 6500, the required distance would be 30-feet even though the table distance is 32-feet).

If there is an auxiliary lane check the clear zone requirements for the auxiliary lane based on its traffic volume and speed conditions. Use the greater of the through traffic lane or auxiliary lane requirement.

D Lateral Clearance requirements per FDM 11-15 Table 1.2 "Required Lateral Clearance from Edge of Driving Lane for Rural Highways".

E Use concrete barrier of the same height as on the approach roadway, unless the above table requires a greater height.

For one-way traffic, vehicle protection concrete barrier of the required height and shape is to begin 25 feet in advance of the upstream substructure unit and to extend 30 feet, or to the end of the downstream substructure unit, whichever is longer.

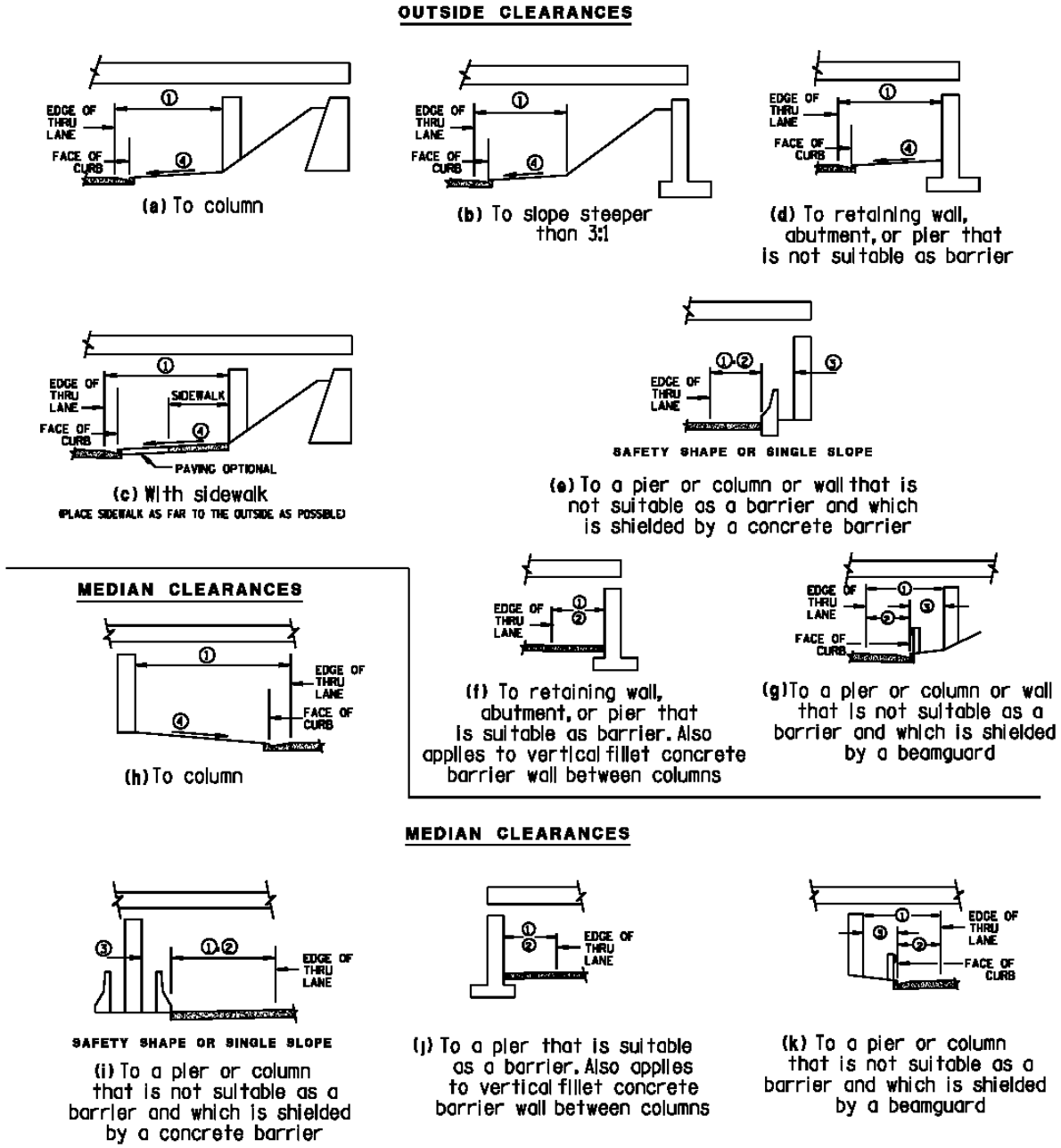
For two-way traffic, vehicle protection concrete barrier of the required height and shape is to begin 25 feet in advance of the upstream substructure unit and to extend 25 feet beyond the end of the downstream substructure unit.

Confer and coordinate with the Bureau of Structures (BOS) and the Bureau of Project Development (BPD) on the required length of structure protection concrete barrier.

Connect other appropriate barrier types to the ends of the concrete barrier and provide appropriate lengths of need, transitions and terminals.

Use a lower minimum transition length of 15 feet to go from/to safety-shape (or single-slope) concrete barrier to/from vertical face concrete barrier. Use an 8:1 taper ratio for vertical height transitions.

LATERAL UNDERCLEARANCES TO STRUCTURES FOR URBAN STREETS



Legend:

①	Lateral Underclearance to structure as defined in text
②	Lateral distance from edge of thru lane to beam guard face or to concrete barrier face at the toe
③	Lateral distance from beam guard face or from concrete barrier face at the toe to face of fixed object (abutment, column, pier, or wall)
④	Cross-slopes: see FDM 11-20-1 and FDM 11-46-5

[A] Lateral Underclearance to Structure for URBAN STREETS

[B] Barrier type used	Distance		Arterial		Non-Arterial
			Left	Right	Left & Right
None (a-d, h)	①	[C] If Clear Zone is provided	**Lower MIN. =** The GREATEST of [C] Clear Zone OR 4 feet OR offset from edge of thru lane to face of curb +2 feet	**Lower MIN. =** The GREATEST of [C] Clear Zone OR 6 feet OR offset from edge of thru lane to face of curb +4 feet	**Lower MIN. =** The GREATEST of [C] Clear Zone OR 4 feet OR offset from edge of thru lane to face of curb +2 feet
			Upper MIN. = The GREATEST of [C] Clear Zone OR 10 feet OR offset from edge of thru lane to face of curb +4 feet	**Upper MIN.** = The GREATEST of [C] Clear Zone OR 12 feet OR offset from edge of thru lane to face of curb +4 feet	**Upper MIN.** = The GREATEST of [C] Clear Zone OR 10 feet OR offset from edge of thru lane to face of curb +4 feet
		[C] If Clear Zone isn't provided	**Lower MIN. =** the GREATER of 4 feet OR offset from edge of thru lane to face of curb +2 feet	**Lower MIN. =** the GREATER of 6 feet OR offset from edge of thru lane to face of curb +4 feet	**Lower MIN. =** the GREATER of 4 feet OR offset from edge of thru lane to face of curb +2 feet
			Upper MIN. = The GREATER of 10 feet OR offset from edge of thru lane to face of curb +4 feet	**Upper MIN.** = The GREATER of 12 feet OR offset from edge of thru lane to face of curb +4 feet	**Upper MIN.** = The GREATER of 10 feet OR offset from edge of thru lane to face of curb +4 feet
Beam guard (g, k)	①		= Dist. ② + Dist. ③	= Dist. ② + Dist. ③, but not < 6 feet	= Dist. ② + Dist. ③
	②		**Lower MIN. =** [D] Lateral Clearance		
	③	Vehicle protection	MIN. = 4'-6"		
[E] Safety shape concrete barrier; Single slope concrete barrier (e, i)	①		= Dist. ②	= Dist. ②	= Dist. ②
	②		**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 4 feet	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 6 feet	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 4 feet
	③	Vehicle protection	{Safety-shape concrete barrier with height >=32-inch } **Lower MIN. =** 2'-6" {Single-slope concrete barrier with height >=32-inch } **Lower MIN. = Working width (see** FDM 11-45-30**)**		
		Structure protection	{Either safety-shape or single-slope concrete barrier with height >=42-inch and <54-inch } **Lower MIN.** = 10'-0" {Either safety-shape or single-slope concrete barrier with height >=54-inch} **Lower MIN. =** 2'6"		
[E] Vertical wall concrete barrier (f, j)	①		=Dist. ②	=Dist. ②	=Dist. ②
	②		**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 4 feet	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 6 feet	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 4 feet
	③	Vehicle protection	Existing structures: {vertical fillet concrete barrier wall between columns with height >=51-inch} **MIN**. = **MAX**. = 0"		
[E] Solid shaft style piers; full retaining abutments (f, j)	①		=Dist. ②	=Dist. ②	=Dist. ②
	②		**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 4 feet	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 6 feet	**Lower MIN. =** The GREATER of [D] Lateral Clearance OR 4 feet

Letters in parentheses (a) thru (k) refer to examples shown on page 1 of this attachment; distance numbers ① thru ③ refer to the legend on page 1.

Notes:

A Lateral underclearance to Structure is non-controlling criteria.

Lateral underclearance to structures requirements to the right applies to both sides of undivided bi-directional roadways, the right side of 1-way streets and ramps, and the outside lanes of divided highways. Lateral underclearance to structures requirements to the left applies to the left side of 1-way streets and ramps, and the median side of divided highways.

B See text under section "Barrier Considerations" for discussion of and criteria for Vehicle Protection Barriers and Structure Protection Barriers.

For new and replacement structures, it is preferred to provide sufficient lateral underclearance so that a barrier is not needed. If barrier is used, then provide appropriate length of need, transitions, and terminals in advance of and beyond the structure.

It may be necessary to provide solid shaft style piers or full retaining abutments at locations where it is not possible to provide a lower minimum distance ③. These need to meet structural load requirements, and to be geometrically, structurally, and texturally suitable as a barrier wall.

For existing structures, it is most important to provide the full approach traveled way and shoulder width (or gutter width) through the structure. Provide the maximum distance ③ possible without encroaching onto the required shoulder width (or gutter width) and Lateral clearance.

C Clear Zone Width per FDM 11-15 Attachment 1.9. This clear distance may not be practical in urban areas where right-of-way costs are higher and traffic conditions are different than in rural areas. If there is an auxiliary lane check the clear zone requirements for the auxiliary lane based on its traffic volume and speed conditions. Use the greater of the through traffic lane or auxiliary lane requirement.

See FDM 11-20 Table 1.6 for clear zone requirements on urban roadways.

D See FDM 11-20 Table 1.5 for Lateral Clearance requirements

E Use concrete barrier of the same height as on the approach roadway, unless the above table requires a greater height.

For one-way traffic, vehicle protection concrete barrier of the required height and shape is to begin 25 feet in advance of the upstream substructure unit and to extend 30 feet, or to the end of the downstream substructure unit, whichever is longer.

For two-way traffic, vehicle protection concrete barrier of the required height and shape is to begin 25 feet in advance of the upstream substructure unit and to extend 25 feet beyond the end of the downstream substructure unit.

Confer and coordinate with the Bureau of Structures (BOS) and the Bureau of Project Development (BPD) on the required length of structure protection concrete barrier.

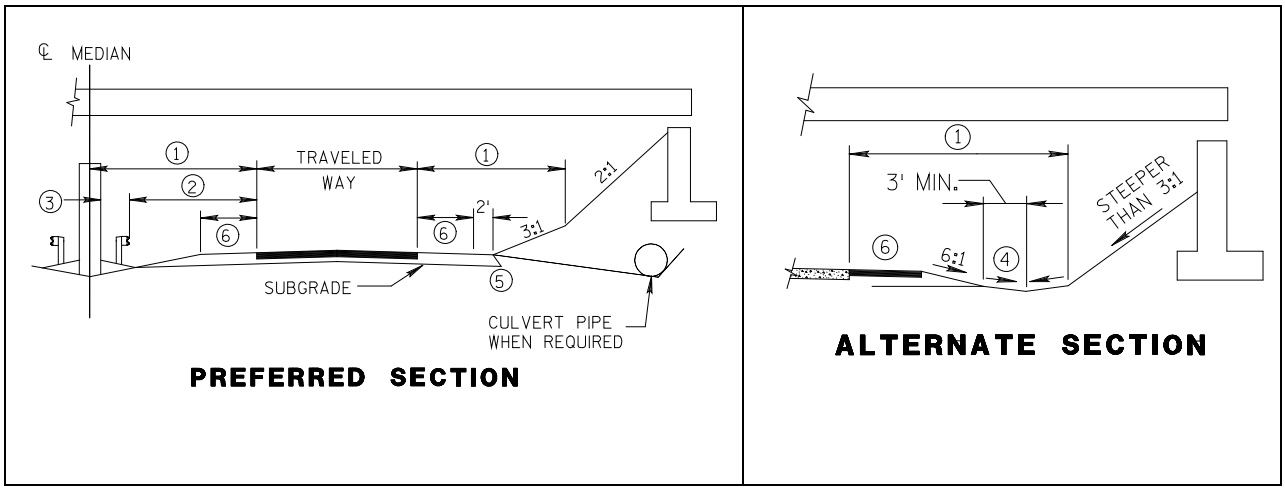
Connect other appropriate barrier types to the ends of the concrete barrier and provide appropriate lengths of need, transitions and terminals.

Use a lower minimum transition length of 15 feet to go from/to safety-shape (or single-slope) concrete barrier to/from vertical face concrete barrier. Use an 8:1 taper ratio for vertical height transitions.

Example 1 – Replacement Bridge over 4-lane rural freeway

Given

- 4-lane rural freeway
- Design year AADT = 25,000
- Design speed = 70 MPH;
- Tangent alignment;
- Lane width = 12 feet;
- Shoulder width = 10-ft RT; 6-ft LT
- Median width = 60 feet
- Structure protection barrier is not needed according to BOS.



Find

A. Required lower minimum lateral underclearance to structure (distance ①) to the right if barrier is not used

Solution

A. Required lower minimum lateral underclearance to structure to the right if barrier is not used:

1. Go to FDM 11-35 Attachment 1.5
2. Start in the 1st column of the table [Barrier type used]
3. Go to the row for "None"
4. Go across this row to the column for "Mainline – Right", which shows the distance ① requirement as:

   "The GREATEST of [C]Clear Zone Width OR [D]Lateral Clearance OR 6 feet for 2-lane highway OR 10 feet for multi - lane divided."

5. Compute clear zone distances for both the PREFERRED and ALTERNATE sections per note C under the table: "Clear Zone Width per Table "Clear Zone Distance Table (In Feet From Edge of Traveled Way)" on FDM 11-15 Attachment 1.9. / For the "PREFERRED SECTION", use the maximum distances shown in the "BACKSLOPES" columns for a 1V:3H slope / For the "ALTERNATE SECTION", use 30-feet or the maximum distances shown in the 1V:6H "FORESLOPES" column, whichever is less"
   - The Clear Zone requirement for the PREFERRED section = the maximum distance shown in the "BACKSLOPES" columns for a 1V:3H slope in the above-mentioned table = 24 feet for a design speed of 70 mph and AADT of 25,000. Therefore, the Clear Zone requirement for the PREFERRRED section is 24 feet.
   - The Clear Zone requirement for the ALTERNATE section = 30 feet or the maximum distances shown in the 1V:6H "FORESLOPES" column, whichever is less.
     The Clear Zone requirement from the table is 34 feet for a design speed of 70 mph and AADT of 25,000. Therefore, the Clear Zone requirement for the ALTERNATE section is 30 feet because it is less than 34 feet.

6. Compute lateral clearance per note D under the table: Lateral Clearance requirements per FDM 11-15 Table 1.2 “Required Lateral Clearance from Edge of Driving Lane for Rural Highways”.
   - Go to the above-mentioned Table 1 for ROAD TYPE = “All STH's / Arterials / non-STH Collector and Local Roads (i.e., non-arterials) with Design Year AADT ≥ 1500”;
   - Use the column for “WITHOUT roadside barrier”. The lateral clearance requirement is shown as: “Upper and Lower Minimum = The GREATER of 6 ft OR finished shoulder width + 2 ft”
   - Lateral clearance is the greater of either 6 feet or (shoulder width + 2 feet) = (10-feet + 2 feet) = 12 feet. Therefore, Lateral Clearance = 12-feet because it is greater than 6-feet.

The lateral underclearance to structure requirement distance ① is based on the clear zone distances because the clear zone distances are greater than both the lateral clearance requirement and the 10-foot lower minimum requirement for multi-lane divided highways. Therefore:

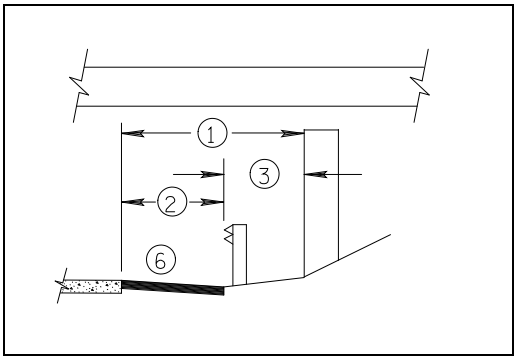
Distance ① = 24-feet, if the PREFERRED section is used.

Distance ① = 30-feet if the ALTERNATE section is used.

Example 2 – existing bridge over 2-lane rural highway

Given

- 2-lane rural STH
- Design year AADT = 2500
- Design speed = 60 MPH;
- Tangent alignment;
- Lane width = 12 feet;
- Shoulder width = 6-ft
- 3-span bridge with face of piers at 12-feet from edge of travel lane
- Structure protection barrier is not needed according to BOS.



Find

A. Determine if vehicle protection barrier is needed to shield the piers.

B. If vehicle protection barrier is needed, determine if beamguard is an option.

Solution

A. Determine if vehicle protection barrier is needed to shield the piers:

1. Go to Attachment 5, page 2
2. Start in the 1st column of the table [Barrier type used]
3. Go to the row for "None"
4. Go across this row to the column for "Mainline – Right", which shows the distance ① requirement as:

   "The GREATEST of [C] Clear Zone Width OR [D] Lateral Clearance OR 6 feet for 2-lane highway OR 10 feet for multi -lane divided."

5. Compute clear zone distances for only the PREFERRED section per note C under the table: "Clear Zone Width per Table "Clear Zone Distance Table (In Feet from Edge of Traveled Way)" on FDM 11-15 Attachment 1.9. / For the "PREFERRED SECTION", use the maximum distances shown in the "BACKSLOPES" columns for a 1V:3H slope / For the "ALTERNATE SECTION", use 30-feet or the maximum distances shown in the 1V:6H "FORESLOPES" column, whichever is less"
   - The Clear Zone requirement for the PREFERRED section = the maximum distance shown in the "BACKSLOPES" columns for a 1V:3H slope in the above-mentioned table = 18 feet for a design speed of 60 mph and AADT of 2500. Therefore, the Clear Zone requirement for the PREFERRRED section is 18 feet.
6. Compute lateral clearance per note D under the table: Lateral Clearance requirements per FDM 11-15 Table 1.2 "Required Lateral Clearance from Edge of Driving Lane for Rural Highways".
   - Go to the above-mentioned Table 1 for ROAD TYPE = "All STH's / Arterials / non-STH Collector and Local Roads (i.e., nonarterials) with Design Year AADT ≥ 1500";
   - Use the column for "WITHOUT roadside barrier". The lateral clearance requirement is shown as: "Upper and Lower Minimum = The GREATER of 6 ft OR finished shoulder width + 2 ft"
   - Lateral clearance is the greater of either 6 feet or (shoulder width + 2 feet) = (6-feet + 2 feet) = 8 feet. Therefore, Lateral Clearance = 8-feet because it is greater than 6-feet.

The lateral underclearance to structure requirement distance ① is based on the clear zone distance because the clear zone distance is greater than both the lateral clearance requirement and the 6-foot lower minimum requirement for 2-lane highways. Therefore, the lower minimum required Distance ①, if barrier is not used, is 18-feet. The existing distance ① of 12-feet is less than this. Therefore:

Vehicle protection barrier is required

B. If vehicle protection barrier is needed, determine if beam guard is an option:

1. Go to Attachment 5, page 2
2. Start in the 1st column of the table [Barrier type used]
3. Go to the row for "Beam Guard"
4. Go across this row to the column for "Mainline – Right", (NOTE: "lateral underclearance to the right" applies to both sides of the road because this is an undivided bidirectional highway.) which shows the distance ① requirement as:

   "Dist. ② + Dist. ③, Not < 6 feet for 2-lane highways; Not <10 feet for multi-lane divided."

5. Compute lateral clearance per note D under the table: Lateral Clearance requirements per FDM 11-15 Table 1.2 "Required Lateral Clearance from Edge of Driving Lane for Rural Highways".
   - Go to the above-mentioned Table 1 for ROAD TYPE = "All STH's / Arterials / non-STH Collector and Local Roads (i.e., nonarterials) with Design Year AADT ≥ 1500";
   - Use the column for "WITH roadside barrier". The lateral clearance requirement is shown as: "Upper Minimum = The GREATER of 6 ft OR finished shoulder width; Lower minimum = The GREATER of 4 ft OR finished shoulder width"
   - Lateral clearance is the greater of either (6-feet upper minimum / 4-feet lower minimum) or (shoulder width=6-feet).

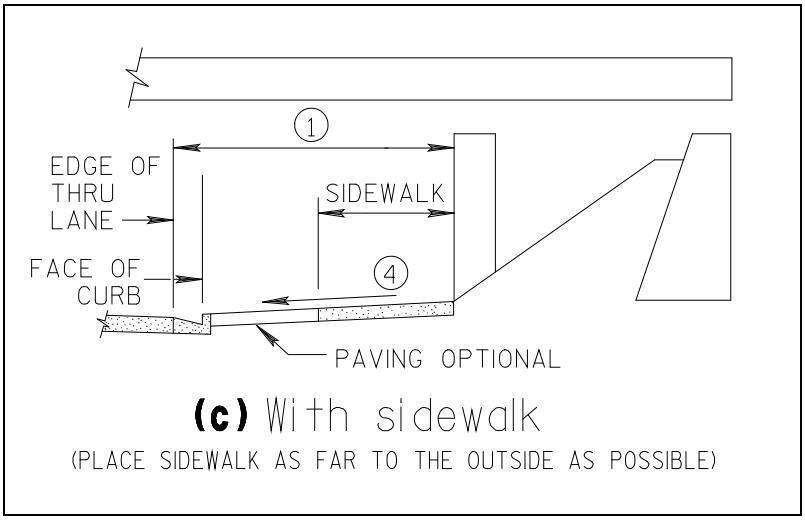
     Therefore, Dist. ②= Lateral Clearance = 6-feet because the shoulder width meets the upper minimum requirement and exceeds the lower minimum requirement.
6. Lower minimum required Dist. ③ for beam guard as vehicle protection barrier = 4'6" (From the table on p.2 of Attachment 5). Distance ③ provided = 6-feet
7. Lower minimum required Distance ① = Dist. ② + Dist. ③ = 6' + 4'6" = 10'6". Distance ① provided = 6' + 6' = 12'

Beam guard may be used to shield the piers because the distance ③ provided of 6-feet is greater than the minimum required distance of 4'-6", and the existing distance ① of 12-feet is greater than the minimum required distance ① of 10'6" and is also greater than the 6-foot minimum requirement for 2-lane highways.

Example 3 – existing bridge over 4-lane urban arterial

Given

- 4-lane un-divided urban arterial in developed area
- Design year AADT = 12,000
- Posted speed = 45 MPH;
- Tangent alignment;
- Lane width = 12 feet;
- Clear zone has not been provided for the roadway based on FDM 11-20 Table 1.6 "Recommended Clear Zone for Urban Roadways—New Construction and Reconstruction"
- Offset from thru lane to curb face = 6-ft
- There is no barrier
- Sidewalk is 5-feet wide and abuts back of curb
- The offset from curb face to outside edge of sidewalk = 5.5 feet
- 3-span bridge with face of piers at 11.5 feet from edge of thru lane – no work is proposed to be done on the structure
- Structure protection barrier is not needed according to BOS.



Find

A. Determine if design criteria for lateral underclearance to structure are met.

B. Determine if the sidewalk meets lower minimum requirements

C. Determine if a barrier is required between the roadway and the sidewalk

Solution

A. Determine if design criteria for lateral underclearance to structure are met:

1. Go to Attachment 6, page 2
2. Start in the 1st column of the table [Barrier type used]
3. Go to the row for "None - Clear Zone isn't provided"
4. Go across this row to the column for "Arterial – Right", (NOTE: The lateral underclearance to the right applies to both sides of the roadway because this is an undivided bi-directional roadway.) which shows the distance ① requirement as:

   *"**Lower MIN**. = the GREATER of 6 feet OR offset from edge of thru lane to face of curb +4-feet*
   ***Upper MIN**. = The GREATER of 12 feet OR offset from edge of thru lane to face of curb +4 feet"*

5. Test for the Lower minimum condition:
   - (Offset from travel lane to pier) = 11.5 feet > 6 feet **[MET]**
   - (Offset from curb face to pier) = (Offset from travel lane to pier) – (Offset from travel lane to curb

face) = 11.5-ft - 6-ft = 5.5 ft > 4-ft **[MET]**
[The MINIMUM condition is met]

6. Test for the ***Upper MININIMUM*** condition:
   - 11.5 feet (offset from travel lane to pier)< 12 feet **[NOT MET]**
     [The DESIRABLE condition is NOT met]

The Design Justification (DJ) isn't required because the lower minimum requirement has been met or exceeded. However, justification is required in the DSR for not meeting upper minimum design criteria.

B. Determine if the sidewalk meets lower minimum requirements:

1. Go to the 2nd and 3rd paragraphs in the subsection for "Sidewalks" in the text: "Sidewalks under new, replacement and existing structures with a terrace between the back of curb and sidewalk shall have a lower minimum width of 5 feet. Sidewalks under new, replacement and existing structures where the sidewalk is adjacent to the back of curb shall have a lower minimum width of 6 feet from face of curb to the back of sidewalk. If a parapet or barrier separation device is used between the roadway and the sidewalk then the lower minimum width of sidewalk under new, replacement and existing structures shall be 6 feet. A wider sidewalk may be justified where high pedestrian usage is anticipated.

   If conditions require that a sidewalk under an existing structure remain in place with less than the lower minimum width then provide justification in the DSR based on an evaluation of current use, width, safety, and ADA requirements."

Justification in the DSR is required because the offset from curb face to outside edge of sidewalk of 5.5 feet is < 6-foot lower minimum requirement for a sidewalk abutting the back of curb.

C. Determine if a barrier is required between the roadway and the sidewalk:

1. In the subsection for "Sidewalks", go to the paragraph just above Table 1 "Barrier Wall Separation Required Between Roadway and Sidewalk":

   "A structure shall include a parapet or barrier wall to separate the roadway from a sidewalk based on Table 1 for the proposed posted speed…."

2. The above-mentioned Table 1 shows that barrier wall separation is required between roadway and sidewalk for a "*new, reconstructed, or rehabilitated structure"* if the posted speed is >= 45 mph. It is not required for structures not meeting these criteria but could be provided if "*requested by community and agreed to by designer*".

A barrier isn't required between the roadway and sidewalk because work is not being done on the structure. However, a barrier could be included if requested by the community and agreed to by the designer.

Vertical Clearance for Construction of New Bridges, Replacement Bridges, and Bridges on which the Superstructure is being replaced [1]

Overpass Facility →	Freeway, Expressway, or STH		Railroad[4], CTH, Town Road, Local Road, or Street	Pedestrian or Shared-use Structures	Sign Structures[2]
Underpass Facility ↓	Interchange	Grade Separation			
Non-arterial either STH, CTH, Town Road, Local Road, or Street	15'-9" Upper Min. 15'-3" Lower min.	15'-3" Upper Minimum 14'-9" Minimum		16'- 9" Upper Minimum 16'-3" Minimum	18'-3" Lower Minimum
Arterial either CTH, Town Road, Local Road, or Street (**excludes** freeway and expressway; also excludes arterial STH)	16'-9" Upper Min. 16'-3" Lower min.	15'-3" Upper Minimum 14'-9" Lower Minimum		17'- 9" Upper Minimum 17'-3" Lower Minimum	
Freeway[3] or Expressway or arterial STH	16'-9" Upper Minimum 16'-4" Lower Minimum			17'- 9" Upper Minimum 17'-4" Lower Minimum	
Railroad[4,5,6,7]	23'-0" Lower Minimum to 23'-3½" Maximum				

General notes:

1 Vertical clearance is needed for the entire roadway width (critical point; to include traveled way, auxiliary lanes, turn lanes, and shoulders), according to the above table.
Vertical clearance for railroads is measured from the top of rail and is required over an area 8 feet 6 inches from the track centerline on each side of a railroad track.
Do not exceed the desirable vertical clearance shown unless justified. Depending on topography and other specific situations vertical clearance for any structure may be greater than that shown when justified. Some things to consider are: over height loads traveling on the roadway; the level of development in the area, the projected growth in traffic volume and importance of the roadway, and the possibility of reclassification.
Coordinate early in the design process with the Bureau of Highway Maintenance and Bureau of Structures in determining the appropriate vertical clearance along an OSOW High Clearance Route. Consider future underpass facility overlay improvements in establishing this vertical clearance.

2 See Bridge Manual Chapter 39 (http://wisconsindot.gov/dtsdManuals/strct/manuals/bridge/ch39.pdf) and bridge Standard Details 39.02 and 39.10 for design considerations and requirements for vertical clearance on new and replacement Sign Structures. A lower minimum vertical clearance of 20'-0" is required on the OSOW High Clearance Route. See the OSOW maps for routes designated as high clearance routes (https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/planning-maps.aspx).

3 See FDM 11-44-1 for vertical clearance guidance specific to Interstate freeways.

4 Consult with the Region Railroad Coordinator if the over-passing or under-passing facility is either a railroad or a "rails-to-trails" trail; or if a structure is owned by a railroad company.

5 A vertical clearance <23'-0" requires both an approved Design Justification (DJ) (see FDM 11-1-20) and early coordination with BTLR R&H, Railroads and Harbors Section (RHS) through the Region Railroad Coordinator. The Design Justification (DJ) shall contain documentation that the Office of the Commissioner of Railroads (OCR) has been petitioned.
See FDM Chapter 17 for additional information.

6 Provide justification for a vertical clearance >23'-3 ½" to the RHS.

7 Vertical clearance less than 23'-0" may be acceptable or desirable in certain situations, such as for spur tracks, lead tracks, some branch lines and even mainline tracks when other impediments to 23'-0" exist. Review such situations with the Railroad Project Coordination Engineer in RHS. Early coordination with RHS is required.

Lower Minimum Vertical Clearance for Existing Bridges which are not Being Replaced and for Existing Bridges on which the Superstructure is not Being Replaced [1, 2]

<table>
<tr><td>Overpass Facility →</td><td colspan="2">Freeway, Expressway, or STH</td><td rowspan="2">Railroad[5], CTH, Town Road, Local Road, or Street</td><td rowspan="2">Pedestrian or Shared-use Structures</td><td rowspan="2">Sign Structures[6]</td></tr>
<tr><td>Underpass Facility ↓</td><td>Interchange</td><td>Grade Separation</td></tr>
<tr><td rowspan="3">Non-arterial
either STH, CTH, Town Road, Local Road, or Street</td><td rowspan="3">15’-3” min. or DJ[3]</td><td colspan="2">If existing is < 14’-0" then increase to 14’-0” min. or DJ [3]</td><td rowspan="3">16’-3” min. or DJ [3]</td><td rowspan="9">18’-0” min. or DJ [3] for existing sign structures on Modernization projects;

17’-0” or DJ [3] for existing sign structures on Perpetuation and Rehabilitation projects</td></tr>
<tr><td colspan="2">If existing is ≥ 14’-0", but < 14’-6” then maintain existing min. or DJ [3]</td></tr>
<tr><td colspan="2">If existing is ≥ 14’-6" then 14’-6” min. or DJ [3]</td></tr>
<tr><td rowspan="3">Arterial
either CTH, Town Road, Local Road, or Street (excludes freeway and expressway; also excludes arterial STH)</td><td>If existing is < 15’-3" then increase to 15’-3” min. or DJ [3]</td><td>If existing is < 14’-0" then increase to 14’-0” min. or DJ [3]</td><td rowspan="3">17’-0” min. or DJ [3]</td></tr>
<tr><td>If existing is ≥ 15’-3", but < 16’-0” then maintain existing min. or DJ [3]</td><td>If existing is ≥ 14’-0", but < 14’-6” then maintain existing min. or DJ [3]</td></tr>
<tr><td>If existing is ≥ 16’ 0" then 16’ 0” min. or DJ [3]</td><td>If existing is ≥ 14’-6" then 14’-6” min. or DJ [3]</td></tr>
<tr><td rowspan="3">Arterial STH (excludes freeway and expressway)</td><td>If existing is < 15’-3" then increase to 15’-3” min. or DJ [3]</td><td>If existing is < 14’-0" then increase to 14’-0” min. or DJ [3]</td><td rowspan="3">17’-0” min. or DJ [3]</td></tr>
<tr><td>If existing is ≥ 15’-3", but < 16’-0” then maintain existing min. or DJ [3]</td><td>If existing is ≥ 14’-0", but < 16’-0” then maintain existing min. or DJ [3]</td></tr>
<tr><td>If existing is ≥ 16’ 0" then 16’ 0” min. or DJ [3]</td><td>If existing is ≥ 16’ 0" then 16’ 0” min. or DJ [3]</td></tr>
<tr><td>Freeway[4] or Expressway</td><td colspan="3">16’-0” min. or DJ [3]</td></tr>
<tr><td>Railroad[5]</td><td colspan="5">Maintain existing vertical clearance - if existing clearance is < 23’-0” then confer with BTLR Railroads and Harbors Section to determine the adequacy of the existing clearance.</td></tr>
</table>

General notes:

1. Vertical clearance is needed for the entire roadway width (critical point; to include traveled way, auxiliary lanes, turn lanes, and shoulders), according to the above table. Provide greater than lower minimum clearance if evaluation shows that greater clearance is needed because bridge superstructure is susceptible to being hit by under-passing vehicles. Vertical clearance for railroads is measured from the top of rail and is required over an area 8 feet 6 inches from the track centerline on each side of a railroad track.
2. Include a low clearance sign (W12-2), on structures if its use is in accordance with WisDOT MUTCD 2C.22.
3. DJ = approved Design Justification (DJ) required (see FDM 11-1-20).
4. See FDM 11-44-1 for vertical clearance guidance specific to Interstate freeways.
5. Consult with the Region Railroad Coordinator if the over-passing or under-passing facility is either a railroad or a “rails-to-trails” trail; or if a structure is owned by a railroad company.
6. See Bridge Manual Chapter 39 for design considerations for vertical clearance on Sign Structures:
   http://wisconsindot.gov/dtsdManuals/strct/manuals/bridge/ch39.pdf

   Do not reduce vertical clearance that is less than or equal to 20'-0" on the OSOW High Clearance Route. Refer to the OSOW maps for routes designated as high clearance routes (https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/planning-maps.aspx).
7. Do not reduce vertical clearance that is less than or equal to 20'-0" on the OSOW High Clearance Route. Refer to the OSOW maps for routes designated as high clearance routes (https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/planning-maps.aspx). Coordinate early in the design process with the Bureau of Highway Maintenance and Bureau of Structures in determining the appropriate vertical clearance along an OSOW High Clearance Route.

FDM 11-38-1 General

February 18, 2020

The purpose of this section is to introduce the expectations of performing safety analysis under Performance-Based Practical Design (PBPD) (FDM 11-1-10) philosophies through implementation of WisDOT's Safety Certification Process (SCP). The SCP adopts the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) analysis methods and economic appraisal process.

1.1 Overview

WisDOT is continuously balancing fiscal realities with competing highway needs. As such, all asset improvements (safety, pavement, structures) must be employed with the right fix at the right time and in the right location. This "right fix, right time, right location" philosophy is fundamental to Performance-Based Practical Design (PBPD) practice.

The safety analysis portion of PBPD places emphasis on substantive safety, i.e., long-term safety performance of a roadway, through consistent identification of safety needs while still considering nominal safety by addressing less than lower minimum design criteria roadway elements. Nominal safety is the safety assumed "built in" to the design criteria. What is important to understand is a roadway's substantive safety does not always correlate to its level of nominal safety. It is not uncommon for a roadway to be nominally safe (i.e., all design elements meet design criteria) but at the same time be substantively unsafe (i.e., has crashes that are higher than expected). Similarly, some roadways that are nominally unsafe (one or more design elements do not meet design criteria) can and do function at a high level of substantive safety. This process will allow for more accurate scoping of the true purpose and need of projects and result in more efficient expenditures throughout the system.

WisDOT's SCP uses network screening tools to identify locations that experience more crashes than similar sites and have a higher potential for safety improvement. These "sites of promise" are then subject to a crash vetting process and ultimately predictive crash modeling and economic appraisal (Benefit-Cost) methodologies, to identify and evaluate safety mitigation alternatives for locations on the highway network.

1.2 Acronyms and Definitions

A list of acronyms used throughout this chapter is in Table 1.1; while brief definitions of key SCP terms are presented in Table 1.2.

***Table 1.1* Acronyms**

Acronym	Definition
AASHTO	American Association of State Highway and Transportation Officials
AADT	Average Annual Daily Traffic
CGA	Contributing Geometric Analysis
CMF	Crash Modification Factor
EA	Economic Appraisal
EB	Empirical Bayes
FDM	Facilities Development Manual
FHWA	Federal Highway Administration
HSM	Highway Safety Manual
IHSDM	Interactive Highway Safety Design Manual
LOSS	Level of Service of Safety
PBPD	Performance-Based Practical Design
RTM	Regression to the Mean
SCD	Safety Certification Document
SCP	Safety Certification Process
SCW	Safety Certification Worksheet
SMCP	Safety Mitigation Certification Process
SPF	Safety Performance Function

***Table 1.2* Definitions**

SCP Element	Definition
Base Case	The base case is the scenario each alternative will be compared to. In most cases, the base case scenario will not include safety improvements and should be modeled as the existing geometric and traffic control conditions for the overall analysis period starting with the construction year.
Calibration Factor	A factor to adjust crash frequency estimates produced from a safety prediction procedure to approximate local conditions. The factor is computed by comparing existing crash data at the state, regional, or local level to estimates obtained from predictive models.
Crash Cost	Crashes result in economic costs including the costs of vehicle repairs, providing emergency services, traffic delays, medical services, workplace productivity losses, and damage to private property and roadway infrastructure. Crashes involving death or severe injury may also result in intangible costs such as physical pain or emotional suffering. These costs are referred to as quality-adjusted life years (QALY). The comprehensive costs of a crash are the sum of the economic and QALY costs. Detailed information regarding FHWA default crash costs can be found in the FHWA Crash Cost for Highway Safety Analysis.
Crash Modification Factor (CMF)	A CMF is a factor estimating the potential changes in crash frequency or crash severity due to installing a specific treatment. The CMFs in the HSM have been developed based on rigorous and reliable scientific process. As an example, a 0.70 CMF corresponds to a 30 percent reduction in crashes. A 1.2 CMF corresponds to a 20 percent increase in crashes.

SCP Element	Definition
Discount Rate	Discount rates, used in the economic appraisal, reflect the time value of money. That is, benefits and costs experienced in the near-term are worth more than benefits and costs experienced at the end of the analysis period. For more information, reference FHWA Highway Safety Benefit-Cost Analysis Guide.
Empirical Bayes (EB)	EB is a statistical method that weights the predicted crash frequency and the observed crash frequency. Weighting the predicted and observed crashes allows us to use the long-term average crash experience of similar sites and bring that prediction closer to the observed crash history of the site being evaluated.
Expected Crash Frequency	The number of crashes obtained by weighting the predicted crash frequency and the observed crash frequency using the EB method.
Facility	This is an HSM term that describes three broad types of roadway facilities for specific application of predictive safety methods. These facilities include Rural Two-Lane, Two - Way Roads, Rural Multilane Highways, and Urban and Suburban Arterials. Within these facility types are several site types that further define project locations. These include diverse types of intersections and segments within the overall facility.
Interactive Highway Safety Design Model (IHSDM)	IHSDM is a suite of software analysis tools used to evaluate the safety operational and economic effects of design decisions on roadways. This software provides a Crash Prediction Module to implement the HSM Part C methodology. Refer to FHWA website for more information.
Intersection Network Screening Spreadsheet	WisDOT's tool for intersection network screening, which contains WisDOT intersection inventory data.
Meta-Manager	WisDOT's facilities asset management database.
Observed Crash Frequency	The number of crashes at a specific, site. Observed crashes are often reported for a 5-year period.
Predicted Crash Frequency	The number of crashes determined by using a safety performance function (SPF).
Regression to the Mean (RTM)	The natural variation in crash data. If regression to the mean is not accounted for, a site might be selected for study when the crashes are at a randomly high fluctuation or overlooked from study when the site is at a randomly low fluctuation.
Safety Flag	Meta-Manager indication for a roadway segment that has a crash rate that is one standard deviation above the statewide average for its peer group. Intersection Network Screening indication for an intersection with a Level of Service of Safety category 4 (LOSS 4).
Safety Performance Function (SPF)	SPFs are equations that predict crash frequency and severity as a function of traffic volume and roadway characteristics (e.g. number of lanes, median type, intersection control, number of approach legs).
Site of Promise	Segment or intersection within a project's limits that have a potential for safety improvement.

FDM 11-38-3 Policy

February 18, 2020

WisDOT's implementation of Performance-Based Practical Design (PBPD) uses the SCP for determining and approving safety-driven roadway improvements to the system. The SCP incorporates AASHTO's HSM analysis methods into WisDOT's project development process.

Refer to FDM 11-1-5 for WisDOT's *Asset Management by a Practical Design System Preservation Approach* that incorporates the SCP.

The product of the SCP is the Safety Certification Document (SCD). See FDM 11-1 Attachment 10.1 for a table showing when a SCD is required.

Questions regarding this policy should be sent to DOTBTOSafetyEngineering@dot.wi.gov.

FDM 11-38-5 Overview of Safety Quantification in the Project Development Process *February 18, 2020*

Quantifying safety early in the project development process is key to determining safety improvement impacts to projects. Proposed safety improvements in a project must be balanced with other competing fiscal needs of the project such as operational, environmental, and pavement concerns. Historically, safety benefits have been assumed inherent, or "built in", to design policies and practices.

There are methods and tools available to quantify safety benefits in the development and analysis of safety mitigation alternatives in projects. These methods and tools allow analysts to quantify the crash frequency and severity of safety mitigation alternatives which allows safety to be explicitly considered in the evaluation of alternatives on projects.

To facilitate the safety comparison of alternatives, WisDOT employs Performance Based Safety Engineering Analysis (PBSEA) which involves predictive crash modeling and Economic Appraisal (EA) to compare the cost of crashes to the cost of roadway improvements. Predictive crash modeling is used to estimate crash frequencies and severities for safety mitigation alternatives on a project and then economic appraisal techniques assign average costs to the identified crashes for each safety mitigation alternative to monetize safety benefits. In this way, safety can be compared with other costs (construction, real estate) to evaluate alternatives.

FDM 11-38-10 WisDOT Safety Certification Process *May 18, 2020*

10.1 General

The Safety Certification Process (SCP) is a step-by-step process of determining whether safety improvements should be included on a project by quantifying safety mitigation alternatives, monetizing the resulting safety benefits, completing benefit-cost comparisons of the mitigation alternatives, and documenting decisions and judgements throughout the process.

This requires the analyst to use and document sound engineering judgement and experience based on specific project conditions, context, and modal priorities.

The SCP will be used to support all safety improvements on a WisDOT project and generally includes the following steps (Refer to Attachment 10.1 for a process flowchart):

1. **Sites of Promise by System Screening:** Safety screening to identify highway segments and intersections with potential for crash reduction.
2. **Crash Vetting for the Sites of Promise:** Investigation of the Sites of Promise to understand crash trends and patterns, identify the contributing factors to crashes at those sites, and vet crashes where there is no engineering solution.
3. **Contributing Geometric Analysis (CGA):** Analyze how geometric features contributed to the crash history and identify possible countermeasures.
4. **Safety Mitigation Certification Process (SMCP):** This two-part process includes Performance Based Safety Engineering Analysis and Economic Appraisal. This involves predictive crash modeling and application of economic appraisals to determine benefit-cost. Overall these two processes allow direct monetary comparison of mitigation alternatives.
5. **Safety Certification Document (SCD):** The final document that describes the process, engineering judgment, and support for safety improvements for a project.

10.2 Sites of Promise by System Screening

10.2.1 General

All WisDOT projects required to complete a SCD start with a safety screening. The goal of this first step is to identify the project's Sites of Promise, which are roadway segments or intersections along the project corridor that have a high potential to reduce crashes with targeted, cost-effective improvements. Only segments or intersections that are identified as a Site of Promise move forward in the SCP.

10.2.2 Sites of Promise by System Screening Process

The following process shall be used to establish Sites of Promise along a specific project corridor:

For segments:

1. Obtain the Meta-Manager spreadsheet for the Region in which the project is located.
    - Refer to the Meta-Manager User Guide for further information regarding the data within the Meta-Manager spreadsheet and the associated calculations.

2. In the Safety tab, locate the PDP segments that make up the project corridor.
3. Identify flagged segments. Segments are flagged if any of the following conditions are true:
   - The Total Crash Rate (RATEFLAG) is at least one standard deviation above the peer group average (has a value of 1.0 or greater).
   - The KAB Crash Rate (MMGR_KAB_CRSH_RT_FL) is at least one standard deviation above the peer group average (has a value of 1.0 or greater).
   - The Pedestrian Crash Total (MMGR_PED_TOT) has at least one crash.
   - The Bicycle Crash Total (MMRG_BIKE_TOT) has at least one crash.

   Refer to Figure 10.1 for a sample screenshot of the Meta-Manager safety worksheet and presentation of crash flags.

PDP_ID	ACSI_INTS_NM	HWY&DIR	RATEFLAG	MMGR_BIKE_CRSH_TOT	MMGR_PED_CRSH_TOT	MMGR_KAB_CRSH_RT_FL
845	USH 66 EB	010E	10.78	1	0	3.86
846		010E	7.81	0	0	0.00
847	OLD HWY 18	010E	1.06	2	0	0.00
848	BRILOWSKI RD	010E	0.00	1	1	0.00
849	BADGER AVE	010E	0.00	0	0	0.00
850	ALGOMA ST	010E	0.00	0	0	0.00
851	STOCKTON RD	010E	0.00	0	0	0.00
852		010E	0.00	0	0	0.00
853	CTH K	010E	1.03	0	0	1.16
854	CTH QQ	010E	1.27	0	0	0.00
872		010E	0.00	0	0	1.01

Figure10.1 Sample Screenshot of Meta-Manager Safety Worksheet

4. Review and validate input data. This includes checking the roadway type (peer group) and annual average daily traffic (AADT) volume for consistency along a corridor. Refer to Figure 10.2 and Figure 10.3 for example screenshots of Meta-Manager data and how to validate the data. If inputs are not accurate, revise the data and recalculate the associated flags.

PDP_ID	PDP_FRM	PDP_TO	PDP_MILE	HWY&DIR	RATEFLAG	HSTL_AADT_5_YR
140	002E126 000	002E128 000	1.08	002E	0.00	3440
141	002E128 000	002E129 000	1.08	002E	0.00	3440
142	002E129 000	002E131 000	1.07	002E	1.29	3440
143	002E131 000	002E132 000	0.30	002E	0.00	4600
144	002E132 000	002E132 029	0.29	002E	0.00	4600
145	002E132 029	002E132 072	0.43	002E	0.00	4600
146	002E132 072	002E133M000	0.28	002E	0.00	4852
148	002E134 000	002E136 000	1.02	002E	0.00	3566

Review the flagged AADT and look for significant inconsistency with adjacent segments

Figure 10.2 Review Flagged Segments for Potential Faulty AADTs

PDP_ID	SPOT_RP_KY	FEATURE_NEAR	SFTY_TRVL_CLS
141	002E128 000	PARK RD (COUNTY PIT 1.6 MI)	420: Rural 2-lane Highways with 2,000 < AADT = 7,000
141	002E128 030		420: Rural 2-lane Highways with 2,000 < AADT = 7,000
141	002E128 080		420: Rural 2-lane Highways with 2,000 < AADT = 7,000
142	002E129 000	DEFER RD	420: Rural 2-lane Highways with 2,000 < AADT = 7,000
142	002E129 010		420: Rural 2-lane Highways with 2,000 < AADT = 7,000
142	002E129 050		420: Rural 2-lane Highways with 2,000 < AADT = 7,000
142	002E129 060		420: Rural 2-lane Highways with 2,000 < AADT = 7,000
142	002E129 070	KIVA TIA RD	420: Rural 2-lane Highways with 2,000 < AADT = 7,000
142	002E129 080		420: Rural 2-lane Highways with 2,000 < AADT = 7,000
142	002E129 090	COMCL DRWY	420: Rural 2-lane Highways with 2,000 < AADT = 7,000
143	002E131 000	N STATELINE RD	310: Multilane Divided Highways Posted at 45 mph or highe
143	002E131 020	COMCL DRWY	420: Rural 2-lane Highways with 2,000 < AADT = 7,000

For flagged location, look for inconsistent peer group

***Figure 10.3* Review Peer Groups for Inconsistencies**

5. Validated flagged segments are identified as Sites of Promise and shall continue the SCP.
6. Document all Meta-Manager PDP segments in the Safety Certification Worksheet. Provide additional documentation for flagged segments in the System Screening - Sites of Promise section of the Safety Certification Worksheet (Attachment 10.2).

For intersections:

1. Obtain the Intersection Network Screening spreadsheet.
2. Identify the INT_IDs for the project intersections using the maps linked in the Intersection Maps tab.
3. Locate the project intersections in the Network Screening tab using the INT_IDs.
4. Review and validate input data. This includes checking the control type and AADT for each intersection. If inputs are incorrect, revise the data and confirm the calculations were updated.
5. Identify flagged intersections. These are Sites of Promise and shall continue the SCP.
   - Intersections are flagged when the Level of Service of Safety (LOSS) is a category 4 for either Total Crashes or KABC Crashes. Refer to the Intersection Network Screening User Guide for more information about LOSS and the Intersection Network Screening spreadsheet.
6. Document all intersections within the project corridor in the Safety Certification Worksheet. Provide additional documentation for flagged intersections in the System Screening – Sites of Promise section of the Safety Certification Worksheet (Attachment 10.2).

A web-based application called the Safety Certification Mapping (SCM) tool is available on the WisTransPortal to assist analysts with documenting Sites of Promise in the Safety Certification Worksheet.

Project corridors that do not have any flagged segments or intersections require no further safety evaluation and shall be documented as such in the SCD. Refer to FDM 11-38-10.6 for information on the SCD.

Attachment 10.3 visually depicts the process of discerning Sites of Promise by System Screening, as described above.

10.3 Crash Vetting for the Sites of Promise

10.3.1 General

After determining the project corridor includes at least one Site of Promise, a comprehensive crash data verification process, “crash vetting”, ensues. Historical crash data are reviewed to verify the crashes are relevant to the project and require further safety analysis.

10.3.2 Crash Vetting for the Sites of Promise Process

1. Obtain crash reports (MV4000 or DT4000) for all the flagged segments and intersections (from the Sites of Promise step).
2. Crash vetting: Review each crash report. Identify which crashes should be targeted for engineering

improvements and which crashes should be vetted out and considered in other safety programs.

Engineering judgement should be applied in this step and documented as described later in this section.

- Vet out crashes involving deer and other animals unless the origins of the crash are unrelated to the animal. For example, if a driver ran off the road and hit an animal but the animal was not the root cause of the crash.
- Vet out crashes outside the flagged segment limits (document points of judgment)
- Vet out crashes relating to roadway conditions not affiliated with the highway or geometric conditions (debris in road, etc.).
- Evaluate crashes relating to driver/pedestrian conditions to determine if human error was the primary contributing factor to the crash. Examples of this include:
    - Use of drugs/alcohol, distracted driving, driver fell asleep, pedestrian entered roadway without proper right of way, etc.
    - Crash that resulted from an obvious case of “road rage”
    - Crash resulted from driver following too close to the vehicle in the lead for the roadway conditions (tailgating, inattentiveness, etc.)
    - Secondary crashes that resulted from a motorist’s inattentive driving while moving through an incident zone, such as a crash in the opposite lanes. Often secondary crashes occur as a result of motorists looking at the first crash.
    - Crash resulting from a motorist excessively speeding
    - Crashes resulting from improper lane changes or violating the rules of the road such as making a U-turn on a two-lane roadway
- Crashes flagged as human error should also be compared to identify any crash trends for potential roadway condition impacts. This evaluation will help to determine if these crashes are impacted by roadway characteristics.
    - For example, a crash where an impaired driver drove off the road along a curved segment should not be removed if there are frequent occurrences of run off the road crashes without the influence of drugs or alcohol.
- Evaluate vehicle factors (e.g., blown tire, defective equipment, engine fires) to determine if they were the primary contributing factor to the crash. Determine if roadway geometric conditions also contributed to the crash. If yes, keep the crash for further data analysis. If not, vet out the crash record for the safety evaluation and document the decision.

3. Analyze the remaining crash data for patterns and trends to identify targeted countermeasures. Consider sorting the remaining crash records of flagged segments and intersections by:
    - Type
    - Severity
    - Contributing factors (geometric conditions, pavement quality conditions, etc.)
    - Daylight condition (day, night)
    - Road condition (dry, wet, snow, ice)
    - Time of day/year
4. At this stage of the process, the analyst should use their judgment to vet out crashes with contributing factors that cannot be linked to a pattern or element correctible by an engineering solution. Document these decisions in the Vetted Comments column in the WisTransPortal crash data spreadsheet. Refer to Figure 10.4 for a screenshot illustrating an example of how an analyst may save their “vetted” comments within the WisTransPortal crash data spreadsheet.

ACCDNMBR	ONHWY	ATSTR	ACCDDATE	NTFYHOUR	MNRCOLL	ROADCOND	ACCDSVR	Vetted Comments
130204427	8		2/14/2013	18	REAR	WET	PD	Inattentive driving, following too close
130301806	8		3/9/2013	18	NO	WET	PD	swerved to avoid object in road
130507368	8		5/24/2013	15	ANGL		PD	Miscoded, not on project corridor
130808069	8		8/30/2013	15	ANGL		INJ	
130808676	8		8/26/2013	5	NO	WET	INJ	Poor visibility and too fast for conditions
131210811	8	SWANSON RD	12/22/2013	20	NO	SNOW	PD	Snowy road, too fast for conditions
140110952	8		1/25/2014	9	NO	ICE	PD	Icy road, too fast for conditions
140210998	8		2/23/2014	2	NO	SNOW	INJ	Snowy road, too fast for conditions
140706007	8		7/25/2014	14	ANGL		INJ	
140909842	8		9/12/2014	9	ANGL		INJ	

***Figure 10.4* Sample WisTransPortal Crash Data Spreadsheet with Vetting Comments**

5. After vetting, are there remaining segmental or intersection crashes that can be mitigated with engineering solutions?
   - No. Further safety evaluation is not required. Include the WisTransPortal crash data spreadsheet with the vetted comments in the Safety Certification Document.
   - Yes. Proceed to step 6.
6. Identify the number of crashes reviewed and the number of crashes correctible by an engineering solution in the Crash Vetting - Sites of Promise section of the Safety Certification Worksheet. The crashes correctible by an engineering solution shall be further evaluated in the Contributing Geometric Analysis (CGA) process.

10.4 Contributing Geometric Analysis (CGA)

10.4.1 General

If there are crashes that can be mitigated with engineering countermeasures, they are evaluated further to determine if existing geometric features contributed to the type and severity of those crashes. If existing geometric features did not contribute to the crashes, other possible countermeasures should be identified to target the contributing factors. This is done through the Contributing Geometric Analysis (CGA) process.

10.4.2 Contributing Geometric Analysis (CGA) Process

1. Determine if geometric features contribute to the type or severity of the crashes.
2. Document the geometric features that contributed to the crashes and the countermeasures identified to target those factors in the Contributing Geometric Analysis columns of the Safety Certification Worksheet (Attachment 10.2).
3. If existing geometric features did not contribute to the type and severity of the crashes, identify possible countermeasures to target the contributing factors identified in the vetted WisTransPortal crash data spreadsheet and summarized for each flagged segment in the Crash Vetting – Sites of Promise section of the Safety Certification Worksheet (Attachment 10.2). See Attachment 10.4 for a Safety Improvement Prompt List that target specific crash types and contributing factors. If no practical countermeasures exist, document in the SCD.

10.5 Safety Mitigation Certification Process (SMCP)

10.5.1 General

The Safety Mitigation Certification Process (SMCP) is initiated if safety improvements were identified in the CGA. Each safety improvement identified shall be evaluated to determine the cost-effectiveness of improving the safety performance at the flagged location(s). The SMCP includes two components:

1. Performance Based Safety Engineering Analysis
2. Economic Appraisal

10.5.2 Performance Based Safety Engineering Analysis (PBSEA)

10.5.2.1 General

The Performance Based Safety Engineering Analysis (PBSEA) process uses predictive modeling when possible to evaluate the future safety performance of each safety improvement alternative. This modeling should be completed using the Interactive Highway Safety Design Model (IHSDM) software. Predictive modeling has the following advantages:

- It allows safety to be quantified so investments in infrastructure improvements have the highest potential to improve long term safety performance.
- It allows for the effects of various design alternatives on crash frequency and severity to be quantified.

10.5.2.2 Performance Based Safety Engineering Analysis Process

This process evaluates the safety impacts of the countermeasures identified in the CGA. The performance based safety engineering analysis process is outlined below:

1. Determine the base case scenario.
2. Determine the analysis method for the base case and each alternative.
3. Compare the analysis methods and determine an overall method for the evaluation.
4. Develop the required data for analysis.
5. Perform the safety analysis.
6. Document the results.

Step 1. Determine the base case scenario.

The base case is the scenario each alternative will be compared to. In most cases, the base case scenario will not include safety improvements and should be modeled as the existing geometric and traffic control conditions for the overall analysis period starting with the construction year.

Step 2. Determine the analysis method for the base case and each alternative.

When determining which analysis method to use, it is important to know the distinction between the types of crash modification factors (CMFs). There are two types of CMFs used throughout this process:

1. HSM Part C CMFs, called CMF adjustment factors herein. CMF adjustment factors are used in conjunction with the HSM Safety Performance Functions (SPFs). These CMFs adjust the base conditions of the SPFs.
2. HSM Part D CMFs, called external CMFs herein. External CMFs are used to modify the SPF prediction to more closely represent the site conditions.

Attachment 10.6 is a flowchart to guide analysts through determining the correct analysis method. Assign each scenario an analysis method.

Method 1: CMF Applied to Observed Crashes

- This method multiplies the Observed Crash Frequency with external CMFs.
- Use when the site configuration or traffic volumes are outside of the applicable ranges of the Safety Performance Functions (SPFs).
- This method does not account for regression-to-the-mean (RTM) bias which is when the short-term crash trend does not reflect the long-term average. RTM can over or under estimate the effect of safety improvements. Figure 10.5 illustrates RTM bias in observed crash frequencies.
- The Highway Safety Benefit-Cost Analysis Tool is used to implement this method.
- This is the least reliable method and should be used only if no other method is appropriate. Attachment 10.5 contains a chart illustrating which design elements are covered by the HSM SPFs.
- The results obtained with this method should be called the “Estimated Crash Frequency”.

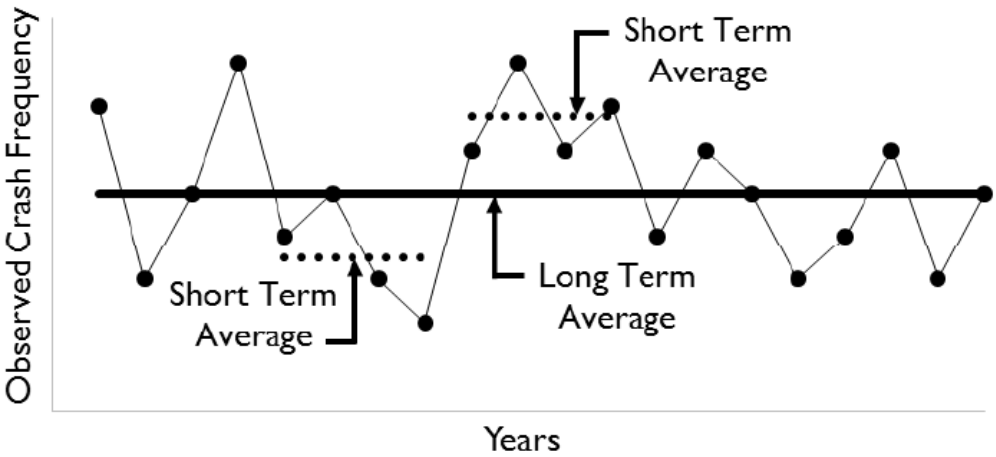


***Figure 10.5** Variation in Short Term Observed Crash Frequency to Illustrate RTM Bias*

Method 2: SPF without External CMFs (2A) and SPF with External CMFs (2B)

- These methods use SPFs to predict the crash frequency.
    - Method 2A is used if only the SPF and its adjustment factors are needed.
    - Method 2B is used if an external CMF is needed in addition to the SPF to more accurately model the conditions or safety improvements.
- Use these methods when Empirical Bayes is not applicable, which the HSM defines as:
    - Projects in which a new alignment is developed for a substantial proportion of the project length.
    - Intersections at which the basic number of legs or type of traffic control is changed as part of the project.
    - Segments where the number of through lanes changes, other than short passing lane sections.
    - Any other major geometric improvement where the observed crash data for the existing conditions is not indicative of the crash experience that is likely to occur in the future.
- The Interactive Highway Safety Design Model (IHSDM) is used to implement these methods.
- These methods are more reliable than Method 1, but less reliable than Methods 3A or 3B.
- The results obtained with these methods should be called the “Predicted Crash Frequency”.

Method 3: SPF without External CMFs weighted by Observed Crashes (3A) and SPF with External CMFs weighted by Observed Crashes (3B)

- These methods utilize Empirical Bayes (EB), which weights the predicted crashes from SPFs with the observed crashes, to obtain the most reliable results. When performing EB, all observed crashes are included, not just the remaining crashes identified in the CGA process.
    - Method 3A is used if only the SPF and its adjustment factors are needed.
    - Method 3B is used if an external CMF is needed, in addition to the SPF, to more accurately model the conditions or safety improvements.
- Use this method when EB is applicable, which the HSM defines as:
    - Sites at which the roadway geometrics and traffic control are not being changed (e.g. the future no-build alternative).
    - Projects in which the roadway cross section is modified but the basic number of through lanes remains the same.

  - Projects in which minor changes in alignment are made, such as flattening individual horizontal curves while leaving most of the alignment intact.
  - Projects in which a passing lane or a short four-lane section is added to a rural two-lane, two-way road to increase passing opportunities.
- The Interactive Highway Safety Design Model (IHSDM) is used to implement these methods.
- These are the most reliable methods and should be used unless EB is not applicable.
- The results obtained with these methods should be called the "Expected Crash Frequency".

Table 10.1 Required Inputs to Safety Mitigation Certification Process (SMCP)

Method			Inputs for Each Analysis Method
1	2	3	
Required	Required	Required	Geometry and traffic control for each segment or intersection with remaining crashes as determined in FDM 11-38-10.4.2
Required	Required	Required	Roadway segment AADTs or intersection approach AADTs for all years in the evaluation period and historical years when using EB.
Required		Required	All observed crash data for each segment or intersection being analyzed.
	Required	Required	SPFs contained in IHSDM.
	Required	Required	WisDOT calibration factors, stored in IHSDM Admin file.
Required	As Needed	As Needed	CMFs for countermeasures.

Step 3. Compare the analysis methods and determine an overall method for evaluation.

Results generated using different methods should not be compared so careful planning is needed to ensure the most reliable analysis method is used at a specific project location. In some rare cases, it may make sense to apply one method at one project location and another method at a separate project location. This should be documented in the SCD and the results should not be compared to one another.

Step 4. Develop the required data for analysis.

Compile the necessary data for your project.

- Determine the years of the observed crash period.
  - Use up to five of the most recent years of crash data.
  - Confirm no geometric or traffic control changes have occurred over the duration of the crash data. If changes have occurred, utilize only the years of crash data after the change, with a minimum of two years of data.
- Obtain the crash data for the observed crash period.
  - Identify the number, type, and severity of the crashes.
- Obtain the AADTs for the observed crash period.
- Determine the years of the evaluation period.

  - The evaluation period is ten years for all safety analyses.
  - The first year of the evaluation period is the construction year.
- Determine the AADTs for the evaluation period.
  - Obtain, at a minimum, the forecasted volumes for the first year and last year of the evaluation period. The analysis tools will automatically interpolate between the two volumes for each year.
  - If additional forecasted volumes are known, they should be included in the analysis.
- If external CMFs are needed for the base case or any alternative, obtain the appropriate CMFs from the WisDOT CMF Table. Refer to TEOpS 12-3 for WisDOT's CMF policy.
  - For each CMF, document the treatment name and CMF# in IHSDM.
  - For each countermeasure, assume the Start CMF Year is the construction year and the End CMF Year is the last year of the analysis period.
- For each analysis location, identify the largest "footprint" for all the alternatives. This is the area that should be evaluated for all alternatives, including the base case.
- For each alternative, obtain roadway characteristics and geometric inputs.

Step 5. Perform the safety analysis.

For the base case and each alternative, perform the safety analysis with the method identified in Step 3. At a minimum, determine the number of total crashes, fatal and injury (KABC) crashes, and property damage only (PDO) crashes.

- Method 1 uses the Highway Safety Benefit-Cost Analysis Tool.
- Methods 2A/2B and 3A/3B use the IHSDM for analysis.

When using IHSDM, select the WisDOT Calibration File, as shown in Figure 10.6.

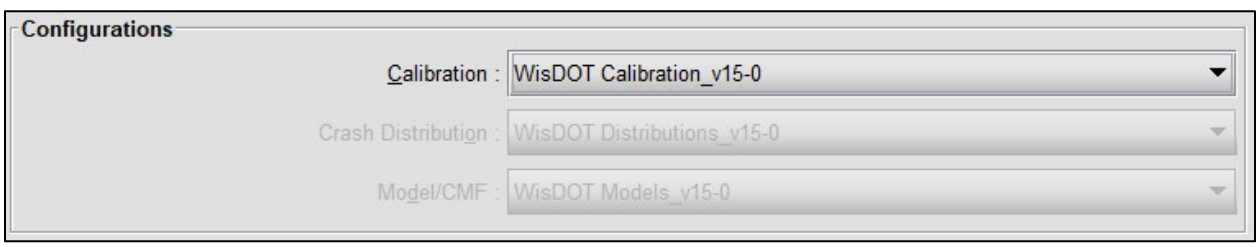


Figure 10.6 IHSDM Crash Analysis Configurations

Step 6. Document the results.

For the base case and each alternative, document the number of total crashes, fatal and injury (KABC) crashes, and property damage only (PDO) crashes in the Safety Certification Document (SCD). Also, document any External CMFs that were used and any other assumptions or judgements pertinent to the analysis.

10.5.3 Economic Appraisal

10.5.3.1 General

The purpose of the economic appraisal process is to compare the estimated benefits of a proposed safety improvement with the estimated costs of that improvement. The economic appraisal process can be used to determine the cost-effectiveness of proposed safety improvements, identify and prioritize improvements with the highest return on investment, and help select an alternative in the decision-making process. To ensure projects are compared consistently, the analysis period (i.e. return on investment period) is assumed to be ten (10) years; the construction year plus nine (9). Key outputs of this process include an estimated benefit-cost ratio and the net-present value of each safety improvement alternative. Each of these outputs should be considered when selecting the most appropriate improvement option. Refer to Table 1.2 for definitions of terms used in the Economic Appraisal process.

Table 10.2 lists the potential benefits of a safety improvements that can be monetized for benefit-cost analysis:

***Table 10.2* Benefits of Safety Improvements**

Element of Benefit	Description
Crash Benefits	Calculates the monetary benefit for annual crash reductions resulting from a reduction in crash frequency and severity.
Travel Time Benefits	Currently not applicable
Reliability Benefits	Currently not applicable
Vehicle Operating Cost Benefits	Currently not applicable
Emission Benefits	Currently not applicable

Table 10.3 lists the descriptions of the safety improvement costs:

***Table 10.3* Costs of Safety Improvements**

Element of Cost	Description
Project Support	Currently not applicable
Construction	Costs of materials and construction to build the improvement.
Real Estate	Costs to acquire property necessary to build the improvement.
Maintenance and Operation	Currently not applicable
Rehabilitation	Currently not applicable
Mitigation	Currently not applicable

The Safety Certification Process focuses on evaluating safety impacts and does not cover any other benefits or costs to a project, such as vehicle travel time, delay, vehicle operating costs, or vehicle emissions.

10.5.3.2 Crash Costs

Crash costs are estimated monetary values that a state agency adopts to quantify the impact of a change in safety performance as part of a benefit-cost analysis.

Table 10.4 summarizes the approved crash costs for use in the economic appraisal process.

***Table 10.4* Crash Costs for Benefit-Cost Analysis in 2016 Dollars**

Crash Severity (WisDOT terminology)	KABCO Abbreviation (Most severe injury in crash)	Crash Severity (HSM Terminology)	WisDOT Crash Cost
Fatal	K	Fatal	$10,897,580
Suspected Serious Injury	A	Serious Injury or Disabling	$613,781
Suspected Minor Injury	B	Evident Injury or Non-disabling	$194,022
Possible Injury	C	Possible Injury	$110,830
Property Damage Only (PDO)	O	No Injury	$10,173

Wisconsin-specific crash costs were developed using the methods described in FHWA's Crash Costs for

Highway Safety Analysis guide. These crash costs were developed along with the Highway Safety Benefit-Cost Analysis tool described in FDM 11-38-10.5.3.2 and can be download for use in IHSDM in the Tools section below. Crash costs are periodically updated to reflect changes in economic measures.

10.5.4 Safety Mitigation Certification Process Tools

The following tools should be used when conducting the SMCP:

1. **IHSDM** – The Interactive Highway Safety Design Model (IHSDM) applies the HSM analysis methods and economic appraisal process. WisDOT created state-specific files to improve the reliability of the crash analysis and economic appraisal results. Analysts shall use the following files:

File Purpose	File Name
Calibration Data Sets	WisDOT_Calibration_v15-0
Crash Distribution Data Sets	WisDOT_Distributions_v15-0
Model Data Sets	WisDOT_Models_v15-0
Economic Analysis Model Data Sets	WisDOT_Economics_v15-0

   These files can be downloaded from WisDOT's website under the "Safety and Speed" section. To utilize these files within IHSDM save a copy in the "config" folder.

   Additional information and detailed tutorials can be found at www.ihsdm.org.

2. Highway Safety Benefit-Cost Analysis Tool – Used only for Method 1. The calculations for the EA are completed in the same manner as those implemented in the IHSDM.

3. **WisDOT CMF Table** – Contains a list of WisDOT approved crash modification factors (CMFs) as well as a CMF calculator to combine CMFs. For more information regarding WisDOT's CMF policy, go to TEOpS 12-3.

Both IHSDM and the Highway Safety Benefit-Cost Analysis Tool can conduct the Economic Appraisal.

10.6 Safety Certification Document (SCD)

10.6.1 General

This section explains the requirements for the Safety Certification Document (SCD), the product of the Safety Certification Process (SCP). The purpose of the SCD is to:

1. Summarize the process consistently across projects.
2. Provide data, assumptions, and details of engineering judgment used throughout the process.
3. Document the safety performance and economic appraisal of safety improvement alternatives.
4. Document formal approval.

The SCD should not state a definitive recommendation for an alternative since safety is only one aspect of the project decision-making process. It is possible that new alternatives may need to be evaluated later in the project development process or an alternative without the highest safety benefit-cost ratio is preferred. A template for the SCD is in Attachment 10.7.

10.6.2 Content

The first piece of the SCD is a summary narrative that is consistent across projects.

Important process outputs shall be attached to the narrative to complete the details of the document. Those important elements associated with each of the process steps as outlined in FDM 11 38-10 are shown in Table 10.5. This table presents the data that the analyst should save from each step of the SCP. The analyst should use judgment to document and save additional data as project-specific issues arise that are beyond the needs described in the table.

***Table 10.5* Documentation Needs and Format**

Step in SCP	Data to Include in SCD Attachments	Format
Sites of Promise by System Screening	Tabular data illustrating safety flags for segments and intersections. This could include Meta-Manager, a SCM report, or the Intersection Network Screening spreadsheet.	PDF
Crash Vetting for Sites of Promise	WisTransPortal crash data spreadsheet with crash vetting comments	PDF
Contributing Geometric Analysis (CGA) Process	Safety Certification Worksheet	PDF
Safety Mitigation Certification Process	IHSDM Crash Prediction Evaluation Reports	PDF
	IHSDM Economic Analysis Reports	PDF
	Highway Safety Benefit-Cost Analysis Tool results	PDF

10.6.3 Approval Process

Concurrence by the Bureau of Traffic Operations (BTO), Traffic Engineering and Safety Section, is required for all projects that complete the Safety Mitigation Certification Process (SMCP). This review and concurrence process shall occur prior to approval by the Regional Planning Chief. The intent of BTO's review is to ensure the policy, methods, and tools described in FDM 11-38 are applied consistently statewide. Review of detailed inputs and outputs shall be completed by the Region.

Send the SCD and all supporting documents to DOTBTOSafetyEngineering@dot.wi.gov. BTO will review the SCD and provide comments or concurrence to the Region within 15 business days.

Regional Planning Chiefs shall approve all project Safety Certification Documents.

10.7 List of Attachments

Attachment 10.1 Safety Certification Process Flowchart

Attachment 10.2 Safety Certification Worksheet

Attachment 10.3 Sites of Promise by System Screening Process Flowchart

Attachment 10.4 Safety Improvement Prompt List

Attachment 10.5 Design Elements Covered in HSM Predictive Methods

Attachment 10.6 Flowchart for Selecting a Safety Analysis Method

Attachment 10.7 Safety Certification Document

FDM 11-38-15 Examples for Safety Certification Process *November 30, 2018*

15.1 General

Examples for the Safety Certification Process can be found on the Traffic Operations Manuals web page:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/manuals.aspx

The examples include all five Performance Based Safety Engineering Analysis methods and associated Economic Appraisals. These examples are limited in nature and are for demonstrative purposes in exemplifying the Safety Certification Process.

FDM 11-38-99 References *February 18, 2020*

99.1 References

1. Highway Safety Benefit-Cost Analysis Guide. FHWA Safety Program. Federal Highway Administration.

February 2018. https://safety.fhwa.dot.gov/hsip/docs/fhwasa18001.pdf

2. Crash Modification Factors in Practice, Quantifying Safety in the Roadway Safety Management Process. FHWA Office of Safety. Federal Highway Administration.

3. Highway Safety Benefit-Cost Analysis Tool: Reference Guide. FHWA Safety Program. Federal Highway Administration.

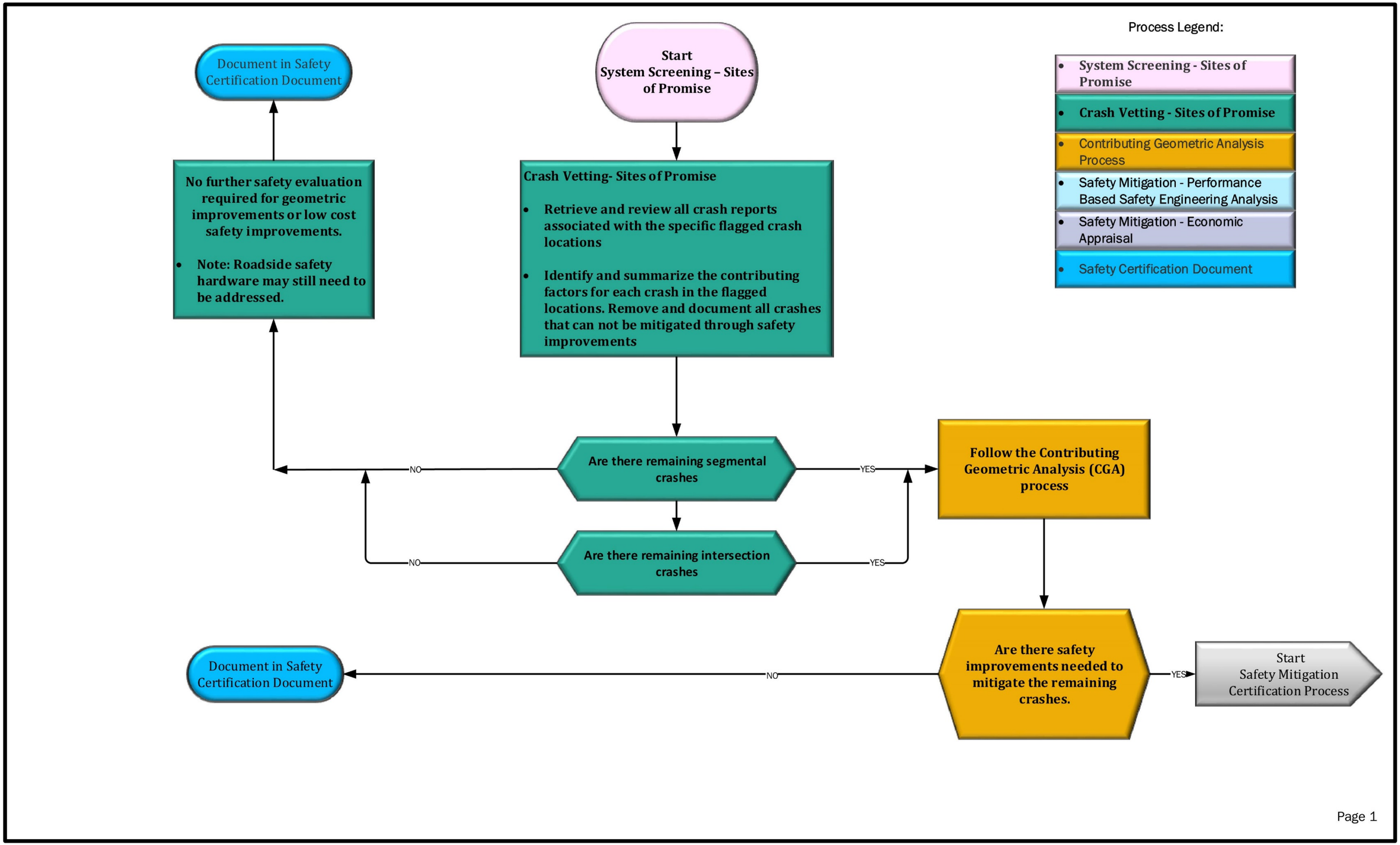
4. Crash Modification Factors in Practice, Using CMFs to Quantify Safety in the Development and Analysis of Alternatives. FHWA Office of Safety. Federal Highway Administration.

5. Highway Safety Manual. American Association of State Highway and Transportation Officials. 2010.

6. Highway Safety Manual User Guide. National Cooperative Highway Research Program 17-50. Lead States Initiative for Implementing the Highway Safety Manual. August 2014.

7. Crash Cost for Highway Safety Analysis. FHWA Safety Program. Federal Highway Administration. January 2018. https://safety.fhwa.dot.gov/hsip/docs/fhwasa17071.pdf

8. IHSDM Economic Analyses Tool Help. FHWA Geometric Design Lab. Federal Highway Administration. September 2017. http://www.ihsdm.org/w/images/b/b6/IHSDM_Economic_Analysis_Tool_Help.pdf


Process Legend:
System Screening - Sites of Promise
Crash Vetting - Sites of Promise
Contributing Geometric Analysis Process
Safety Mitigation - Performance Based Safety Engineering Analysis
Safety Mitigation - Economic Appraisal
Safety Certification Document
Start
System Screening – Sites of Promise
Crash Vetting- Sites of Promise
Retrieve and review all crash reports associated with the specific flagged crash locations
Identify and summarize the contributing factors for each crash in the flagged locations. Remove and document all crashes that can not be mitigated through safety improvements
Are there remaining segmental crashes
NO
YES
Are there remaining intersection crashes
NO
YES
Follow the Contributing Geometric Analysis (CGA) process
Are there safety improvements needed to mitigate the remaining crashes.
NO
YES
Document in Safety Certification Document
No further safety evaluation required for geometric improvements or low cost safety improvements.
Note: Roadside safety hardware may still need to be addressed.
Document in Safety Certification Document
Start
Safety Mitigation Certification Process
Page 1

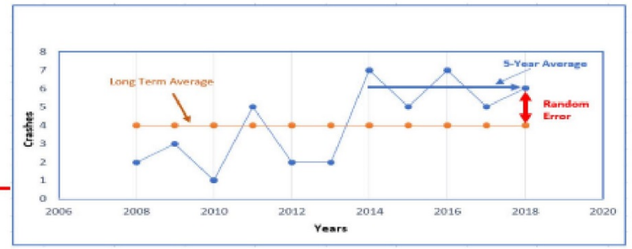
Start Safety Mitigation Certification Process

Performance Based Safety Engineering Analysis And Economic Appraisal

Identify and employ the MOST RELIABLE method and means for quantifying safety impacts based on required inputs applicable applications.

Reliability Increases

Methods	Required Inputs	Applications
1. Apply CMF to observed crashes to obtain the Estimated Crash Frequency	1. Observed Crash History and Applicable CMFs	1. Site configuration or traffic volumes are outside of the applicable ranges of the SPFs.
2A. Use SPF to obtain the Predicted Crash Frequency	2A. Applicable SPFs, Traffic Volumes, and Geometric Parameters	2A. Site configuration can be evaluated using HSM SPFs and EB Method not applicable.
2B. Use SPF with additional CMF to obtain the Predicted Crash Frequency	2B. Applicable SPFs and CMFs, Traffic Volumes, and Geometric Parameters	2B. CMF is needed to modify the SPF prediction to more closely represent the site conditions and EB Method not applicable.
3A. Apply EB method to weight Observed Crash Frequency with Predicted Crash Frequency from method 2A to obtain Expected Crash Frequency	3A. Applicable SPFs, Traffic Volumes, Geometric Parameters, and Observed Crash History.	3A. Site configuration can be evaluated using HSM SPFs and EB Method is applicable.
3B. Apply EB method to weight Observed Crash Frequency with Predicted Crash Frequency from method 2B to obtain Expected Crash Frequency	3B. Applicable SPFs and CMFs, Traffic Volumes Geometric Parameters, and Observed Crash History.	3B. CMF is needed to modify the SPF prediction to more closely represent the site conditions and EB Method is applicable.



Note: Observed Crash Frequency with CMF Adjustments Methodology:

- Can over state crash reductions
- Regression to mean bias (i.e., random variation in crashes over time)

Interactive Highway Safety Design Model (IHSDM) & Highway Safety Benefit -Cost Analysis Tool & Spreadsheets

Apply economic appraisal to the chosen safety mitigation alternatives

Does the safety mitigation alternatives have acceptable benefit cost

NO

Document in Safety Certification document

YES

Document range of reasonable acceptable safety mitigation alternatives for consideration in the project improvement process. Finalized by Project Life Cycle 11

Document in Safety Certification document

Page 2

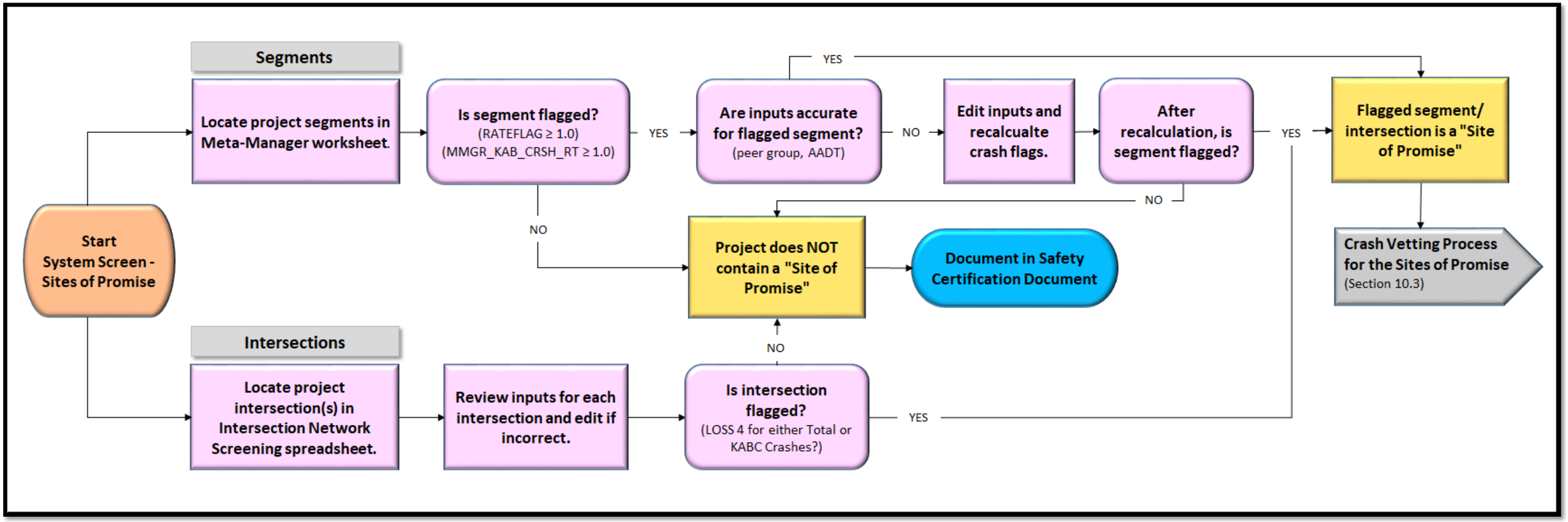
A working copy of this form is available on the Traffic Operations Manual Library website:
https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/manuals.aspx

Safety Certification Worksheet

Analyst: .....
Agency: .....
Date of Analysis: .....
Meta Manager Version: .....
Meta Manager Crash Years: .....

Design ID: .....
Highway: .....
Project Title: .....
Project Description: .....
Worksheet ID: (if using WisTransPortal SCM tool)

System Screening - Sites of Promise									Crash Vetting - Sites of Promise			Contributing Geometric Analysis	
See FDM 11-38-10.2 for guidance									See FDM 11-38-10.3 for guidance			See FDM 11-38-10.4 for guidance	
Segments: Meta-Manager													
PDP ID	From RP	RP Description	To RP	Length (PDP_Mile)	Crash Rate Flag (RATEFLAG) (Insert value if ≥ 1.0)	KAB Crash Rate Flag (MMGR_KAB_CRSH_RT) (Insert value if ≥ 1.00)	Pedestrian Flag (MMGR_PED_TOT) (Insert value if ≥ 1.0)	Bicycle Flag (MMGR_BIKE_TOT) (Insert value if ≥ 1.0)	Number of Crashes Reviewed	Number of Remaining Crashes	Summarize the contributing factors for ALL crashes in the flagged segment.	Which geometric features contribute to the type and severity of the crashes?	Possible Countermeasures for Safety Mitigation Process
Intersections: Intersection Network Screening													
INT_ID	Intersection Name (IX_NAME)				LOSS (TOTAL)	PSI (TOTAL)	LOSS (KABC)	PSI (KABC)	Number of Crashes Reviewed	Number of Remaining Crashes	Summarize the contributing factors for ALL crashes in the flagged intersection.	Which geometric features contribute to the type and severity of the crashes?	Possible Countermeasures for Safety Mitigation Process


Segments
Locate project segments in Meta-Manager worksheet.
Is segment flagged?
(RATEFLAG ≥ 1.0)
(MMGR_KAB_CRSH_RT ≥ 1.0)
YES
Are inputs accurate for flagged segment?
(peer group, AADT)
NO
Edit inputs and recalcualte crash flags.
After recalculation, is segment flagged?
YES
Flagged segment/ intersection is a "Site of Promise"
Crash Vetting Process for the Sites of Promise
(Section 10.3)
NO
Start System Screen - Sites of Promise
NO
Project does NOT contain a "Site of Promise"
Document in Safety Certification Document
Intersections
Locate project intersection(s) in Intersection Network Screening spreadsheet.
Review inputs for each intersection and edit if incorrect.
NO
Is intersection flagged?
(LOSS 4 for either Total or KABC Crashes?)
YES

Location Type	Target Crash Type	Contributing or Geometric Factor	Potential Safety Countermeasure(s)
Intersection: All	All	Driveway within functional area	Restrict access
Intersection: All	Pedestrian	Marked crosswalk	Install advanced stop/yield markings, install high visibility crosswalks
Intersection: All	Right Turn Rear End	Approach angle	"Square up" right turn lane
Intersection: Minor Stop	Rear End/Right Angle	Limited intersection sight distance	Clear sight triangles
Intersection: Minor Stop	Rear End/Right Angle	Nighttime/Inattentive Driving	Install LED blinker stop signs, install intersection lighting
Intersection: Minor Stop	Rear End/Right Angle	Occluded vehicles, right turn lane alignment	Offset mainline right turn lane
Intersection: Minor Stop	Rear End/Right Angle	Speed Related	Install "Stop Ahead" signs, install transverse rumble strips, install Through Route Activated Warning System (TRAWS)
Intersection: Minor Stop	Right Angle	Inadequate gaps in traffic	Use alternative intersection design (RCUT, J-Turn, MUT, etc.)
Intersection: Minor Stop	Right Angle	Intersection skew angle	Improve intersection skew
Intersection: Signalized	Left Turn	Occluded vehicles, left turn lane alignment	Positively offset left turn lanes
Intersection: Signalized	Left Turn	Occluded vehicles, vertical crest curve	Use more restrictive turn phasing
Intersection: Signalized	Left Turn	Split phasing	Install Flashing Yellow Arrow (FYA)
Intersection: Signalized	Pedestrian	Marked crosswalk	Install pedestrian countdown timers, install pedestrian push buttons, start with a leading pedestrian phase
Intersection: Signalized	Rear End	Limited queue storage	Add exclusive turn lane, extend turn lane length
Intersection: Signalized	Rear End/Right Angle	Poor signal timing	Adjust signal timing plan
Intersection: Signalized	Rear End/Right Angle	Poor signal visibility	Install a signal head per lane, install retroreflective signal backplates
Intersection: Signalized	Right Turn	Limited intersection sight distance	Don't allow right turns on red
Segment	Run-Off-Road: All Types	Inattentive driving, narrow lane width, narrow shoulder width	Install shoulder rumble strips, widen travel lanes, widen paved shoulder
Segment	Run-Off-Road: All Types	Polished pavement	Install High Friction Surface Treatment (HFST)
Segment	Run-Off-Road: All Types	Poor delineation	Install wet reflective pavement markings/edge lines
Segment	Run-Off-Road: Fixed Object	Object in clear zone	Remove fixed object, shield fixed object
Segment	Run-Off-Road: Head On & SSO	Inadequate median width	Install median barrier
Segment	Run-Off-Road: Head On & SSO	Inattentive driving	Install centerline rumble strips
Segment	Run-Off-Road: Nighttime	Poor sign visibility	Install retroreflective sign sheeting, install post mounted retroreflectors
Segment	Run-Off-Road: Nighttime	Poor visibility	Install or improve roadway lighting
Segment: All	Run-Off-Road: Weather Related	Pavement design	Improve pavement drainage
Segment: Bridge	Fixed Object	Low vertical clearance	Bridge height warning system
Segment: Rural	Run-Off-Road: Overturn	Non-traversable side slopes or ditch	Flatten side slopes, round ditches
Segment: Rural	Run-Off-Road: Overturn	Pavement edge drop off	Install Safety Edge, pave shoulder
Segment: Urban	Pedestrian	Cross-section	Install pedestrian refuge island
Segment: Urban	Pedestrian	Mid-block crossing	Install Pedestrian Hybrid Beacon (PHB), install Rectangular Rapid Flashing Beacon (RRFB)

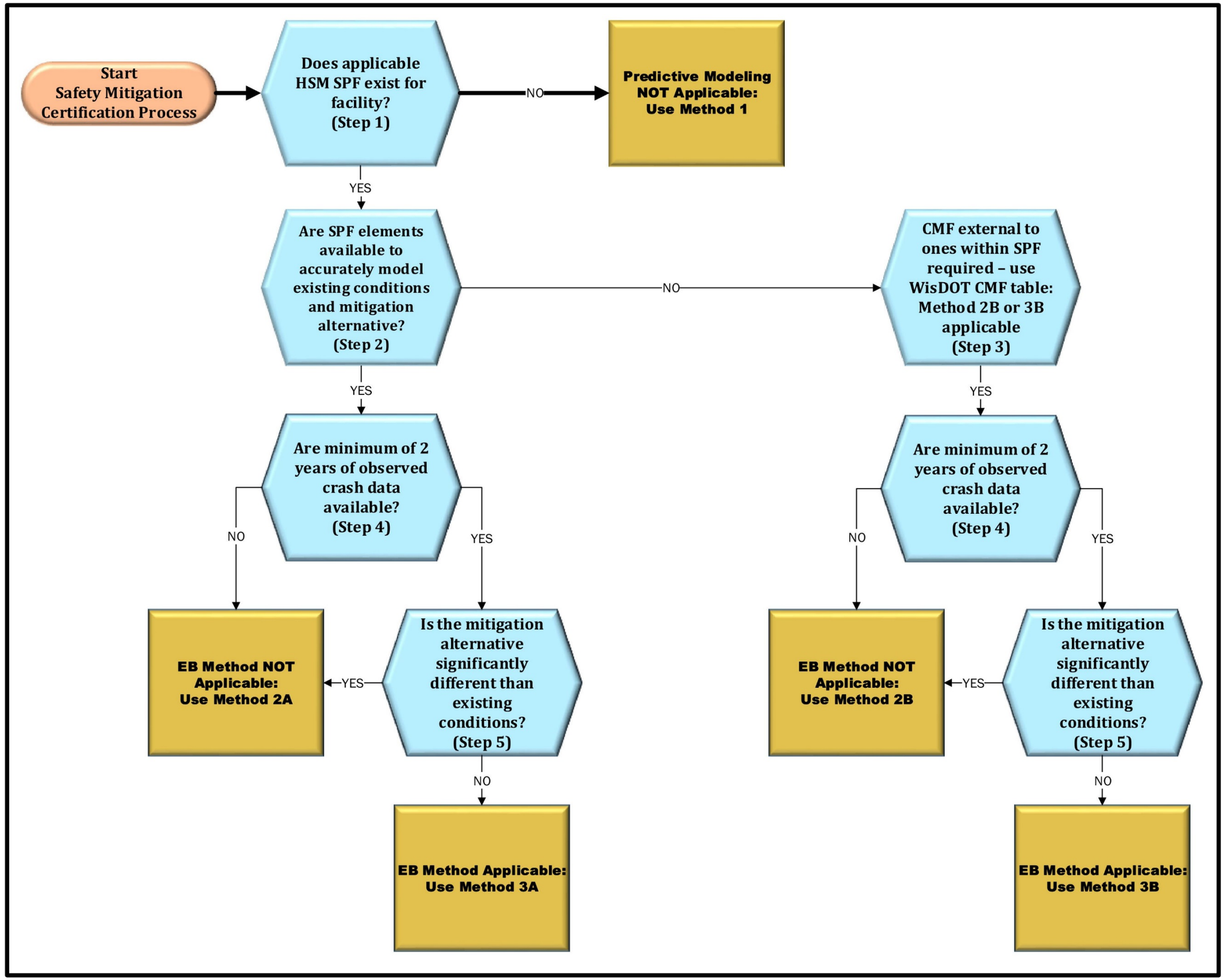
Geometric Factors Covered with IHSDM Predictive Methods

Design Elements covered in HSM Chapters 10-12, 18-19 and by NCHRP Report 888

Design Elements NOT covered by the HSM.
(There may be a CMF that covers the Design Element)

Revised 12/10/2019

	Facility Type HSM 1st Edition Chapter	Rural Two-Lane Highways 10	Rural Multilane Highways 11	Urban & Suburban Arterials 12	Freeways & Interchanges 18 & 19
Roadway Segments	Horizontal and Vertical Alignment	Curve Radius, Superelevation, & Grade	No	No	Curve Radius
	Lane Width	Yes	Yes	No	Yes
	Shoulder Width & Type	Width & Type	Width, Type for Right Shoulder Only	No	Width Only
	Median Width	No	Yes	Yes	Yes
	Access	Driveway Density	No	Driveway Type & Number	Distance Between Ramps & Terminals, Roadways Attached to Ramps
	Roadside	Roadside Hazard Rating	Fill/Ditch Slopes for Divided Roads Only	Fixed Object Density	Roadside (Clear Zone/Barriers)
	Lighting	Yes	Yes	Yes	No
	Other Elements Covered	- Vertical Grade - Centerline Rumble Strips - Passing Lanes - Two-Way Left-Turn Lanes - Auto Speed Enforcement	- Divided or Undivided Median - Shoulder Surface Types - Auto Speed Enforcement	- Divided and Undivided Facilities - Facilities with Two-Way Left Turn Lanes - On-Street Parking Type & Percent of Curb - Speed > or ≤ 30 MPH - Auto Speed Enforcement	**Segments** - Number of Through Lanes - Presence of Rumble Strips - Median Barrier - Type "B" Weaving Segment **Ramps & Collector/Distributor Lanes** - Number of Through Lanes - Freeway Speed
	Elements Not Covered	- Auxiliary Lanes - Lane/Shoulder Cross-Slope - Shoulder Rumble Strips	- Auxiliary Lanes - Lane/Shoulder Cross-Slope - Shoulder Rumble Strips	- Auxiliary Lanes - 6 or More Lanes Total - One-Way Roads - Lane/Shoulder Cross-Slope - Shoulder Rumble Strips	- High Occupancy Vehicle (HOV) & High Occupancy Toll (HOT) Lanes - Tunnels (Light/Dark Difference) - Freeway Along Another Roadway Without Barrier Between Them - Ramps Along Roadways - Lane/Shoulder Cross-Slope
Intersections	Skew Angle	Stop Control Only	Stop Control Only	No	No
	Intersection Sight Distance	No	No	No	No
	Ped & Bike	No	No	Ped Volume & Max Lanes Crossed at Signals	No
	Lighting	Yes	Stop Control Only	Yes	Yes
	Left and Right Turn Lanes	Yes	Yes	Yes	Yes
	Other Elements Covered	**Roundabouts** - 3 and 4 legs - 1 and 2 circulating lanes	**Roundabouts** - 3 and 4 legs - 1 and 2 circulating lanes	**Signals** - Type of Left Turn Phasing, Right Turn on Red Prohibited, Red Light Cameras - Bus Stops, Schools, & Alcohol Sales within 1000' of Int. **Roundabouts** - 3 and 4 legs - 1 and 2 circulating lanes	- Number of Through Lanes - Left & Right Turn Lane Channelization **Roundabouts** - 3 and 4 legs - 1 and 2 circulating lanes
	Elements Not Covered	- 3 leg Signalized - More than 4 Legs - All-Way Stop Intersections - Intersections with Control Type of "Other"	- 3 leg Signalized - More than 4 Legs - All-Way Stop Intersections - Intersections with Control Type of "Other"	- More than 4 Legs - All-Way Stop Intersections - Yield-Controlled Intersections - Uncontrolled Intersections	- More than 4 Legs - Single Point Urban Interchanges - Diverging Diamond Interchanges


Start
Safety Mitigation
Certification Process
Does applicable HSM SPF exist for facility? (Step 1)
NO
Predictive Modeling NOT Applicable: Use Method 1
YES
Are SPF elements available to accurately model existing conditions and mitigation alternative? (Step 2)
NO
CMF external to ones within SPF required – use WisDOT CMF table: Method 2B or 3B applicable (Step 3)
YES
Are minimum of 2 years of observed crash data available? (Step 4)
NO
YES
EB Method NOT Applicable: Use Method 2A
YES
Is the mitigation alternative significantly different than existing conditions? (Step 5)
NO
EB Method Applicable: Use Method 3A
YES
Are minimum of 2 years of observed crash data available? (Step 4)
NO
YES
EB Method NOT Applicable: Use Method 2B
YES
Is the mitigation alternative significantly different than existing conditions? (Step 5)
NO
EB Method Applicable: Use Method 3B

A working copy of this form is available on the Traffic Operations Manual Library website:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/manuals.aspx

CORRESPONDENCE/MEMORANDUM_____State of Wisconsin

Date: _____, 20___

To: <Region Name> Region Planning Chief: <Chief Name>

Bureau of Traffic Operations – Traffic Engineering and Safety Section
(BTOSafetyEngineering@dot.wi.gov)

From: _____
_____ Region

Subject: SAFETY CERTIFICATION DOCUMENT
Project I.D. (design) _____
(STH, IH, USH (choose one)) _____
_____ County

Having considered the safety performance of the existing corridor and any proposed improvements, we believe this document reflects the intent of the policy and guidelines described in section 11-38 of the Wisconsin Facilities Development Manual.

Concurrence:

_____ _____
Bureau of Traffic Operations Date
Traffic Engineering and Safety Section

Approval:

_____ _____
Region Planning Chief Date

SAFETY CERTIFICATION DOCUMENT

Analyst: **Design ID:**

Agency: **Highway:**

Date: **Project Title:**

Improvement Concept Code:

1. **Did the project have Sites of Promise from the system screening?** Yes ☐ No ☐

   Comments:
   Identify the number of Sites of Promise (i.e. "flagged" locations) within the project area. Include the Meta Manager PDP or the Intersection ID as well as other contextual information (i.e. street names) to describe the location of the SItes of Promise.

2. **Did relevant crashes remain after the initial Crash Vetting Process?** Yes ☐ No ☐

   Comments:

   Identify which crashes should be targeted for engineering improvements and which were vetted out. Describe the trends and contributing factors for the crashes in each Site of Promise that is moving forward in the CGA process.

3. **Were possible safety mitigation alternatives identified in the CGA Process?** Yes ☐ No ☐

   Comments:

   For each Site of Promise evaluated in the CGA process, explain if safety improvements will be evaluated to target the crash trends and contributing factors.

4. **Were safety mitigation alternatives analyzed in this project?** Yes ☐ No ☐

   4.1. **Provide narrative of existing geometric conditions and describe any geometric features that contributed to the type or severity of the crashes.**

   4.2. **Provide narrative of crash history, crash trends, and contributing factors that were targeted in the safety mitigation alternatives.**

   4.3. **Provide narrative and the name for each safety mitigation alternative analyzed in SMCP**

4.4. **Analysis Results**

Analysis Location:

Analysis Method:

External CMF Value:

External CMF Source:

	Base	Alt. A	Alt. B	Add/Remove columns
Alternative Name				
Fatal & Injury Crashes				
Property Damage				
Total Crashes				
Benefits				
Cost				
B/C				

Comments:
Describe the analysis results, including the CMF values and IDs (for sources) used.

4.5. **Provide narrative of reasonable and acceptable safety mitigation alternatives for consideration in the project improvement process**

ATTACHMENTS

Include all attachments in the final SCD and submit as a PDF

A. Project Information
    a. Project Location/Overview Map
    b. Crash Diagram(s)
B. Sites of Promise Documentation
    a. Meta-Manager spreadsheet
    b. Intersection Network Screening spreadsheet
C. Crash Vetting Documentation
    a. WisTransPortal crash data spreadsheet with vetting comments
D. Contributing Geometric Analysis Documentation
    a. Safety Certification Worksheet
E. Safety Mitigation Certification Documentation
    a. Layout/Schematic for each alternative
    b. Cost estimate for each alternative
    c. IHSDM Crash Prediction Evaluation Report for each alternative
    d. IHSDM Economic Analysis Report
    e. Highway Safety Benefit Cost Analysis Tool results

FDM 11-40-1 General Perpetuation and Rehabilitation Requirements for Highways

August 17, 2020

1.0 Introduction

This section contains design guidance for Perpetuation and Rehabilitation projects on highways (formerly referred to as 3R projects). These include State Trunk Highways (STH), non-STH (local roads), Expressways and non-Interstate Freeways, and Interstate Highways.

1.1 Overview of Perpetuation and Rehabilitation Projects

The intent of Perpetuation and Rehabilitation projects is to preserve and extend the service life of existing highways and to enhance highway safety when needed. The development of Perpetuation and Rehabilitation projects must ensure that the design features of the existing roadway are preserved or enhanced. System functions including serviceability and safety of operations must not be degraded[1].

The design of Perpetuation and Rehabilitation projects shall be in accordance with the Facilities Development Process described in FDM Chapter 3. One of the first tasks to do is to determine the appropriate scope of work to best address the purpose and need for a proposed project.

Funding constraints and practical limitations to upgrading existing highways, especially where additional right-of-way is required, are major factors in determining the scope of work for Perpetuation and Rehabilitation projects.

Application of design criteria for Perpetuation and Rehabilitation projects shall be in accordance with FDM 11-1-10, including the application of ancillary factors.

1.1.1 Definitions

Perpetuation and Rehabilitation projects are typically those that address pavement needs or deficiencies, and which tend to follow or minimally deviate from existing horizontal and vertical alignments. Perpetuation and Rehabilitation projects differ from Modernization projects (new construction and reconstruction) in that they do not substantially deviate from existing horizontal and vertical alignments nor add capacity.

The typical scope of work for Perpetuation and Rehabilitation projects exceeds the scope of work for routine maintenance projects but is less than the scope of work for Modernization projects.

FDM 3-5-1.1 contains definitions for Perpetuation and Rehabilitation improvement strategies.

1.2 Safety Analysis

While safety may not be the primary reason for initiating a Perpetuation or Rehabilitation project, it is an essential element of these projects.

1.2.1 Safety Certification Process

See FDM 11-1 Attachment 10.1 for when the Safety Certification Process (SCP) is required for improvement projects. The SCP is described in detail in FDM 11-38.

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[1] The FHWA 1988 Technical Advisory on 3R projects[2] and TRB Special Report 214[3] indicate that a “Safety-Conscious Design Process” should be used on 3R projects.

1.2.1.1 Safety Certification Process – Local Roads

For non-STH Perpetuation, Rehabilitation and Reconstruction Type Modernization projects, local officials may complete their own SCD. New construction type Modernization projects on non-STH routes will not require an SCD. These projects will use S-3 application which uses the upper end of the design criteria range. See FDM 11-1-10 for additional information regarding S-3 application. Local Bridge Assistance Program projects do not require an SCD as the Replace in Kind Policy issued by the Division of Transportation Investment Management (DTIM) January 2018 applies (See FDM 3-20 Attachment 1.1).

If an SCD is not prepared for a project S-3 application must be used. Use of criteria less than S-3 application require Design Justifications documented in the DSR. A local public agency may complete a SCD as a justification for use of criteria less than S-3 application.

Non-STH (local roads) crash information can be obtained from the University of Wisconsin Traffic Operations and Safety (TOPS) Lab or from local crash data bases maintained by the engineering or police departments. The crash information can then be analyzed to identify specific safety problems that might be mitigated within the project scope of work and determine if the location(s) are considered a safety risk/hazard compared to the performance of similar highways.

Similar steps in the SCP (found in FDM 11-38) can then be followed to produce a SCD. Techniques and results should be documented similarly to the process used for STH projects shown in FDM 11-38. Details regarding content and complexity of the SCD should be coordinated with the regional local program project manager (LPPM). Please note: Local public agencies should consider completing their safety analysis prior to submitting their project application to accurately size their funding request.

1.3 Design Criteria Application

Geometric design criteria have been developed for Perpetuation and Rehabilitation projects (formerly referred to as 3R projects) in accordance with Part 625 of Title 23, Code of Federal Regulations, "Highways" and FHWA Technical Advisory T 5040.28, "Developing Geometric Design Criteria and Processes for Non-freeway RRR Projects."[2]

The principal sources of information used to develop these criteria were the FHWA Technical Advisory and Transportation Research Board's Special Report 214, "Designing Safer Roads."[3]

Perpetuation and Rehabilitation projects will incorporate the existing nationally recognized 3R Standards as the base design criteria values for geometric and cross-sectional roadway features.

The mechanisms that WisDOT will use to apply these criteria will be through S-1 and S-2 applications. These applications will apply to both Federal-aid and State funded projects.

See FDM 11-1-10 for additional information regarding S-1 and S-2 applications.

1.3.1 Intersection Control Evaluations

Perpetuation and Rehabilitation projects designed and constructed with federal or state funding must comply with the Intersection Control Evaluation (ICE) process when considering intersection traffic control improvement alternatives.

See FDM 11-25-3 for additional information regarding the ICE process.

1.4 Bridge Improvements

Coordinate development of a Bridge or Structure Certification Document (BOSCD) on Perpetuation and Rehabilitation projects that contain bridge improvements with the Bureau of Structures (BOS). Bridge replacement, whether as part of a Perpetuation or Rehabilitation project or as another project, shall be done to new construction design criteria.

The BOSCD process will evaluate bridges within the limits of Perpetuation and Rehabilitation projects to determine their structural and operational adequacy to determine whether replacement or widening of the

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[2] Developing Geometric Design Criteria and Processes for Non-freeway RRR Projects. FHWA Technical Advisory T 5040. 28. Federal Highway Administration, 10-17-1988. http://www.fhwa.dot.gov/design/t504028.cfm. Ref ID: 340

[3] TRB Special Report 214: Designing Safer Roads: Practices for Resurfacing, Restoration, and Rehabilitation. Transportation Research Board, National Research Council, Washington, DC, 1987. http://onlinepubs.trb.org/Onlinepubs/sr/sr214/sr214_001_fm.pdf. Ref ID: 341

bridges would be cost-effective. Table 1.1 shows the location of FDM guidance for bridges.

Table 1.1 FDM Reference Guidance for Bridges

Bridge Element	FDM Chapter
Railing	FDM 11-45-20 and FDM 11-45-30
Vertical Clearance	FDM 11-35 Attachments 1.8 and 1.9
Width	Table 1.2

Table 1.2 Lowest Roadway Widths for 2-Lane Bridges, with Lengths < 100 feet, to Remain in Place*

Design AADT	State Trunk Highways and County Trunk Highways[2]	Town Roads[2]
0 – 100	The greater of either 18 ft.[1] or Traveled Way width	The greater of either 18 ft.[1] or Traveled Way width
101 – 400	The greater of either 20 ft.[1] or Traveled Way width	The greater of either 20 ft.[1] or Traveled Way width
401 – 750	The greater of either 22 ft.[1] or Traveled Way width	The greater of either 22 ft.[1] or Traveled Way width + 1 ft. on each side
751 – 1000	The greater of either 22 ft.[1] or Traveled Way width + 1 ft. on each side	The greater of either 22 ft.[1] or Traveled Way width + 2 ft. on each side
1001 – 2000	The greater of either 24 ft.[1] or Traveled Way width + 1 ft. on each side	The greater of either 24 ft.[1] or Traveled Way width + 2 ft. on each side
2001 – 4000	The greater of either 28 ft.[1] or Traveled Way width + 2 ft. on each side	The greater of either 28 ft.[1] or Traveled Way width + 2 ft. on each side
4001 - 5000	The greater of either 28 ft.[1] or Traveled Way width + 3 ft. on each side	The greater of either 28 ft.[1] or Traveled Way width + 2 ft. on each side
>5000	The greater of either 32 ft.[1] or Traveled Way width + 3 ft. on each side	The greater of either 32 ft.[1] or Traveled Way width + 2 ft. on each side

* Widths shown may not meet bridge roadway width requirements for bridge reconstruction or bridge rehabilitation.

[1] Lowest Bridge Roadway Width, Curb-To-Curb, To NOT Be Considered Functionally Obsolete Reference[4] - Item 68, Table 2A - Rating Code 4

[2] If lane widening is planned as part of a Rehabilitation project, the lowest usable bridge width is the paved roadway (traveled way plus surfaced shoulders).

1.4.1 Bridges on Expressways, Non-Interstate Freeways and Interstates

Bridges to remain in place must have 12-foot wide traffic lanes, 10-foot wide shoulders on the right, and 3.5-foot wide shoulders on the left. On bridges 200 feet or longer, the lowest shoulder widths will be 3.5 feet for both left and right shoulders.

1.5 Pavement Design

Pavement design (lanes and shoulders) for Perpetuation and Rehabilitation projects shall be in accordance with FDM 14-10.

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[4] FHWA. Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges. FHWA-PD-96-001. Office of Engineering, Bridge Division, Bridge Management Branch, Washington, DC, 12-1995. http://www.fhwa.dot.gov/bridge/mtguide.pdf. Ref ID: 233

1.5.1 Shoulder Paving

On Perpetuation and Rehabilitation projects, the following apply:

1. The shoulder next to designated driving lanes shall be paved on STHs functionally classified as arterials, regardless of traffic volume. See Table 1.3.
2. The shoulder next to designated driving lanes shall be paved 3 feet on County Trunk Highways (CTH) functionally classified as arterials, regardless of the traffic volume. See Trans 205.
3. Shoulders on STHs classified as collectors or locals and having a current AADT above 750 vehicles shall be paved in accordance with Table 1.3.
4. CTHs functionally classified as collectors or locals, and other local highways may have paved shoulders at the discretion of the local officials. See Trans 205.
5. Continuity of shoulder paving between logical termini is desirable. Do not leave gaps of unpaved shoulders. For purposes of continuity and the closing of short gaps, it may be desirable to pave the shoulders on sections of highway where resurfacing or rehabilitating traffic lanes may not be planned for several years, provided the shoulder paving is done in conjunction with surfacing or resurfacing, or rehabilitating an abutting highway segment.
6. When paving is warranted on highways with existing narrow travel lanes it may be desirable to increase the travel lane width. Shoulder paving width is in addition to the revised travel lane width and in accordance with Table 1.3.

Table 1.3 Rural STH Paved Shoulder Width Requirements [1]

DESIGN CLASS		PAVED SHOULDER WIDTH
RA1		3 ft.
RC3, RL4		3 ft.
RA2		3 ft.
RC4, RL5		3 ft.
RA3	4 - LANE DIVIDED EXPRESSWAY	R[2] - 8 ft. L - 3 ft.
RA3	6 - LANE DIVIDED EXPRESSWAY	R - 8 ft. L - 8 ft.
RA3	4 - LANE INTERSTATE OR FREEWAY	R - 10 ft. L - 4 ft.
RA3	6 - LANE INTERSTATE OR FREEWAY	R - 10 ft. L - 10 ft.
RA3	1 - LANE RAMPS	R - 5 ft. L - 3 ft.

[1] See FDM 11-46-15 for shoulder criteria to accommodate bicycles.

[2] These shoulder widths also apply to the initial two-lane roadways of ultimate four-lane highways except when construction of the second roadway is not expected for at least six years. In these cases, initially pave only 3 feet R along concrete roadways and 5 feet R along asphaltic roadways.

1.5.2 Usable Shoulder Width

Usable shoulder width is the design criterion for shoulder width[5]. Usable shoulder width equals the total graded shoulder width if the contiguous foreslope is 4:1 or flatter. Usable shoulder width is less than the total graded shoulder width if the contiguous foreslope is steeper than 4:1. See Figure 1.1. It is not necessary to make a reduction for foreslopes that are 3.6:1 or flatter, because the reduction is relatively nominal. For foreslopes that are steeper than 3.6:1, use Table 1.4 to determine the reduction in usable shoulder width.

Table 1.4 Useable Shoulder Width Reduction for Foreslopes Within Clear Zone

Foreslope Contiguous with Graded Shoulder (H : V)	Reduction in Usable Shoulder Width (feet)
3.6:1 or flatter	Nominal (0.40 or less) – no reduction required
3.5:1	0.50
3:1	1.00
2.5:1	1.50
2:1	2.00
1.5:1	2.50
1:1	3.00

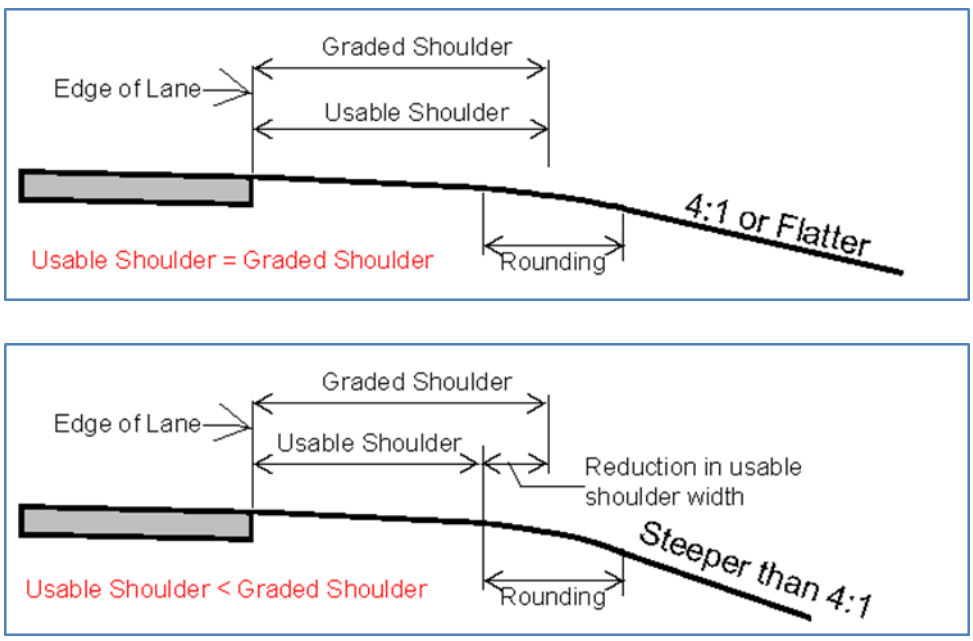

Figure 1.1 Usable Shoulder Width

1.6 Traffic Control Devices and Pavement Marking

Upgrade all traffic control devices and pavement marking to be in conformance with the current MUTCD,

[5] FHWA SA-07-11, "Mitigation Strategies for Design Exceptions", page 36:(8) Clarification: Usable and Paved Shoulders: ". A usable shoulder width is the actual width available for the driver to make an emergency or parking stop. This is measured from the edge of traveled way to the point of intersection of the shoulder slope and mild slope, or to beginning of rounding to slopes steeper than 1V:4H (note: this definition is also in the 2001 AASHTO GDHS, chapter 4, page 317:(1)). Usable shoulders do not have to be paved.

Wisconsin MUTCD and Wisconsin Traffic Engineering, Operations and Safety Manual (TEOpS).

Apply new pavement marking on all Perpetuation and Rehabilitation projects where the existing pavement marking is damaged or obliterated.

1.7 Rumble Strips

See FDM 11-15-1.8 for additional rumble strip design guidance.

1.7.1 Rural Shoulder Rumble Strips

Rural shoulder rumble strips may be installed on Perpetuation and Rehabilitation projects that have at least a 5-foot paved shoulder, subject to the conditions listed in FDM 11-15-1.8 and approval by the Region Pavement Engineer.

1.7.2 Rural Centerline Rumble Strips

Rural centerline rumble strips may be installed on all Perpetuation and Rehabilitation projects that have asphalt pavement with 12-foot lane widths and where the Region Pavement Engineer has determined that the centerline joint will be in good, stable condition to mill-in rumbles after the work is completed.

See FDM 11-15-1.8 for additional rural centerline rumble strip design guidance.

1.8 Passing Sight Distance for Vertical Curves

This section is provided for configuring project pavement marking and providing a reference for Safety Screening Process evaluation.

There is no existing policy or design criterion specifying the percentage of the length of a roadway to be used for passing opportunities. The decision to improve passing opportunities is made individually for each project. Items to be considered are the terrain, annual average daily traffic (AADT), design class and existing percent passing. The following text about non-striping distances is advisory and is to be used to evaluate when an improvement in passing opportunities is desirable.

The earthwork required to flatten a vertical curve to achieve safe Passing Sight Distance (PSD) is usually beyond the scope of a typical Perpetuation or Rehabilitation project. However, S-2 application highway segments and locations on Rehabilitation projects with grading may provide opportunities to improve sight distance at crest vertical curves.

Table 1.5 shows the lowest non-striping sight distance to provide when the Passing Sight Distances (PSDs) for Modernization Projects FDM 11-10 Attachment 5.1 and FDM 11-10 Attachment 5.5 cannot be achieved on Perpetuation or Rehabilitation projects. Use this table sparingly because, although the use of non-striping sight distances avoids the need for a no-passing zone marking, the distance provided is not the same as the lowest PSD for S-3 application.

Because the non-striping distances are considerably less than the PSDs used for Modernization projects, fewer vehicles will be able to pass within any single passing zone. Therefore, it is generally safer, more cost effective and improves traffic operations more to re-grade one or two vertical curves to achieve the sight distance values for the S-2 segments and locations on Rehabilitation projects than it is to re-grade a series of curves to the non-striping distance values shown in Table 1.5. If employing this strategy, ensure that the spacing between successive passing zones both within and beyond the ends of the project are reasonable.

Table 1.5 Non-Striping Sight Distances

Design Speed (mph)[1]	Non-Striping Distance (ft.)	No-Passing Zone Distance (ft.)[2]
30	800	528
35	950	686
40	1100	686
45	1240	845
50	1380	845
55	1540	1108
60	1700	---

[1] Speed limit is used to determine no-passing zone distances.
2 The Manual on Uniform Traffic Control Devices (MUTCD) is the source of no-passing zone distances.

These distances are used to determine where No-passing zones are marked on the highway. Do not use no-passing zone distances for design.

1.9 Passing and Truck Climbing Lanes

The addition of passing or truck climbing lanes may be applicable for use on Rehabilitation projects in segments or locations with S-2 application, to provide or improve the desired frequency of safe passing zones.

Perpetuation projects will typically not include the construction of passing or truck climbing lanes.

See FDM 11-15-10 for additional passing and truck climbing lane design guidance.

1.9.1 Passing Lane Clear Zones

On Rehabilitation projects, typical passing lane clear zones are the greater of the AS-BUILT clear zone distances from previous construction or the Rehabilitation clear zone requirements in FDM 11-45-30.

See FDM 11-15-10 for additional passing lane design guidance.

1.10 Bicycle and Pedestrian Accommodations

Curb ramps with detectable warning fields shall be installed or upgraded to the max extent feasible on all state or federally funded Perpetuation and Rehabilitation projects with sidewalk that meet the Americans with Disabilities Act (ADA) definition of an “alteration” (see FDM 11-46 Attachments 1.2 and 1.3).

See FDM 11-46 for guidance on bicycle and pedestrian accommodations.

1.11 Roadside Design

Roadside characteristics are important in determining the overall level of safety provided by a highway. The cost-effectiveness of some roadside improvements is highly dependent on the site-specific conditions and interactions between different roadside features.

Perform a roadside hazard analysis (RHA) in accordance with the guidance in FDM 11-45-10.

See FDM 11-15 and FDM 11-45 for guidance on roadside hazards and treatments.

1.11.1 Clear Zone and Lateral Clearance

Clear Zone and Lateral Clearance are not the same and are not controlling design criteria.

1.11.1.1 Clear Zone

Clear zone is defined in FDM 11-15-1.13.1.

WisDOT design criterion for constructing side slopes that contain traversable but non-recoverable slopes within the clear zone is that a recoverable slope (4:1 or flatter) be constructed contiguous with the shoulder before introducing the traversable but non-recoverable slope, (see page 2 of FDM 11-15 Attachment 1.9). However, if an existing side slope does not meet this requirement, then an existing CLEAR runout area at the foot of this slope would still be considered part of existing clear zone. This existing clear runout area should be at least 10-feet wide, recoverable and free of fixed object hazards. The existing clear zone distance in this case is equal to the existing usable shoulder width (see FDM 11-40-1.5.2) plus existing clear runout area.

See FDM 11-45-15.1.3 for preferred roadside hazard treatment sequence.

Do not reduce existing clear zone width on Perpetuation and Rehabilitation projects.

If no as-builts exist that previously established a clear zone use the following:

Rural Highways

- Where the design AADT is less than 1,500, the minimum clear zone width shall be the greater of either 10 feet or existing clear zone, but not farther than the right-of-way limits.
- Where the design AADT is greater than or equal to 1,500, the minimum clear zone width shall be the greater of either 18 feet or existing clear zone but not farther than the right-of-way limits.

Urban and Suburban Roadways - With Shoulders

- Where the posted speed is 45 mph or less the minimum clear zone width shall be the greater of either 10 feet or existing clear zone but not farther than the right-of-way limits.
- Where the design AADT is less than 1,500 and the posted speed is greater than 45 mph, the minimum clear zone width shall be the greater of either 10 feet or existing clear zone, but not farther

than the right-of-way limits.

- Where the design AADT is greater than or equal to 1,500 and the posted speed is greater than 45
- mph the minimum clear zone width shall be the greater of either 18 feet or existing clear zone, but not farther than the right-of-way limits.

Roadways with Curbs and Posted Speeds of 40 mph or Less

- Provide clear zone to the extent practical.

Roadways with Curbs and Posted Speeds of 45 mph or Greater

- The clear zone width shall be as required for rural highways measured from the edge of the through traffic lane - see above.

The extent of the clear zone depends on the design speed and the probability of a vehicle leaving the roadway. Clear zone establishes the "Zone" in which obstructions or steep slopes warrant evaluation. This "Zone" includes any clear runout areas. Therefore, the proposed clear zone and the basis for its selection should be documented in the DSR. If the clear zone width is less than the bottom of the range for a proposed project, the reason must be documented in the DSR. Approval of the DSR establishes individual project design justifications (DJs) to the WisDOT clear zone policy.

1.11.1.2 Lateral Clearance

Lateral clearance is required for all urban and rural roadways.

Lateral Clearance (also known as "operational offset") is defined in FDM 11-15-1.13.2.2.

See FDM 11-15 Table 1.2 and FDM 11-15 Attachment 1.14 for guidance on rural lateral clearance.

See FDM 11-20-1.9.1 for guidance on urban lateral clearance.

1.11.2 Roadside Hazards

FDM 11-45-20 and FDM 11-45-30 is the primary source for guidance for roadside hazards and treatments. The following sections will provide some additional discussion about roadside hazards on Perpetuation and Rehabilitation projects.

1.11.2.1 Utilities

Avoid allowing utilities to locate/relocate in locations where Run off the Road crashes are likely to occur. Above ground utility features such as poles, guy wires, pedestals, etc. shall be relocated outside the lower minimum clear zone. In addition, do not allow above ground utility features near ditch bottoms or on ditch foreslopes.

Departmental utility accommodation policy[6] states that both above-ground and below-ground utility" lines shall be on uniform alignment and located as near as practical to the R/W line without affecting the R/W and geodetic control monuments".

At some locations, it can be difficult to move a hazardous utility pole because of utility design requirements (e.g. electrical transmission lines need to have safety zone around the electrical lines, or a significant amount of fiber optic may need to be replaced to fix a minor conflict). At other locations, other constraints make it difficult (e.g. a downtown area with limited terrace width and buildings at the right of way line). If it is not possible to move a hazardous pole then provide mitigation such as breakaway or energy absorbing poles. Reducing the number of poles may also help. Methods to minimize the number utility poles include:

- Utilities sharing poles,
- Taller poles with greater post spacing
- Underground utilities

Note: Utility companies have a legal right to occupy highway right of way through a permit process. Coordinate with regional utility staff.

1.11.2.2 Trees

Trees can be a significant hazard – see FDM 11-45-20.3.5.1. Avoid adding new trees on Perpetuation and Rehabilitation projects.

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[6] Location Requirements. In WisDOT Highway Maintenance Manual Chapter 9, Section 15: Utility Accommodation Policy. Wisconsin DOT, Madison, WI, 2010, subject 25, pp. 1-4. http://www.dot.wisconsin.gov/business/rules/docs/09-15-25.pdf. Ref ID: 897

In rural areas, it is more likely that trees can be removed. In urban, suburban or transitions between urban and suburban areas it may be more difficult to remove trees.

In some cases, other factors such as project type or crash history may influence the decision to remove existing trees. For example, it may not be feasible to remove existing trees in an urban area when an overlay project is on existing alignment. The presence of a bike lane or parking lane also helps to reduce the chances of a vehicle hitting a tree because of the increased distance from the travel lane.

However, removal of hazardous trees should become more of a priority on Perpetuation and Rehabilitation projects with a longer life cycle, or where a section of the project is off the original alignment.

1.11.2.3 Hazardous Mailboxes and Supports

Hazardous mailboxes and supports within the clear zone shall be identified and either modified or replaced in cooperation with the owners in S-2 and S-3 areas. See FDM 11-45-10 for discussion on when to perform an RHA for further detail. See FDM 11-15-1.13.2.5 for additional guidance on hazardous mailbox supports.

1.11.2.4 Sign and Light Supports

See FDM 11-45-20.3.4, FDM 11-45-20.4.2.4 and FDM 11-55-20 for roadside design guidance regarding overhead sign supports, sign bridges, mono tube signs, and message boards. These devices are typically too heavy or large to be breakaway.

Use crashworthy supports when adding new lights or other non-utility poles and for small signs. Provide documentation in the DSR when crashworthy supports are not used.

1.11.2.5 Bridge Piers and Abutments

Review the location of bridge piers and abutments to determine if shielding for vehicle protection is required (see FDM 11-45-15.1.3.5).

1.12 Final Scope Certification (FSC) Document Preparation

Perpetuation and Rehabilitation projects will have FSC document prepared. See FDM 11-4-3 Final Scope Certification for more details regarding preparation of the FSC document.

FDM 11-40-6 Design Criteria for Perpetuation Projects *August 17, 2020*

6.0 General

This procedure applies to Perpetuation projects (Preservation/Restoration, Resurfacing and Bridge Rehabilitation work types) on STH, non-STH, Expressways and non-Interstate Freeways and Interstate Highways. See FDM 3-5-1 for additional information on Perpetuation projects.

Perpetuation projects that have no safety or operational issues as indicated by the SCD will use S-1 application (which retains the existing roadway features as design criteria). Consideration can still be given to the addition of low-cost safety mitigation measures if they are determined to be effective and appropriately fit within the project scope.

The SCD described in FDM 11-38 is not available for non-STH (local roads) Perpetuation projects.

See FDM 11-1-10 for additional information regarding S-1 application.

6.1 General Perpetuation Design Criteria with S-1 Application

The existing roadway features listed below shall be retained on all routes (including both NHS and non-NHS).

- Design Speed
- Horizontal Curve Radius
- Superelevation Rate
- Stopping Sight Distance
- Crest Vertical Curves
- Sag Vertical Curves
- Grades

6.2 Intersections

See FDM 11-25 for design guidance on intersections.

6.2.1 Intersection Sight Distance

Existing Intersection Sight Distance (ISD) shall be retained on all routes (including both NHS and non-NHS). See FDM 11-10-5.1.4 for additional guidance regarding ISD.

6.2.2 Vision Triangles

See FDM 11-10-5.1.4.3 for additional guidance regarding vision triangles.

6.2.3 Intersection Angles

See FDM 11-25-2.8 for guidance on intersection angles.

6.2.4 Intersection Design Vehicle and Intersection Check Vehicle

See FDM 11-25-2.1 and FDM 11-25 Table 2.1 for guidance on intersection design vehicles.

6.3 Roadway Cross Section Elements

6.3.1 Rural Highway Design Criteria

The existing two-lane rural highway features listed below shall be retained on all routes (including both NHS and non-NHS):

- Rural Lane Width
- Paved Shoulder Width - Typically minimum paved shoulder on most STH's should be 3'.
- Rural Pavement Cross Slope
- Rural Auxiliary Lanes (See FDM 11-25-35 for additional information about auxiliary lanes)
- Rural Two-Way Left Turn Lanes (See FDM 11-25-5.4.2 for additional information about TWLTLs)
- Side Slope and Ditch Design Criteria

6.3.1.1 Rural Shoulder Unpaved Width and Cross Slope

Unpaved shoulder widths and shoulder cross slopes may be altered due to an increase in the net pavement elevation if existing typical section and safety review allow. These changes may allow for matching at the subgrade shoulder point. Usable shoulder width should be taken into consideration when determining alterations to unpaved shoulder width and cross slope (See FDM 11-40-1.5.2.) Coordinate with BPD and Regional Safety Engineer.

6.3.2 Urban Highway Design Criteria

The existing urban roadway features listed below shall be retained on all routes (including both NHS and non-NHS):

- Urban Lane Width and Shoulder Width
- Urban Auxiliary Lanes (See FDM 11-25-35 for additional information about auxiliary lanes) - Urban Two-Way Left Turn Lanes (See FDM 11-25-5.4.2 for additional information about TWLTLs)
- Lateral Clearance Design Criteria (See FDM 11-40-1.11.2 for additional information about lateral clearance)

6.3.2.1 Urban Pavement Cross Slope

The pavements of urban roadways typically have crowns in the middle and slope downward toward both edges. The downward cross slope should be plane rather than curved (parabolic) sections.

Urban pavement cross slopes may need to be altered on RSRF20, RSRF30 and COLD20 projects due to an increase in the net pavement elevation. See Table 6.1 for cross slope rates to use.

Table 6.1 Cross Slopes for Urban Roadways

Lanes	Lower	Higher
Driving	2%	3%
Parking, Turning, etc.	2%	4%

6.3.3 Pavement Edge Drops

Pavement edge drops are undesirable, no matter how they develop, because of safety implications associated

with the vehicle recovery maneuver. Pavement edge drops can develop between the pavement surface and the adjacent unpaved shoulder or roadside. Avoid potential edge drops on Perpetuation projects by:

1. Paving the shoulders when warranted by policy.
2. Selectively paving shoulders at points where encroachments are likely to create pavement edge drops, such as on the inside of horizontal curves.
3. Providing a safety-edge as described in FDM 11-45-30.7.
4. Restoring gravel shoulders.

6.3.4 Clear Zone Design Criteria

Do not reduce existing clear zone width on Perpetuation projects. The existing clear zone width shall be retained on all Perpetuation projects (including both NHS and non-NHS routes).

See FDM 11-45 for additional information about clear zones.

FDM 11-40-7 Design Criteria for Rehabilitation Projects

May 15, 2019

7.0 General

This procedure applies to Rehabilitation projects (Reconditioning, Pavement Replacement and Bridge Rehabilitation work types) on STH, non-STH (local roads), Expressways and non-Interstate Freeways, and Interstate Highways. See FDM 3-5-1 for additional information on Rehabilitation projects.

Rehabilitation projects will typically contain both S-1 and S-2 applications. Rehabilitation projects will use S-2 application on segments and at locations with safety or operational issues (as indicated by the SCD) that have been determined to need safety enhancements beyond what can be provided with low-cost safety mitigation measures. See FDM 11-1-10 for additional information regarding S-2 application.

These Segments or locations on Rehabilitation projects will evaluate the use of cross-sectional and geometric improvements to existing roadway features beginning with the use of the lower end of the range (when a range exists) for design criteria values. These values shall be considered a starting point. An iterative design approach along with the application of a predictive safety benefit/cost analysis will be used to determine the final design values to apply.

Those segments or locations that have no safety or operational issues (as indicated by the SCD) will use S-1 application which maintains the roadway cross section and geometric features as design criteria. SCD preparers should refer to FDM 11-40-6 for guidance on S-1 application segments.

SCD preparers can reference Attachment 7.1 for S-2 application design criteria that apply to Rehabilitation projects.

LIST OF ATTACHMENTS

Attachment 7.1	S-2 Application Design Criteria for Rehabilitation Projects
Attachment 7.2	Design Criteria for Rehabilitation Projects on Rural State Trunk Highways Functionally Classified as Arterials
Attachment 7.3	Design Criteria for Rehabilitation Projects on Rural State Trunk Highways Functionally Classified as Collectors and Locals
Attachment 7.4	Design Criteria for Rehabilitation Projects on Town Roads
Attachment 7.5	Design Criteria for Rehabilitation Projects on Rural County Trunk Highways Functionally Classified as Arterials
Attachment 7.6	Design Criteria for Rehabilitation Projects on Rural County Trunk Highways Functionally Classified as Collectors and Locals

FDM 11-40-8 Design Standards for 3R Projects on Expressways and Freeways (Non-Interstate)

November 30, 2018

This section has been deleted and its contents have been merged into FDM 11-40-6 and FDM 11-40-7.

S-2 Application of Design Criteria for Rehabilitation Projects

Overview

Segments or locations on Rehabilitation projects will evaluate the use of cross-sectional and geometric improvements to existing roadway features ***beginning with the use of the lower end of the range*** (when a range exists) for design criteria values. The values shown should be considered a starting point. An iterative design approach along with the application of a predictive safety benefit/cost analysis will be used to determine the final design values to use.

See FDM 11-38 for additional information regarding predictive safety benefit/cost analysis.

This attachment applies to S-2 Application unless otherwise noted.

Controlling Criteria

1. Design Speed

- STH routes (NHS and non-NHS): The lower end of the range for design speed for both rural and urban routes is the posted speed with the upper end of the range being the posted speed plus 5 mph.
- Non-STH routes: The lower end of the range for design speed for both rural and urban routes is the posted speed with the upper end of the range being the posted speed plus 5 mph.
- Expressways and non-Interstate Freeways: The design speed is the posted speed plus 5 mph.
- Interstate Highways: The design speed is the posted speed plus 5 mph.

See FDM 11-10-1.5 for additional guidance on Design Speed selection.

2. Superelevation Rate

Superelevation Rate is a controlling criterion if the project design speed is 50 mph or greater.

Ideally, superelevation rate modifications should be consistent with adjacent sections of the roadway, and not reduce the existing curve speed rating.

Superelevation rates exceeding 8% are undesirable and should be flattened if possible within the project scope. According to AASHTO, "Superelevation rates above 8 percent are only used in areas without snow and ice"[1], page 144.

See FDM 11-10-5.3 for guidance on superelevation rates.

Superelevation Rate Design Criteria

- STH and non-STH routes (NHS and non-NHS): Determine the existing emax that was the basis for the existing original superelevation design by inspecting super-elevation information on as-built plans. Use FDM 11-10 Table 5.7 to determine the design emax. Rehabilitation projects will use the Design Lower values for emax.
- Non-STH routes: Determine the existing emax that was the basis for the existing original superelevation design by inspecting super-elevation information on as-built plans. Use FDM 11-10 Table 5.7 to determine the design emax. Rehabilitation projects will use the Design Lower values for emax.
- Expressways and non-Interstate Freeways: Provide superelevation rate based on the project design speed and design emax for S-3 application. See FDM 11-10 Table 5.7. Rehabilitation projects will use the Design Upper values for emax.
- Interstate Highways: Superelevation rates should be improved to meet the appropriate rate for S-3 application. See FDM 11-10 Table 5.7. Rehabilitation projects will use the Design Upper values for emax.

See FDM 11-1-10 for additional information regarding S-3 application.

3. Horizontal Curve Radius

Horizontal Curve Radius is a controlling criterion if the project design speed is 50 mph or greater.

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[1] A Policy on Geometric Design of Highways and Streets 2004, 5th. AASHTO, Washington, DC, 2004.

Ref ID: 350

All horizontal curves located within project limits will be screened through the Safety Certification Process (SCP).

Horizontal curves that have been identified as not having discernable safety or operational issues will use S-1 application. This will allow the retention of the existing curve radii. Even if a curve doesn't contribute to crashes, improvements may still be desirable.

Horizontal curves that have been identified as having discernable safety or operational issues will be evaluated for reconstruction using S-2 application and low-cost safety mitigation measures as shown in FDM 11-38.

If a deflection without a horizontal curve exceeds the maximum shown in FDM 11-10 Table 5.4 then it is considered a deficient horizontal curve.

See FDM 11-10-5.2 for guidance on horizontal curve radii.

See FDM 11-1-10 for additional information regarding S-1 and S-2 applications.

Horizontal Curve Radius Design Criteria

- All routes (NHS and non-NHS): Determine the curve radius that was used for the existing horizontal curve by inspecting horizontal curve information on as-built plans. Starting with the existing curve radius, perform an iterative predictive safety benefit/cost analysis to determine a curve radius value that acceptably meets the project purpose and need.

  The final curve radius value chosen will be based on the results of the predictive safety benefit/cost analysis in conjunction with the social, economic, or environmental impact evaluations completed as part of the environmental process described in FDM Chapter 20.

  See FDM 11-38 for additional information regarding predictive safety benefit/cost analysis.

4. Stopping Sight Distance

Stopping Sight Distance (SSD) is a controlling criterion if the project design speed is 50 mph or greater.

SSD applies to horizontal alignments and vertical alignments. Deficient SSD is caused by a physical obstruction along the SSD line-of-sight (e.g., roadside structures, crest vertical curves, overpasses, ditch backslopes, barrier located along the inside of a horizontal curve). Sag vertical curves are not a physical obstruction along the SSD line-of-sight.

All SSDs associated with existing horizontal and vertical curves located within the project limits will be screened through the SCP.

SSDs that have been identified as not having discernable safety or operational issues will use S-1 application. This will allow the retention of the existing SSD.

SSDs that have been identified as having discernable safety or operational issues will use S-2 application and low-cost safety mitigation measures as shown in FDM 11-38.

See FDM 11-10.5.2 for guidance on SSD.

See FDM 11-1-10 for additional information regarding S-1 and S-2 applications.

Stopping Sight Distance Design Criteria

- All routes (NHS and non-NHS): Use S-2 application based on the project design speed for the sight distance categories as shown in FDM 11-10-5.

5. Maximum Grades

Maximum Grades is a controlling criterion if the project design speed is 50 mph or greater.

See FDM 11-10-5.4.1 for design guidance on grades.

Maximum Grade Design Criteria

- All routes (NHS and non-NHS): Perform an iterative predictive safety benefit/cost analysis using the existing grade as a starting point to determine a grade that acceptably meets the project purpose and need.

  The final grade value chosen will be based on the results of the predictive safety benefit/cost analysis in conjunction with the social, economic, or environmental impact evaluations completed as part of the environmental process described in FDM Chapter 20.

  See FDM 11-38 for additional information regarding predictive safety benefit/cost analysis.

6. Lane Width

Lane width is a controlling criterion if the project design speed is 50 mph or greater.

a. Rural Lane Width Design Criteria

- STH routes (NHS and non-NHS): Lane widths for rural STH two-lane highways shall be the greater of either existing or as shown in Attachment 7.2 and 7.3, unless the existing width is greater than the higher value requirement for S-3 Application for Modernization projects as shown in FDM 11-15 Attachments 1.1 to 1.3. In that case, the width may be reduced to match the higher value requirements for S-3 application for Modernization projects.
- Non-STH routes: Lane widths for rural non-STH two-lane highways shall be the greater of either existing or as provided on Attachments 7.4, 7.5 and 7.6, unless the existing width is greater than the higher value requirement for S-3 application as shown in FDM 11-15 Attachments 1.1 to 1.4 and FDM 11-15 Attachments 1.15 to 1.17. In that case, the width may be reduced to match the higher value requirement for S-3 application for Modernization projects. For CTH highways, see Trans 205.
- Expressway and non-Interstate Freeways: Use lane width requirements for Design Class A3 per FDM 11-15 Attachment 1.1.
- Interstate Highways: All lanes shall be at least 12 feet wide.

See FDM 11-1-10 for additional information regarding S-3 application.

b. Urban Lane Width Design Criteria

- STH and non-STH routes (NHS and Non-NHS): Through lane widths shall meet the requirements in FDM 11-20 Attachment 1.1 and FDM 11-20 Attachment 1.5. Federally designated long truck routes (i.e. the "National Network" as defined in 23 CFR Part 658) shall contain at least one 12-foot lane in each direction of travel.

  Lowest curb offsets are 1-foot when the design speed is 40 mph or less.

  Transitions from rural to urban cross section are desirably located on tangent where drivers have an unobstructed view. Introduce curbs at the edge of the shoulders and then continue with a tapered urban cross section to transition to the typical urban section. In general, use sloping curbs where the design speed is more than 45 mph.
- Expressways and Non-Interstate Freeways: Use lane width requirements for Design Class A3 per FDM 11-15 Attachment 1.1.
- Interstate Highways: All traffic lanes shall be at least 12 feet.

7. Shoulder Width Design Criteria

Shoulder width is a controlling criterion if the project design speed is 50 mph or greater.

See FDM 11-40-1.5.1 for paved shoulder guidance.

- STH Routes (NHS and non-NHS): See Attachments 7.2 and 7.3 for shoulder width design criteria.

  Shoulder widths (useable)[2] for rural two-lane highways shall be the greater of either existing or as provided in Attachments 7.2 and 7.3, unless the existing widths are greater than the higher value requirements for S-3 application as shown in FDM 11-15 Attachments 1.1 to 1.3. In those cases, the widths may be reduced to match the higher value requirements for S-3 application.

  Parking lanes widths shall meet the requirements of FDM 11-20-1.
- Non-STH routes: See Attachments 7.4, 7.5 and 7.6 for shoulder width design criteria.

  Shoulder widths (useable)[1] for rural two-lane highways shall be the greater of either existing or as provided in Attachments 7.4, 7.5 and 7.6, unless the existing widths are greater than the higher value requirements for S-3 application as shown in FDM 11-15 Attachments 1.1 to 1.4 and FDM 11-15 Attachments 1.16 to 1.18. In those cases, the widths may be reduced to match the higher value requirements for S-3 application. For CTH highways, see Trans 205.
- Expressway and non-Interstate Freeways: Shoulder widths (usable)[1] shall be per shoulder width requirements for Design Class A3 per FDM 11-15 Attachment 1.1.

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[2] Usable shoulder width is controlling criteria per FHWA when design speed is 50 MPH or greater. See FDM 11-40-1.5.2 for additional discussion and guidance on computing usable shoulder width.

- Interstate Highways: All right shoulders shall be paved to a full width of 10 feet. On all highways of six or more lanes, the left shoulders shall be paved 10 feet in width. The left shoulders on all four-lane highways shall be paved to a width of 4 feet.

See FDM 11-1-10 for additional information regarding S-3 application.

8. Pavement Cross Slope Design Criteria

Pavement cross slope is a controlling criterion if the project design speed is 50 mph or greater.

- STH and non-STH Routes (NHS and Non-NHS): Provide a pavement cross slope of 2% when Rehabilitation projects include new pavement or pavement resurfacing.

  A cross slope of 1.5% lower minimum may be provided when resurfacing Portland cement concrete pavements which have a cross slope of 1% or flatter.

  The existing pavement cross slope may be retained on projects involving patching only or patching and grinding. The rollover rate between adjacent travel lanes cannot exceed 5%.
- Expressway and Non-Interstate Freeways: Normal pavement cross slope is 2.0 percent per FDM 11-15-1.3.

  The pavement cross slope may be a lower minimum of 1.5 percent when necessary to match the existing pavement cross slope. However, increase the pavement cross slope to 2.0 percent if the cost is reasonable.

  Where multiple adjacent lanes are sloped the same way (i.e., no crown between them) the cross slope should be 2.0 percent.
- Interstate Highways: On tangent sections, the pavement cross slope should be a lower minimum of 2.0 percent.

  For resurfacing or widening projects when necessary to match existing cross slopes the lower minimum shall be 1.5 percent and desirably 2.0 percent. However, the cross slope should be increased to 2.0 percent when practicable.

9. Vertical Clearance

Vertical Clearance is a controlling criterion if the project design speed is 50 mph or greater.

- Vertical Clearance for construction of new bridges, replacement bridges, and bridges on which the superstructure is being replaced: see FDM 11-35 Attachment 1.8
- Lower Minimum Vertical Clearance for existing bridges which are not being replaced and for existing bridges on which the superstructure is NOT being replaced: See FDM 11-35 Attachment 1.9

See FDM 11-10-5.4.3 for additional guidance on vertical clearance criteria.

Non-Controlling Criteria

1. Vertical Alignments

A Vertical alignment consists of a series of tangents (aka “grades”) that are either ascending, descending or flat, which are typically (but not always) connected by vertical curves. A vertical curve provides a safe, smooth transition between two consecutive tangents.

There may also be other safety issues besides the SSDs themselves contributing to crashes. Examine potential hazards at crest vertical curves. Potential hazards such as intersections, sharp horizontal curves or narrow bridges hidden by vertical curves may require reconstruction or other less costly safety mitigation measures including relocating or correcting the hazards and providing warning signs.

See FDM 11-10-5.4.2 for guidance on vertical alignments.

a. Crest Vertical Curve Design Criteria

Although a crest vertical curve is a non-controlling design criterion, it is evaluated based on whether it obstructs the line-of-sight of the required sight distance along a roadway. The lower minimum required sight distance along a roadway is SSD.

See FDM 11-10 Attachment 5.4 for crest vertical curve design criteria.

Perform an iterative predictive safety benefit/cost analysis to determine a design value that acceptably meets the project purpose and need.

The final design value chosen will be based on the results of the predictive safety benefit/cost analysis in conjunction with the social, economic, or environmental impact evaluations

completed as part of the environmental process described in FDM Chapter 20.

See FDM 11-38 for additional information regarding predictive safety benefit/cost analysis.

- STH and non-STH Routes (NHS and Non-NHS): Evaluate the application of appropriate low-cost safety mitigation measures as shown in FDM 11-38 if deficient crest vertical curves are not reconstructed or are reconstructed to less than the project design speed. Use lower minimum values as a starting point per FDM 11-10 Attachment 5.4.
- Expressway and Non-Interstate Freeways: Use S-3 application (upper minimum values) as a starting point per FDM 11-10 Attachment 5.4.
- Interstate Highways: Use S-3 application (upper minimum values) as a starting point per FDM 11-10 Attachment 5.4.

See FDM 11-1-10 for additional information regarding S-3 application.

b. Sag Vertical Curve Design Criteria

Perform an iterative predictive safety benefit/cost analysis to determine a design value that acceptably meets the project purpose and need.

The final design value chosen will be based on the results of the predictive safety benefit/cost analysis in conjunction with the social, economic, or environmental impact evaluations completed as part of the environmental process described in FDM Chapter 20.

See FDM 11-38 for additional information regarding predictive safety benefit/cost analysis.

- STH and non-STH Routes (NHS and non-NHS): Deficient sag vertical curves may be retained unless they are contributing to a crash problem. If sag vertical curves are contributing to a crash problem, use lower minimum values as a starting point per FDM 11-10 Attachment 5.6.
- Expressways and non-Interstate Freeways: Use S-3 application (upper minimum values) as a starting point per FDM 11-10 Attachment 5.6.
- Interstate Highways: Use S-3 application (upper minimum values) as a starting point per FDM 11-10 Attachment 5.6.

2. Minimum Grades

See FDM 11-10-5.4.1 for guidance on grades.

Minimum Grade Design Criteria

- All routes (NHS and non-NHS): Perform a predictive safety benefit/cost analysis using the existing grade as a starting point to determine a grade that acceptably meets the project purpose and need.

  The final grade value chosen will be based on the results of the predictive safety benefit/cost analysis in conjunction with the social, economic, or environmental impact evaluations completed as part of the environmental process described in FDM Chapter 20.

  See FDM 11-38 for additional information regarding predictive safety benefit/cost analysis.

3. Shoulder Cross Slopes

Shoulders must have adequate strength and stability to support occasional vehicle tire loads under all weather conditions without rutting or other surface variations.

Shoulder Cross Slope Design Criteria

- STH and non-STH Routes (NHS and non-NHS): Shoulder cross slopes should be as provided in FDM 11-15-1.7 except on tangent sections and crown runoff sections, a maximum slope of 6% downward from the adjacent pavement edge may be used, provided that the rollover rate between the travel lane and shoulder doesn't exceed 8%.
- Expressway and non-Interstate Freeways: Use shoulder cross slope requirements per FDM 11-15-1.7 except a maximum shoulder cross slope of 6 percent is allowed.
- Interstate Highways: Use shoulder cross slope requirements per FDM 11-15-1.7 except shoulder cross slopes should range between 4 and 6 percent and should be at least 1 percent more than the pavement cross slope on the tangent sections to facilitate drainage.

4. Intersections

See FDM 11-25 for design guidance on intersections.

5. Intersection Sight Distance

Guidance for Intersection Sight Distance (ISD) can be found in FDM 11-10-5.

If the SCP has determined that ISD is contributing to crash problems, then perform an iterative predictive safety benefit/cost analysis using the existing ISD as a starting point to determine an ISD that acceptably meets the project purpose and need.

The final ISD value chosen will be based on the results of the predictive safety benefit/cost analysis in conjunction with the social, economic, or environmental impact evaluations completed as part of the environmental process described in FDM Chapter 20.

See FDM 11-38 for additional information regarding predictive safety benefit/cost analysis.

6. Vision Triangles

See FDM 11-10-5.1.4.3 for additional guidance regarding vision triangles.

7. Intersection Angle

See FDM 11-25-2.8 for guidance on intersection angles.

8. Auxiliary Lanes

a. Rural Auxiliary Lanes

See FDM 11-25-35 for a discussion and definition of auxiliary lanes.

See FDM 11-25-5.4.2 for additional guidance about TWLTLs.

Rural Auxiliary Lane Design Criteria

- All routes (NHS and Non-NHS): The lower value for the width of auxiliary lanes shall be the greater of existing or 10-feet. The lower value for auxiliary lane shoulder width shall be the greater of existing or 3 feet.

b. Urban Auxiliary Lane Design Criteria

- All Routes (NHS and Non-NHS): Turning lane widths shall meet the requirements in FDM 11-25 Attachment 5.1 (but not be less than existing).

  The lowest lane width of an existing two-way left turn lane (TWLTL) shall be the greater of existing or 12 feet. See FDM 11-25-5.4.2 for additional guidance about two-way left turn lanes.

9. Lateral Clearance

Lateral clearance (also known as “operational offset") is defined in FDM 11-15-13.2.2 as an obstruction free area beginning at the edge of driving lane and extending a lower minimum distance so as not to interfere with the operation of the roadway.

Lateral Clearance Design Criteria

- All routes (NHS and Non-NHS): Lateral clearances for urban and rural roadways shall meet the following:
  - For rural highways, lateral clearances should be as shown in Table 7.2.
  - For urban and suburban roadways with shoulders, lateral clearances should be as shown in Table 7.2.
  - For roadways with curbs, the lateral clearance design criteria widths are 2-feet measured from face of curb, but not less than the existing lateral clearances. The least lateral clearance widths are 1.5-feet measured from the face of curb, but not less than the existing lateral clearances.

***Table 7.2* Lateral Clearances from Edges of Driving Lanes for Rural Highways[1]**

ROAD TYPE	WITHOUT roadside barrier[2]	WITH roadside barrier[3]
All STHs Arterials non-STH Collector and Local Roads (non-arterials) with Design Year AADT >1500	The GREATER of 6 ft. OR finished shoulder widths[4] + 2 ft.	The GREATER of 4 ft. OR finished shoulder widths[4]
non-STH Collector and Local Roads (non-arterials) with Design Year AADT<1500	The GREATER of 2 - 6 ft. OR finished shoulder widths[4] + 2 ft.	The GREATER of 2 - 4 ft. OR finished shoulder widths[4]

[1] *Applies to all fixed objects other than mailboxes. Clearances to mailboxes are based on the guidelines from Chapter 11 of the 2002 AASHTO Roadside Design Guide, titled "Erecting Mailboxes on Streets and Highways."*

[2] *Lateral Clearances extend beyond the edge of the finished shoulders. Also, additional clearances may be needed at some locations - particularly at intersections - to compensate for off-tracking.*

[3] *Lateral Clearances should be provided to the face of the barriers, but not extend behind them. Other offsets behind the barriers or beyond the edges of the finished shoulders may apply. Consider the potential deflections of the roadside barriers (see FDM 11-45). Also, additional clearances may be needed at some locations - particularly at intersections - to compensate for off-tracking.*

***Table 7.3* Lateral Clearances from Edges of Driving Lanes for Urban Streets[1]**

Parking Condition	Urban Roadway Type	WITHOUT roadside barrier[2] **Upper end of range** (Lower end of range)	WITH roadside barrier at curb face[3] **Upper end of range** (Lower end of range)
With Parking	ALL	**Parking lane width + 4-feet[4]** (Parking lane width + 2 feet[4])	**Should not allow parking where roadside barrier is used**
Without Parking	HIGH SPEED and TRANSITIONAL	The Larger of 6 feet *OR* **the offset from edge of driving lane to face of curb + 4 feet[5]** (The offset from edge of driving lane to face of curb + 2 feet[5])	The Larger of 6 feet *OR* **the offset from edge of driving lane to face of curb[5]** (The GREATER of 1.8 feet *OR* the offset from edge of driving lane to face of curb[5])
	LOW SPEED and TURNING LANES	The Larger of 4 feet *OR* **the offset from edge of driving lane to face of curb + 2 feet[5]** (The offset from edge of driving lane to face of curb + 2 feet[5])	The Larger of 4 feet *OR* **the offset from edge of driving lane to face of curb[5]** (The GREATER of 1.8 feet *OR* the offset from edge of driving lane to face of curb[5])

[1.] *Applies to all fixed objects other than mailboxes. Clearances to mailboxes are based on the guidelines from Chapter 11 of the 2006 AASHTO Roadside Design Guide (2), titled "Erecting Mailboxes on Streets and Highways."*

[2.] *Lateral clearances extend behind the curb faces.*

[3.] *Lateral Clearances must be provided to the faces of barriers, but do not extend behind them. Other offsets behind barriers or curb faces may apply. Also, consider the potential deflections of the roadside barriers (see FDM 11-45).*

[4.] *Parking lane widths include gutter widths.*

5. Include gutter widths - see this Procedure for guidance on offsets from edges of driving lanes to faces of curbs.

10. Roadside Hazards

See FDM 11-40-1.11.2 for general guidance regarding roadside hazards.

11. Clear Zones

Do not reduce existing clear zone widths on Rehabilitation projects.

Clear zone widths on Rehabilitation projects are the greater of the existing clear zone width or the lower minimum clear zone widths shown below. If the original Modernization project clear zone widths still exist, then retain that clear zone width, unless it is less than the lower minimum clear zone widths shown below. If subsequent projects have reduced the clear zone widths to less than the original Modernization project clear zone widths, then document in the DSR why the original Modernization project clear zone widths are not being reestablished. Include the width of existing clear zones, the safety impacts of not reestablishing clear zones and any potential safety countermeasures being considered for use.

Clear Zone Design Criteria

- STH and non-STH Routes (NHS and Non-NHS): Provide Clear Zones per guidance in FDM 11-15-1 and FDM 11-15 Attachments 1.9, 1.10 and 1.11.
- Expressways and non-Interstate Freeways: Provide Clear Zones per guidance in FDM 11-15-1 and FDM 11-15 Attachments 1.9, 1.10 and 1.11.
- Interstate Highways: Provide Clear Zones per guidance in FDM 11-15 Attachments 1.9, 1.10 and 1.11 and the AASHTO Roadside Design Guide for guidance regarding warranted clear zone widths. Any fixed objects within the clear zone limits shall be removed, made breakaway, or made safe through shielding by roadside barriers, crash cushions, or a combination of both.

12. Side Slopes

Steep foreslopes can be safety hazards and are difficult and costly to maintain. Steep foreslopes also reduce the safety and functionality of shoulders and clear zones.

The likelihood of crashes increases as shoulder widths decrease (Highway Safety Manual, Volume 3 (HSM3), chapter 13 page 13-11[3]; Also, FHWA-RD-99-207, "Prediction of the Expected Safety Performance of Rural Two-Lane Highways", pages 31-34[4])

Clear zones should not contain any critical slopes, i.e. non-traversable slopes or any traversable but non-recoverable slopes unless there are clear run-out areas at the toes of the slopes. See page 2 of FDM 11-15 Attachment 1.9.

The likelihood of crashes increases for reduced clear zones and steeper side slopes (HSM3, chapter 13, pages 13-19 to 26[3]; Also, FHWA-RD-99-207, page 41[4]) and TRB Special Report 214, pages 83-86[5])

TRB's Special Report 214, page 200[5](2), recommends:

- "Flatten slopes of 3:1 or steeper at locations where run-off -road crashes are likely (e.g. outside of sharp horizontal curves).
- Retain current slope widths (without steepening sideslopes) when widening lanes and shoulders unless warranted by special circumstances."

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[3] Highway Safety Manual Part D: Crash Modification Factors, volume 3, 1st edition. AASHTO, Washington, DC, 2010. https://bookstore.transportation.org/collection_detail.aspx?ID=135. Ref ID: 938

[4] Harwood, D. W., F. M. Council, E. Hauer, W. E. Hughes, A. Vogt, and Midwest Research Institute. FHWA-RD-99-207: Prediction of the Expected Safety Performance of Rural Two-Lane Highways. Federal Highway Administration, Office of Safety Research and Development, McLean, VA, 2000. http://www.fhwa.dot.gov/publications/research/safety/99207/99207.pdf. Ref ID: 968

[5] TRB Special Report 214: Designing Safer Roads: Practices for Resurfacing, Restoration, and Rehabilitation. Transportation Research Board, National Research Council, Washington, DC, 1987. http://onlinepubs.trb.org/Onlinepubs/sr/sr214/sr214_001_fm.pdf. Ref ID: 341

Side Slope Design Criteria

- STH and non- STH Routes (NHS and Non-NHS): Don't steepen foreslopes on a Rehabilitation projects beyond what is described below in Table 7.4, including when widening or raising lanes and shoulders.

Table 7.4 Rehabilitation Project Foreslope Criteria

Existing Foreslopes in Clear Zone	Maximum Constructed Foreslopes in Clear Zone
4:1 or flatter*	4:1
Between 3:1 and 4:1**	Not steeper than existing
Steeper than 3:1**	3:1

* If there are Run off Road crash (ROR) history issues at locations that are already 4:1 or flatter, maintain the existing foreslopes and try to determine the ROR crash history cause(s) and provide appropriate safety countermeasures.

** Improve foreslopes steeper than 4:1 at locations with a ROR crash history and at locations on the outside of sharp horizontal curves where ROR crashes may occur. Options include:

- Provide 3:1 slopes with flat runout areas at the toes of slopes with no fixed objects on slopes and no fixed objects in the runout areas.
- Provide a 4:1 slope with appropriate clear zones for the projects.
- Provide a foreslopes flatter than 4:1 if there are issues with ditch traversability or if the ditches are within the clear zones.

Proposed unshielded foreslopes to be constructed outside the clear zones under rehabilitation work should not be steeper than 3:1.

If there are traversable, but non-recoverable foreslopes (i.e. between 3:1 and 4:1) within the clear zone, recovery areas, per FDM 11-15 Attachment 1.9, may be required.

Evaluate shielding hazardous slopes where slope flattening is not possible or not practical. Typically, shielding is less desirable than slope flattening for roadside safety.

Existing critical foreslopes (i.e. steeper than 3:1) that are outside of the proposed construction limits should be evaluated for possible flattening or shielding.

- Expressway and non-Interstate Freeway Routes: Use S-3 application per FDM 11-15 Attachment 1.7 for side slopes on Rehabilitation projects whenever practicable. This means re-grading existing side slopes not meeting S-3 application and maintaining recoverable slopes and clear zones when Rehabilitation projects raise the surface elevations of pavements.

  Regrading side slopes to S-3 application is sometimes not practical. For these cases, use the following guidance, but only if using S-3 application will result in unacceptable social, economic or environmental consequences:

  - Construct enough recoverable slopes (4:1 or flatter) to meet the clear zone requirements of FDM 11-15 Attachment 1.9. Embankment slopes between 3:1 and 4:1 are considered traversable but non-recoverable. These steeper embankments may be built into the clear zone provided there is enough 4:1 or flatter slope contiguous to the shoulder to meet the requirements shown on page 2 of FDM 11-15 Attachment 1.9 (Note: recoverable slopes contiguous with the finished shoulders are required). Traversable slopes between 3:1 and 4:1 may require clear runout areas of at least 10 feet wide beyond the toes of the non-recoverable slopes.
  - Slopes outside the clear zones should not be steeper than 3:1

    If it is not practicable to correct an existing non-recoverable slope, then investigate if roadside barrier is warranted.

- Interstate Highways: Foreslopes shall be either recoverable (4:1 or flatter), traversable (3:1 MAX) with adequate recovery areas to meet the clear zone requirements of FDM 11-15 Attachment 1.9, or barriers should be installed as warranted in accordance with current criteria.

See FDM 11-1-10 for additional information regarding S-3 application.

13. Ditches

Traversable ditches are a Clear Zone element.

Ditch Design Criteria

- STH and non-STH Routes (NHS and Non-NHS): Evaluate ditch cross sections to determine whether they are traversable. Preferred ditch cross sections are shown in FDM 11-15 Attachment 1.11.

  Perpetuate existing traversable ditches. Consider safety improvement of ditches with rehabilitation work, when practical.
- Expressway and non-Interstate Freeways and Interstate Highways: Ditch cross sections within clear zones must be traversable. See FDM 11-15 Attachment 1.11 for preferred ditch cross sections.

  Evaluate non-traversable ditch cross sections outside of clear zones for safety improvements if the SCD indicates ROR crash problems.

Miscellaneous Items

1. Intersection Design Vehicle and Intersection Check Vehicle

See FDM 11-25-2.1 and FDM 11-25 Table 2.1 for guidance on intersection design vehicles.

2. Rural Rumble Strip Design Criteria

Install centerline and shoulder rumble strips in accordance with FDM 11-40-1.7.

3. Pavement Edge Drop Design Criteria

Pavement edge drops are undesirable, no matter how they develop, because of safety implications associated with the vehicle recovery maneuver. Pavement edge drops can develop between the pavement surface and the adjacent unpaved shoulder or roadside.

Avoid potential edge drops by:

- Paving the shoulders when warranted by policy.
- Selectively paving shoulders at points where encroachments are likely to create pavement edge drops, such as on the insides of horizontal curves.
- Providing safety-edges as described in FDM 11-45-30.7.
- Restoring gravel shoulders.

4. Curb & Gutter Design Criteria

A 4% gutter cross slope is the typical slope and replaces the longstanding 3/4" per foot (6.25%) gutter cross slope. The 3/4" per foot (6.25%) gutter cross slope may be used for select conditions per criteria below.

Select the appropriate gutter cross slope based on the following criteria:

- Use 4% gutter cross slope on Rehabilitation projects where new curb and gutter will be constructed.
- Use 3/4" per foot (6.25%) gutter cross slope to match existing slopes for curb and gutter spot improvements on resurfacing/preservation improvement projects. Use 4% gutter cross slope for longer (e.g. approximately one continuous block) segments of curb and gutter replacement.
- Maintain consistent gutter cross slopes within contract plans whenever possible. An acceptable setting to include two different gutter cross slopes, for example, is a project with separate reconstruction segments (e.g. 4%) and spot improvement, hand-formed curb and gutter replacement segments (e.g. 6.25%).

Refer to FDM 11-46-10.3 for gutter cross slope design guidance with curb ramp applications. Provide inlet spacing per FDM 13-25-15 for the selected gutter slope design.

Label any non-typical (i.e. other than 4%) gutter cross slope locations within the plans. At a minimum, include gutter cross slope labels or notes within the contract typical cross sections and miscellaneous quantities. Include additional labels or notes within contract construction details and cross sections for all gutter cross slopes as needed and to provide further clarity.

S-2 Application for Rehabilitation Projects on Rural State Trunk Highways Functionally Classified as Arterials

TRAFFIC			ROADWAY WIDTH DIMENSIONS [1]			
Design Class	Design AADT	Design Speed [3] (mph)	Traveled Way Width [2] (feet)		Shoulder Width [4] (feet)	Roadway Width (feet)
			>= 10% Trucks	< 10% Trucks		
RA1-1	0 - 750	All	NHS 22 Non-NHS 20	NHS 22 Non-NHS 20	2	Traveled Way width plus 2 x shoulder Width
RA1-2	751 - 2,000	< 50	22	NHS 22 Non-NHS 20	2	
		>= 50	24	22	3	
RA1-3	2,001-3,499	All	24	22	6	
RA2-1	>=3,500	All	24	24	6	

1 Do not use a value less than existing - unless using S-1 application.

2 Use a traveled way width of 24 feet on federally designated long truck routes (i.e. the “National Network” as defined in 23 CFR Part 658).

A traveled way width of 24 feet is acceptable on state truck routes and other highways having current heavy vehicle (six or more tires) traffic volumes exceeding 10% of design AADT.

3 The upper end of the range for design speed is 5 mph greater than the posted speed. The lower end of the range for design speed is equal to the posted speed limit.

4 See FDM 11-40-1.5.1 for Shoulder Paving and FDM 11-40-1.7 for Rumble Strip Policy. Provide adequate shy distance at bridge railings and roadside safety barriers.

S-2 Application for Rehabilitation Projects on Rural State Trunk Highways Functionally Classified as Collectors and Locals

TRAFFIC			ROADWAY WIDTH DIMENSIONS [1]			
			Traveled Way Width (feet) [2]			
Design Class	Design ADT	Design Speed [3] (mph)	>= 10% Trucks	< 10% Trucks	Shoulder Width [4] (feet)	Roadway Width (feet)
RC1	0 - 750	< 50	NHS 22 Non-NHS 20	NHS 22 Non-NHS 18	2	Traveled Way width plus 2 x shoulder Width
		>= 50	NHS 22 Non-NHS 20	NHS 2 Non-NHS 20	2	
RC2	751 – 2,000	< 50	22	NHS 22 Non-NHS 20	2	
		>= 50	24	22	3	
RC3	Over 2000	All	24	22	6	

1 Do not use a value less than existing - unless using S-1 application.

2 Use a traveled way width of 24 feet on federally designated long truck routes (i.e. the “National Network” as defined in 23 CFR Part 658).

A traveled way width of 24 feet is acceptable on state truck routes and other highways having current heavy vehicle (six or more tires) traffic volumes exceeding 10% of design AADT.

3 The upper end of the range for design speed is 5 mph greater than the posted speed. The lower end of the range for design speed is equal to the posted speed limit.

4 See FDM 11-40-1.5.1 for Shoulder Paving and FDM 11-40-1.7 for Rumble Strip Policy. Provide adequate shy distance at bridge railings and roadside safety barriers.

S-2 Application for Rehabilitation Projects on Town Roads [1]

TRAFFIC VOLUME			ROADWAY WIDTH DIMENSIONS		
Design Class	Design AADT	Design Speed [2] (mph)	Traveled Way (feet)	Shoulder (feet)	Roadway (feet)
TR1	0-250	Less than 50	18	2	22
		50 or greater	20	2	24
TR2	251 – 400	50 or greater	20	2	24
TR3	401- 750	50 or greater	22	2	26
TR4	Over 750	55	22	4	30

1. Source: TRANS 204, Existing Town Road Improvement Standards.
2. The upper end of the range for design speed is 5 mph greater than the posted speed. The lower end of the range for design speed is equal to the posted speed limit.

S-2 Application for Rehabilitation Projects on Rural County Trunk Highways Functionally Classified as Arterials[1]

TRAFFIC VOLUME			ROADWAY WIDTH DIMENSIONS		
Design Class	Design AADT	Design Speed (mph)	Traveled Way[2] (feet)	Shoulder (feet)	Roadway (feet)
3RA1	Under 750	55	22	3	28
3RA2	750 – 2000	55	24	4	32
3RA3	Over 2000	55	24	6	36

1. Source: TRANS 205, County Trunk Highway Standards
2. The traveled way width shall be 24 feet on federally designated long truck routes (i.e. the “National Network” as defined in 23 CFR Part 658.) A traveled way width of 24 feet is acceptable on state truck routes and other highways that have current heavy vehicle (six or more tires) traffic volumes greater than 10 percent of Design AADT.

S-2 Application for Rehabilitation Projects on Rural County Trunk Highways Functionally Classified as Collectors and Locals[1]

TRAFFIC VOLUME			ROADWAY WIDTH DIMENSIONS		
Design Class	Design AADT	Design Speed (mph)	Traveled Way[2] (feet)	Shoulder (feet)	Roadway (feet)
3RC1	Under 750	55	20	3	26
3RC2	750 – 2000	55	22	4	30
3RC3	Over 2000	55	22	6	34

1. Source: TRANS 205, County Trunk Highway Standards.
2. The traveled way width shall be 24 feet on federally designated long truck routes. A traveled way width of 24 feet is acceptable on state designated long truck routes and other highways which have current heavy vehicle (six or more tires) traffic volumes greater than 10 percent of Design AADT.

FDM 11-45-10 Roadside Design Application - Improvement Strategy

August 17, 2020

10.1 Introduction

This procedure will serve to supplement existing FDM references with guidance specific to roadside design application for improvement strategies as defined in FDM 3-5-1.

The principal references for the development of roadside designs and the application of traffic roadside barriers and roadside hazard analysis are:

- FDM 11-45-20 - Roadside Hazard Analysis
- FDM 11-45-30 - Roadside Barrier Design Guidance

Roadside hazard analysis and treatment requirements will be categorized under three improvement strategies as described under FDM 11-45-10.2. Follow FDM 11-45-10.3 for roadside hazard analysis and treatment guidance.

Refer to FDM 11-45-10.4 for roadside hardware evaluation and treatment requirements. It provides guidance for the analysis and treatment of existing roadside hazards and guardrail hardware for specific improvement strategies. Roadside barrier guidance in this procedure will be limited to:

- existing guardrail condition
- terminal ends, and
- transition connections to rigid barriers

Note that guidelines in this procedure do not pertain to existing linear, non-Midwest Guardrail System (MGS)/Class A steel plate beam guard systems such as curved beam guard, bullnoses, concrete barrier, crash cushions and sand barrel arrays.

For new Energy Absorption Terminal (EAT) installations, the preferred grading referenced throughout this procedure is shown in SDD 14B44 (Midwest Guardrail System (MGS) EAT) and as described in FDM 11-45-30.4.1.3.

Follow FDM 11-45-20 and FDM 11-45-30 guidance for Modernization improvement projects.

10.2 Application of Improvement Strategy

Roadside hazard analysis (RHA) will be performed and treatments recommended based on the project improvement strategy:

- Perpetuation
- Rehabilitation
- Modernization

Refer to the project's Final Scope Document for the expected improvement strategy.

10.3 Roadside Hazard Analysis and Treatments

The degree of roadside hazard analysis and treatment will depend on the improvement strategy. Guidance is provided below for the various strategies.

Do not degrade roadside safety along the existing roadway corridor while finalizing the improvement's roadway typical cross-section and pavement structural needs. Pavement surface elevation increases should only be applied to the extent that the existing foreslopes or other cross-sectional features, such as shoulder slopes and widths, can be altered within the required range of design criteria. Foreslope adjustments will be confined within the existing subgrade shoulder points (i.e. shoulder foreslopes) with all Perpetuation and many Rehabilitation improvement projects. Roadside hazards include steep roadway foreslopes and fixed objects along a facility and as further described in FDM 11-45-20.

Adhere to Perpetuation and Rehabilitation guidance and its design flexibility under FDM 11-40 if needing to implement lower-end range shoulder widths and cross slopes. If countermeasure(s) are pursued, provide documentation through the Safety Certification Process (SCP). See FDM 11-38 for SCP guidance.

For all improvement projects, document final decisions and outcomes with roadside hazard analysis and treatments in the Design Study Report (DSR).

10.3.1 Roadside Hazard Analysis/Treatment – Perpetuation Improvement Strategy

A roadside hazard analysis (RHA) generally will not be required for this strategy, including Preventative Maintenance (PM) projects. Re-evaluate roadside fixed objects and their potential removal/relocation with the next improvement project. Hazardous mailbox identification and evaluation is not required.

Conduct limited RHA for projects working on retaining walls, bridges, box culverts, or other structures (see FDM 11-45-20.3.3 for more discussion). Research shows that crashes near these features are more severe and more likely to occur. Installing safety hardware is more important at these locations. Examples are (the list is not all-inclusive):

- A road project has a "net project length exception" for a bridge (i.e. the bridge is not part of the road project). Include the bridge in the road project's RHA.
- A road project terminus is near a bridge or beam guard installation that connects to the bridge. Include the bridge and associated beam guard in the road project's RHA.

Even though a road project may not have originally planned to incorporate work on these features, a barrier system may need to connect to these features. Connecting road barriers to these features may need extra engineering.

10.3.2 Roadside Hazard Analysis/Treatment – Rehabilitation Improvement Strategy

At locations using S-2 Applications - Perform RHA per FDM 11-45-20 for S-2 area(s) within the improvement project corridor. S-2 areas include spot improvement(s) or other location(s) where three-dimensional roadway element(s) (i.e. alignment, profile, cross section) are improved with the project. Remove existing roadside hazards within the S-2 area(s) that qualify for removal under the RHA. An RHA along with a hazardous mailbox identification and evaluation is not required for adjacent S-1 area(s). Refer to FDM 11-1-10 for S-1 and S-2 application definitions.

Not all roadside hazards analyzed for elimination per FDM 11-45-20 qualify for removal. Refer to FDM 11-45-20.6.2 for the preferred roadside hazard treatment in order of desirability (e.g. removal, traversable, relocation, etc.) for qualifying hazards. Document these findings in the DSR.

10.3.3 Roadside Hazard Analysis/Treatment – Modernization Improvement Strategy

Perform RHA per FDM 11-45-20. Remove existing roadside hazards that qualify for removal per the analysis. Refer to FDM 11-45-20.6.2 for the preferred roadside hazard treatment in order of desirability (e.g. removal, traversable, relocation, etc.) for qualifying hazards. Roadside hazard analysis should be consistent with improvement strategy context and the safety certification document. (SCD).

10.4 Roadside Hardware Evaluation and Treatments

Perform field assessment of existing roadside hardware per FDM 11-45-30.5 on all Perpetuation and Rehabilitation projects. All improvement projects will replace existing downturned or blunt terminal ends, including breakaway cable terminals (BCTs) and modified eccentric loader terminal (MELT) systems, with appropriate anchorages.

Apply the following roadside hardware guidance for all Perpetuation and Rehabilitation improvement projects:

- Replace/restore existing roadside hardware where determined to be operationally deficient/missing.
- Replace roadside hardware where the remaining service life is less than the improvement's pavement treatment service life. If the existing roadside hardware has a reasonable service life remaining, it is not mandatory to replace it.
- Install or replace any roadside hardware identified as a safety countermeasure in the Safety Certification Document (SCD). Refer to FDM 11-38 for Safety Certification Process (SCP) guidance. Also, document decisions in DSR.
- If entire roadside hardware system is replaced, install new beam guard Midwest Guardrail System (MGS) per FDM 11-45-30. Determine guardrail length of need (LON) per FDM 11-45-30.3.1.2. If installation is not achievable per calculated LON, then coordinate with the WisDOT project manager and the regional design oversight engineer. Document justifications in the DSR.
- Replace unconnected or non-compliant beam guard transitions to rigid barriers per FDM 11-45-30.5.2.10.
- Replace existing non-EAT end treatments with EATs (see FDM 11-45-30.5.4). Existing EATs may be left in place if determined to be in good condition.
- Analyze preferred EAT grading for S-1 applications as described in FDM 11-45-30.4.1.3. Where preferred EAT grading is not possible, refer to FDM 11-45-10.4.1 for guidance on end treatment grading for S-1 applications.
- Provide EAT grading for S-2 applications as described in FDM 11-45-30.4.1.3. Acquire right-of-way, if

necessary, to accommodate preferred EAT grading for S-2 applications. See FDM 11-45-10.4.2 for additional right-of-way acquisition guidance. Refer to FDM 11-1-10 for S-1 and S-2 application definitions.

- If the beam guard will not be replaced as part of the project, sample the post depths using non-destructive testing to ensure appropriate post lengths and replace substandard posts and or installations. See Attachment 10.1 for sampling procedure.

10.4.1 Guardrail and End Treatment Considerations for S-1 Applications

Evaluate whether preferred EAT grading installation is attainable per FDM 11-45-30.4.1.3. If preferred EAT grading is not possible, consider opportunities to slightly adjust the new EAT location from the existing end terminal location using optional applications per FDM 11-45-30.4.1.4. Apply guardrail length factor and cost ratio principles as needed. Some existing locations may already have reasonably flat shoulder foreslopes that can provide the desirable EAT grading within the existing right-of-way and with minimal to no additional grading. Ensure through the plan delivery process there are no utility impacts or environmental issues with any terminal end adjustments. Existing terminal ends adjacent to existing above-ground utilities or other objects (e.g. power poles, signs) are also good candidates for a slight terminal end location adjustment with the EAT installation.

As a last resort, install EATs per FDM 11-45-30.4.1.5 only when adjusting and providing acceptable EAT grading, as aforementioned referenced, is not feasible. The EAT offset from edge of shoulder may be reduced to zero feet (i.e. no flare) if grading for the EAT platform is non-practicable. Coordinate with the Region Maintenance section early in the scoping/design process to determine if a reduced offset would best serve the user's needs for this location. Shoulder width, approach alignment and adjacent driveway(s) are several factors, for example (not totally inclusive list), that may influence the final decision, as a no-flare EAT has a higher propensity for nuisance vehicular or maintenance equipment strikes.

The existing end terminal's longitudinal location can be replicated with the new EAT to take advantage of any existing level, widened shoulder. This may slightly reduce the installed guardrail's LON, as the EAT LON is over 53 feet. However, previous standards' LON calculations with blunt end terminals tended to estimate a conservative (i.e. longer) LON versus current estimated methodology.

For all EAT replacement installations, document in the DSR the EAT shoulder offset and longitudinal locations and associated grading decisions and the basis for these decisions, including any LON comparison of existing and new guard rail assemblies/terminal ends.

10.4.2 Right of way Acquisition Considerations

Right-of-way acquisition for:

- S-1 applications - if optional applications listed in FDM 11-45-10.4.1 do not eliminate the need for additional Real Estate, right of way should be acquired. Document any deviations from preferred or optional applications as justifications in the DSR.
- S-2 and S-3 applications - right of way acquisition will be required to attain proper beam guard system installation.

LIST OF ATTACHMENTS

Attachment 10.1	Existing Guardrail Post Sampling Procedure

FDM 11-45-15 Roadside Barrier - General

February 18, 2020

15.1 Introduction

FDM 11-45-15 and FDM 11-45-30 addresses various methods to reduce run off the road crash frequency and/or crash severity. This section of the FDM addresses run off the road crashes by providing:

- tools to aid in the selection of suitable treatments
- information on how to design various treatments
- commentary on common problems
- guidance on when to document decisions in the Design Study Report
- information on when an existing barrier system needs removal or spot improvements

Other sections of the FDM do provide guidance on roadside design. Some other sections of the FDM are (the list is not all-inclusive):

- 11-15-1
- 11-15-10
- 11-20-1

For some projects, other sections of the FDM may have modified guidance.

15.1.1 Run Off the Road Crash

A simple definition of a run off the road crash is: A crash where a vehicle has left its lane of travel and interacted with a fixed object, slope, ditch, or barrier system. Run off the Road crashes also include cross-median crashes, head-on crashes, rollover crashes, and sideswipe crashes from the opposing direction.

15.1.2 Causes of Run Off the Road Crashes

A driver experiences the following[i]:

- Commits at least one error every two minutes
- Is in a hazardous situation every two hours
- Has one or two near crashes a month
- Averages one crash every six years

A study into tree crashes showed the following reasons, in order of frequency of occurrence, for run off the road crashes[ii]:

- An avoidance maneuver
- A non-intentional traffic violation
- Mechanical failure

In the early 60's, General Motors found that professional drivers on their private test facility would make errors and run off the road because they are human.

The road or the environment may make it easier to have run off the road crashes. A location may show up as a hot spot for run off the road crashes. However, a significant portion of run off the road crashes are the result of human error and occur at random locations.

Steps are taken in other areas to reduce the frequency and results of human error (e.g. power tools have safety features…). So, a roadside should allow for some human error.

Several issues may limit how much the Department can account for human error on a given project or location. In these cases, staff are encouraged to ask for help and document their decision-making.

15.1.3 Preferred Treatment Sequence

In an ideal world, the roadside would be free of all possible objects that could injure a vehicle's occupants, other roadway network users, workers, and others. In the real world, it is not possible to develop a 100 percent risk free roadside. Some examples are (the list is not all-inclusive):

- A river is beside the road and cannot be moved.
- A stop sign or speed limit sign is needed.
- A retaining wall is needed
- A bridge pier is needed
- allow utilities within the right-of-way

Minimize the risk to the traveling public and others by using the preferred treatment sequence (in order of preference):

1. Remove hazard

2. Make hazard traversable
3. Move hazard
4. Use breakaway hardware
5. Shield hazard
6. Delineated

What treatment(s) to use depends on the following (the list is not all-inclusive):

- Nature of the hazard
    - A point hazard versus a series of point hazards versus a continuous hazard
    - Severity of hazard
    - Location of the hazard
- Function of the Hazard
    - Hazard is needed for operation of the road (e.g. stop sign versus a tree)
    - Structural need (e.g. bridge piers are not breakaway, but most traffic signs are)
- Benefit and cost of proposed treatment
- Consequence of Collision
    - Minor interaction with some hazards can cause significant injuries to a vehicle's occupants, other roadway network users, or community
- Nature of Work
    - Type of work within a project prevents the use of a treatment (e.g. a culvert-lining project probably will not move the culvert further away from the road).

Often, there is flexibility when selecting a treatment. After selecting a treatment, there may be less flexibility how to use the treatment. For example, a designer has determined to use a breakaway pole. The designer could have also had the pole removed, moved or shielded.

Once the designer has determined that the pole is to be breakaway, the pole should be designed so that breakaway features will work. Putting too much weight on a pole or installing a sign at the wrong height on a pole may negate the breakaway features.

Sections FDM 11-45-15.1.3.1 to FDM 11-45-15.1.3.6 have various examples of different roadside treatments. These examples are provided to show how various treatments can improve roadside safety. Some of these examples will use crash costs created in Roadside Safety Analysis Program (RSAP) v3. Crash cost is one variable, out of several variables, used to select a roadside treatment.

Other variables are not in the examples. Do not use these examples by themselves as design guidance. Additional analysis is needed at each location.

15.1.3.1 Remove Hazard

The AASHTO Roadside Design Guide points out that removing hazards is the most desirable roadside treatment. Removing a hazard reduces recorded crash frequency and severity. Vehicles will still leave the road. Potentially, no one has a serious injury, and the vehicle drives away. The Department will have no records of a crash.

Hazard removal typically focuses on fixed objects (e.g. poles, rocks, barrier systems). Flattening a hazardous slope could be a form of removal.

Figure 15.1 is an example how removing hazards (i.e. changing pole density) influences safety. Reducing the number of poles in an area can improve safety.

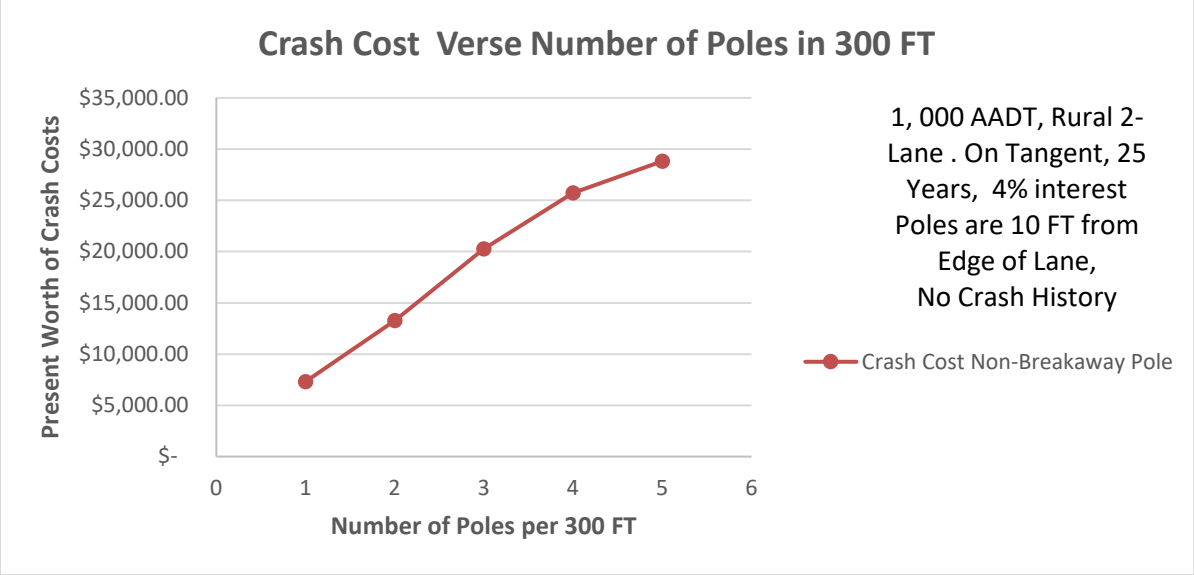

Figure 15.1 Influence of Removing Hazards From a Roadside[1]

Other potential methods of removing hazards could be (the list is not all-inclusive):

- Using drop inlets versus open culvert pipes in a median
- Removing barrier systems that are no longer needed (although this is recognized as difficult to do when considering public input)
- Having utilities share poles or go underground

Removing hazards also eliminates long-term maintenance costs.

15.1.3.2 Make Traversable

The AASHTO Roadside Design Guide indicates that making a hazard traversable is the second most desirable treatment. Traversable slopes reduce recorded crash frequency and severity. Vehicles will still leave the road, but many vehicles will drive away, and occupants will have no serious injuries.

Traversability focuses on foreslopes, backslopes, ditches, and slopes parallel to the direction of travel (e.g. driveways, side roads, and median openings…).

Location of the slope relative to the road, and steepness of slope influences the safety performance.

Traversable slopes also reduce long-term maintenance.

Traversability is also an issue for safety hardware. Traversability of safety hardware will not reduce the number of recorded crashes. However, if safety hardware is non-traversable, crash severity may increase. This is discussed more under breakaway hardware (see FDM 11-45-15.1.3.4).

15.1.3.3 Move Hazard

Moving a hazard changes the frequency a hazard is hit. Therefore, a lower crash frequency increases safety. Crash severity does not change. Moving a hazard is not the most desirable roadside treatment. It is still possible to have a severe crash. The following sections will talk about various methods to move a hazard.

Moving hazards typically focuses on fixed objects (e.g. poles, rocks, barrier…). Other features may be moved. For example, moving a hazardous slope further from the travel lane can improve safety.

Occasionally, it may not be possible or reasonable to move a hazard. Some examples are (the list is not all-inclusive):

- A body of water
- A stop sign needs to be at a specific location
- Existing bridge abutment cannot be moved
- A light pole has to be able to light road

Other treatments may be more applicable for these hazards.

Moving hazards may reduce long-term maintenance. FDM 11-45-15.1.3.3.1 and FDM 11-45-15.1.3.3.2 discuss different ways a hazard may be moved.

In many cases, one or both methods of moving a hazard can be combined with other treatments to have a

[1] Graph developed by RDSU staff utilizing Roadside Safety Analysis Program (RSAP) v3 with the noted parameters.

greater improvement on safety than one treatment alone. Some examples are (the list is not all-inclusive):

- Move hazards away from the traffic and switch to breakaway hardware
- Move hazards away from the traffic and remove unnecessary hazards
- Move hazards away from traffic, relocate hazard out of a curve and use breakaway hardware

15.1.3.3.1 Moving Hazards Away from Traffic

Several studies exist on how far a vehicle will travel perpendicularly from the edge of lane[2]. Figure 15.2 has data from one of these studies.

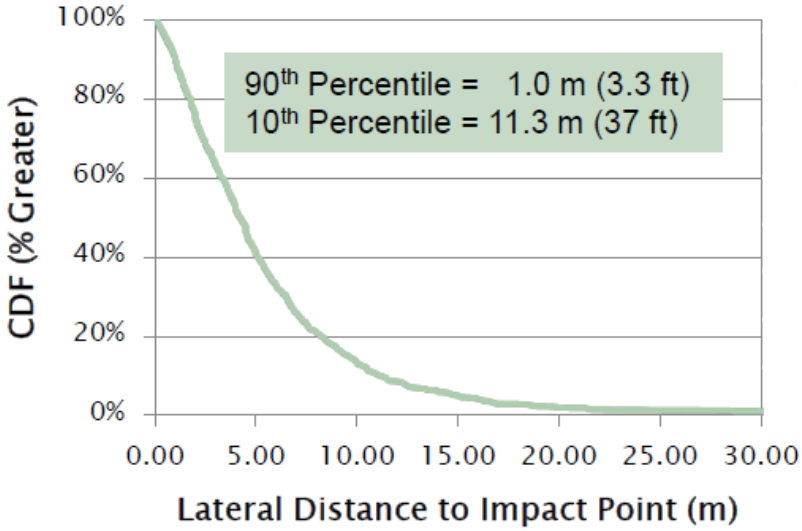

Figure 15.2 Vehicle Encroachment Distribution[iii]

Cumulative Distribution Function (CDF) showing percent of crash cases lateral trajectories exceeding given lateral distance. Figure 15.2 and other studies show that a significant percentage of vehicles will travel beyond a 30-foot (9 m) clear zone. Depending on the hazard and road, moving the hazard may provide sufficient safety improvement.

Figure 15.3 is an example, where moving trees further away from a road can increase safety. This example also shows how removing trees, even a few trees can improve safety. Combining the moving of trees farther from the roadway and decreasing the number of trees can improve safety more than using just one treatment alone.

[2] GM, Kennedy and Hutchinson, Cooper, Sicking

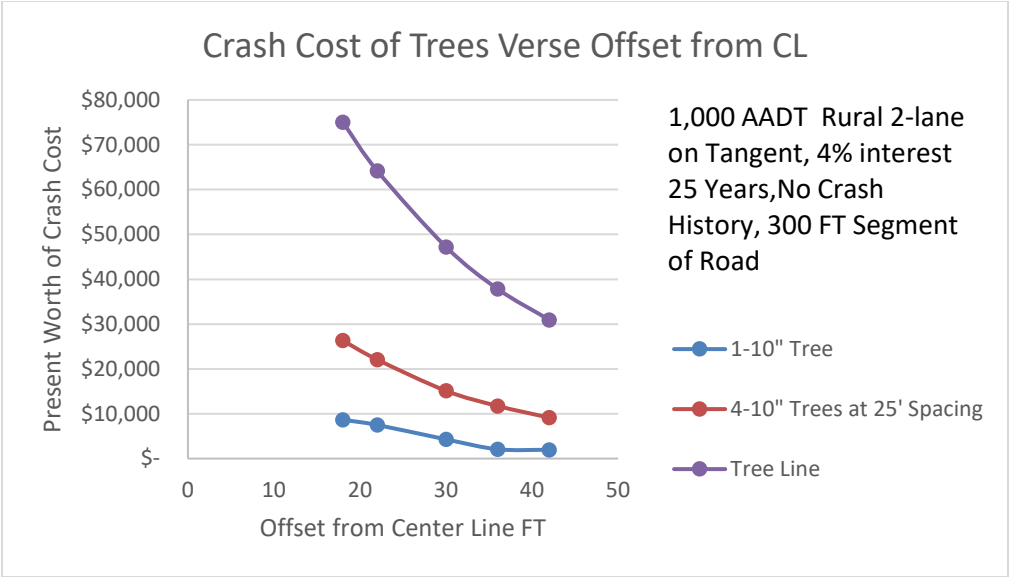

Figure 15.3 Influence of Removing Hazards From the Roadside and Moving Hazards Away From the Centerline[3]

Sometimes moving a hazard away from the road may not possible – an object may need to be closer to the road (ie. signs); it is not cost effective to move; or cannot be moved (river).

Figure 15.4 Fatal Crash into Bridge Piers Just beyond the Clear Zone

Figure 15.4 shows a location where there was a fatal crash into the bridge columns, and they are noted to be just outside the clear zone.

In Figure 15.5, a project team determined that installing a barrier was unneeded because it would ruin the aesthetic view and the hazard (i.e. deep water) was beyond the clear zone. A few years after the road was reconstructed, beam guard was installed because of a fatal crash involving the deep water.

[3] Graph developed by RDSU staff utilizing Roadside Safety Analysis Program (RSAP) v3 with the noted parameters.

Figure 15.5 Fatal Crash Beyond the Clear Zone

15.1.3.3.2 Moving Hazard out of Areas Where Run Off the Road Crashes are Likely to Happen

Certain locations are more prone to have run off the road crashes. By simply moving hazards away from these locations, safety can be improved. For example, run off the road crashes are 3 times more likely to happen in a curve versus a tangent[iv]. By moving a hazard out of a curve, the crash frequency will be reduced.

The utility poles in the foreground of Figure 15.6 are in a series of poles along the edge of the freeway's clear zone. The foreground poles are more likely to be struck than the other poles because these poles are in a ramp gore. Vehicles tend to run off the road in ramp gores. Consideration should be given to moving these poles, and if not, shielding could be appropriate.

Figure 15.6 Location where run off the road is more likely to happen

Figure 15.7 Treatment Example[v]

Figure 15.7 is like Figure 15.6; the high mast light pole is beyond a normal clear zone. Project staff installed a sand barrel array to shield the high mast light pole. From a roadside design perspective, the design on Figure 15.7 is better than Figure 15.6.

15.1.3.4 Use Breakaway Hardware

Using breakaway hardware does not change the frequency of crashes. On average, crash severity is less. Because crash severity is reduced the overall safety is improved. However, breakaway hardware still can have serious crash outcomes (Figure 15.8). Typically, breakaway hardware is crashworthy.

Figure 15.8 Less than Desirable Crash Into Breakaway Hardware

Typically, light poles, signs, and similar hardware are breakaway[4]. Most roadside hardware provides a direct benefit for road users, and needs to be close to the road to work correctly.

Some hardware that directly benefits road users and has to be near the road does not need to be breakaway. This hardware typically falls into the following categories:

- Structurally Not Feasible
    - Examples (the list is not all-inclusive):

[4] There are also breakaway utility poles and guy-wires.

        - Bridge piers and abutments
        - Retaining walls
        - Sign bridges, overhead sign supports
- AASHTO Roadside Design Exception
    - Examples (List is all-inclusive):
        - Traffic signal
        - High mast lighting
        - Railroad gates, signals, and some supports
- Location Specific Safety Needs
    - Examples (The list is not all-inclusive):
        - Dropping a pole off a structure onto a road below
        - Dropping a pole where there is a significant concentration of pedestrians

Breakaway hardware needs to be traversable. Slopes leading to the breakaway hardware or around the breakaway hardware may have more strict requirements than "normal" traversable slopes. If a vehicle does not properly engage the breakaway hardware, the hardware may not work as expected.

Figure 15.9 shows how using breakaway hardware can improve safety. This figure also shows how moving breakaway hardware can improve safety. Combining breakaway hardware and moving hardware can have a greater safety benefit than one treatment alone.

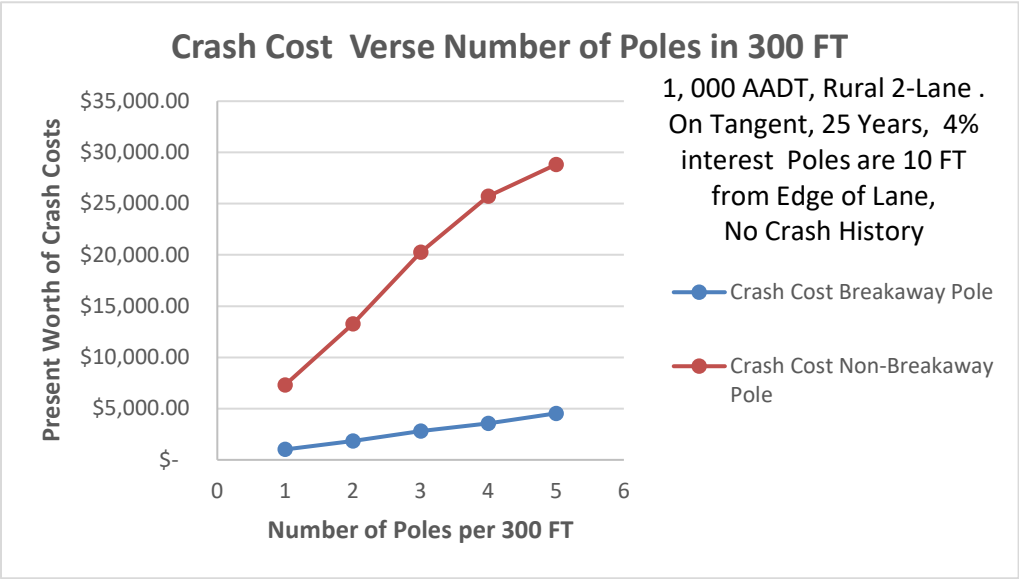

Figure 15.9 Crash Cost Breakaway Hardware[5]

15.1.3.5 Shielding

Shielding a hazard is less desirable because no barrier system is 100 percent effective, 100 percent of the time. Striking a barrier system can cause serious injury or death. Typically, barrier systems are crashworthy. Figure 15.10 is an example of a less than desirable crash into barrier system.

[5] Graph developed by RDSU staff utilizing Roadside Safety Analysis Program (RSAP) v3 with the noted parameters.

Figure 15.10 Less than Desirable Crash into Barrier System

Installing barrier systems typically increases crash frequency. In most cases, the severity of the crashes is lower.

Sometimes, the severity of a crash, consequence of collision, or cost to moving an object may make installing a barrier system the best choice. Figure 15.11 is an example that compares the crash cost of hitting a bridge's piers, crash cost of striking beam guard and the cost of moving a bridge's piers away from the road.

Figure 15.11 does not have other cost associated with building a bridge longer (e.g. right-of-way, earthwork). Likely the cost of building a longer bridge is higher than shown. This example does not address the need for structural protection of the bridge.

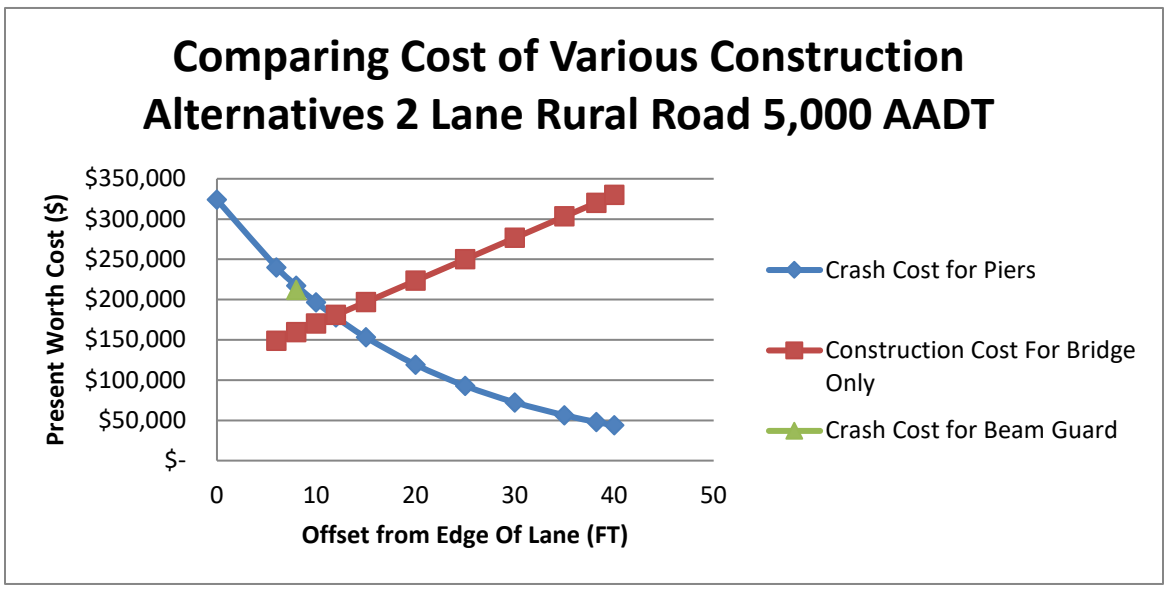

Figure 15.11 Cost Comparison of Various Pier Offsets[6]

Given the likelihood of a severe crash when hitting a bridge pier, installing a barrier system may be the preferred alternative. This could be true even in situations where the benefit cost of such an installation is low. See 11-45-20.3.5.7.4 for more information on when to shield bridge piers.

Sometimes, shielding may not be the best alternative. Figure 15.12 is an example of a two-lane rural road with the following characteristics:

- 55 mph

[6] Graph developed by RDSU staff utilizing Roadside Safety Analysis Program (RSAP) v3 with the noted parameters.

- 6 FT shoulder
- 30 FT clear zone with a 4:1 slope
- 1-mile segment of road
- 5,000 AADT
- The road is not a run off the road hot spot

Alternatives analyzed are:

- 30 FT clear zone
- 19 evenly spaced breakaway poles 25 FT from edge of lane
- 19 evenly spaced rigid poles 25 FT from edge of lane
- Beam guard at edge of shoulder to shield the poles

Analysis variables:

- 25-year analysis period
- 4% interest rate

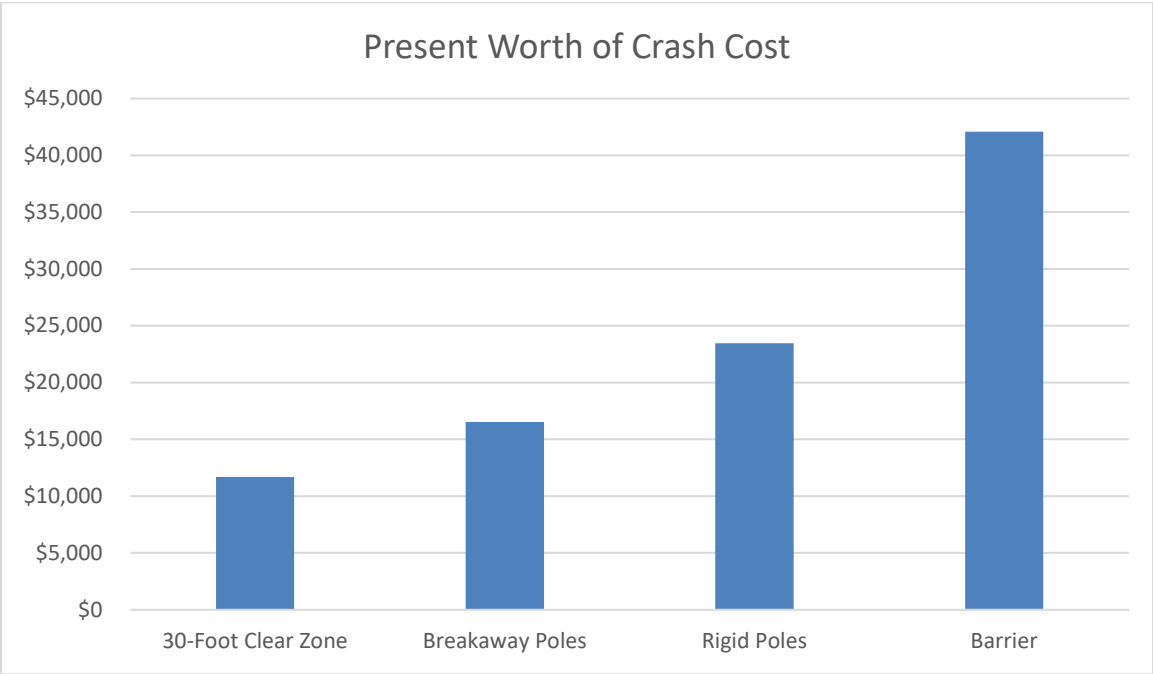

Figure 15.12 Roadside Alternative Crash Cost Comparisons[7]

For the example above, placing barrier may not be the most effective treatment. More information about the location, what the poles are being used for, consequence of collision, and other factors would need to be reviewed to determine what course of action to take.

15.1.4 Roadside Design and Aesthetics

AASHTO states the following:

> "While aesthetics are a concern, they should not be the controlling factor in the selection of a roadside barrier. Even in environmentally sensitive locations such as recreation areas and parks, it is important that the barrier be selected crashworthy as well as visually acceptable."[vi, vii]

The Roadside Design Guide also states:

> "Five factors should be considered in selecting a bridge railing: (1) performance, (2) compatibility, (3) cost, (4) field experience, and (5) aesthetics. Despite the relative importance placed on these factors, the capability of a railing to contain and redirect the design vehicle should never be compromised."[viii]

Another section of the Roadside Design Guide states:

> "Although there is no question that an aesthetic bridge railing in scenic areas or along park roads may be particularly important in response to public input, the safety performance of a railing should not be sacrificed."[ix]

[7] Graph developed by RDSU staff utilizing Roadside Safety Analysis Program (RSAP) v3 with the noted parameters.

As previously stated, installing a barrier system is less desirable than other roadside design treatments. Use caution when using aesthetics to justify not using a barrier system, or other more preferred roadside design alternatives.

15.1.5 Crashworthiness of Roadside Hardware

Crashworthiness tries to minimize the risk of injury from (the list is not all-inclusive):

- Deceleration forces
- Parts of the hazard penetrating the cab
- Deformation of vehicle cab
- Vehicle rollover
- Flying debris

Some types of roadside hardware have more requirements for crashworthiness. Some of these are (the list is not all-inclusive):

- Structurally adequate to redirect the design vehicle
- Vehicle trajectory after a crash.

Using crashworthy hardware does not make an object risk free. Under some crash conditions, crashworthy hardware may not function as intended. This is because crashworthy roadside hardware is tested using several assumptions. Violation of crash testing assumptions could cause unexpected outcomes. Many of the variables that determine hardware performance's during a specific crash are not under the control of the design, construction, or maintenance staff.

The Department strives to install new hardware that conforms to the most current crash test standard. However, in some situations, it may not be possible to install new hardware that conforms to the current crash tested standard (the list is not all-inclusive):

- Not all the components needed in a barrier system meet the current standard
- Site, project, or other restrictions prevents installing hardware as it was crash tested

The Department addresses these less-than-ideal situations with published policies, or on a case-by-case basis. In less than ideal situations, the Department may (the list is not all-inclusive):

- Use roadside hardware tested to a lower or higher crash test level than it would normally use
- Use roadside hardware tested to an older crash test standard
- Adjust roadside hardware using computer modeling, other research, and expert opinion.
- Allow the use of non-crash tested hardware.

Some of the situations require the approval of BPD. Document a less-than-ideal situation in the Design Study Report. Other situations may require the approval of others in the Department. Coordinate with the WisDOT project manager and the regional design oversight engineer for assistance.

The Department has policies to address existing barrier system and some roadside hardware on projects. Existing barrier systems and roadside hardware is reviewed (see FDM 11-45-10.4). If reasonable, spot improvements or replacement may be implemented. Spot improvements may not meet the most current crash test standard. Spot improvements are based on (the list is not all-inclusive):

- Older crash tested hardware
- Adjust roadside hardware using computer modeling, other research, and expert opinion.

See other parts of the FDM for guidance for existing barrier systems and some hardware on projects.

15.1.6 High Angle Crash Locations

Longitudinal barrier systems (e.g. beam guard, concrete barrier…) are not designed for crashes greater than 25 degrees. Installing a longitudinal barrier system where a high angle hit can happen should be documented in the DSR. Examples where longitudinal barrier can be hit at a high angle are (the list is not all-inclusive):

- Top of a "T" intersection
- Median gap between bridges

Situations, like the top of a "T" intersection, a longitudinal barrier system may be the only choice available. For example, a lake is in the right-of-way near the top of a "T" intersection. On the other hand, removing a hazardous pole from the top of the "T" intersection is better than placing a barrier system.

Some bridges have beam guard installed in the median gap between bridges (See Figure 15.13). 90-degree crashes can happen here as well. The grading approaching a barrier system between bridges may prevent the barrier system from operating correctly. Many of the barriers installed at these locations are not crashworthy systems.

Avoid installing longitudinal barrier system in a median gap between bridges. Avoid using mowing and pedestrian concerns for installing a barrier in the median gap between bridges.

Figure 15.13 Beam Guard Installed in Median Gap Between Bridges

Other roadside hardware alternatives are better choices in the median gap between bridges. Some of these options are (the list is not all inclusive):

- Increasing the length of barrier along the road
- Flaring barrier along the road
- Thrie beam bullnose
- Flaring concrete barrier from both sides of the median and installing a crash cushion

The first two options may not prevent some vehicles from going between two bridges. However, this type of crash has a low probability. Review Length-of-Need discussion in FDM 11-45-30.3.1.2.

The last two options will likely prevent a vehicle from going between the bridges. Crash cushions and arrays are designed for some 90-degree hits. These alternatives may have other issues (e.g. drainage, longer barrier installations, cost maintenance…).

15.1.7 Request for Technical Assistance

Request for technical roadside design assistance should be directed through the regional project manager or others in the region. If there is a need for additional assistance, coordinate with the WisDOT project manager and the regional design oversight engineer.

Typically, request for technical assistance should include:

- AADT
- Speed
- Type of project
- Drawings or photos of the situation
- Deadline for a response

Other information may be requested.

15.1.8 Documentation of Roadside Design Decision

Provide a design justification (DJ) in Design Study Report when not following roadside design guidance in FDM 11-45-30 or other sections of the FDM. Documentation may be needed years after the design or construction and key decision makers may not be available.

Typical items that should have a DJ in the Design Study Report are (the list is not all-inclusive):

- Decision not to implement a warrant for a specific treatment. Some examples are:
  - not to shield the blunt ends of an existing bridge.
  - not to remove a tree that warrant removal.
- Decisions not to install crashworthy hardware as specified. Some examples are:

  - install barrier without adequate length-of-need.
  - not to provide grading for a barrier system.
  - modify a thrie beam approach transition.
- Decisions not to use crashworthy hardware. Some examples are:
  - install a sloped end treatment.
  - install a blunt end on the approach end of a barrier system.
- Decisions not to provide indicated plan information. Some examples are:
  - not provide individual construction details.
  - not provide soil boring information in plans for cable barrier project.
- Decision not to review or upgrading existing hardware. An example is:
  - not to adjust beam guard height.
- Decisions to use a non-typical installation of hardware. An example is:
  - to install a flared barrier system.
- Decisions to use special provisions or unique hardware.
- Decisions that require review, coordination with other groups, or additional engineering. Some examples are:
  - review a situation where other factors were required to make a treatment decision.
  - coordinate with Bureau of Structures about work near or attached to a structure.
  - decided they want to design a special concrete barrier transition.

The WisDOT project manager and the regional design oversight engineer have the responsibility of reviewing and approving a DJ. Questions about what needs a DJ and what documentation is needed should be directed toward the them.

15.1.9 Delineation of Roadways at Hazards

Marker posts, delineators, and appropriate signing may be used to alert motorists of highway alignment or roadside conditions where the roadside barrier is not cost-effective, and yet a safety hazard remains.

FDM 11-45-20 Roadside Hazard Analysis And Treatments *August 17, 2020*

20.1 Introduction

Roadside Hazard Analysis (RHA) is a multi-step process of reviewing roadside hazards and locations of concern. The intent of RHA is to help staff:

- Create an accurate estimate during scoping or preliminary design.
- Limit redesign in later stages of the project
- Allow for more time to get technical help
- Allow for implementation of technical solutions
- Allow a quicker and more systematic review of roadside design decisions
- Allow more experienced staff to aid less experienced staff
- Help decide what clear zone to use for a project or a location

RHA has three phases:

1. Scoping/Preliminary Design/SCP
2. Design Study Report
3. Final Design

The scoping/preliminary design/SCP phase identifies roadside hazards and areas of concern that can have a significant influence on project type and what resources a project needs. This effort is accomplished during the Project Definition Phase – see FDM 3-1-10.

The Design Study Report phase has two steps. The first step creates a list of roadside hazards or locations of concern. The second step documents what roadside design methods are being used. This effort is accomplished during the Project Delivery Phase – see FDM 3-1-15.

The final design phase is a holistic review of the overall design. Identify new hazards or less than desirable situations, and discuss the use of non-standard roadside safety hardware.

This section will discuss the following:

- What projects need to use the RHA process?
- What is a hazard?
- What is an Area of Concern?
- How far from the road do I look for hazards or Areas of Concern?
- What documentation do I provide?
- Where does this documentation belong?

20.2 Roadside Hazard

One of the key functions of the RHA is to identify and decide on treatments for roadside hazards. FDM 11-45-20.2 discusses some of the most common roadside hazards along with known warrants. Not all possible hazards are listed.

The following roadside hazards need documentation in the RHA. Unless noted otherwise, the following hazards do not need to be documented in the scoping/preliminary design/SCP phase. Some situations, an early review of a hazard or hazards may have a benefit. Examples are (the list is not all-inclusive):

- A significant quantity of work is required (e.g. many culvert pipes need traversable grates…).
- Work on an item will add significant cost (e.g. extend large culvert pipe…).
- Right-of-way may be needed.

Document issues found during scoping/preliminary design/SCP in the Design Study Report phase.

20.2.1 Roadside Hazard Warrants

Warrants have been developed for various roadside situations. Many of the warrants present are based on results from crash tests, computer modeling, crash analysis, benefit cost analysis, or a combination of them.

20.2.2 Warrant Assumptions

Many of these warrants use an “average road.” An “average road” is:

- Built to a suitable standard
- Does not need to consider consequences of a collision
- Road is straight and level
- Road does not have a history of run off the road crashes

Unless noted otherwise, warrants use the following assumptions:

- Road is a two-lane highway
- Road has a speed of 50 to 55 mph
- Warrants do not include the interaction of hazards at a location. Examples are (the list is not all-inclusive):
    - A shielding warrant for a slope will not include influences of fixed objects on a slope.
    - A shielding warrant for a slope assumes that a 3:1 slope has a flat run-out area at the bottom of the slope.
    - A shielding warrant for a culvert does not look at the interaction of other fixed objects or water near the culvert.
    - How curb and gutter may influence the performance of a barrier system, safety hardware or hazard.
    - A hazardous object is outside the area where shielding would be recommended, but slopes between the road and the hazard are non-recoverable.
- The roadside hardware or barrier system can be correcty installed.
- The useful life of the barrier system is 20 to 25 years.
- The cost of installing a barrier system is near the statewide average cost.

20.2.3 Proper Application of Warrants

To properly apply the warrants, use the roadside design treatment sequence. A warrant to shield a hazard requires review of other more desirable roadside design treatments first. If the warranted roadside treatment is not feasible, other roadside design treatments are to be reviewed.

A warrant does not automatically allow:

- for improper installation of the barrier system.
- for a design justification to a standard
- “no action” to take place at locations where:

- The frequency of run off the road crashes is high.
- The severity of run off the road crashes is high.
- The consequence of collision is high.

Warrants are from multiple sources. Each source may have made different assumptions to develop its warrant. Warrants may be in conflict. If there is a conflict, look to:

- Consult with an engineer trained and experienced in roadside design issues.
- Error on the side of driver safety.
    - Use a preferred roadside design treatment before a less desirable treatment.
    - If two shielding warrants conflict each other, provide shielding.
    - Look for other hazards nearby
    - Review Attachment 20.1, and Table 20.1

If a location does not match the assumptions in the warrant, error on the side of safety of the traveling public. Some examples are (the list is not all-inclusive):

- A "Do Nothing" alternative for a lower speed road may not be suitable for a higher speed facility.
- A warrant for a two-lane road points to installing a barrier system, a freeway or expressway would likely warrant a barrier system.
- A warrant for a two-lane road points to not shielding a hazard, installing a barrier system may be correct on a freeway or expressway.

Many of the warrants do not consider consequence of collision. If there are significant consequences of collision, it is not appropriate to use these warrants to take no action. Discuss with the WisDOT project manager and the regional design oversight engineer.

20.3 Hazards

20.3.1 Slopes

Identify hazardous slopes during the scoping/preliminary design/SCP phase. Grading may need more right-of-way, drainage or environmental work. Slopes are either:

- Perpendicular to the direction of travel
    - Foreslope
    - Backslopes
- Parallel to the direction of travel
    - Driveway slopes
    - Side road slopes
    - Median crossovers
    - Ditch checks

Perpendicular slopes steeper than 4:1 are hazards. A vehicle will travel to the bottom of the slope. A vehicle on this steep of slope will engage:

- The backslope
- Fixed objects on the slope
- Fixed object at the bottom of the foreslope

Perpendicular foreslopes between 4:1 to 3:1 that lack the clear runout area at the toe of slope are hazards. See FDM 11-15 Attachment 1.9. Any ditch at the bottom of these foreslopes can cause the vehicle's bumper to snag on the backslope of the ditch.

For perpendicular backslopes, see the discussion on ditches in the culverts and other associated drainage items section.

Slopes parallel to the direction of travel that are too steep will launch a vehicle into the air. Occasionally a parallel slope will cause a vehicle to flip over (rear bumper rotated over front bumper). Information in FDM 11-45-30.6.2 contains information on acceptable speed and maximum parallels slopes.

Occasionally, cross-drain pipes without the proper grading may have a hazardous parallel slope – see Figure 20.1, Figure 20.3 and Figure 20.4. A good parallel slope and traversable endwall is shown in Figure 20.2.

Figure 20.1 Parallel Slope Hazard

Figure 20.2 Good Parallel Slope and Traversable Endwall

Figure 20.3 Installation of a Traversable Culvert but Retaining Wall is a Hazard

Figure 20.4 Vehicle Hit a Hazardous Driveway Slope

It may be possible to decide if slopes are hazards by reviewing the as-built plans. However, unrecorded construction or maintenance, utility work, or natural erosion may have steepened slopes. Conduct a field review to verify what slopes are present along a road.

Perform an on-site visual survey with spot-measurements on the road to determine the following:

- Slope break points
- Extent of hazardous slope
- Ditch location

Spot-measurements are not a project's survey. These measurements are for identifying if hazardous slopes are present and roughly quantify the extent of the hazard. Use on-site visual survey and spot-measurements to answer the following questions about hazardous slopes:

- How long is the slope?
- How tall is the slope?
- How steep is the slope?
- How far from the edge of lane is the slope?
- Are there other hazards on or near the slope?
- Where is the slope located?

Without this information, it is difficult to decide a course of action.

At a minimum, use a 4-FT carpenters level and tape to measure slopes. Use the following guidance when measuring the slopes with a 4-FT carpenter level on projects without already completed or proposed future survey:

- Once every 500 feet
- Spot locations (e.g. driveways, near structures, drainage features, and transitions from cut to fills…).
- Parallel slopes need at least one measurement in the direction of travel.

On two-lane roads and in divided medians, parallel slopes have two approaches. One approach for each direction of travel.

20.3.1.1 Barrier Installation Warrant for Foreslopes

20.3.1.1.1 Roadside Design Guide – Foreslope Warrant

Attachment 20.2 is a warrant for shielding embankments.[x] Embankments falling within the shaded area are more of a hazard than installing a barrier system. This warrant is not based on:

- Fixed objects or other hazards on the slope
- A 3:1 slope that lacks a flat run-out area at the toe of the slope
- steep existing foreslopes.

20.3.1.1.2 FHWA Barrier Warrant for Low Volume and Low-Speed Roads Publication

Attachment 20.3 has warrants for shielding foreslopes based on Adjusted Traffic Factor (ATF), speed, slope rate, slope height, and offset from travel way.[xi]

This warrant does not automatically remove slopes that are shorter than the distance given or flatter than the slope given from shielding. Review flattening the slope before shielding a slope.

The following information will discuss proper application of this warrant. This warrant is based on crash severity and crash frequency on low speed, low AADT roads.

It is not proper to use these tables on roads with higher AADTs to justify leaving a hazard unshielded. If shielding is warranted in these tables, it is likely that shielding would be warranted on roads with higher AADTs or speeds. In many high-speed or higher AADT roads, other roadside treatments would be more desirable (e.g. remove, move, make traversable,...).

This warrant uses hazard type, ATF, speed, and offset from the road to decide if shielding should be used. The ATF value adjusts the vehicle encroachment rate for the effects of curves, traffic growth, and grade. Calculate ATF as follows:

$$ATF = AADTxTGxHCxDG$$

Where:

AADT= AADT

TG= Traffic Growth Factor (Attachment 20.3, Table A.1)

HC= Horizontal Curve Adjustment Factor (Attachment 20.3, Table A.2)

DG= Down Grade Adjustment Factor (Attachment 20.3, Table A.3)

Note: If a project has projected AADT values, use projected AADT values and do not use TG Factor in calculations of ATF. If a project does not have projected AADT value, use existing AADT and traffic growth factor.

The warrant has three classifications (1) Not Warranted, (2) Possibly Warranted, and (3) Warranted.

The Possibly Warranted column has benefit-cost ratios between 2 and 4. Warranted column has benefit-cost ratios greater than 4.

For roads that fall within the ranges in the tables, shield hazards that:

- Are within the Warranted column
- Are within Possibly Warranted columns on projects where there is a run off the road flag in Metamanager or if a Metamanager AK flag can be traced to run off the road crashes

On roads that fall within the Possibly Warrant column in the table, review locations that are within the Possibly Warranted column for shielding. Use Table 20.1 and Attachment 20.1 when considering shielding.

Table 20.1 Factors to Consider [xii]

Consideration	Barrier is more warranted if:	Barrier is less warranted if:
Adjusted Traffic Factor	ATF is at the high end of range	ATF is at the low end of range
Road Cross-Section	Section elements are more severe than assumed	Section elements are less severe than assumed
Size of hazard does not fit the assumption	Hazard is larger	Hazard is smaller
Hazard does not fit the description in the warrant table	Hazard is more severe	Hazard is less severe
Expected cost of barrier	Expected costs will be low	Expected costs will be high
Multiple hazards exist at the site	Many additional hazards	
Operating speed	Likely to exceed design speed	At or below design speed
Crash history	Clear crash pattern	No crash pattern

Many roads on the STH network have speeds greater than the maximum speed in the tables. Provide shielding on roads when the speed is greater than 50 mph, and the ATF value falls within the Possibly Warranted or

Warranted columns.

20.3.1.1.3 Traversable Grate for Hazardous Parallel Culverts Warrant

Hazardous parallel drains within the clear zone on roads with AADTs of 100 or greater warrant traversable endwalls.[xiii] See discussion in FDM 11-45-30.6.

20.3.2 Drainage Features

20.3.2.1 Culverts

Working on culverts and similar drainage features may need grading, right-of-way, and changes to existing barrier systems. Identify large drainage features early in the scoping/preliminary design/SCP phase.

Culverts or similar drainage features may need significant amount of grading or other work. Identify these culverts or drainage features early in the scoping/preliminary design/SCP phase.

If needed, coordinate with Bureau of Structures (BOS).

See FDM 11-45-30.6 for guidance on hazardous culverts and other typical hazards near culverts.

Other openings wider than 24 or 36 inches (depending on opening orientation to the road) are roadside hazards[xiv,8]. Examples are (the list is not all-inclusive):

- Inlets or manholes with no cover
- Three 12-inch culverts placed near each other
- Basins, drop structures, channels, (see Figure 20.5)
- culvert pipe headwalls (see Figure 20.6)

Figure 20.5 Width of Basin allowed Bumper Contact with Inside Wall[9]

[8] Opening smaller than 24 or 36 inches may be hazards for pedestrians and bikes.
[9] Wall of basin is approximately 1 foot tall. In the direction of travel, the inside dimensions of the basin is 10 feet. Contact with the wall caused excess decelerations.

Figure 20.6 Headwall for Culvert Pipe is a Hazard[xv][10]

Improperly installed pipe grates (See Figure 20.7, Figure 20.8, and Figure 20.9) are hazards. For a traversable grate to work, the grate's bars need to be perpendicular to the direction of travel. Grates that do not have the correct hardware may not have the strength to support a vehicle. Review SDD 8F7 or SDD 8F8 for proper spacing and orientation of bars in a traversable grate.

Grate in Figure 20.8 is a hazard because the horizontal bar in the foreground is too far off the ground. This bar should be flush with the ground. A horizontal bar only 1 FT off the ground rolled a vehicle over during crash testing.

Figure 20.7 Pipes are Installed Parallel to Direction of Travel[11] Hazard

[10] 4-inch tall hazard on a 5-FT chord

[11] Ends of endwall are 4-inch tall hazards on 5-FT chords

Figure 20.8 Grate Does Not Extend to Bottom of Apron End Wall or Culvert[xvi] Hazard

Figure 20.9 Grate Should Have Covered All of the Opening[12] Hazard

20.3.2.1.1 Traversable Grate for Hazardous Cross-Drains Warrant

Hazardous cross-drains within the clear zone on roads with AADTs of 750 or greater warrant traversable endwalls.[xvii] See discussion in FDM 11-45-30.6.

20.3.2.1.2 Shielding Hazardous Cross-Drains or Cattle Passes Warrants

20.3.2.1.2.1 Shielding Hazardous Cross-Drains or Cattle Passes Warrant on Perpetuation and Rehabilitation Projects

Attachment 20.4 is a warrant for shielding hazardous cross-drains.[xviii] Locations that are on or below/right the line for the given box warrant shielding.

This warrant was developed for minor S-1 projects. It is not appropriate to use this warrant to justify installing a new drainage feature or cattle pass that is narrow. See discussion in FDM 11-45-30.6. Review more desirable treatments on S-2 and S-3 projects before shielding a hazard.

The warrant also assumes:

- Slopes near drainage feature or cattle pass are traversable
    - Slopes and culvert may need shielding
- Drainage feature or cattle pass is not a fixed object hazard (the e.g. headwall is not a 4-inch object on 5 foot chord hazard).

[12] Head and sidewalls of the box culvert are 4-inch hazards on a 5-FT chord

- Head wall may need to be shielded regardless of AADT.

- Hazardous water is not always present
  - Hazardous water may need to be shielded regardless of AADT.

20.3.2.1.2.2 Shielding Hazardous Cross-Drains or Cattle Passes Warrant on Rural Local Roads

More recent research shows that shielding a hazardous cross-drain can have a benefit cost ratio of 4 or more before 500 AADT.[xix] Some situations where these occur are:

- Road width less than 36 feet
  - Rural two-lane or rural one-lane road
    - AADTs of 250 or greater
    - Perpendicular slopes leading to the hazardous culvert are 2:1 or steeper
- Road width less than 36 feet
    - Rural two-lane or Rural one-lane road
    - With AADTs of 450 or greater
    - Perpendicular slopes leading to the hazardous culvert are 3:1 or steeper
- Road width of 36 feet or greater
    - Rural two-lane roads
    - With AADTs of 400 or greater
    - Perpendicular slopes leading to the hazardous culvert are steeper than 2:1

This research also shows that shielding hazardous cross-drains and cattle passes can have a benefit cost ratio of 2 or more in the following situations:[xx]

- Rural two-lane or one-lane road
    - Road has AADT of 250 or greater.
    - Slopes leading to the culvert are 2:1 or steeper

Shield when projects match conditions that have a benefit cost ratio of 4 or more. In areas, where run off the road crash frequency is high, shield hazardous cross-drains and cattle passes that match the conditions that have a benefit cost ratio of 2 or more. In areas, where run off the road crash severity is high, shield hazardous cross-drains and cattle passes that match the conditions that have a benefit cost ratio of 2 or more.

The consequence of a collision may suggest shielding as well. For example, the amount of drop from the culvert or the presence of deep water may make shielding a culvert the best treatment.

Review locations that match conditions listed for benefit cost ratio of 2. Use Table 20.1 and Attachment 20.1 when considering shielding these locations.

This research assumed:

- That no other hazard is present
- Analysis was done up to 500 AADT
- Highway's functional class is a rural local road
- 3:1 slopes have flat traversable areas at the toe of slope

Do not use this warrant to justify:

- Leaving hazardous cross-drains or cattle passes unshielded on higher AADT roads.
- Leaving hazardous cross-drains or cattle passes unshielded on higher functional roads.
- To install steeper slopes near a new cross-drain or cattle pass.

It may be proper to use this warrant to justify shielding hazardous cross-drain or cattle pass:

- On a higher AADT road
- On a road of higher functional class

Review more desirable treatments on higher functional class or AADT roads before shielding.

20.3.2.2 Ditches

Ditches that fall outside the typical ditch cross-sections in FDM 11-15 Attachment 1.11 are hazards. Non-traversable ditches can allow the bumper to engage the backslope. Engaging the backslope of the ditch can cause excessive deceleration or flip a vehicle. Ditches can also steer a vehicle into a fixed object (Figure 20.4).

20.3.2.3 Other Drainage Related Hazards

Identify water with a normal depth of 2 feet or more during scoping/preliminary design/SCP phase. If a vehicle

rolls into the water this deep, occupant drowning is a higher risk.

Medium, heavy, and extra heavy riprap is a hazard. Riprap of this size can trip a vehicle or cause excessive deceleration.

Figure 20.10 Riprap is a Hazard[13]

20.3.2.3.1 Shielding Hazardous Water Warrant

Attachment 20.5 is a warrant for shielding hazardous water. See FDM 11-45-20.3.1.2 to use this warrant.

This warrant assumes the slopes between the water and the road are recoverable.

Figure 20.11 Shielding Hazardous Water

20.3.3 Structures - Bridges, Box Culverts, Large Drainage Conduit, Retaining Walls and Similar Features

A 2005 study of Kansas crash data indicated fatalities from hitting bridge parapets or barrier systems attached to the bridge are over-represented[xxi]. Research conducted on Iowa local bridges suggests that bridges narrower than the approaching road are more likely to have crashes than bridges as wide as the approaching road.[xxii]

Review the following structures during preliminary scoping/design (the list is not all-inclusive):

- Box culverts
- Bridges
- Retaining walls
- Large drainage conduits

Review the interaction of grading, other hazards, and barrier systems near these features.

Coordinate with BOS and the WisDOT project manager and the regional design oversight engineer. Structural issues may limit options available, and what barrier systems can be used near these features.

Coordinate changes to these features with the road project. This limits impact on road users and allows for the correct installation of hardware.

[13] Individual rocks are 4-inch hazards on a 5-FT chord

Pay attention to the slopes that wrap-around a structure and blend into the slopes perpendicular to the direction of travel. These wrap-around slopes may increase the length of barrier because they are hazards.

Figure 20.12 Bridge Rail[14]

Use only approved bridge parapet or road barrier systems on bridges, box culverts, retaining walls or large drainage conduits. In some existing situations, it may not be feasible to install an approved parapet or barrier system. If not feasible to install an approved parapet or barrier system, it is typically possible to improve an existing parapet or barrier system. The WisDOT project manager, BOS and the regional design oversight engineer will decide if an approved parapet design or changes to the existing parapet or barrier systems are needed.

20.3.3.1 Parapets

Review parapets on or connected to a bridge, retaining wall or other structure. Contact the WisDOT project manager and the regional design oversight engineer and BOS if parapet is not shown on:

- Standard detail drawings
- LRFD Bridge Manual
- Within BOS's standard detail drawings

The parapet may have crashworthiness issues. For example, parapet designs before 1964 may lack the strength to contain a crash.[xxiii] Parapets designed after 1964 may have enough strength, but the parapet may have other issues (e.g. snagging, pocketing...).

Some problems that parapets can have are (the list is not all-inclusive):

- Brush curb is present
- Elements of the parapet can allow snag during a crash
- Elements of the parapet can spear into the vehicle cab
- Elements of the parapet are missing or in poor condition
- Lack of connections between elements
- Parapet design prevents smooth redirection
- Parapet is not strong enough to absorb crash loads
- Fixed objects are too close to or on top of parapet
- Parapet lacks or has an insufficient transition from parapet to semi-rigid barrier system

Figure 20.13 has multiple issues that should be addressed during the scoping or preliminary design phase of a project. Some of the issues are:

- Brush curb is present
- Vertical elements of parapet may cause snag
- Height of horizontal element may be too low to contain a vehicle
- Structural strength of parapet elements and connections to bridge may not be strong enough
- Parapet has an insufficient transition from parapet to semi-rigid barrier

[14] Note that this bridge parapet lacks appropriate thrie beam transition to beam guard.

Figure 20.13 Brush Curb

Figure 20.14 Roadway Project Significant Damage to Bridge Railing

Review the quality and condition of the top, sides, and bottom of a deck that have parapets or barriers mounted to them. A deck that looks good on top may have issues on the sides or bottom. A weak deck can influence parapet or barrier performance (see Figure 20.15). Provide photos of the parapet and deck (i.e. top, bottom and side of deck) to the WisDOT project manager, regional design oversight engineer, and BOS.

Figure 20.15 Damage to Side of a Deck that May Influence Parapet Performance

Figure 20.16 Strength of Barrier Connection Critical to Barrier Performance and Structural Maintenance

Some sources of information that can help evaluate an existing parapet are:

- Chapter 6 of the 2006 Roadside Design Guide has pictures of inadequate parapets.
- FDM 11-45-30.5.3 has a discussion on concrete barrier issues that can apply to parapets (e.g. structural strength, smooth transitions).
- FDM 11-45-30.5.2.10 discusses transitions to parapets.
- CMM 1-45.12.5 has discussion and photos on potential snag issues and damage to the temporary barrier. This information can apply to parapets.
- CMM 6-25.3.4 has photos of damaged post, beams and blocks that can apply to parapets.
- Bridge Design Manual has standard parapet designs.

It can be difficult to fit crashworthy hardware on a structure when a driveway or intersection is nearby (e.g.150 FT). Identify these situations during scoping/preliminary design/SCP.

20.3.3.2 Blunt Ends

Blunt ends can sometimes be present on barrier systems, end of retaining walls, parapets, and other objects. Even some “sloped” bridge parapets are blunt ends. All blunt ends are significant hazards. Identify blunt ends that a vehicle can hit head on during scoping/preliminary design/SCP. See FDM 11-45-30 for more discussion

on blunt ends.

20.3.3.3 Shielding Blunt End of Parapets or Railing Warrant

Blunt ends of parapets are significant hazards.[15]

Shield the blunt ends of parapets on roads with AADTs of 400 or greater.[xxiv]

Review Attachment 20.1 when deciding to shielding blunt ends on roads with AADTs between 150 and 399.[xxv].

Multiple research studies have shown that bridges narrower than the approaching road width are more likely to be hit. Shield the blunt ends of parapets on structures that are narrower than a road's normal width when AADT is between 150 and 399. Shield blunt ends of parapets on drainage features or cattle passes that are narrower than approaching road when AADTs is between 150 and 399.

Delineate blunt ends of parapets or railings on roads with AADTs less than 150.

Review FDM 11-45-20.3.3.4 and 11-45-20.3.3.5 for more information on bridges and barriers that approach bridges. Review FDM 11-45-30.5.2.10 and FDM 11-45-20.3.3 for more information about shielding blunt ends of parapets or railing.

20.3.3.4 Crashworthy Bridge Parapets and Railings Warrant

All bridge parapets and railings are to be National Cooperative Highway Research Program (NCHRP) 350 or Manual for Assessing Hardware (MASH) compliant. Refer to LRFD Bridge Manual 30.1 for more information. New bridge rail installations LET after December 31, 2019, need to meet MASH requirements.

It may not be reasonable to install a crashworthy parapet or railing on an existing structure. Often, safety improvements can be made to the existing parapet or railing. Coordinate with the WisDOT project manager, BOS, and the regional design oversight engineer.

Review FDM 11-45-20.3.3.3 and 11-45-20.3.3.5 for more information on bridges and barriers that approach bridges. Review FDM 11-45-30.5.2.10 and FDM 11-45-20.3.3 for more information about shielding blunt ends of parapets or railing.

20.3.3.5 Area with High Frequency of Run Off the Road Crashes by Bridges Warrant

Research in Wisconsin shows that cross-median crashes, a specific subset of run off the road crashes, are more likely to occur near bridges. Research in Iowa suggests that 80 percent of their bridges have 2 or fewer parapet or railing crahes in 10 years.[xxvi]

If a bridge's parapet, railing or attached barrier system has more than two crashes in 10 years, the location has an issue with run off the road crashes. Improve roadside design near this bridge.

This is not a warrant to provide median protection shielding.

20.3.3.6 Bridge Piers

Crashes into bridge piers can have serious consequences. Identify piers as hazards early in the scoping or design process. See FDM 11-35-1 and FDM 11-45-30 for more information on piers.

20.3.3.7 Retaining Walls

Retaining walls are typically not designed for crash loads. A crash can cause damage to the retaining wall, or in the worst-case wall failure. Repairing a retaining wall can be expensive. A wall with a rough face [16]or edges can cause excessive vehicle compartment crush, rollover, or large deceleration force.

Identify retaining walls as a hazard when:

- The vehicle can leave the road and fall off an unshielded retaining wall.
- Barrier system on top of a retaining wall is in poor condition or substandard.
- The vehicle can leave the road and strike an unshielded retaining wall.

A chain-link fence is not considered a barrier system for vehicles.

20.3.3.8 Pedestrian Rails

Pedestrian railings using steel pipes with diameters of 2 inches or more are hazardous. Crash testing of a road sign using a single 2-inch diameter steel pipe caused excessive vehicle deceleration. Also, pedestrian rails can

[15] In one study, 58% of all fatal crashes on a bridge involved a vehicle hitting the blunt end of a parapet or railing [Michie, Jarvis, Bronstad, Maurices, Upgrading Safety Performance in Retrofitting Traffic Rails, FHWA-RD-77-40, 1976]. Another study compared the safety performance of bridges with exposed blunt ends to bridges with shielding [Gates, Tim, Noyce, Dave, Stine, Paul, TRB 2006 Annual Meeting CD-ROM, Safety and Cost-effectiveness of Approach Guardrail for Bridges]. Bridges with exposed blunt ends had 4.5 times more K and A crashes than bridges with shielding.

[16] Crash testing has indicated that sand blasted textures with a relief 3/8 of an inch or more can negatively affect crashworthiness of a concrete barrier system

spear into a vehicle's passenger compartment[17]. In Figure 20.17, the pedestrian rail is a hazard to a vehicle. A pedestrian railing can prevent a pedestrian from evading a vehicle. See FDM 11-45-20.4.1 for discussion of Areas of Concern for more information.

Figure 20.17 The Pedestrian Rail is a Hazard[xxvii]

Figure 20.18 Pedestrian Rail Entered Cab of Vehicle

20.3.4 Signs and Poles

Signs and poles are fixed objects that engineers decide to install along a road. Traffic signals and railroad crossing warning devices are not hazards.[xxviii,18]

Luminaires may use non-breakaway hardware.[19] Identify these luminaires as hazards for RHA.

Table 20.2 contains a list of conditions for a sign or pole that would make the pole a hazard.

[17] Top of railing is typically at 42 inches. Average eye height of a vehicle's occupants is 42 inches.
[18] See 2011 AASHTO Roadside Design Guide for more information
[19] Non-breakaway pole may be used in locations where dropping a pole on pedestrians, other road users or buildings is a risk.

Table 20.2 Signs or Poles

Issues	Condition	Discussion
Breakaway Feature	Type I signs are missing post clips, post clip bolts, washers or nuts) are hazards (see Sign Plate A4-6 and A5-2)	Post clip hardware allows the overhead sign to detach from the posts during a crash. During a crash, the clips temporarily delay the release of the sign. This delay prevents the sign from falling on the vehicle or causing excessive deceleration.
Breakaway features	Breakaway features are missing or are not installed correctly (see Figure 20.19 to Figure 20.24).	Sign or pole may not breakaway as intended (see discussion below).
Breakaway features	A sign is heavier, is larger than, located differently on a pole, or other hardware has been added to a pole than what was crash tested.	Signs that are heavier than what was crash tested can prevent the breakaway hardware from functioning or allow the sign to crash onto the vehicle. Signs that are larger than what was crash tested may enter a vehicle's cab. Adding mass or moving a mass can change the rotational inertia of a pole or sign. Changing the rotational inertia of a sign or pole may lock it into place versus rotating over the top of a vehicle. Sometimes, changes in rotational inertia can cause the pole to crush the vehicle's cab.
Breakaway features	Signs or poles that use weathering or Cor-Ten Steel (See Figure 20.25)	This steel can cause breakaway features to rust shut and not work.
Breakaway features	Steel poles with a diameter of 2 inches or more	Without changes that weaken the pipe or the use of breakaway features, pipes this size can cause a vehicle to decelerate too quickly.
Placement and Breakaway Features	Signs that do not conform to WisDOT's Sign Plates A3-1, A4-1, A4-2, or A4-3	Signs that do not follow these details have issues with proper sign placement, or the sign is not using breakaway hardware.
Placement	Breakaway features for a sign or pole is more than 4 inches tall on a 5-foot chord (See Figure 20.19, Figure 20.20, Figure 20.22 and Figure 20.31).	Grading near a sign or pole can cause the breakaway feature to become a snag hazard.
Placement	Sign or poles installed in poor soils, wet soils or near the bottom of a ditch are hazardous	Poor or wet soils may not allow breakaway features to engage. Ditch slopes can steer a vehicle into a sign or pole.
Placement	Signs or poles are within the working width, or the zone of intrusion of a barrier system	The vehicle may engage the sign or pole behind the barrier. See working width discussion in other sections of FDM 11-45-30.
Placement	Installing signs or poles within 70 feet of an EAT. See figure in CMM 6-26 and Figure 20.44	The vehicle may try to avoid the sign or pole and steer into the EAT. A vehicle may gate through the EAT and then hit the sign or pole.
Placement	Guy wires and poles are near the road.	Poles and guy wires are significant hazards. (See Figure 20.27 and Figure 20.28).
Placement	Grading leading to or around object can prevent object from working correctly	If vehicle engages breakaway pole too high, the pole may not work as designed (Figure 20.29)

Overhead sign supports, sign bridges, or message boards that do not follow guidance in FDM 11-55-20 are hazards.

Figure 20.19 Light Pole using Non-Breakaway Hardware[20]

Figure 20.20 The Footing is a 4-inch Hazard[21]

Figure 20.21 Non-Breakaway Sign

[20] Footing is a 4-inch tall object on a 5-foot chord hazard – see Figure 20.31
[21] This fixed object serves no purpose and should be removed.

Figure 20.22 Buried Breakaway Feature [xxix]

Figure 20.23 Breakaway Holes are too High[22]

Figure 20.24 Breakaway Holes in the Wrong Location[xxx]

[22] There are other issues with this sign and location. The sign should only have an arrow board on it (see discussion about the maximum size of sign on a breakaway feature). There also appears to be some edge drop issues from the paved shoulder to the gravel shoulder.

Figure 20.25 Cor-Ten/Weathering Steel Prevented Breakaway Hardware from Working [xxxi] [23]

Figure 20.26 Pole with Cabinet did not Breakaway [xxxii]

Figure 20.27 Utility Poles are Hazard

[23] Note that these signs need new steel posts and new footings.

Figure 20.28 Guy Wire Cut Car into Two Pieces [xxxiii]

Figure 20.29 Grading Leads to Improper Pole Engagement [xxxiv]

Figure 20.30 Message Board is too Heavy for Breakaway Features[24]

20.3.5 Other Objects

Objects that are 4 inches tall on a 5-foot chord can cause a small vehicle to flip, rip open its' gas tank or decelerate the vehicle too quickly. See Figure 20.30 for a drawing of the 4-inch hazard on a 5-foot chord.

Breakaway hardware or other safety features not installed correctly can become a fixed object hazard as well. Within this procedure, various objects are fixed object hazards because of the 4-inch on a 5-foot chord criteria. It may not be possible to install a sign or pole without violating the 4-inch on a 5-foot chord criteria. Minimize the situations where an object is taller than a 4-inch on a 5-foot chord. See examples in Figure 20.32, Figure 20.33, and Figure 20.34.

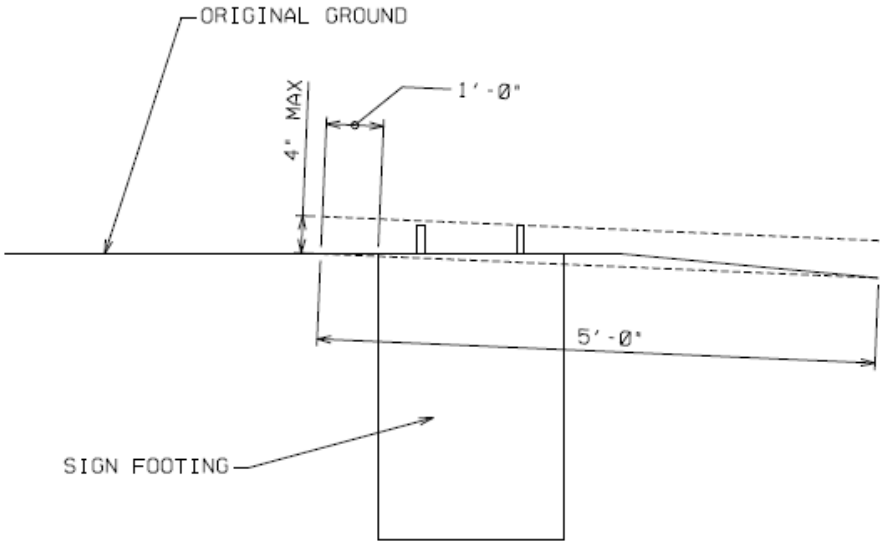

Figure 20.31 4-inch tall hazard on 5-foot chord

[24] Concrete foundation is a 4-inch tall hazard on 5-foot chord, and control box and power conduit are hazards. More than likely, the message board is not using the required breakaway clips. Message board is likely too heavy to allow proper operation of breakaway features.

Figure 20.32 Rock is a Fixed Object Hazard

Figure 20.33 Manhole is Fixed Object Hazard

Figure 20.34 Portions of Endwall and Culvert are 4-inch Hazard on 5-foot Chord

20.3.5.1 Trees

Preliminary results from NCHRP Project 17-43 shows the following:[xxxv]

- 50% of serious injury crashes are within 13 feet of road
- 50% of serious injury and fatal crashes with trees have a change of velocity near 22 mph (e.g... Hit tree at 22 mph and came to a full stop, or hit at 42 mph and leave the tree traveling 20 mph).

In another study, trees located in the median of urban/suburban roads had an increase in crash frequency and crash severity.[xxxvi]

A tree with a diameter of 4 inches or more, or will grow to be more than 4 inches in diameter, is a hazard. [xxxvii] Bushes or groups of closely spaced small trees with a group diameter of 4 inches or more are hazards.[xxxviii] Measure a tree's diameter 4 inches from the ground.[xxxix] Include stumps in hazardous tree identification.

Figure 20.35 is an example of what a vehicle crash looks like on a tree. Review existing trees for similar scars.

Woody limbs can become spearing hazards. In Figure 20.36, a branch from the shielded tree fatally speared an occupant of a vehicle.

Figure 20.35 Small Tree Crash

Figure 20.36 Trees speared vehicle's occupant[xl]

Figure 20.37 Smaller diameter tree fatality

Roadside landscaping and aesthetic issues can conflict with roadside design. Planting a small tree near traffic may not seem like a big issue during the design. However, the tree will grow into a long-term hazard that can cause significant injury or fatality. Even smaller diameter trees can contribute to fatalities – see Figure 20.37.

Removing existing trees is inexpensive, reduces run off the road frequency and severity. It may not be possible to remove all hazardous trees. Examples are (the list is not all-inclusive):

- A tangent section of a PM project within a suburban setting that does not have run off the road history.
- A tree or grove of trees is:
  - a documented "Witness Tree" for surveying
  - where a historically significant event took place[25]
  - a memorial to an important person, group, or historical event
  - a endanger/threatened tree species or habitat for endanger/threatened species
  - a documented exceptional example of a tree species [26]

[25]In these locations, the trees are part of the original historical setting.
[26] For an example, a given tree is the third largest white pine in the state.

- The road is[27]:
  - a rustic roadway
  - on the Great River Roadway network
- Other locations that it may be difficult to remove trees are:
  - scenic overlooks
  - historic properties
  - parks

Provide more discussion in RHA for a hazardous tree, or grove of trees, that needs to remain in-place.

20.3.5.1.1 Road Segment Warrant with High Rate of Tree Crashes

Attachment 20.6 has a threshold rate of tree crashes for various rural roads[xli]. If a road segment has a rate of tree crash greater than the values in Attachment 20.6, take corrective action. Trees are being hit more frequently than they should.

Break the project into quarter mile pieces. Use 3 to 5 years of crash reports to create the crash rate to compare to Attachment 20.6.

Review FDM 11-45-30.2.6, FDM 11-45-30.2.18 and FDM 11-45-20.3.5.1 for more information about trees. Do not use this warrant to override other warrants.

Other warrants indicate that it is cost effective to use other roadside design treatments on average roadway (i.e. roads without a high frequency of tree crashes). These other warrants combined crash severity and frequency.

20.3.5.1.2 Shielding of Hazardous Trees Warrant

Attachment 20.7 is a warrant for shielding hazardous trees. Refer to FDM 11-45-20.3.1.1.2 on how to use this warrant.

A tree with a diameter 4 inches or more, or will grow to be 4 inches or more is a hazard. Measure a tree's diameter 4 inches from the ground.[xlii]

It is difficult to avoid hitting trees when the spacing between trees is less than 15 feet.[xliii] Treat trees with spacing less than 15 feet as a group of trees.

Typically, removing trees is the most desirable roadside design treatment.

Projects removing trees may need to include grubbing items to make sure that stumps are removed. Stumps not properly cut can be hazardous because they are taller than a 4-inch hazard on a 5 FT chord (see FDM 11-45-20.3.5).

Review FDM 11-45-30.2.5, FDM 11-45-30.2.18 and FDM 11-45-20.3.5.1 for more information about trees.

20.3.5.1.3 Tree Removal Warrant

On roads with AADTs as low as 125 the benefit cost ratio of tree removal is usually 4 or more.[xliv] Occasionally, removing trees can be justified when AADT is at 50 or lower. Removal depends on spacing of the trees, the diameter of the trees, and offset from the edge of lane to the trees.[xlv]

Typically, removing trees is less expensive than installing a barrier system. Removing trees is a more desirable roadside design treatment. Provide documentation when trees are remaining in-place.

Projects removing trees may need to include grubbing items to remove stumps.

Review FDM 11-45-30.2.5, FDM 11-45-30.2.6, FDM 11-45-30.2.18 and FDM 11-45-20.3.5.1 for more information about trees.

20.3.5.2 Mailboxes

Identify hazardous mailboxes during the RHA (see FDM 11-45-10.3 to determine when to perform an RHA).

FDM 11-15-1 provides guidance on how designers are to treat hazardous mailboxes. See CMM 3-15.5 for a handout on mailboxes. Mailboxes mounted on barrier systems are hazards. Identify hazardous mailboxes during the RHA.

20.3.5.3 Fences

Chain-link fences with a top rail are a hazard[xlvi]. Top rails can be pipe or steel channels. Top rails can penetrate into vehicle cab. Identify hazardous fences.

20.3.5.4 Barrier Systems

Barrier systems are hazards. Identify barrier systems during the scoping/preliminary design/SCP phase. See FDM 11-45-30.5 for more information on reviewing barrier systems.

[27] Statement is not to imply that trees will not be removed from these locations. Designers may need to be more selective on what trees are removed or may need more justification to remove trees (i.e. crash history).

20.3.5.5 Vertical Drops

Identify vertical drops early in the scoping or early design as hazards for vehicles.

Vertical drops of 8 feet or taller are hazardous (see Figure 20.38)[28].

Drops of 6 feet or more combined with other hazards (e.g. water with a normal depth of 2 feet or more, riprap, drainage ditch or channel slopes) are hazards.

Vertical drops with high consequence of collision (see Attachment 20.1)

Figure 20.38 Vertical drop and water hazards are hazards

Drops of lesser height may be hazards for other users (e.g. bike and pedestrians...).

20.3.5.6 Planters, Monuments, and Similar Objects

Identify planters, monuments, and similar objects as hazards early in scoping and design.

These objects may allow (the list is not all-inclusive):

- Structural failure
- Blunt end Crash
- Snagging a vehicle
- Excessive cab crush
- Rollovers
- Large deceleration forces

[28] Vehicles have a tendence to flip or rollover when they traverse vertical drops of 8 feet or more.

Figure 20.39 Planter is not a crashworthy design[29]

20.3.5.7 Additional Warrants

20.3.5.7.1 Median Barrier on New Freeway Construction Warrant

Attachment 20.8 is a warrant for installing a median barrier on new freeways. It may not be proper to use this warrant to install a barrier on an expressway. The influence of crossroads was not considered in developing this warrant (e.g. intersection spacing, sight distances…). On a case-by-case basis, evaluate the need for a median barrier on non-freeway projects.

Do not use Attachment 20.8 for deciding allowable median width.

20.3.5.7.2 Retrofit Cross-Median Crash Warrant

Review crashes for cross-median crash (CMC) events using the most current 5 years of crash data. A minimum of three crashes are needed to do the analysis.

1. Calculate the distance between the farthest crashes in miles
2. Divide the total number of crashes by distance in step 1
3. Divide the number in step 2 by the number of years between crashes

If the value from step 3 is greater than 0.48 CMC/mile/year, take corrective action.

See FDM 11-45-30.8 for more information on cross-median crashes.

20.3.5.7.3 Shielding Fixed Objects Warrant

Attachment 20.9 is a warrant for shielding a fixed object. Refer to FDM 11-45-20.3.1.1.2 of this procedure on how to use this warrant.

This warrant is not appropriate for considering the consequence of a collision. For overhead sign supports, sign bridges, monotube signs, and message boards follow the guidance in FDM 11-55-20.

Shield bridge piers and similar fixed objects when the road's posted speeds is 55 mph or greater and object is within the desirable clear zone distance.

This warrant does not address the need for structural protection. See FDM 11-35-1 for guidance on structural protection.

20.3.5.7.4 Low-Volume Road Warrant

Barrier systems may not be cost-effective for highways that have a current traffic volume under 400 AADT.[xlvii]

However, review installing a barrier system under the following conditions:

- Crash frequency warrants a barrier system
- Crash severity warrants a barrier system
- Consequence of a collision warrant a barrier system

[29] Planter has various other roadside design issues. Curb and gutter in front of the planter can cause a vehicle improperly engage the planter. Texture of planter may cause excessive decelerations or vehicle rollover. Blunt ends of planter may cause significant deceleration.

All other warrants presented in this section will override this warrant.

20.3.5.7.5 Strike Warrant

Review objects that have had three reportable crashes within a 5-year period. Desirably, remove the object.

20.4 Additional Areas of Concern

One of the functions of the RHA is to identify Areas of Concern. Areas of Concern are locations where: run off the road crashes are more likely to occur, crash severity is high, or the consequence of a collision is severe. See Attachment 20.1 for more discussion. Identify Areas of Concern during the scoping/preliminary design/SCP phase of a project.

The list of areas of concern in this subsection is not all-inclusive.

It may not be possible to address an Area of Concern with a project as it may not be reasonable to shield it. However, it may be possible to lessen the overall risk. Examples are (the list is not all-inclusive):

- Move bus stop out of a curve
- Remove hazards that are likely to be hit
- Provide signing
- Remove visual obstructions

20.4.1 Pedestrians

Areas of concern for pedestrians are:

- Locations where pedestrians would have no escape route or little time to react to a vehicle (See Figure 20.17 and Figure 20.40).
- Locations where there is often a high concentration of pedestrians (See Figure 20.41).[30]
- Locations where a vehicle would not normally expect to see a pedestrian (e.g. a hill or horizontal curve “hides” a pedestrian trail crossing on a rural road.).

Figure 20.40 Pedestrians have no Escape Route and Little Time to React to Vehicle

[30] The presence of a sidewalk does not indicate that there is a high pedestrian concentration.

Figure 20.41 University Avenue on UW-Madison Campus during Exchange of Classes

Other areas that could have frequent high pedestrian concentrations are (the list is not all-inclusive):

- Memorials
- Parks
- Scenic outlooks
- Trail crossings
- Athletic fields
- Playgrounds
- Transit shelters
- Schools
- Senior centers
- Medical facilities

The presence of these facilities does not automatically indicate there is a high pedestrian concentration. For example, a road may run along a school property but the road maybe far from the main entrance.

Consider the abilities of the pedestrians using the facility. For example, children in a playground may not be as focused or have the same ability to escape a vehicle as a group of college students waiting to cross a street.

20.4.2 Areas of Concern - Locations with High Run Off the Road Crashes

Areas of Concern for high run off the road crashes are:

- Areas with known high run off the road crash rates
  - Road segments with Metamanager run off the road flags
  - Other spot locations where crash reports show a run off the road problem
- Areas where research points to run off the road being more likely to occur

Review Attachment 20.1.

20.4.2.1 Curves

Research shows that curves are more likely to have run off the road crashes. In one study, 70% of fatal crashes occurred on or near the outside of horizontal curves.[xlviii] Other studies also show that vehicles are more likely to leave the road on curves. Curves that are likely to experience run off the road crashes are:

- An entrance curve that leads into a series of curves[xlix]
- A curve that is significantly sharper than other curves in the series (e.g. second curve in series is sharper than curves one, three or four)[l]
- Compound curves that have a ratio of 1.5 or more between radii[li, 31]

[31] This type of curve can be especially problematic for semi-trucks if they have to decelerate (i.e. loop ramps) and the first radius the truck encounters is the larger radius.

- Curves with advisory speed significantly lower than the approaching tangent roads' posted speed
- Sharp curves within or at the bottom of a steep grade

20.4.2.2 Other Locations

Other areas that are likely to experience run off the road crashes are (the list is not all-inclusive):

- Top of the "T" of a T intersection
- Areas alongside or downstream of a merge/diverge area
- A road segment where there is weaving
- Upstream of taper, taper and gore area of an off-ramp
- Gore area, taper and downstream of taper of an on-ramp
- Upstream and near a major fork
- Upstream and downstream of a bridge
- Areas with inadequate sight distance.

20.4.2.3 Areas of Concern-Locations that Violate Driver Expectation

Locations that violate a driver's expectations are likely to experience run off the road. Potential locations are (the list is not all-inclusive):

- Left hand off or on-ramps
- Sharp curves hidden by profile changes

Figure 20.42 and Figure 20.43 shows a road where driver expectation is violated. In Figure 20.42, a driver expects the road to go straight. However, Figure 20.43 shows the "straight" road is a side road and not the mainline.

Figure 20.42 Drivers Expect the Road to go straight

Figure 20.43 Main Road does not go Straight

20.4.2.4 Areas of Concern-Locations with High Consequence of a Collision

Review discussion in Attachment 20.1 on Consequence of Collision. The following are Areas of Concern for vehicles and other users of the road network (the list is not all-inclusive):

- See Vertical Drop section of this procedure
- Overhead sign, sign bridge, or other similar structure
- Message board

Other areas with high consequence of collision for the whole community are (the list is not all-inclusive):

- Power plants/substations
- Chemical plants/storage areas
- Natural gas/petroleum facilities

20.5 Area of Analysis

Identify all hazards and Areas of Concern within the area of analysis. Measure the width of the area of analysis like clear zone. It is measured from the edge of lane of travel toward the right-of-way. Measure the area of analysis differently when the edge of lane is not defined, or other lanes act as through lanes. Measure from the outside edge of lane or the flag of curb. Some examples when to measure from outside edge of lane or flag of curb are:

- Long auxiliary lane
- Unmarked parking
- Unmarked bike lane
- Wide curb lane

The width of the analysis area is the smaller of the following values:

- Distance to existing right-of-way or permanent easement
- Clear zone based on FDM 11-15 Attachment 1.9 and curve corrections in FDM 11-15 Attachment 1.10
- Distance to buildings that are to remain in-place

If existing right-of-way is less than the desirable clear zone distance and the project is not buying right-of-way, use existing right-of-way to limit the area of analysis. If a property or portion of a property cannot be bought within the project that is buying right-of-way, use existing right-of-way at that specific location to limit the area of analysis. Document in Design Study Report when using existing right-of-way to limit analysis instead of when the clear zone dimension indicated.

Include significant hazards that are just beyond the area of analysis. For example, include a cliff that is 1 foot outside the area of analysis in the RHA.

Break the road into segments with similar geometrics (e.g. number of lanes, lane width, shoulder width…), AADT and speed when documenting hazards. Cutting up a project this way allows for a simple comparison of exposure and crash severity without complicated analysis.

Treat median divided road as either a two-way road (e.g. one road running north, one running south) or as one road (e.g. northbound and southbound roads together). When documenting the median of divided highways as two, two-way roads, indicate which road has the median hazards.

20.6 Roadside Hazard Analysis (RHA) Documentation

20.6.1 Scoping/Preliminary Design/SCP

Use Attachment 20.10 during scoping/preliminary design/SCP. Discovering items in Attachment 20.10 may change the scope of the project.

List hazards found during the scoping/preliminary design/SCP in the Design Study Report phase of the RHA.

20.6.2 Design Study Report Phase

Use the form in Attachment 20.11 to document hazards for Design Study Report phase. Attach the form to Design Study Report. For some more complicated situations, provide additional documentation. Discuss with the WisDOT project manager and the regional design oversight engineer.

See FDM 11-45-15.1.3 for preferred roadside hazard treatment sequence.

Provide justification when shielding, delineating or not acting on a hazard. Address why more preferred methods of treatment are not being used.

Use caution when using construction or right-of-way cost to justify a treatment or lack of treatment. Cost justifications are to review maintenance and crash cost. Use Attachment 20.1 to help decision-making.

20.6.3 Final Design

During the final design, review plans looking for the following issues (the list is not all-inclusive):

- Plan has enough detail to allow for proper installation of safety hardware
- New hazards are not being created without justification
- New areas of concern have not been created without justification
- Interaction of grading, safety hardware, drainage features, and other aspects of the design do not interfere with safety hardware or other features - see Figure 20.44 and Figure 20.45.

By using the RHA and properly installing safety hardware, few issues should be found during the final design process. However, given the complexity of plans and the number of people involved in putting plans together issues can appear.

Figure 20.44 Drainage and Safety Hardware Installation Not Coordinated

Figure 20.45 ITS and Safety Hardware Installation Not Coordinated

Designers should strive to eliminate the issues above. If it is not possible to eliminate the issues above, coordinate with the WisDOT project manager and the regional design oversight engineer. Provide an amendment to the Design Study Report. Address why these issues cannot be eliminated.

LIST OF ATTACHMENTS

Attachment 20.1	Roadside Design Factors to Consider
Attachment 20.2	AASHTO's Warrant for Shielding Foreslopes
Attachment 20.3	FHWA Warrants for Shielding Foreslopes
Attachment 20.4	Shielding Hazardous Cross-Drains
Attachment 20.5	Shielding Hazardous Water
Attachment 20.6	Roadway Segments with High Tree Crash Rates
Attachment 20.7	Shielding Hazardous Trees
Attachment 20.8	Median Barrier Warrant for New Freeways
Attachment 20.9	Shielding Hazardous Fixed Objects
Attachment 20.10	Scoping/Preliminary Roadside Hazard Design Review List
Attachment 20.11	Roadside Hazard Analysis Sheet Template
Attachment 20.12	Roadside Hazard Analysis Sheet Example

FDM 11-45-30 Roadside Barrier Design Guidance *May 18, 2020*

30.1

This section is intentionally left blank.

30.2

This section is intentionally left blank.

30.3 Barrier System Design

Improperly designed barriers systems may not work when needed. If a barrier system cannot be designed correctly, additional engineering is needed. The following contains basic guidance for almost all barrier systems. Specialty applications of barriers need additional engineering.

30.3.1 General Design Criteria

30.3.1.1 Working Width

Working width is combining barrier’s width and either the maximum barrier deflection or the maximum distance a

crash test vehicle extended behind the barrier (see Figure 30.16, Figure 30.22, Figure 30.37). Lack of working width could cause a vehicle to strike the hazard.

Provide working width for barrier systems.

As working width decreases, the likelihood of injury or death increases. From a general performance perspective, use barrier systems that use all available working width before using barrier systems with less working width (i.e. cable barrier over semi-rigid barrier, semi-rigid barrier over rigid barrier).

Occasionally, only a small section of an overall barrier system may need a reduced working width. Typically installing a small section of the barrier with reduced working width is more desirable than installing a whole barrier system with reduced working width (See Attachment 30.12).

Use proper transition between barrier systems with significant differences in working width. Examples are (the list is not all-inclusive):

- Beam guard systems and concrete barrier (SDD 14B20, or SDD 14B45)
- Beam guard with normal post spacing and quarter post spacing (see Attachment 30.12)
- Beam guard with half post or quarter post spacing to:
    - Short Radius System (SDD 14B27)
    - EATs (SDD 14B24 or SDD 14B44)
    - Long-Span (SDD 14B25 or SDD 14B43)
    - Type 2 Terminals (SDD 14B16 or SDD 14B47)

Where working width is measured depends on the barrier. Attachment 30.13 has a table of working widths for various barriers. This table also indicates where to measure working width. Figures 30.13 to Figure 30.21 show working width and Zone of Intrusion for a single slope concrete barrier. Most of the working widths are for Test Level (TL) -3 crash tests using NCHRP 350 or MASH crash test criteria.

Provide individual construction details showing reduced working width in spot locations. Identify the beginning/end of reduced working width, fixed object that has reduced the working width and overall length of barrier needing reduce working width.

For bidirectional traffic, reduce the working width of a barrier system 25 feet before and after the hazard' and along the hazard. Bidirectional traffic has two approaches. For unidirectional traffic, reduce working width 25 feet before the hazard, along the hazard and 12.5 feet down stream of the hazard.

Guidance on the amount of reduced working width assumes that the barrier system is installed at the edge of shoulder. Barriers installed further away from the edge of shoulder use different guidance.

See Attachment 30.12 for some examples on how to install beam guard with reduced working width

Lack of enough working width can cause a barrier installation to increase in length. See FDM 11-45-30.3.1.4 and Attachment 30.12 for more discussion. Use special provisions to pay for non-MGS beam guard with reduced working width (e.g. half post spacing, quarter post spacing).

Some of the barrier systems listed in Attachment 30.13 are rarely utilized in Wisconsin. Those barriers need approval by the WisDOT project manager and the regional design oversight engineer before use. Coordinate with them. More engineering may be required. Engineering may include special details, individual construction details, special provisions, and other efforts.

30.3.1.1.1 Working Width and Larger Vehicle Crashes

Most barrier crashes are from pick-up trucks or smaller vehicles; however, larger vehicles do strike barriers. Design the barrier systems based on hits from pick-up trucks or smaller vehicles unless:

- Crash history points to frequent larger vehicle hits
- Consequence of a collision is severe (e.g. light pole or sign bridge drops across lanes of travel on a freeway)

National research, using nine years of crash data, shows that 3% of reported barrier crashes involve vehicles larger than a pickup truck, SUV or van.[lii] Spots with more than 3% heavy vehicle crashes into a barrier or fixed object within 9 years may be candidates for a barrier with a higher crash test level.

A barrier with a higher test level may be needed because of a combination of issues. Adverse geometrics, large truck volume and significant consequence of collision may combine making it reasonable to install TL-5 or TL-6 barrier. Examples are (the list is not all-inclusive):

- A road has a steep downgrade followed by a sharp curve near a port with heavy truck traffic. On the outside of the curve is a school.
- Tanker trucks can have difficulties keeping control when there is a large algebraic difference in cross slope (e.g. when a shoulder breaks in the opposite direction of superelevated lanes)[liii].

Locations that do not meet the 3% in nine-year criteria and there is a consequence of a collision, may use taller standard single slope barrier. A taller standard barrier will not withstand a critical hit by a vehicle larger than a pickup truck. Large vehicle crashes are rare. A taller standard barrier will provide some additional shielding for less than critical crashes from a larger vehicle.

Coordinate with the WisDOT project manager and the regional design oversight engineer before using higher test level barrier. Plan for additional engineering. Coordinate early in the design.

Working widths for larger vehicles are bigger than the working width for pickup trucks. Barriers that are designed for larger vehicles are typically more expensive than a normal barrier. The extra working width and barrier cost can have significant influence on a project's design and cost.

The guidance in this section does not apply to bridge substructures needing structural protection. See FDM 11-35-1 for guidance on structural protection for bridge substructures. **30.3.1.2 Length-of-Need**

The length of a barrier system needed to shield a hazard is called "length-of-need" or "LON". LON is dependent on:

- Location of hazard
- Size of the hazard
- Direction of traffic
- Design speed
- Design traffic volume
- Distance between edge of lane and barrier
- Distance between barrier and hazard
- Horizontal curve

Typically, LON provides enough distance for most cars and pickups to stop before striking the hazard. The distance between the Length-of-Need point of the barrier and hazard being shielded should free of other hazards.

Proper hazard identification is important. This is especially true by bridges or in other locations where there are secondary hazards.

Provide LON to shield the primary hazard. Review installations for secondary hazard. Review if secondary hazards can be removed or shielded (see Figure 30.1).

Document in a DJ barrier installations that are significantly longer or shorter than LON. Minor adjustments of a barrier's location to accommodate for hardware, grading, and other issues do not need documentation.

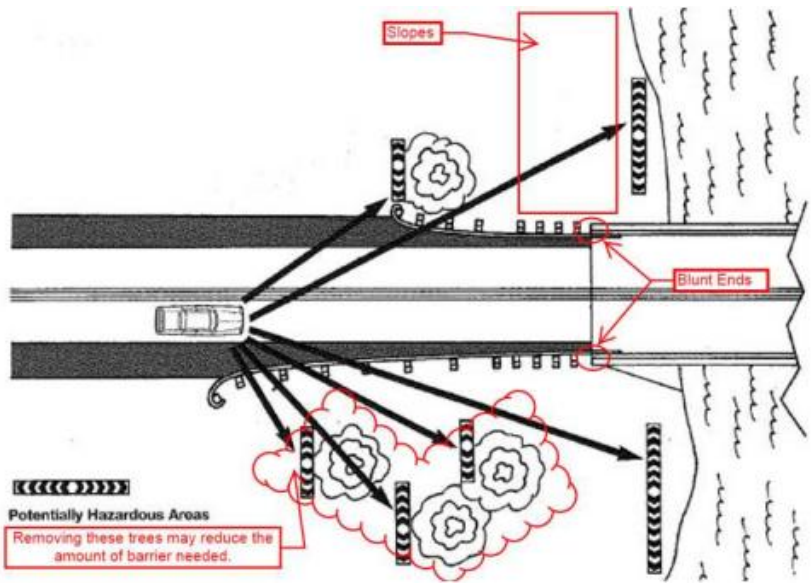

Figure 30.1 Hazard Identification[liv]

Calculate length-of-need using runout length values from Table 30.2 and Equation 1 (see below).[lv] Equation 1 uses the parallel method from the Roadside Design Guide. The Roadside Design Guide has an equation that allows a barrier system to be flared away from the edge of lane. Flaring a barrier system (which includes the beam guard plus the end treatment) reduces its overall length and will make it harder to hit the end terminal. Barrier systems that are flared will need more grading and may need additional right-of-way. See FDM 11-45-30.3.1.5 and Roadside Design Guide for more information on flaring barriers.

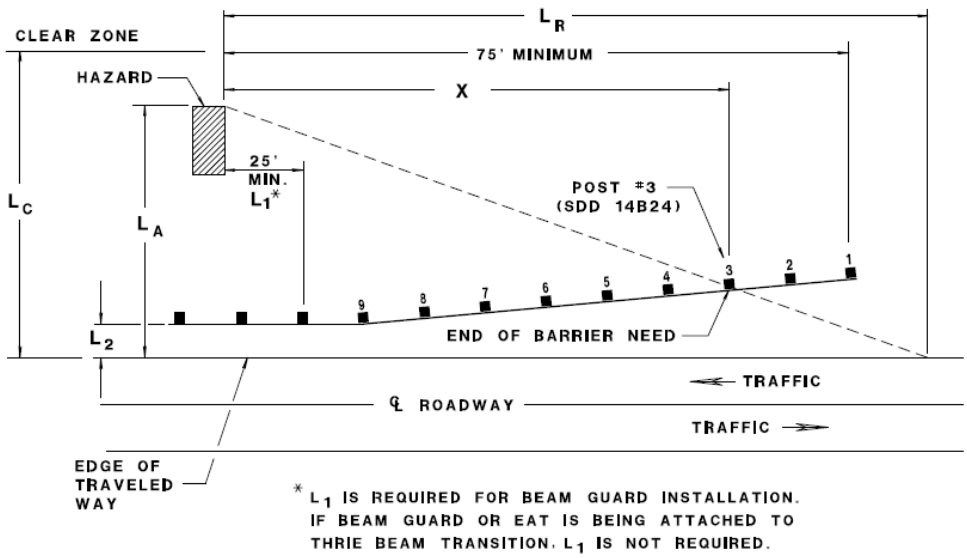

Figure 30.2 Near side Length of Need Calculations

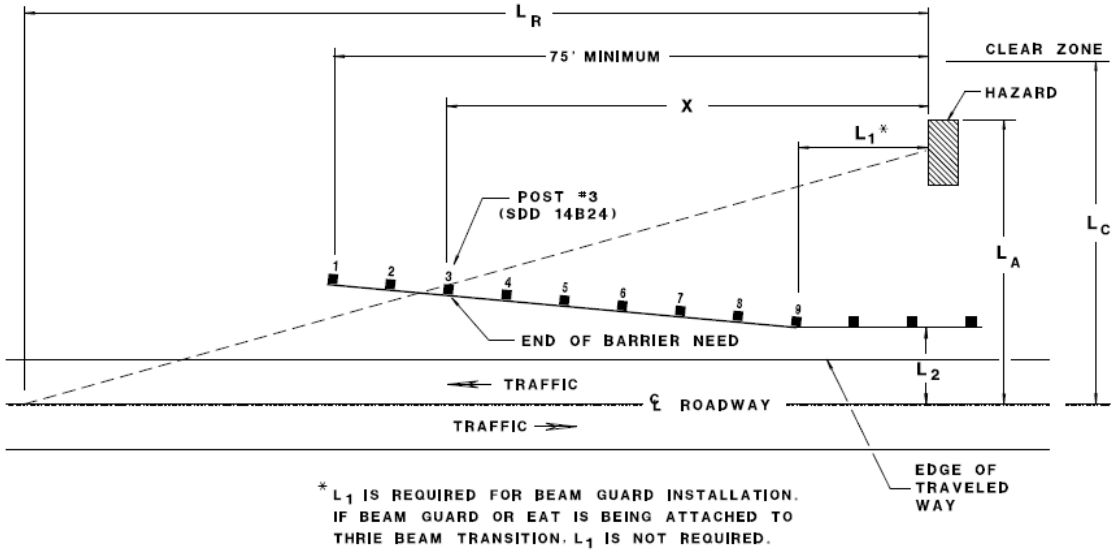

Figure 30.3 Far side Length of Need Calculation

Using the LON equation, calculate the minimum distance from hazard to “end of barrier need (see Figure 30.2 and Figure 30.3). Depending on the barrier system and end treatment used, the “end of barrier need” location may vary. Discussion on where the “end of barrier need” is located is in other parts of the FDM 11-45-30.

Table 30.2 Runout Lengths for Barrier Design (LR)[32]

Design Speed mph	AADT			
	10,000 or more	**5,000 to 9,999**	**1,000 to 4,999**	**Less than 1,000**
80	470 FT	430 FT	380 FT	330 FT
75	415 FT	380 FT	335 FT	290 FT
70	360 FT	330 FT	290 FT	250 FT
65	330 FT	290 FT	250 FT	225 FT
60	300 FT	250 FT	210 FT	200 FT
55	265 FT	220 FT	185 FT	175 FT
50	230 FT	190 FT	160 FT	150 FT
45	195 FT	160 FT	135 FT	125 FT
40	160 FT	130 FT	110 FT	100 FT
35	135 FT	110 FT	95 FT	85 FT
30	110 FT	90 FT	80 FT	70 FT

Equation 1

$$X=\frac{(L_A-L_2)}{L_A/L_R}$$

L_2 = Distance from edge of lane to barrier

L_A = Distance from edge of lane to back of hazard

L_c = Distance from edge of lane to clear zone

L_R= Runout length per Table 30.2

X= LON = Minimum distance from hazard to the end of barrier need.

Use L_A equal to L_C if there is no definable back of hazard or if there are multiple hazards within a given area. Examples could be (the list is not all-inclusive):

- Water hazard
- A stand of trees
- Non-traversable slopes
- Non-recoverable slopes without runout distances

Secondary hazards by a bridge may increase the amount of barrier needed. At bridges, use clear zone in the length-of-need calculation (L_A= L_C) to protect water, road below, or steep slopes that wrap around the structure. The stationing of these secondary hazards may need to be used to calculate where a barrier is to begin.

When shielding a bridge pier or abutment, review if the slope that wraps around the structure is a hazard for the roadway on the bridge and the roadway below the bridge.

In high-speed narrow medians, setting L_a equal to the offset to the opposing structures median parapet may be reasonable. See Figure 5-45 of the 2011 AASTHO Roadside Design Guide for an example. Review if a thrie beam bullnose or crash cushion with concrete barrier is possible at this location before using a wider L_a. Document in a DJ the decision to use the distance between median parapets for L_a.

Verify location of a steep slope when calculating length-of-need. The transition between a traversable slope and a non-traversable slope may move during construction. Adding length to a barrier system to allow for proper shielding is acceptable. For example, a steep slope is at STA 10+00. A traversable slope is at STA 11+00. It is acceptable to assume that the steep slope starts at station 10+50. Extending the barrier may make it easier to install the grading for the end treatment.

Figure 5-47 in the 2011 AASTHO Roadside Design Guide provides an example on how to shield a hazardous slope. This example discusses the selection of appropriate L_a and L_c values, and the use of a buried-in-backslope terminal. For steep slopes within the clear zone, use clear zone value in the length-of-need calculation (L_a= L_c). The department does not use buried-in-backslope terminals.

Note the example in the Roadside Design Guide is shielding a 3:1 slope. A 3:1 slope may not need shielding (see FDM 11-15-1).

On multi-lane, one-way facilities assume that traffic is in the travel lane closest to the hazards when calculating length-of-need. Do not include the width of the travel lane or lanes in L_a, L_2, or L_c in the length-of-need calculations.

Travel lanes do not include turn lanes or taper to turn lanes in length-of-need calculations. Auxiliary lanes are typically not considered travel lanes for length-of-need calculations unless the auxiliary lanes perform more like

[32] Table is based on 2011 Roadside Design Guide and linear interpolations.

through lanes. Auxiliary lanes need to extend some distance to act as a through lane.

Review if there are short gaps between different barrier systems. Close gaps of 400 feet or less.

30.3.1.2 LON on Curves

Length-of-need equation is for tangent sections of road. On the outside of curves, vehicles tend to take a tangential path. Determine LON on the outside of curves by:

1. utilizing the design speed and AADT, find L_R.
2. drawing a line that starts tangent from the edge of lane to the back of hazard or edge of the clear zone.
3. measuring line drawn in step 2.
4. using the smaller of either L_R or the length of the line determined in steps 2 and 3

On the inside of curves, use L_R to locate the LON point for the barrier system. See Attachment 30.4.

For more examples of LON, see the following attachments:

- Attachment 30.1: Example Problem 1: West Side of Structure
- Attachment 30.2: Example Problem 2: Rock Wall
- Attachment 30.3: Example Problem 3: Outside of Curve Cattle Pass
- Attachment 30.4: Example Problem 4: Inside of Curve Cattle Pass

30.3.1.3 Individual Construction Detail Drawings

Individual construction details are site specific and used to minimize construction issues, communicate designer's intent, and to make it more likely that a barrier system will be installed appropriately. Provide individual construction details when there is a close interaction between grading, drainage, barrier system, hazards, underground obstructions, structures, or changes in working width.

Some examples are (the list is not all-inclusive):

- Figure 30.36 has a pole too close to the barrier system
- Figure 30.12 has a post driven through a culvert
- Figure 30.41 the thrie beam missing a post
- Figure 30.42 lacks proper grading near thrie beam transition. Flume does not capture water. There is slope erosion near structures.
- Figure 30.43 Within a year of construction the grading by the thrie beam transition is starting to fail because of water and improper grading.
- Figure 30.4 Drainage conflict with thrie beam transition

Figure 30.4 Inlet and Post Conflict

Some examples of when to provide individual construction details are (the list is not all-inclusive):

- End treatments
    - EAT
    - Crash cushion
    - Sand barrel array
- Beam guard
    - Long-spans
    - Short radius
    - Flared or tapered applications
    - Anchor Post Assemblies
- Thrie beam bullnoses
- Approach transitions to rigid barriers

Some locations are more likely to need individual construction details (the list is not all-inclusive):

- Areas with limited post embedment or post rotation is limited
    - Shallow fill box culverts (less than 5 FT of cover)
    - Large culverts that cross under semi-rigid barriers
    - Inlets or flumes near posts
    - Utilities near posts
    - Near footings
- Areas near structures
    - Bridge approaches
    - Bridge (e.g. piers, abutments, footings)
    - Slopes that wrap around structures
    - Barriers on top of retaining walls
    - Barriers shielding retaining walls
- Areas with reduced working width

Post location may also influence retaining wall design. For example, the reinforcement straps for an MSE wall

may conflict with post placement. Typically, retaining wall designs cannot absorb crash loads without damage. Consult a structural engineer when placing a barrier system on or nearby a retaining wall. More discussion is in FDM 11-45-30.3.6.4.

A example of individual construction details are in Attachment 30.5.

Include the following in individual construction detail drawings (the list is not all-inclusive):

- Drainage pipes
- Cross-section/contours
- Hinge points
- Slope intercepts
- Structures (e.g. bridges, box culverts, retaining wall)
- Underground obstructions (e.g. utilities, rock)
- Post location and embedment,
- Curb and gutter changes,
- Radius of shop bent beam guard
- Fixed object or hazard
- Changes in curb and gutter
- Changes in working width

Use cross sections or more detailed earthwork analysis for complicated grading locations (e.g. wrapping slopes around a structure that has a transition to rigid barrier installed nearby). Perpetuation projects may need additional survey within the areas of replacement barrier system.

If a barrier system is within the grading limits of a contract, incorporate the grading for the barrier system into the standard bid items. If the barrier system is not within the grading limits of a contract, use grading and shaping standard bid item for the barrier system's earthwork.

When using the grading and shaping bid item use a table like Table 30.3. Add a note to miscellaneous quantities that points out that other items in the table are for bidding purposes only. Avoid adding other items into the grading and shaping bid item. Typically, other items (e.g. installing a pipe, other erosion control measures…) need more design.

Table 30.3 Barrier System Grading, Shaping, and Finishing

Location	Excavation Common*	* Borrow	* Salv. Topsoil	* Fert. Type (-)	* Seeding	* Mulching	Each
	C.Y.	C.Y.	S.Y.	CWT.	L.B.	S.Y.	
Sta.__ to Sta.__							
Totals							

** = Items & Quantities listed for Bid Information Only. Show the quantities and units clearly in the table.*

Provide termini for each location using grading item. Use discrete locations to identify where grading and shaping bid item is being used. For example, a given EAT may need the grading and shaping item, then stationing for the EAT is acceptable. In other locations a whole barrier system (EAT, beam guard, transition to rigid barrier) may need grading; the stationing for the whole barrier system can be used. Grading and shaping bid item can be used on all barrier systems.

30.3.1.4 Length of Barrier System

Do not use the guidance in this section to install barrier systems that are shorter than is required by Length-of-Need calculations or other reasons. This guidance is to point out:

- When short installations of barrier system needs documentation
- Lengths of barrier systems that should be avoided

A barrier system needs a minimum length to absorb crash loads, or to shield a hazard. Minimum length of a barrier system can depend on:

- Crash testing

- Traffic direction
- Expert opinion
- Computer modeling
- How other components of the barrier system work together

Potential issues with installing a barrier system that is too short are (the list is not all-inclusive):

- Barrier failure
- Pocketing
- Pulling foundation/soil tubes out of the ground
- Vehicles gating through terminal and hitting hazard
- Increased working width

Attachment 30.12 and Attachment 30.14 have some examples of how components of a barrier system or traffic direction can influence the minimum length.

Attachment 30.15 has "Recommended Minimum Barrier Lengths.". Barriers shorter than the "Recommended Minimum Barrier Lengths" may not work as expected.

Concrete barrier and cable barrier shorter than "Recommended Minimum Barrier Lengths" may be acceptable,.

EATs and Type 2 Terminals set the minimum length of beam guard (see comment section of Attachment 30.15). Avoid installing beam guard shorter than the comment section in Attachment 30.15.

Specialty barriers have different length requirements that are not in Attachment 30.15. Some specialty barriers are (the list is not all-inclusive):

- Concrete barrier transitions
- Concrete barrier integral to bridge piers
- Long-span beam guard
- Thrie beam bullnose
- Transitions to rigid barrier

Review other sections or SDDs for more information.

Additional engineering may be required. The additional engineering could include special details, individual construction details, special provisions, documentation and other efforts.

30.3.1.5 Flaring Barrier Systems

Some barrier systems can have their position relative to the edge of lane change. Typically, the department does not install flared barriers (See FDM 11-45-30.4.1.7 for discussion on flaring EATs). In some circumstances, flaring a barrier system is done because the barrier system must (the list is not all-inclusive):

- match into and existing narrow bridge
- change offset to provide working width
- change offset to provide grading
- change offset to match changes in road's cross-section
- have a shorter overall installation length

Most special applications of barriers, end treatments, or cable barrier cannot be flared. Examples are (the list is not all-inclusive):

- Long-Span beam guard
- Approach Transitions to rigid barriers or bridge parapet
- Type 2 End Treatments
- Short Radius
- Short Radius Terminal

A flared barrier system needs to absorb more crash energy than a normal barrier system. The flaring of a barrier causes the crash angle to be higher. As shown in Attachment 30.13, for the same crash test condition, flared MGS needs a larger working width than tangent MGS.

More engineering effort is required to install a flared barrier system correctly.

Avoid having sharp angles or abrupt changes in barrier system (see Figure 30.56). A vehicle can experience significant deceleration, snag, vaulting, rollover, or be abruptly redirected into traffic if it hits a sharp angle or abrupt change.

Most projects place the face of a barrier system at the edge of shoulder. Shifting a barrier system towards the lane may be possible at some locations. Typically, shifting a barrier's location is done over a short segment of

road, for a specific hazard. Decreasing the shoulder width may need a DJ.

A small section of the barrier system closer to the lanes may develop into a choke point for incident management or future construction. Use caution when reducing shoulder width over a long segment because the barrier system may cause operational issues. Possible examples are (the list is not all-inclusive):

- More crashes into the barrier system
- A plow is more likely to hit the barrier system
- Less shoulder room for disabled vehicles
- Less shoulder room for maintenance operations
- Less room for future construction

Attachment 30.20 has some example layouts of shifting beam guard location closer to the lane. The AASHTO Roadside Design Guide has examples flaring barrier systems away from the lane. Review guidance in FDM 11-45-30.

The department does not install flared cable barrier systems. There has been no research on how flaring a cable barrier will work during a crash.

Provide individual construction detail drawings when shifting barrier location.

30.3.1.5.1 Grading for Flared Installations

Grading from the edge of lane to the face of most barrier systems is 10:1 or flatter (see 11-45-30.3.2.5.7 for cable barrier grading guidance). Grading behind the barrier system follows other requirements listed in the FDM. A flared barrier system without suitable grading may not perform as intended. Some examples of poor barrier performance are (the list is not all-inclusive):

- Vehicle rolls over before striking the barrier
- Vehicle vaults over the barrier
- Barrier moves too much during crash

Grading requirements for end treatments, crash cushions, or sand barrel arrays do not change if these systems are outside the clear zone.

30.3.1.5.2 Flare Rate

According to AASHTO's Roadside Design Guide, the usable flare rates for barrier systems depends on speed, barrier system offset, and barrier system type. Barrier systems that are closer to a lane may cause the vehicle to slow or shift positions with in the lane. Barriers that are closer to a lane use flatter flare rates to mitigate changes in vehicle speed and position.

Use flare rates in Table 30.4 for Concrete Barriers, Class A Beam Guard, and other non-MGS semi-rigid barriers. Flare rates that are flatter than the values in Table 30.4 are acceptable.

Table 30.4 Shy-line and Flare Rates for Different Barriers

Design Speed	Shy Line Offset	Within Shy-line	Outside of Shy-Line	
MPH	**FT from edge of Lane**	**Semi-Rigid and Rigid**	**Max. for Rigid**	**Max. for Semi-Rigid**
80	12	No information available		
75	10			
70	9	30:1	20:1	15:1
60	8	26:1	18:1	14:1
55	7	24:1	16:1	12:1
50	6.5	21:1	14:1	11:1
45	6	18:1	12:1	10:1
40	5	16:1	10:1	8:1
30	4	13:1	8:1	7:1

Shy-Line offset or distance from the edge of travel lane is typical, but not required design criteria for barrier system placement. Some early research indicated that traffic might shift location and slow down if a barrier system started abruptly close to the road. If choosing between providing shy-line offset or working width, provide working width.

Avoid using flare rates steeper than the outside shy-line maximum values in Table 30.4.

30.3.1.5.3 Flare Rate for MGS

Normal post spacing of MGS was crash tested using flare rates steeper than the values in Table 30.4. The flare rates for MGS and working widths for TL-3 applications of MGS are in Attachment 30.13. Flatter flare rates are acceptable with MGS. MGS may use the shy-line offsets from Table 30.4.

These flare test were done using NCHRP 350 testing criteria and have not been tested to MASH criteria. The small car had significant damage after striking MGS with a 5:1 flare. It is recommended that designers limit using MGS with 5:1 flare rate.

30.3.2 Cable Barrier

In recent years, WisDOT has been installing cable barrier on freeways and expressways to limit cross-median crashes (CMC). Most existing roadside installations of cable barrier are strong post installations that are not crashworthy. See Figure 30.33 for an example of a low-tension cable barrier system.

The department is not installing cable barrier on the outside of roads. More information on cable barrier's performance and proper installation is required before the department would use cable barrier on the outside of a road. Coordinate with the WisDOT project manager and the regional design oversight engineer if considering installing cable barrier on the outside of a road.

Use the following when installing proprietary cable barrier system:

- SDD 14B52
- Standardized Special Provision Spec 613-010
- Bid items:
    - 613.1100.S (Cable Barrier Type 1)
    - 613.1200.S (Cable Barrier End Terminal Type 1)

Approved Product List

The proprietary nature of the cable barrier systems makes designing cable barrier different from other barriers systems. The Department depends more on the manufacturer's knowledge of their system. Some of the guidance that is in the FDM, Standard Detail Drawings or the Standardized Special Provision will overrule manufacturer's recommendations. Examples are (the list is not all-inclusive):

- Manufacturers have tested cable barriers with large line post spacing, but the Department limits the

maximum post spacing to 15 FT.

- Some manufacturers have provided connection hardware that is weaker than the cable. Using a weaker connection can allow barrier failure.
- Some manufacturers have crash tested cable barriers on steeper slopes than the design guidance. Research that is more recent suggests that it may be more difficult for a vehicle to engage a cable barrier on steep slopes.

The cable barrier market is competitive. Contact the manufacturer for the most current information on their system. Designers should verify with the WisDOT project manager and the regional design oversight engineer before using the manufacturer's recommendations.

30.3.2.1 Cable Barrier Selection

WisDOT's policy is to have at least two different cable barrier manufacturers in each county. Two systems are used so that there is competitive bidding. See Approved Products List for what systems are available in each county. If a county has no system listed, contact the WisDOT project manager and the regional design oversight engineer . The regional design oversight engineer will provide you with guidance on what systems to use. Contact them early in the design process. They will review existing information on cable barriers and update the approved products list.

If a county no longer wishes to use one of the cable barrier systems approved, provide documentation to the WisDOT project manager and the regional design oversight engineer stating the reasons a specific cable barrier system is no longer desired.

Design cable barrier installations using the "worst" features of either cable barrier system. Examples are (the list is not all-inclusive):

- "Cable Barrier System A" has a 25% greater working width than "Cable Barrier System B". Use "Cable Barrier System A's" working width to layout cable barrier.
- "Cable Barrier System B's" length-of-need point is further downstream than "Cable Barrier System A's "length-of-need point. Use "Cable Barrier System B's" length-of-need point to layout cable barrier.

By designing for the "worst" feature of either cable barrier system, both manufacturers can bid the project.

30.3.2.2 Components of a Cable Barrier System

There are three major components of a cable barrier system: the line posts, steel cable, and the cable barrier terminal.

Line posts consist of the following parts: reinforced concrete foundation, steel sleeve, steel post, and connection hardware. The reinforced concrete foundation and steel sleeve allow for quick removal and replacement of damaged posts. Steel posts hold the cables at the proper height to capture the vehicle and absorb some crash energy by breaking or yielding when hit. Connection hardware holds the cables at the proper height to allow for proper contact and interlocking of the cable into the vehicle.

Cables and cable splice hardware transfers most of the crash's energy to the cable barrier end terminals.

Cable barrier end terminals transfer the crash energy to the ground. Cable barrier end terminals are crashworthy and have more design requirements (see FDM 11-45-30.3.2.5.1, and FDM 11-45-30.3.2.5.2).

30.3.2.3 Use of Mow Strips with Cable Barrier

Install cable barrier without mow strips. Other methods of weed control are more cost-effective. If line posts are properly located and designed for the soil conditions present, there is little need for mow strips. Mow strips will increase a project's cost, make installation of the cable barrier more difficult, increase long-term maintenance, or create difficulties for future projects.

30.3.2.4 Cable Barrier to Beam Guard Connections

Avoid connecting a cable barrier to EAT or beam guard. Coordinate with the WisDOT project manager and the regional design oversight engineer when connecting cable barrier to EAT or beam guard. More engineering and special provisions may be needed.

Manufacturers have various designs to connect cable barrier to a EAT or beam guard. These connections have FHWA eligibility letters. Many of these connections are not crash tested. Manufacturers are basing their designs from a generic low-tension cable barrier crash test.

Although the generic low-tension system passed crash testing, there are some concerns about the stability of the vehicle. Adding more tension to the cable barrier would likely increase vehicle instability.

Other states have noticed that cable barrier connected to EAT or beam guard have caused damage to the EAT, or the beam guard. These states also have had difficulties repairing these connections, EATs, or the beam guard. Maintenance staff would need to stockpile more parts and have additional training to maintain these special cable connections.

30.3.2.5 Design Requirements

30.3.2.5.1 LON Point for Cable Barrier End Terminals

Like EATs, vehicles can pass through the beginning of the cable barrier end terminal with little or no decrease in speed. Contact the manufacturers for the most current information on the LON point for their cable barrier end terminals.

Use LON procedures in FDM 11-45-30.3.1.2 when shielding a fixed object (see Attachment 30.16) with cable barrier. Desirably, where CMC is an issue, cable barrier terminals would overlap the LON of other barrier systems. Attachment 30.16, Attachment 30.17, Attachment 30.18 have some examples of overlapping LON. Next choice would be to extend cable barrier to a point beyond where CMC are likely to occur.

30.3.2.5.2 Shielding Cable Barrier End Terminals

Cable barrier end terminals are crashworthy. However, it is desirable to shield cable barrier end terminals with other barrier systems. Crashes to a cable barrier end terminal can make a whole installation of cable barrier inoperative and cause expensive repairs. For example, a vehicle can bend the connection plate on the footing. To fix the connection plate, the whole footing would need to be removed and replaced.

30.3.2.5.3 Factors that Influence Working Width of Cable Barrier

Each cable barrier system has a different working width.

Manufacturers will provide working width information based on crash testing. As the distance between cable barrier end terminals increases, working width will increase. A typical road application of cable barrier is longer than most test installations. It is likely that real-world cable barrier working width is larger than what the manufacturers report. To find out if cable barrier is an alternative for a location, assume a working width of 12 feet.

There is a direct relationship between line post spacing and working width. The larger the distance between lines posts the larger the working width.

The maximum line post spacing WisDOT uses is 15 feet[33]. Do not use larger line post spacing because of concerns with:

- Increased working width
- Difficulties keeping cable heights relative to the road's profile
- Increased likelihood of penetration of the cable barrier.

Most cable barrier manufacturers use 15 feet for their normal line post spacing. Some manufacturers use normal line post spacing as low as 10 feet.

Use reduced line post spacing to reduce working widths at spot locations (e.g. a long run of normally spaced cable barrier needs reduced post spacing near a sign bridge). See FDM 11-45-30.3.2.5.1 on how to design for reduced line post spacing by a fixed object.

Some current crash tests with reduced line post spacing have shown significant damage to crash test vehicles (e.g. A-pillar of the vehicle partially cut through, windshield cut through, holes in floorboard.). Avoid reducing line post spacing to less than 7 feet.

Crashes on the convex side of a curved cable barrier installation can cause a temporary loss of cable tension. This loss of tension will create a larger working width (See Figure 30.5). Provide more room to allow the increased working width on curves when placing the cable barrier on the convex side of the median (See Attachment 30.17).

Avoid installing cable barrier on curves with a radius of 1,300 feet or less when a vehicle can hit the convex side of the cable barrier[lvi]. Review using another barrier system. The WisDOT project manager and the regional design oversight engineer may grant DJ's for cable barrier installed on a radius of 1,300 feet or less and the convex side of the cable can be struck.

For curve installations that cannot have a convex crash, the minimum radius to install cable barrier is 500 FT or the minimum radius the manufacturer allows. Radii less than 500 FT or less than the manufacturer's recommendation should use a different barrier system.

[33] State Guidelines for Cable Barriers"; FHWA; April 2016

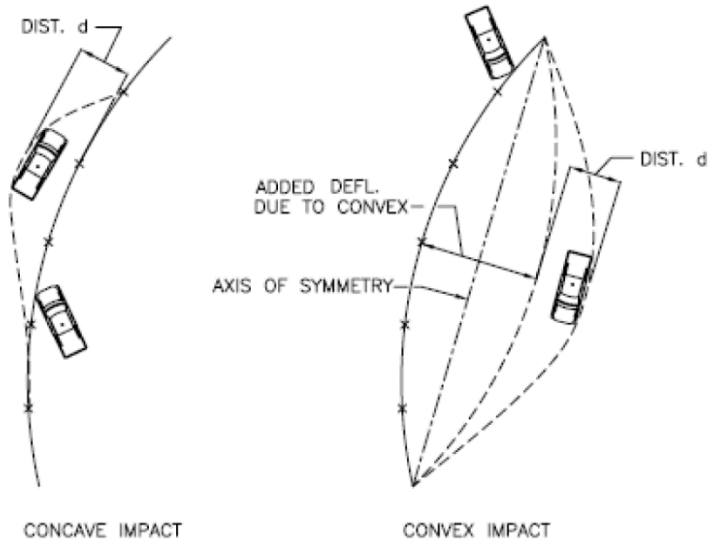

Figure 30.5 Concave verses Convex Crashes on Cable Barrier[lvii]

30.3.2.5.3.1 Designing Working-Width of Cable Barrier

Typically for median applications, the cable barrier's working width would not use more than 1/2 of the total shoulder width. For example, if a vehicle from the far side of the median hits the barrier. This vehicle should not pass beyond the 1/2 point of the median shoulder.

Provide working width for large fixed objects (e.g. piers, overhead sign supports, sign bridges, drainage features). Sometimes, the designer may need to use other barrier systems with reduced working width or more than one installation of cable barrier to shield large fixed objects. Attachment 30.16 has some examples. Review the need for structural protection in FDM 11-35-1.

Provide the following in the plan:

- Where working width is measured to:
    - Examples are:
        - cable barrier to the middle of the shoulder
        - cable barrier to the edge of lane
        - cable barrier to large fixed object
- Value or values of the cable barrier's working width
- Location or locations where the working width is different (e.g. reduced post spacing is used near a sign bridge, but the rest of the barrier system will have a larger working width).

Provide individual construction details for location changes in working width.

Install small breakaway devices outside the working width of the cable barrier. Small breakaway signs may have restrictions on where signs can be placed. Review signs with region's traffic staff. Determine if there are unnecessary signs or if signs can be moved outside the working width of the cable barrier.

30.3.2.5.4 Soils Information

Cable barrier is more sensitive to soil conditions than other barrier systems. Provide soils information on all projects with cable barrier installations. Manufacturers design their foundations with the soils information in the plan and how their system transfers energy. Not providing soil information could cause cable barrier to malfunction or the cable barrier could become a hazard. Projects that do not provide soils information can experience significant delay and cost increases.

Include soil boring information in plan sheet(s) for each cable barrier end terminal. Sometimes, nearby cable end terminals may be able to use one soil boring. For example, each side of a maintenance crossover needs a cable barrier end terminal; one soil boring may provide enough information to design the cable barrier.

Place boring near end terminal locations.

Information from a manufacturer indicates that soil boring should be a minimum of 15 feet deep in good soils. If the soils are soft, the boring need to be a minimum of 20 feet deep. Individual manufacturers vary on what information the soils information is needed. Some of the information that could be required are:

- Water table (if present)

- Soil type and general description
- The following tests should be conducted at standard intervals:
  - Dynamic Cone Penetrometer
  - Standard Penetration Test
  - Shear Vane

Discuss with regional soils engineer what soil testing needs to be conducted.

If a regional soils engineer decides an alternative source of information is acceptable, make this information available to the contractor. For example, soil boring for a nearby bridge is representative of conditions near cable barrier terminal. Show in the plan that other sources of information are available. Point out whom to contact for soil information. Place contact information on the cable barriers individual construction detail drawings.

30.3.2.5.5 Cable Barrier and Curb

Avoid installing curb and gutter by a cable barrier. Curb and gutter will change the vehicle's trajectory or could trip vehicle into the cable barrier.

If a cable barrier must have adjacent curb, use the following curb styles (in order of most desirable to least desirable):

1. Driveway curb
3. 4-inch sloped curb

30.3.2.5.6 Median Width for Installation of Cable Barrier

Use cable barrier in medians that are 48 feet or wider[34]. A design justification is needed for median widths between 40 feet and 48 feet. Working width issues and cable barrier placement relative to ditch may make it difficult to install a cable barrier in medians that are 48 feet or narrower. There may also be concerns of having maintenance staff working in narrow medians (e.g. Does a lane need to be shut down? Are the hours of work restricted?).

There may be working width problems with using one cable run in a median. For example, for nearside hits a cable barrier needs to be placed close to the lane of travel to avoid a working width issue with a sign bridge. The working width for an opposite side hit on the same cable barrier is in the lane of travel. The designer may need to install cable barriers on both median edges of shoulder to avoid the working width problem at this location. Another option would be to install two different barrier systems.

Cable barrier is not typically installed in medians that are 70 feet or wider unless one of the following conditions are present:

- There is known cross-median crash (CMC) history (see FDM 11-45-20.3.5.7.3).
- Department's CMC Hotspot Analysis shows there is a cross-median crash issue at a location.
- Analysis has shown that cross-median crashes are likely to occur (See FDM 11-45-30.8.1)

30.3.2.5.7 Median Grading

Predicting the path of a vehicle in a simple "V" or flat bottom ditch is difficult. The more complicated the median cross-section, the more difficult it is to predict vehicle trajectory. If it is difficult to predict vehicle trajectory, then it is difficult for any barrier system to capture a vehicle.

Install a single run of cable barrier on 6:1 slopes or flatter. Consider using slopes flatter than 6:1 for cable barriers. Flatter slopes may allow future work on the road to proceed without requiring adjustments to the cable barrier. Median ditch for a single run of cable barrier is to be a 6:1 to 6:1 traversable ditch or flatter.

Avoid having multiple grading break points within the median. Even if these break points are traversable or flatter than 6:1 (e.g. 6:1 slope goes to 8:1 then 7:1). The break points make it more difficult to predict a vehicle's path through a median.

Installing cable barrier or other barrier systems on both sides of the median shoulder may be a better treatment. Examples are (the list is not all-inclusive):

- A significant amount of earthwork is required to get appropriate slopes
- Median ditch already has drainage problems
- Large drainage features would require a significant amount of modification
- A significant number of fixed objects are in the median

If a project cannot get the suitable median grading or other issues are making it difficult to install two barrier systems at the edge of median shoulder, coordinate with the WisDOT project manager and the regional design

[34] Other barrier system can be used on wider medians.

oversight engineer.

When using two runs of cable barriers at the edge of shoulder (i.e. where beam guard is installed), grade slopes behind cable barrier to 4:1 or flatter. During a crash, the vehicle will traverse the area behind the cable barrier.

Conduct field survey for all cable barrier installations. Create cross-sections at a minimum of 100 FT intervals. Provide additional cross-sections near drainage features or other locations with grade changes. These grade changes can influence cable barrier height. Projects that have relied on "As Built Plans" or Typical Sections have had significant construction problems, delays and cost over runs..

Adjust drainage features to install cable barrier. This work typically includes (the list is not all-inclusive):

- Grading around drainage features
- Regrading of ditches
- Adjusting the height of inlets
- Installing traversable grates, or drop inlets
- Removal of 4-inch tall hazards on a 5 FT chord
- Extending drainage features

See FDM 11-45-30.6 for discussion on roadside design for drainage features. Problems with drainage features may make it more difficult for cable barriers to work. For example, if a vehicle hits a culvert, flips over, hits the cable barrier, and then penetrates the cable barrier.

Pay attention to grading in the following areas:

- Curve and transitions
- Narrow medians
- Other cross-sectional transitions
- Special ditches
- Flat medians

Drainage concerns or maintenance work may have caused adjustments to the existing grading.

30.3.2.5.8 Placement in Median

FHWA's research shows that vehicles can go under the cable barrier when the cable barrier is too close to a median ditch bottom. At a minimum, place cable barrier at least 8 feet up from a median ditch bottom.

Cable barrier should be no closer than 8 feet from a ditch bottom (see SDD 14B52). Other factors can influence how far from the ditch bottom the cable barrier can be. Examples are (the list is not all-inclusive):

- Working width
- Likelihood of being hit
- Room for maintenance staff

Placing cable barrier away from median ditch keeps the cable from wet or poor soils. Installing cable barrier up a slope also lessens the likelihood that line post will freeze into line post footings.

It can be easier to measure from the edge of lane or other feature to locate cable barrier. If the median ditch is hard to define or meanders, grade the ditch or move the cable barrier closer to the travel lane.

Place cable barrier at a constant offset from the ditch. Show in the plan where the cable barrier is located in the median.

There has been no crash testing of flared cable barrier.

30.3.3 Beam Guard

This section discusses the design of new installations of beam guard and some new installations of special applications of beam guard. Beam guard includes Class A Beam Guard (SDD 14B15), and MGS (SDD 14B42). Some special applications of beam guard are (the list is not all-inclusive):

- Reduced working width
    - Reduced Post Spacing
- Reduced grading
    - Longer posts at half post spacing
- Reduced embedment
    - Long-Span
    - Anchor Post Assemblies Top Mounted

Besides the general beam guard guidance provided, special applications of beam guard may have additional

design guidance in other sections of the FDM.

Some guidance in this section may apply to other semi-rigid barrier systems. Other semi-rigid barriers may have additional design guidance in other sections of the FDM. Examples of this are (the list is not all-inclusive):

- Thrie Beam Bullnoses
- Thrie Beam Transitions
- Short Radius

Some of the guidance in this section can apply to beam guard end treatments. End treatments have additional design guidance in FDM 11-45-30.4.

Identify new installations of beam guard and special applications of beam guard and other semi-rigid barrier systems in the plan.

Some special applications of beam guard need individual construction details. Some standard installation of beam guard may need individual construction details. See other parts of 11-45-30 for more information.

30.3.3.1 General Design Issues with Beam Guard

The following subsections deal with common design issues associated with beam guard beyond those listed in the design criteria found in FDM 11-45-30.3.1. Information provided may be useful to designing special applications of beam guard, other semi-rigid barrier systems, or end treatments as well.

30.3.3.1.1 Class A or MGS

Install MGS based systems for all new beam guard installations.

Individual construction details may be required.

Some of the information in this subsection may be applicable to existing beam guard systems.

30.3.3.1.2 Beam Guard Anchorages

Nearly ½ the crash force is transferred to the beam guard's anchorages.[lviii] Without proper anchorage, a vehicle may pass through a beam guard system. Lack of anchorages can defeat the purpose of having beam guard. Figure 30.6 shows how much an anchor can move during a crash in the middle of a beam guard installation.

Figure 30.6 Upstream (top) and Downstream (bottom) End Anchors after Crash Test

Proper anchorages for beam guard are:

- Beam guard end treatments
  - EATs
  - Type 2
- Approach or Departure transitions to a rigid barrier and the rigid barrier.
- Crash cushion

See other sections of the FDM for guidance on anchorages.

Provide anchorages for semi-flexible barrier systems.

30.3.3.1.3 Proper Grading for Beam Guard

Grading for beam guard includes:

- from lane to beam guard
- behind the beam guard post
- for anchorages

For beam guard to work, grading from edge of lane to the beam guard must allow for proper vehicle engagement. Grading from edge of lane to beam guard is typically not an issue because the shoulders are usually 10:1 or flatter. However, standard detail drawings may not work when beam guard is installed in the following situations (the list is not all-inclusive):

- down a foreslope

- up a backslope
- on an uneven slope
- on a shoulder that breaks away from superelevation[lix]

Soil behind the post helps to absorb crash loads. Changes to the soil behind the post will influence performance. Figure 30.7 shows the estimated decrease in energy absorbed when there is less grading behind the post.[lx]

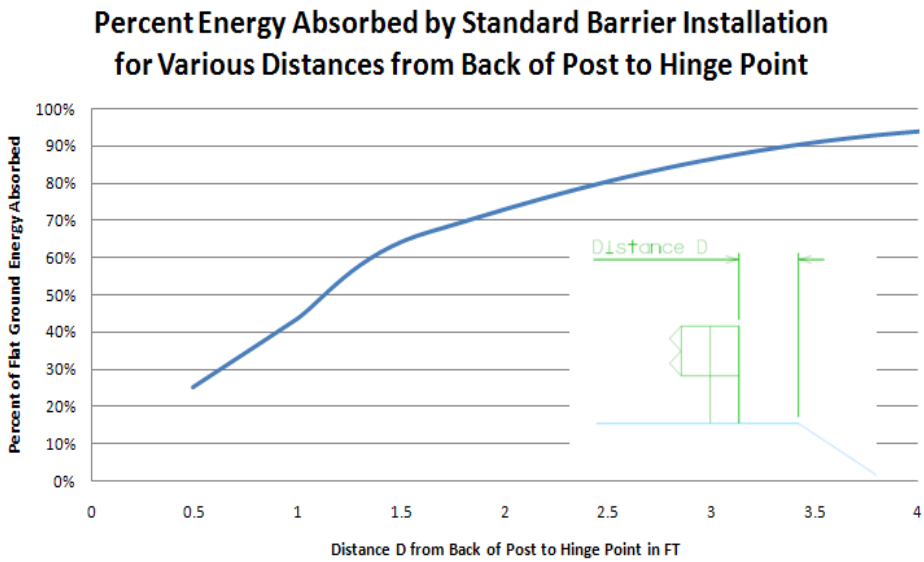

Figure 30.7 Energy Absorbed by Post During an Impact for Various Soil Conditions[lxi]

When normal grading is not an option by the posts, try the following:

- Install long post with reduced spacing – see SDD's for MGS Type K or Class A LHW
- Use concrete barrier
- Shift beam guard location to allow proper installation

MGS Type K and Class A LHW make up for the lack of soil behind the beam guard. See FDM 11-45-30.3.1.5 on adjusting beam guard location to allow proper installation.

Lack of grading near anchorages can cause beam guard to fail or move too much during a crash (see Figure 30.6). Too much movement can lead to beam guard failure or expensive repairs.

Review guidance on the grading and shaping bid items for barrier systems in FDM 11-45-30.5.

If there are issues with the grading design, coordinate with the WisDOT project manager and the regional design oversight engineer.

30.3.3.1.4 Post Rotation and Embedment

All beam guard applications, and other semi-rigid barrier use post rotation to absorb crash energy. In some crashes, beam guard end terminals use post rotation.

Beam guard posts with limited rotation break earlier than a post that can rotate through the soil. A broken post will not absorb as much energy as a post that can rotate in the soil.

Figure 30.8 Photos of Post Rotation[lxii]

Underground obstacles can limit post rotation. Occasionally, the underground obstacle may become damaged because of post rotation. See Attachment 30.20 for guidance on how close underground obstacles can be. It does not address damage to the underground obstacle from installation or performance of the barrier system. This is covered in other parts of this sub-procedure. Some underground obstacles have additional guidance in the following subsections, and may have different requirements than what is in Attachment 30.20.

Occasionally a post or foundation/soil tube may hit a shallow solid object (e.g. rock, buried concrete, breaker run) during installation. In some cases, posts have been cut shorter to avoid hitting objects below ground. In other cases, posts or foundation/soil tubes have had the bottom damaged (see Figure 30.9).

Figure 30.9 Foundation/Soil Tube Damaged from Shallow Obstacles

Cutting or damaging the bottom of a post or foundation/soil tube reduces embedment depth. Reduced embedment depth limits how much energy can be absorbed (see Figure 30.10).

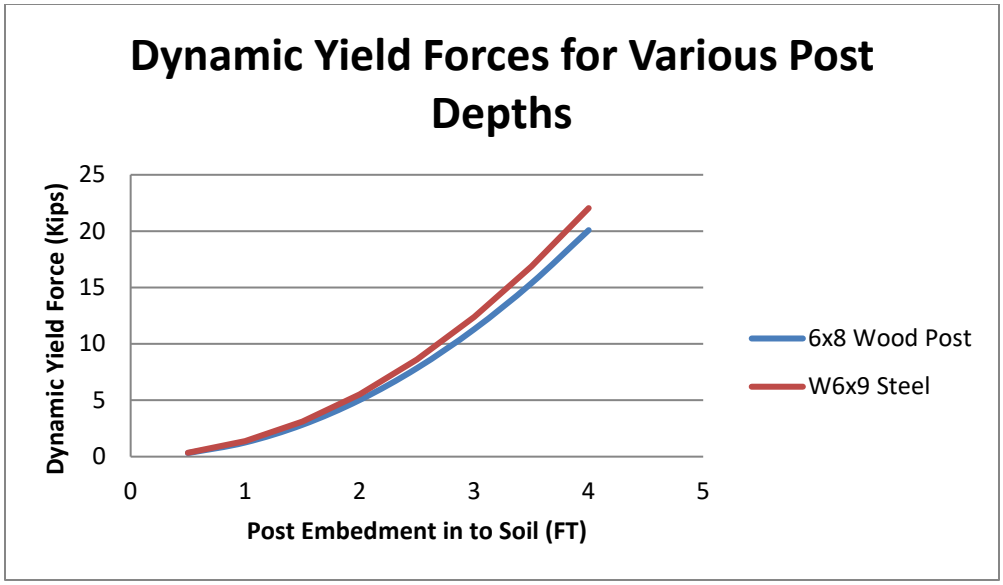

Figure 30.10 Energy Absorb by Post for Various Depths[35]

Do not use Figure 30.10 to change beam guard designs. Other factors do influence beam guard performance.

Crash energy is transferred from the sides of the posts to the soil. Soil support under the post does not help absorb energy. There have been failed crash tests using lesser post embedment.

A barrier system may not work as intended without proper embedment. If the clear cover is 5 FT or less, extra engineering is required. Special applications of beam guard, other semi-rigid barrier systems, and end terminals need more embedment depth.

The following sections provide methods for dealing with common issues that interfere with post rotation and embedment.

30.3.3.1.4.1 Mow Strips

Concrete, asphalt, or other similar objects can reduce post rotation.[lxiii, lxiv] It has been observed:

- Failed beam guard crash test in asphalt mow strips less than 3 inches deep when box-outs are not provided.
- Beam guard post failing early in bogie tests when 2 inches or less of hand packed asphalt is placed around post
- Foundation/soil tubes causing significant damage to concrete and asphalt mow strips when no leave out is provided.

If a mow strip is needed, use SDD 14B28 for crashworthy mow strip alternatives.

Most semi-rigid barrier systems, beam guard end terminals, and specialty barrier applications can use the mow strip alternatives in SDD 14B28. Include individual construction details if changing the layout of SDD 14B28.

It may not be cost-effective to install mow strips or other devices near beam guard or semi-rigid barrier systems to control weeds. Delaware Department of Transportation evaluated different weed control methods under beam guard.[lxv] They reviewed hand mowing, herbicides, special grass plantings, and some commercially available weed barriers. The commercially available weed barrier systems were some form of plastic barrier placed under the beam guard. The cost of the commercially available weed barriers ranged from $1,700 to $2,500 per 100 FT of beam guard. Delaware's research shows that weed barrier systems are the most costly form of vegetative control under beam guards when annualized over 10 years.

Use caution when selecting emulsified asphalt mow strips. Emulsified asphalt mow strips may not be able to prevent heavy erosion. Avoid locations that are sensitive to overspray or pooling of emulsified asphalt. Examples could be near (the list is not all-inclusive):

- Environmentally sensitive locations
- aesthetic treatments
- property owner's flowerbed
- high pedestrian concentration

[35] AASHTO MASH 2016

Installing a mow strip to prevent erosion may only shift the erosion from paved/gravel shoulder edge to other locations (e.g. mow strip/grass foreslope edge). Use other measures to control erosion (e.g. installing a flume, erosion mat). Review drainage and erosion concerns when installing a mow strip. Verify quantity of run-off and potential for erosion when using a mow strip. Curb and gutter may be a more viable alternative to control water flow.

30.3.3.1.4.2 Shallow Rock

Shallow rock is an obstacle typically found that interferes with post rotation or embedment. See FDM 11-45-30.3.3.1.4 for more discussion. Standard Spec 614 and SDD 14B15 and SDD 14B42 have information on how to deal with shallow rock. The normally used methods should take care of most rock and post conflicts. The department typically does not pay for rock excavation for beam guard, special applications of beam guard, and other semi-rigid barrier system.

Be aware of locations where guidance on rock excavation may not be the best answer. Examples are (the list is not all-inclusive):

- If the pavement structure is less than 2 FT (measured at edge of lane) and the road placed on shallow rock
  - Special modifications are needed to the standard detail drawing
- When a road must cut down rock to install road pavement, subgrade, or subgrade improvements
  - Because rock is already being remove, it may be more cost effective to cut additional rock out for the barrier system
- Breaker or pit run materials in subgrade improvements are near posts
  - Providing special detail that stops installing pit run or breaker run just short of the barrier system.
  - Verifying that there is sufficient cover over the subgrade treatment to install barrier system
- Overhead utilities may cause problems with rock removal
  - Contractor may be prevented from using large equipment to drill the holes.

Additional engineering is needed for situations like this. Coordinate with statewide or regional soils engineer, the WisDOT project manager, and the regional design oversight engineer for these situations.

30.3.3.1.4.3 Surface Object that Prevent Rotation

Avoid placing surface objects near post that prevent post rotation (e.g. rip rap, asphalt millings, fill slopes, flumes). Remove objects that prevent post rotation.

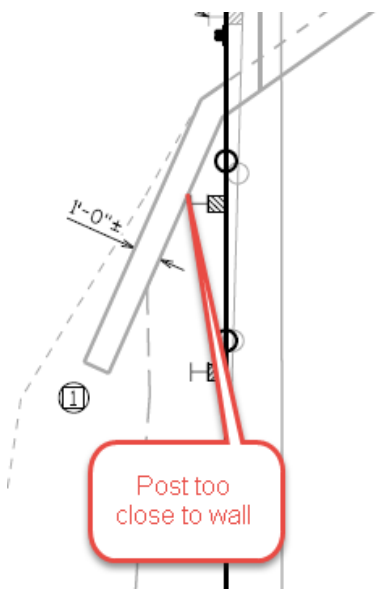

Figure 30.11 Wing of Box Culvert Prevents post Rotation

30.3.3.1.4.4 Other Obstacles

Occasionally, existing drainage systems or other utilities have been damaged during installation of beam guard. During design, identify all post conflicts with buried utilities, storm sewers, culverts, and structures.

In Figure 30.12, a beam guard post was driven through a culvert pipe. A storm two years after construction

caused a failure near the edge of shoulder. In another case, a post driven through a culvert has caused a road to flood.

Figure 30.12 Post Driven Into a Culvert

It is unknown how the beam guard in Figure 30.12 will work in a crash. .

Some potential conflicts are (the list is not all-inclusive):

- Drainage features
- Cattle passes
- Retaining walls
- Bridge abutments
- Pier footings
- Utilities

Possible solutions are (the list is not all-inclusive):

- Shifting beam guard location relative to the lane
- Shifting a beam guards location upstream or down stream
- Switching to concrete barrier
- Using a special application of beam guard
- Adding blocks to an installation of beam guard

Occasionally, just shifting beam guard upstream or downstream may help avoid some underground conflicts. Attachment 30.20 has examples how shifting beam guard upstream or downstream can avoid conflict. Post spacing does not change in a shifted beam guard system. Provide individual construction details when shifting beam guard.

Sometimes, typical MGS without one post (i.e. 12.5 FT span) can be used to bridge over an obstacle. These installations have additional requirements. Some of these requirements are (the list is not all-inclusive):

- A minimum of 2 FT of flat ground is behind all other beam guard posts in the installation
- Enough room both upstream and downstream of 12.5 FT span (See SDD 14B42)
- Individual construction details to locate the missing post are in the plan
- The missing post is in a tangent installation of beam guard

Use caution when near the maximum span length. Do not use this detail for spans greater than 12.5 FT. Use the Long-Span details (see FDM 11-45-30.3.3.3.

Do not use the missing post detail when curb and gutter is near the missing post location or within (the list is not all-inclusive):

- an end terminal
- an approach transition to a rigid barrier
- a special applications of MGS

- Class A beam guard

Although not the most desirable alternative, details that add blocks to an installation (SDD 14B15 and SDD 14B42) may be used to avoid underground conflicts.

30.3.3.1.5 Curb and Gutter

Curb and gutter can negatively influence how beam guard and other semi-rigid barrier systems work. Curb and gutter are likely to influence barrier performance by:

- Preventing vehicles from properly engaging beam guard
- Loading the post bolt to rail connection causing a rail tear and allowing vehicle penetration.

To minimize these issues, SDD 14B15 provides guidance on proper placement of curb and gutter and Class A beam guard. Use Table 30.5 to decide what combinations of Class A beam guard and curb to use.

Table 30.5 Class A Beam Guard and Curb Combinations

Speed	6-Inch Vertical	4-Inch Sloped Face Curb
<35	Standard Class A	Standard Class A
≥35 to <45	Nested Installation (i.e. Type NW)	Standard Class A
≥45	Not Permitted	Nested Installation (i.e. Type NW)

MGS Beam guard has been TL-3 crash tested with 6-inch vertical curb and gutter in front of the rail (see SDD 14B42). This testing allows MGS to use curb on high-speed roads. The MGS SDD show only one curb type. Other standard curbs shapes can be used with MGS. Special curbs 6 inches or less may be used with MGS. Discuss the use of curb with the WisDOT project manager and the regional design oversight engineer. Curb is in front of MGS to lessen the likelihood that a snowplow will scrape the beam guard's rail.

At 45 mph or less MGS can be placed further away from the face of curb. The additional design requirements to place MGS further back from the face of curb are:

- Face of rail is 4 to 12 feet behind the face of curb
- Grading between MGS and curb is 10:1 or flatter
- Top of Rail is 31 to 32 inches above the top of the curb

Note: approach transitions and end terminals have not been tested further back from the face of curb.

30.3.3.1.6 Pay Quantities for Beam Guard

Once the overall length of the barrier system has been determined, anchorage types are selected, and working width is checked, calculate pay quantities.

To calculate the pay quantity for beam guard, subtract EAT length from the overall length of the barrier system. The length of a Type 2 end treatment is included in the overall length of a barrier to determine the linear foot quantity for beam guard.

Pay for special applications of beam guard within the total length of a barrier system (e.g. long-span, Type K,…) with separate bid items. Subtract the length of special applications of barrier from the overall length of the barrier system to determine the linear foot quantity for beam guard.

30.3.3.1.7 Other Considerations

Beam and thrie beam railings are typically manufactured in 25 FT or 12.5 FT lengths. Look to use multiples of 12.5 FT when installing beam guard and thrie beam systems. Odd lengths of rail may be required. For example, a shorter piece of beam guard will allow a beam guard to avoid a driveway. It is possible to order odd lengths of beam guard, but it is not recommended. Standard Spec 614 has contract language on how to field cut, punched, and galvanized railings.

Place a note in the individual construction detail showing that a rail needs to be field cut, punch and galvanize. No note is needed in the plan if the odd lengths of rail are on an SDD.

30.3.3.2 Short Radius Systems

Installing a short radius system is not a desirable option. Review and document other options before installing a short radius system (see 11-45-30.9 for more discussion).

Review using a short radius system early in scoping or design. Short-radius systems may need right-of-way,

grading or additional work on drainage features.

There are times when an intersection or driveway prevents a normal barrier system from being installed tangent to the mainline. A short radius system may be used.

A short radius system consists of:

- Radius Components
  - Curved beam guard rail
  - Controlled Releasing Terminal (CRT) posts
  - Grading
- Non-Radius Components
  - Beam guard rail height transition
  - Anchorage

Short radius systems do not neatly fit into one category of roadside hardware (i.e. beam guard, sand barrier array, end treatment…). A short radius system uses many of the same parts as beam guard. It can act like beam guard under certain crash conditions. Examples are (the list is not all-inclusive):

- Post rotation
- Maintaining rail tension
- Redirection of vehicles in some crashes

Short radius systems can act like a sand barrel array under certain crash conditions. Both the short radius systems and a sand barrel array need to limit deceleration to minimize injury. A vehicle is likely to stop within a short radius system like what happens in a sand barrel array (see Attachment 30.24).

However, a short radius system cannot perform like a sand barrel array. For example, vehicles can gate through a sand barrel array. Typically, a short radius system cannot allow a vehicle to gate through. Usually, there are hazards close to the short radius system (e.g. steep slopes, water…).

Historically, it has been difficult for short radius systems to perform adequately during a crash test. Some crash tests have failed because it:

- Launched vehicles into the air
- allowed the beam guard rail to go over a small car's hood and enter the vehicle cab through the windshield.
- caused anchor failures (see Attachment 30.24)
- caused rail failures

See SDD 14B27 (Class A) and SDD 14B53 (MGS) for information on short radius systems. The SDDs uses information from some NCHRP 230 crash testing and expert opinion. Some research done by the Texas Transportation Institute (TTI) suggests a similar system is NCHRP 350 TL-2 compliant[lxvi]. TTI performed no crash testing to determine NCHRP 350 compliance.

This section does not address the design of bullnose systems. Review SDD 14B26 or other sections of 11-45-30 to design thrie beam bullnose. See guidance in FDM 11-45-30.5.2.11 for existing bullnose design information.

See FDM 11-45-30.5.2.12 for guidance for existing bent beam guard.

30.3.3.2.1 Required Design Documentation and Construction Details

Provide individual construction detail drawings for short radius systems. Attachment 30.24 and other sections of 11-45-30 for more information.

Following is a list of design documentation and construction details needed for a short radius beam guard system (the list is not all-inclusive):

- System type
- Design speed
- Radius
- Cross hatch the no fixed object placement zone
- Drainage concerns
- Barrier length along tangents
- Anchorage selection
- Grading

30.3.3.2.1.1 System Type

All projects will use the MGS version of the short radius system. Lettings before December 31, 2017, may have used either the Class A or the MGS version.

30.3.3.2.1.2 Design Speed

Installing a short radius system is not the preferred alternative on roads with design speeds of 45 mph or more.

Consider the utilization of short radius beam guard system on roads with a design speed of 45 mph or less after analyzing, removing, or moving side roads and driveways.

30.3.3.2.1.3 Radius

Radii when using the SDDs are between 8 FT and 149 FT. Rails within this range are shop bent. Use straight rail sections for radii 150 FT or greater. Do not use the short radius details for radii greater than 150 FT.

Installing a short radius system on an oversize-overweight truck route may need more engineering. Turning radii for these vehicles can be large (Figure 30.13). A short radius system may limit movement of oversize–overweight trucks, or become damaged by these vehicles. See other sections of the FDM for information on design vehicles and oversize-overweight vehicles.

Figure 30.13 Truck Hung Up on Thrie Beam Transition and Short Radius

If designing for a larger vehicle, review if moving short radius systems further away from the edge of shoulder allows for large vehicle movement. Provide proper grading when designing for large vehicle movement.

Manufacturers can bend beam guard rail to the nearest foot. Manufacturers typically stock bent rails between radii of 10 and 50 FT in 5 FT increments. Picking a radius that is typically stocked may lessen the cost of the system. However, the radius needs to fit the location.

Show the radius and total length of bent beam guard in the plan.

An installation may need an odd length of beam guard to fit a location. See FDM 11-45-30.3.3.1.7 for more information.

Short radius systems may partially block sight distance. Review sight distances.

30.3.3.2.1.4 Fixed Object Placement

When a vehicle strikes a short radius system, the vehicle typically stops behind the initial rail position. See Attachment 30.24 for more information.

On the short radius SDDs, the hatched area should be free of fixed objects. The vehicle may interact with the fixed object after hitting the short radius. Hitting the short radius system and the hazard may have unintended results.

Figure 30.14 Utility Pole Will Prevent Proper Operation of Short Radius System[lxvii]

Objects typically not acceptable in the hatched area are (the list is not all-inclusive):

- Utility poles (see Figure 30.14) or cabinets
- Control boxes for signals or lights
- Lights
- Trees
- Overhead sign supports and sign bridges
- ITS poles

Move or remove fixed objects. Short radius may require utility coordination.

There may not be a choice but to put a fixed object in the hatched area in the SDDs or Attachment 30.24. For example, a side road likely needs a stop sign. Document in the DSR why the fixed object is necessary, cannot be removed, or moved. Indicate actions taken to minimize the risk during a crash. For example, installing a smaller stop sign on a 4x6" breakaway post is better than installing a large overhead sign support at the same location.

30.3.3.2.1.5 Drainage Concerns

Avoid installing short radius system near curbs or flumes. Flumes within the short radius system are problematic. Curb and flumes may cause the short radius system not to work. Use other methods to control drainage (e.g. mow strips or drop inlets).

If curb must be used, use the following curb and gutter (in order of preference):

- Driveway curb and gutter with a maximum height of 2 inches
- 4-inch sloped curb and gutter

Review post locations for underground conflicts.

30.3.3.2.1.6 Length of Barrier on Tangents

Review FDM 11-45-30.3.1.1, short radius SDDs, Attachment 30.24 and other SDDs to decide if there is enough room to install a short radius system. The minimum length of tangent beam guard on the side road or driveway is found on the SDD. Attachment 30.24 shows what can happen when too little barrier is along the side road or driveway.

30.3.3.2.1.7 Anchorage Selection

Possible anchorages for short radius system could be (the list is not all-inclusive):

- Short Radius End Treatment
- Rigid barrier with approach transition
- EATs

Guidance for most end terminals is in other sections of 11-45-30 or SDDs. This section concentrates on when to use the short radius terminal.

The short radius end terminal is not crash tested. Use the short radius end terminals on roads with a posted

speed of 35 mph or less.

The short radius terminal may look like a type 2 end terminal. Do not interchange these terminals. The short radius terminal has an extra-long cable connection and additional hardware that allow the rail to rotate on the post. Allowing the beam guard rail to rotate around the last post maintains rail tension and prevents the rail from ripping apart.

30.3.3.2.1.8 Grading

The maximum grade from the edge of lane to the face of a short radius system or short radius terminal is 10:1. Flatter grades are acceptable. Short radius system and short radius terminal require 2 FT of flat grading behind the posts (see SDDs).

Grading in the hatched area on the SDDs would be traversable. The area behind the rail is where the vehicle ends up after a crash. However, it is not required that this area be traversable.

Extend culvert pipes to get proper grading for short radius system. On side roads with low fills, the posts for the short radius system may conflict with underground obstacles. For example, a culvert may interfere with post installation. See FDM 11-45-30.3.3.1.4 for more information.

30.3.3.2.2 Short Radius Layout

Recommended steps to layout Short radius systems are:

1. Layout a radius that fits the location and other requirements of a short radius system.
2. Review turn template of larger vehicles and adjust radius as needed.
3. Review if adequate grading can be provided
4. Break radius into individual 12.5' sections of rail
5. Determine if odd length rail is required.
6. Locate splice joints and CRT post on drawing

30.3.3.3 Long-Span Beam Guard

SDD 14B24 for Class A or SDD 14B43 for MGS can be used to span larger culverts or other underground obstacles. The maximum distance between post 1 to post 1 in the long-span system is 25 FT. SDD 14B24 and SDD 14B43 can be used for shorter spans. Detail the span length in the plans.

Use caution when near the maximum span length. Posts may conflict with culvert walls or other structural features. Verify that a long-span system can fit the location early in scoping and design. WisDOT is aware of a failed crash test with longer span lengths[lxviii].

Long-span beam guard is more sensitive to grading than normal beam guard. Provide 2 FT of flat grading behind the posts of a long-span system. Review grading requirements early in scoping and design.

Do not use curb and gutter near a long-span beam guard. Headwalls of culverts are to be flush with the ground line. Curb and headwalls may cause vehicle instability or cause a rail to fail.

When the part of the long-span that is over the underground obstruction is hit, the vehicle will travel over the underground obstruction (i.e. working width). For example, if the underground obstruction is a culvert, the vehicle will traverse over the culvert opening. In essence, the vehicle will be partially suspended in the air by the beam guard rail. See Attachment 30.25 for some examples. It is acceptable to have the vehicle travel over the culvert opening. However, it is not acceptable to have other objects within the working width (e.g. poles, trees, signs).

A long-span beam guard needs beam guard up and downstream to work as intended. See SDD 14B43 for the minimum beam guard length needed both upstream and downstream for a long-span beam guard. Review that there is adequate room upstream and downstream of the long-span beam guard early in scoping or design.

The beam guard adjacent to a long-span system should be normal 6 FT 3 inch post spacing or have a similar working width. Going directly to a system with more or less working width could cause performance issues for the long-span beam guard. Avoid going directly from a long-span beam guard to a short radius system without some normal beam guard with 6 FT 3 inch post spacing between these two systems.

Do not flare a long-span system. Flare beam guard before or after long-span system (see Attachment 30.20).

Provide individual construction details for long span installations.

Occasionally, a single beam guard post may be skipped in an MGS beam guard (see FDM 11-45-30.3.3.1.4.4).

30.3.3.4 Anchor Post Assemblies

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30.3.4 Thrie Beam

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30.3.5 Transitions to Rigid Barriers

This section will discuss the use of transitions to a rigid barrier. Transitions to rigid barrier are:

- Steel Plate Beam Guard Structure Approach (SDD 14B20)
- Midwest Guardrail System (MGS) Thrie Beam Transition (SDD 14B45).

Normal beam guard is too flexible to connect directly to a rigid barrier. Some crashes with beam guard directly connected to a rigid barrier can allow the vehicle to hit the rigid barrier's blunt end (See Figure 30.57, Figure 30.64 and Attachment 30.21). Transitions need to be gradually stiffened to match the working width of the rigid barrier. A vehicle can have excessive deceleration or vaulting if working width does not gradually stiffen.

Approach transitions (i.e. traffic goes from beam guard toward rigid barrier) are more critical than departure transitions (i.e. traffic goes from rigid barrier towards beam guard).

On roads with bidirectional traffic:

- A bridge would have four approach transitions.
- A road with a concrete barrier on one side of the road would have two approach transitions and no departure transitions.
- A road with concrete barrier on both sides of a road would have four approach transitions and no departure transitions

On roads with unidirectional traffic:

- A bridge would have 2 approach transitions and 2 departure transitions
- A road with a concrete barrier on one side of the road would have one approach and one departure transition.
- A road with a concrete barrier on both sides of a road would have two approach transitions and two departure transitions.

Approach transitions can be installed on the downstream end of a rigid barrier on a one-way road. However, it is not necessary.

Approach transitions use closer post spacing, nested rails, and posts with deeper embedment than a typical beam guard installation. Approach transitions are more sensitive to changes in grading than typical beam guard. Provide individual construction details.

Do not flare or bend a transition.

Thrie beam transition posts need to rotate in soils.

Attachment 30.22 provides guidance on how to layout approach and departure transitions to a rigid barrier. This guidance concentrates on MGS. Some of the comments apply to Class A transitions.

Use semi-rigid barrier system's working width for the transition working width.

Grading and drainage are more of a concern with approach transitions. Review grading and drainage near transitions. See Figure 30.58, Figure 30.59, and Figure 30.60 for common grading and drainage problems.

Concrete Barrier Transition Type NJ42SF to S42
Concrete Barrier Transition Type NJ32DF to S32
Concrete Barrier Transition Type NJ42DF to S42
Concrete Barrier Transition Type NJ51DF to S42
Concrete Barrier Transition Type F42DF to S42
Concrete Barrier Transition Type F51DF to S42
Contact Bureau of Project Development (BPD) for details.

30.3.6 Concrete Barrier

Concrete barriers work in a different manner than flexible or semi-rigid barrier systems. Concrete barriers redirect crash energy versus absorbing energy.

The two main methods of redirecting crash energy are vehicle lift and vehicle crush. During a crash, a vehicle climbs the concrete barrier. Climbing up the barrier converts kinetic energy into potential energy. Energy is lost because of damage to the vehicle during a crash. Crashes into concrete barrier are more severe because:

- Lifting a vehicle off the ground increases the chance of vehicle roll over
- Forces that crush a vehicle can injure a vehicle's occupants

On average, concrete barrier is twice as likely to produce an injury crash as a flexible barrier system.

It is important to distinguish between different concrete barrier shapes and heights. This is especially true if a new concrete barrier needs to match into an existing bridge or roadside barrier.

30.3.6.1 Shape

There are five different shapes of concrete barrier in Wisconsin: GM, NJ, F, Single Slope and Vertical (see Figure 30.15 for the difference in various shapes). GM shaped barrier was designed in the 1970s and tends to roll smaller, lighter cars.

Do not install new runs of GM shaped barrier. Spot replacement of damaged barrier is acceptable. Replacing of GM shaped barrier to aid installing or repairing of other facilities is acceptable. For example, an inlet underneath GM shaped barrier needs repair. Replacing a small segment of GM shaped barrier to aid in the repair of the inlet is acceptable.

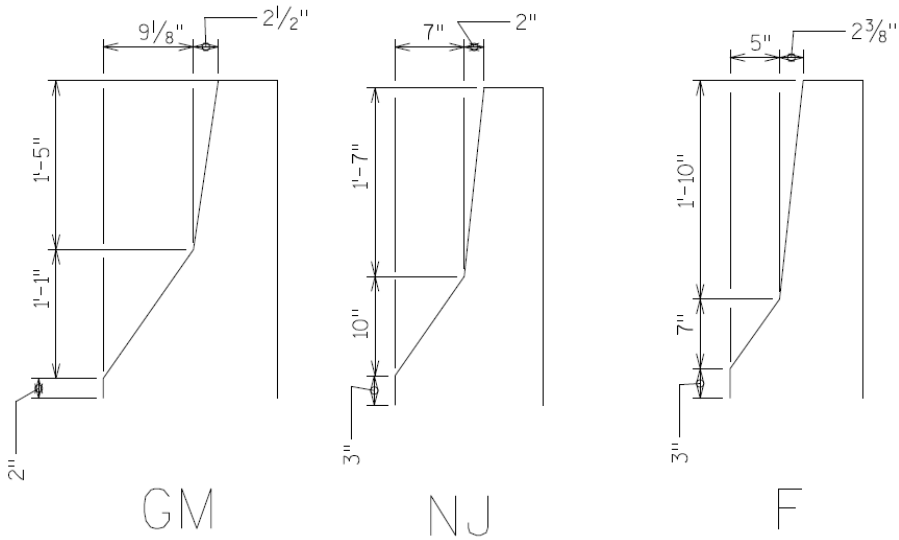


Figure 30.15 Barrier Shape

NJ shaped barrier has been the standard style of barrier for both roads and bridges in Wisconsin for many years. Bureau of Structures (BOS) has used F shaped parapets on various bridges. Since the 1990's, SE region has used F shaped barriers on some roads.

Since 2010, WisDOT has used the Concrete Barrier Single Slope (CBSS) developed by Caltrans. Advantages of the CBSS design are:

- Lower maintenance cost
- Better crash performance
- More flexibility with overlays

Vertical shaped barrier may exist at various locations. For example, vertical shaped barrier is likely to be at an approach transition to a concrete barrier. Minimize the use of vertical barrier.

Barriers that do not conform to NJ, F, single slope, or vertical shapes are not acceptable. NJ, F, single slope and vertical shaped barriers have been crash tested. It is not desirable to change barrier shape for drainage, or to allow placement of hardware on or near barrier.

30.3.6.2 Concrete Barrier Height

Most existing installations of concrete barrier are 32 inches tall. Barriers that are 42 and 51 inches tall have been installed on some freeways and expressways (mostly SE region) and various bridges.

The standard CBSS heights are in Table 30.6.

Table 30.6 Standard Barrier Heights for Specific Types of Road

Road	Standard Barrier Height (Inches)
Freeways and Expressways	42
STH	36
Local	36*

** Local road projects may use 32-inch tall CBSS if the local unit of government has provided a written request to use 32-inch CBSS. Within the written request, the local unit of government must recognize that overlays should not be placed near 32-*

inch CBSS. MASH crash testing has shown that taller vehicles (i.e. single unit van trucks) have gone over 32-inch barriers[lxix]. Attach local unit of government's written request to the project's Design Study Report.

Vertical shaped barrier taller than 34 inches is acceptable between bridge piers or other bridge substructures. The vertical barrier should be flush with the face of pier or substructure. Vertical-shaped barrier taller than 34 inches is not desirable at other locations because of the increased risk of "head slap". Limit the use of taller or shorter barrier.

Other issues to consider when selecting the height of CBSS are:

- Sight Distances
  - Stopping Sight Distance
  - Intersection Sight Distance
  - Decision Sight Distance
- Working Width
- Zone of Intrusion
- "Head Slap"
- Crash history

30.3.6.2.1 Sight Distances

Concrete barrier on the inside of a horizontal curve can obstruct stopping sight or decision sight distance (SSD or DSD). A barrier within the clear sight window of an intersection can obstruct intersection sight distance (ISD). If the available sight distance is less than the minimum sight distance, a shorter barrier may be acceptable.

If it is necessary to install barrier that obstructs SSD, DSD or ISD then provide mitigation. See FDM 11-10-5 for more discussion on sight distance.

30.3.6.2.2 Vacant

This section intentionally left blank.

30.3.6.2.3 Zone of Intrusion

Figure 30.17 to Figure 30.21 show the differences between working width and Zone of Intrusion (ZOI). Table 30.7 has the working width and ZOI values for various heights and types of barrier. Measure ZOI from the top, traffic side of the barrier.

ZOI is a region within the working width where secondary hazards (e.g. breakaway signs…) have been placed. Secondary hazards have entered the vehicle cab during testing and real world crashes. Avoid placing objects within the ZOI of a concrete barrier (see Figure 30.16).

Figure 30.16 Vehicle Interactions with Object on Barrier

Many safety devices (sign poles, lights) are designed to break away when a vehicle's bumper engages it. A safety device on the top of a barrier engages the top of the vehicle. The safety device may not work as intended. For example, a crash test done by Caltrans of a sign post mounted on top of a single slope barrier drove the hood of the pickup truck into the vehicle cab.[lxx]

Coordinate with the WisDOT project manager and the regional design oversight engineer when installing an object on top of a concrete barrier. More engineering may be required.

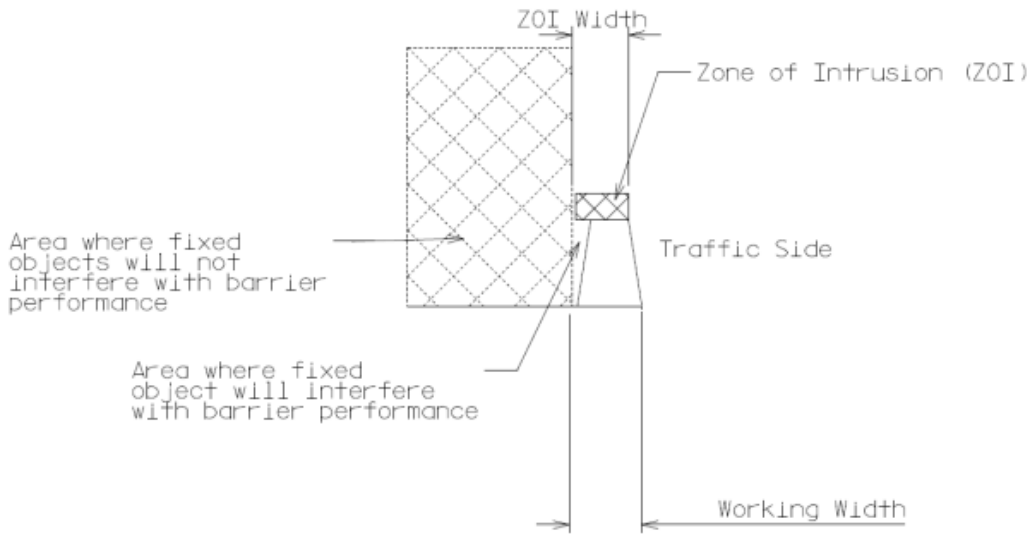


Figure 30.17 Zone of Intrusion and Working Width

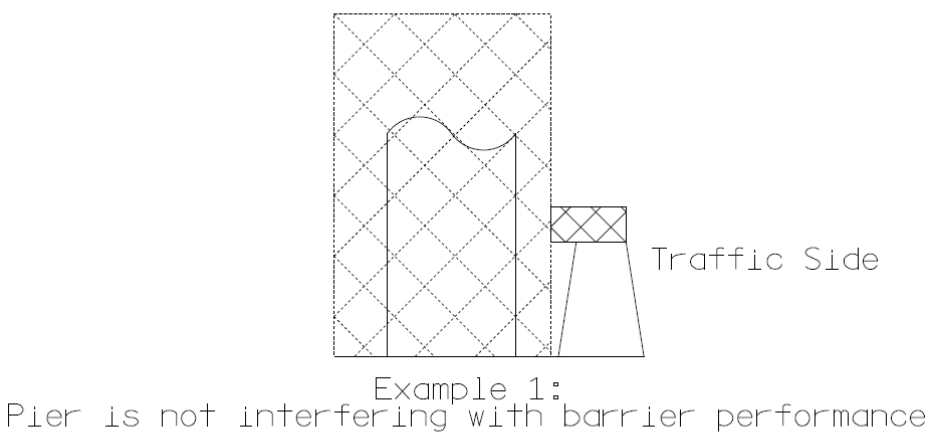
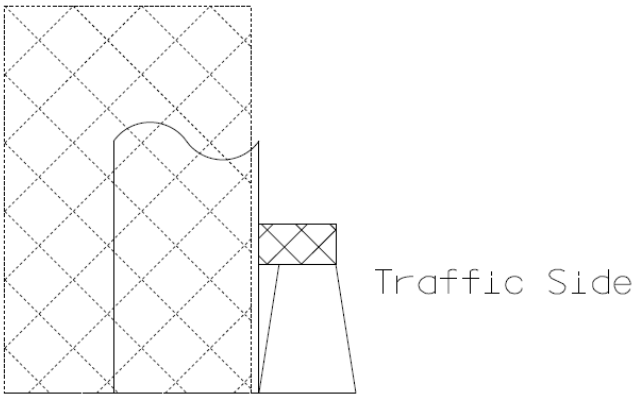
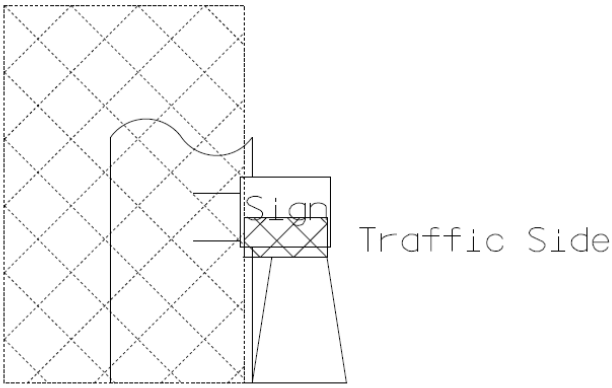


Figure 30.18 Example 1



Example 2:
Pier is interfering with barrier performance.

Figure 30.19 Example 2



Example 3:
Pier is interfering with barrier performance.
Sign likely to be hit by vehicle or vehicle occupant.

Figure 30.20 Example 3

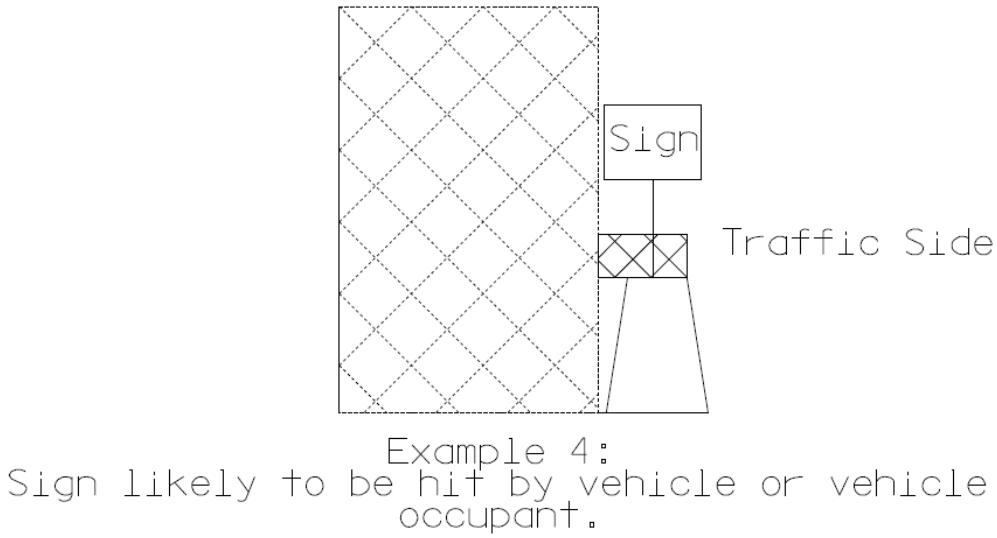


Figure 30.21 Example 4

Table 30.7 ZOI Dimensions[lxxi]

Concrete Barrier	ZOI Width (Inch)
32-Inch CBSS	21
36-Inch CBSS	21
42-Inch CBSS	21
56-Inch CBSS	6
32-Inch Vertical Concrete Barrier	24

30.3.6.2.4 Head Slap

"Head slap" is a condition where an occupant's head is outside the cab of a vehicle during crash and it hits the concrete barrier or object on top of the barrier (See Figure 30.22). Head slap is more of an issue when smaller vehicles crash into taller barriers.

Figure 30.22 Crash test showing occupant's head out of vehicle[lxxii]

30.3.6.2.5 Crash History

Taller barriers may be used if crash history suggests passenger vehicles have:

- Vaulted over barrier
- Traveled along top of the barrier
- Engaged objects on the barrier
- Engaged objects that are behind barrier

Taller barrier may be used if there is a crash history of larger vehicles striking barrier. See FDM 11-45-30.3.1.1 for more discussion.

30.3.6.2.6 Glare/Gawking Screen

Avoid installing glare screens in medians 20 feet or wider, or in locations with ambient lighting. Ambient lighting includes roadway lighting, high-mast lighting, or neighboring properties provide significant lighting. Provide analysis when installing glare or gawk screen. Coordinate with the WisDOT project manager and the regional design oversight engineer.

Project staff will need to:

1. Document that there is a need for glare or gawking screen
2. Develop multiple alternatives to address the glare or gawking problem
    a. What is the effectiveness of each alternative at blocking glare or gawking?
    b. What is the cost of providing glare or gawking alternative?

If there is counter directional traffic on a frontage road next to the main line, a glare screen may be suitable.

SHRP2 report points to taller permanent barriers not being cost effective at reducing non-recurrent congestion.[lxxiii]

30.3.6.3 Parts of a CBSS System

CBSS systems have the following parts:

- Standard Barrier Sections
- End Anchors
- Transitions
    - Shape
    - Height

Review if a location has room to install different parts of the CBSS system. If SDDs do not fit a given location, coordinate with the WisDOT project manager and the regional design oversight engineer. Designer is responsible for developing crashworthy designs for these unique situations (see FDM 11-45-30.3.6.4.6).

30.3.6.3.1 Standard Barrier Sections

Of all the parts of a CBSS system, the standard barrier section (i.e. the middle section of the concrete barrier

system) is the most often used and simplest section. A standard section of CBSS needs less reinforcement steel than other parts of the concrete barrier system. This is because crash forces are distributed in two directions, (see Figure 30.23) and over a longer distance.

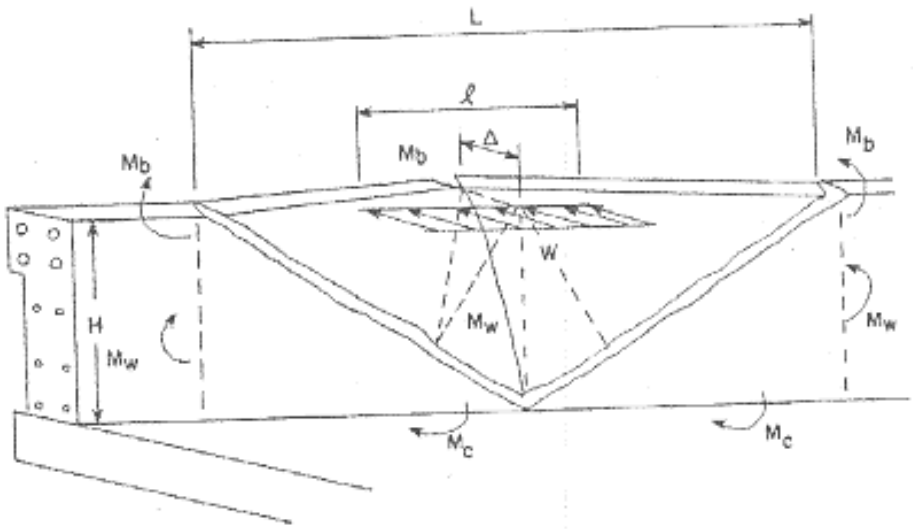


Figure 30.23 Forces in Normal Barrier Section[lxxiv]

The CBSS standard section does not need a footing. However, a concrete pad is placed under the barrier to limit crack propagation. The minimum pad dimensions are on SDD 14B32.

The cost of installing the CBSS includes the pad. The concrete pad extends behind the barrier to help provide a stable foundation under the concrete barrier.

Review grading behind the concrete barrier for stability and erosion concerns. Loss of soil stability can cause the barrier to slide out of position and form a snag point. Provide 1 foot of flat grading behind the concrete barrier on fill slopes.

Put a note in the plan when there is less than 1 foot between the back of concrete barrier and a rigid object.[36] Include bid items for reflectors and brackets.

A contractor may use a cold joint to connect to a previous day's pour (See notes on SDD 14B32). However, the overall barrier run must have end anchors, or expansion joint transitions at the terminals of the barrier system (see FDM 11-45-30.3.6.3.2).

30.3.6.3.2 End Anchors

End anchors need vertical steel and footings to absorb crash loads and to prevent the anchor from rotating (in Figure 30.24 crash forces cannot travel in both directions). End anchors use a cold joint[37] to connect to standard CBSS. It is not necessary to detail the use of a cold joint with the SDD.

[36] When there is less than 1 foot between fixed object and back of barrier, it may be difficult to perform finishing work.

[37] A cold joint has sufficient length of reinforcement steel extended beyond the previous concrete pour to allow the end section reinforcement to properly tie into the previously place reinforcement. This allows for the distribution of crash energy.

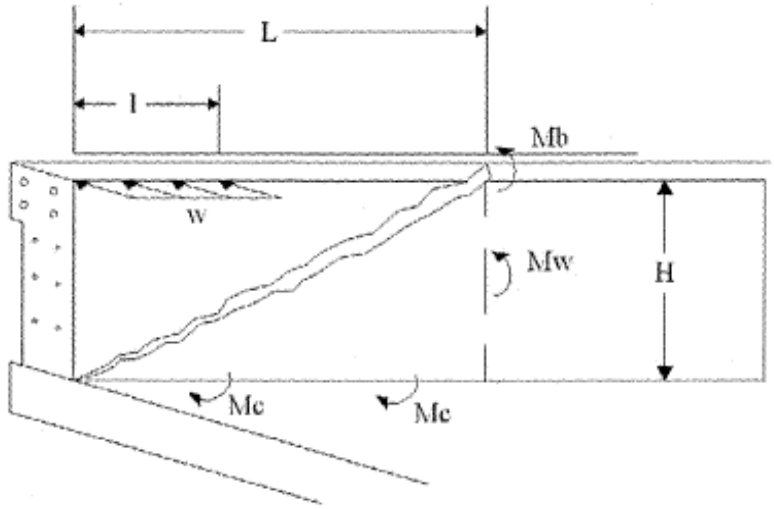


Figure 30.24 Forces in End Section[lxxv]

There are two types of end anchors for CBSS: thrie beam anchors and normal end anchors. Do not pay for anchors separately, because anchors are needed for the normal barrier section to work. Include anchor length in the pay length of the CBSS.

The thrie beam anchor is designed to prevent a vehicle's front wheel from snagging the barrier. It is not necessary to install curb and gutter near a thrie beam anchor. Review SDD 14B45 when installing curb and gutter. On taller thrie beam anchors, the top of the thrie beam anchor is sloped to prevent a vehicle from leaning over and snagging on the top of the anchor. Show in the plan (e.g. plan view) where thrie beam anchors are and include proper SDD (SDD 14B33) in the plan set.

Use normal end anchors when an expansion joint is needed in a barrier run (e.g. on both sides of the sign bridge) or on the downstream end of a one-way road. There may be a project specific reason that would cause the use of typical end anchors. Examples are (the list is not all-inclusive):

- A specific location needs an expansion joint
- Traffic control staging needs a normal end anchor

Review grading and drainage near end sections. A location may satisfy length-of-need, it may not have room for other barrier system parts, or it may have drainage issues (e.g. crash cushion, sand barrier array, or steel thrie beam structure approach). CBSS may have to be longer to provide space for proper drainage or other roadside hardware when installing barrier in a cut section, or in other areas where there is a drainage needed.

Stability of the soil by the anchor is important. The anchor provides resistance to crash loads along the whole run of the concrete barrier. If an end anchor shifts, it may form a snag point. For example, an end anchor for a barrier may no longer be flush with a bridge parapet. Provide 1 foot of flat grading behind the concrete barrier on fill slopes.

30.3.6.3.3 Transitions

CBSS may need to connect to taller or different shaped barriers. These sections of concrete barrier are called transitions.

Review the need for transitions early in design. A new barrier matching into an existing thrie beam transition may need a vertical faced transition. Use "each" items to pay for shape transitions. Show the location and shape transitions in the plan views and MQ sheets.

There are two types of height transitions: double cold joint and the expansion joint design. Typically, designers would use the double cold joint transition detailed on SDD 14B32**.** Double cold joint height transitions act like a normal barrier section by being able to transfer crash energy in both directions. Include the length of the double cold joint height transitions in the cost of the tallest barrier installed.

Use expansion joint height transition, SDD 14B39, at locations where it is not possible to transfer forces in both directions. Some examples are

Roadway barrier is not allowed to tie into a bridge parapet

A bridge parapet is a different height than the roadway barrier

Pay for the expansion joint height transition with an "each" item. Show the expansion joint height transitions in the plan views and MQ sheets.

Shape transitions are shown on the following SDDs:

- SDD 14B35
- SDD 14B36
- SDD 14B37
- SDD 14B38
- SDD 14B40

Pay for shape transition with an “each” item.

Review the stability of the soil near transitions. If a transition shifts, it may form a snag point. Provide 1 foot of flat grading behind the transition on fill slopes. This grading will help stabilize the transition on fill slopes.

30.3.6.4 Unique Situations

30.3.6.4.1 Short Sections of Barrier

The minimum length for the standard CBSS is 40 feet (end of end anchor to end of the end anchor). When lengths are shorter than 40 feet use Concrete Barrier, Type B, (i.e. SDD 14B34). These barriers are more robust and can absorb crashes within the total length of the barrier.

The minimum length of CBSS Short Section depends on the anchors used:

- When using two thrie beam anchors, the minimum length is 31 feet (end of the thrie beam anchor to the other end of the thrie beam anchor).
- When using one thrie beam anchor (e.g. one-way traffic), the minimum length is 21 feet.
- When using no thrie beam anchor (e.g. a sign bridge is close to a bridge), then the minimum length is 10 feet.

30.3.6.4.2 Fixed Object Protection

SDD 14B32 provides two details on how to install barrier near fixed objects. Use fixed object protection when using a single run of barrier in a median and there is a fixed object installed in the median.

These details provide for additional steel, use of fill material and a small footing. Pay for fixed object protection using linear feet. Show the location of fixed object protection in the plan views and MQs.

Include bid items for reflectors and brackets.

Other designs (e.g. integrating a sign bridge or light pole into the barrier run), must account for the crash forces in the structural design of the fixed object. Many crashes on a barrier are from vehicles of pick-up truck size or smaller (see FDM 11-45-30.3.6.4.6).

The designer may adjust taper rates in the transition at large or small fixed objects using Table 30.4. When adjusting taper rate, provide construction details and special provisions. Include special bid item. Include bid items for reflectors and brackets.

30.3.6.4.3 Median Widening or Narrowing a Hazard for a Crash Cushion/Array

Use sections A-A and B-B of SDD 14B32-b transitions at large or small fixed objects as a guide on how to transition from a single run of median barrier to two runs of median barrier. Use the same sections to narrow a hazard to allow for the installation of crash cushion or sand barrel array. Designer may adjust the taper rates using Table 30.4.

Make the height of concrete barrier 32 inches where the crash cushion or array is installed. Combine height and width transitions together to minimize the number of transitions near the crash cushion or array. During a crash, a vehicle can lean over and strike the edge concrete barrier taller than 32 inches. Provide end anchorage for changes in median width and crash cushions and arrays. Review guidance on crash cushions and arrays for back width (FDM 11-45-30.4.4).

Provide structural analysis and design of median widening, or narrowing a hazard, for crash cushions or arrays (see FDM 11-45-30.3.6.4.6).

Provide individual construction details, special bid items, and special provisions. Include bid items for reflectors and brackets.

30.3.6.4.4 Retaining Walls

There are two designs for concrete barrier retaining walls: median and roadside. Use median retaining wall design when the barrier is between two roads of different height. The median design has a maximum wall height of 3 feet (see SDD 14B32). Show the location of in median retaining wall in the plan (e.g. plan view and MQ sheets). Earthwork associated with median retaining walls is included in the cost of the median retaining wall. Include bid items for reflectors and brackets.

If the height of median retaining walls is greater than 3 feet, provide a structural design. Design taller median

retaining wall to retain soil, other loads, and crash loads (see FDM 11-45-30.3.6.4.6). Show in the Miscellaneous Quantities the maximum median retaining wall height for each installation.

Insert construction details, special provision, and special bid items for median retaining walls taller than 3 feet. If the use of taller median retaining walls needs significant earthwork or special earthwork, include earthwork bid items. Include bid items for reflectors and brackets. Show in plans the maximum height of the median retaining wall for each installation.

A study conducted by TTI showed that a minimum of 35 to 60 feet of median barrier was needed to prevent movement during a crash. [lxxvi] BOS indicates a minimum of 60 feet of median retaining wall is required to prevent movement of the barrier during a crash.

Note: it may not be possible to slip-form the median retaining wall from the low side road.

Avoid using median retaining wall barrier design on the outside of the road. Contact BOS and Technical Services (TS) soil staff for help.

The roadside retaining wall does not have a maximum fill height (see SDD 14B41). A soils or structural engineer is to review the location to see if SDD 14B41 is suitable. Show the location of roadside retaining wall barrier in the plan (e.g. plan view and MQ sheets). Soil or structural engineer is to decide the gradation of structural backfill.

If SDD 14B41 is not structurally acceptable, provide a design (see FDM 11-45-30.3.6.4.6). Insert construction details, special provision, and special bid items for special roadside retaining walls.

Design roadside barriers (SDD 14B41) and other retaining wall barriers to prevent overturning or sliding during a crash.

Pay for associated earthwork for roadside retaining wall with separate items (e.g. common excavation, rock excavation, select borrow). Include bid items for reflectors and brackets. Insert special provision for select borrow.

Review drainage behind the retaining wall. Water should not flow over the top of the barrier wall. Pay for drainage items associated with retaining wall with separate items (e.g. inlets, inlet covers).

Normal retaining walls are not barrier systems. Retaining walls may not have a crashworthy surface, shape, or strength. A report by TTI using computer modeling of a NCHRP-350 TL-4 crash states, “panels alone cannot resist direct impact of such severity.”[lxxvii]

Repairing a damaged retaining wall may be difficult. Review the consequences of retaining wall failure from a crash. Provide additional engineering when using a retaining wall as a barrier.

30.3.6.4.5 Use of Concrete Barrier Single Slope (CBSS) on Bridges

Designer may use CBSS on a bridge in a non-outer parapet application (See SDD 14B32). Figure 30.25 is an example of CBSS on a bridge deck. Separating vehicles from a multi-use path or pedestrians needs a crashworthy bridge parapet (see Figure 30.26).

When using a crashworthy barrier on a bridge, coordinate with BOS early in design. Show the location of this barrier in the plan. Use SDD 14B32**,** special provisions, and special bid items for this barrier. Include bid items for reflectors and brackets.

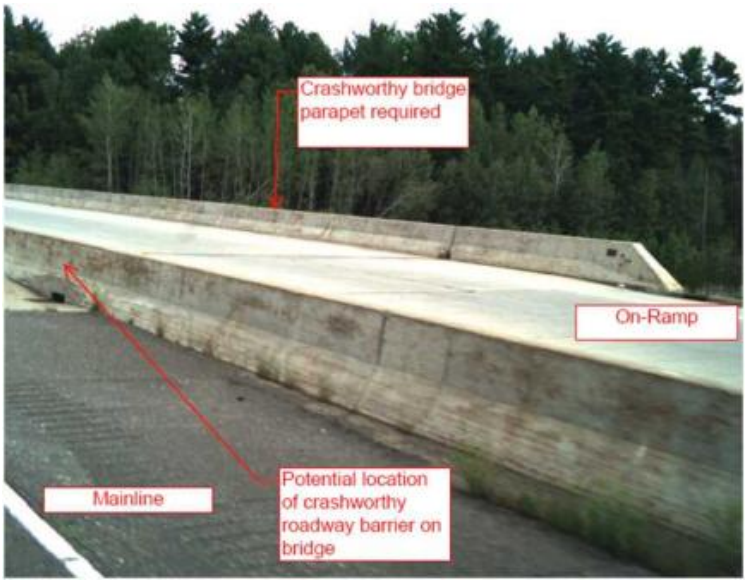


Figure 30.25 Crashworthy Barrier on Bridge

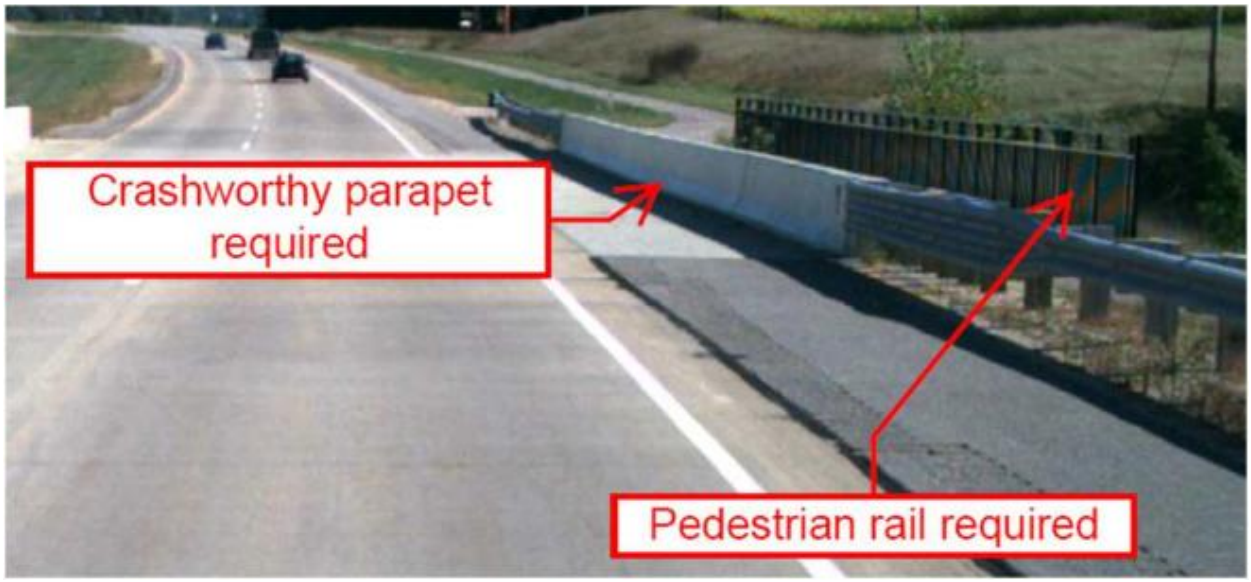


Figure 30.26 Crashworthy Parapet on Bridge

30.3.6.4.6 Other Situations

Use standard barrier as much as possible. Use of non-standard barrier may increase barrier cost (e.g. contractor may have to purchase a special shoe for the paver, or use traditional formwork to install barrier). Contractors may not be able to slip-form tall vertical barriers.

There may be situations where SDDs may not fit. In these situations, design barriers or fixed objects to:

- Have enough reinforcement for:
  - Shrinkage and temperature steel
  - Contain TL-3 crash loads (See AASHTO LRFD Manual Chapter 13)
  - As necessary contain other loads (wind loads, dead loads…)
  - Vertical steel and associated footings to prevent barrier rotation during a crash
- Provide clear cover for steel
- Provide working width (See FDM 11-45-30.3.1.1)
- Use crashworthy shape (See FDM 11-45-30.3.6.1)
- Allow for smooth redirection
- Be free of snag points
- Limit potential for vehicle vaulting
- Limit potential for flying debris

Coordinate with the WisDOT project manager, the regional design oversight engineer and BOS when using a non-standard barrier. Provide structural analysis. Avoid abrupt angles that could concentrate crash loads on the vehicle, abrupt redirection (see Figure 30.57), or snag the vehicle.

Provide constructible designs that are structurally and functionally adequate. Use construction details, special provisions, and special bid items.

30.3.6.5 Concrete Barrier Placement

At a minimum, place the CBSS toe either at the shoulder width or the horizontal clearance width, whichever is greater. On some high-speed divided highways, CBSS has been placed 2-feet beyond the edge of shoulder (i.e. shy distance). See FDM 11-45-30.3.1.5 for discussion on flare and shy-line for concrete barrier. See FDM 11-45-30.3.1.1 for information on working widths.

30.3.6.6 Median Barrier

Typically, use a concrete barrier in medians 40 feet or less. Wider medians may use a concrete barrier.

In narrow medians, install two runs of concrete barrier. Advantages of two runs are:

- Fixed objects (e.g. signs, light poles, sign bridges, bridge piers…) placed between the barriers are less likely to be hit.
- Fixed objects do not need to accommodate crash loads
- Snow storage

- A vehicle is less likely to penetrate or go over two barriers

In general, it is typical to use two runs of barrier when:

- 4-lane A3 road's median width is 19 feet or greater
- 6-lane A3 road's median width is 31 feet or greater

A single run of concrete median barrier may be acceptable for some projects or locations.. Include the following:

- Lack of room for two runs
- No or few fixed objects in median
- Construction staging and work zone traffic control

If using a single run of median barrier and a large object placed on top of the barrier, design each object using FDM 11-45-30.3.6.4.6. Provide concrete end anchors next to the large object on top of the barrier.

This design prevents crash loads from the barrier damaging the large object. Maintenance staff does not need to replace a large object on top of the barrier if the nearby barrier is damaged.

30.3.6.7 Extending Concrete Barrier

Occasionally, existing concrete barrier may need to be extended. Portions of the existing end anchorage will need to be removed. If end anchorages are not modified there may be issues with snag or barrier failure. Review SDD 14B32 sheet E and FDM 11-45-30.3.6.4 for single slope barriers.

Older safety shaped barrier may need to be extended a few hundred feet. Some options are:

- Removal of the 6.5 FT safety shape to vertical shaped transition (see SDD 14B22 sheet B).
    - Vertical steel within this area may need to be removed. Horizontal steel should remain to tie in the new barrier (see Attachment 30.23). Special details and special provisions may be required.
- Use a vertical to single slope transition and install single slope barrier
- Detail that a contractor needs to install the 6.5 FT safety shaped to vertical transition abutting the existing safety shape transition.

30.4 End Treatments

End treatments provide strength for the entire barrier system. Review guidance in FDM 11-45-30.5.4.

Provide individual construction details for end treatments and cross-sections. End treatments may not fit without individual construction details in the plan. Sometimes, improperly installed end treatments can degrade the strength of an entire barrier system.

Some end treatments are proprietary products and are on an approved products list. Avoid placing multiple end treatments near each other (see discussion in FDM 11-45-30.4.1.2).

Avoid aesthetic reasons to justify not installing a crashworthy end terminal correctly. Review FDM 11-45-30.1.4.

Research shows that beam guard terminal crashes are: [lxxviii]

- 2.5 times more likely to cause driver injury when compared to crashes into beam guard.
- NCHRP 350 compliant terminals are about 5 times safer than striking other terminal designs.
- End terminals are twice as likely to cause rollover crashes as striking beam guard.

30.4.1 Energy Absorbing Terminals (EAT)

EATs are attached to the end of beam guard, are proprietary, and crashworthy. With other hardware, an EAT can shield the blunt end of a concrete barrier.

Install EATs when a vehicle could have a head-on crash with the blunt end of a semi-rigid barrier. If an EAT cannot be installed, review other crashworthy options.

Downstream ends of a beam guard installation on a one-way road may use an EAT. These locations typically use a Type 2 terminal.

CMM 6-26 contains more information on construction problems faced installing an EAT.

During a head-on crash, an EAT can absorb a significant amount of energy by reshaping the rail. Angle hits between the head and post 3 will result in limited reshaping of a short section of rail before the vehicle passes behind the EAT and barrier. For crashes beyond post 3 (e.g. post 4, 7), an EAT works like normal beam guard. To shield a hazard, the end of barrier need (i.e. LON point) is post 3 of the EAT (see FDM 11-45-30.3.1.2).

SDD 14B24 is the EAT SDD for Class A beam guard. SDD 14B44 is EAT SDD for MGS beam guard. Use the EAT with the correct beam guard (e.g. MGS EAT with MGS, EAT with Class A). Identify EAT location in the plan by using the station and offset of post 1.

Usually, the department installs TL-3 EATs. In some locations, installing a TL-2 EAT may be acceptable.. Use

special details and special provisions when installing a TL-2 EAT. Coordinate with the WisDOT project manager and the regional design oversight engineer early in the design.

EATs cannot accommodate the following modifications (the list is not all-inclusive):

- Bending the rails to a radius
- Different post spacing than shown on the SDDs
- Connecting to beam guard with significantly reduced working width without some intermediate beam guard (see FDM 11-45-30.3.1.1)
- Connecting to a rigid barrier without a transition.
- Connecting to a short radius system without a normal section of beam guard before the EAT.
- Installing with nested rail within the EAT.
- Installing railing or planks on the backside of the EAT.
- Using longer posts

Coordinate with the WisDOT project manager and the regional design oversight engineer about adjusting an EAT to fit a location.

30.4.1.2 Fixed Object Placement and EATs

Figure 30.27 is a plot where test vehicles came to rest after hitting various end treatments at 62 mph. This figure also includes AASHTO's Roadside Design recommended 75-foot by 20-foot area that should be traversable and free of fixed objects (i.e. yellow area). Crash testing is conducted under controlled conditions. In the real world, vehicles may travel further than Figure 30.42.

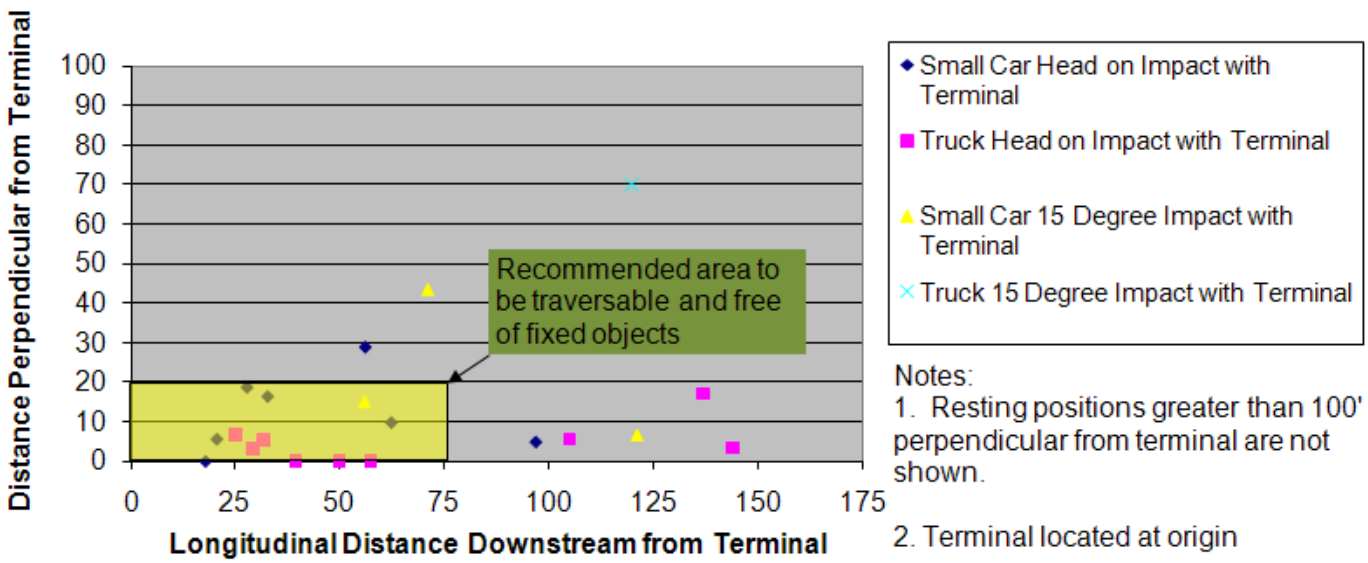


Figure 30.27 Final Resting Position of Test Vehicle after Hitting End Treatments

Figure 30.28 Hazard within Area End Treatment Gates

Avoid placing objects, even breakaway hardware, just behind an EAT (i.e. yellow box). Desirably a vehicle would engage one object during a crash. Crashes into multiple objects are complicated and are more likely to have negative results. In Figure 30.28, the rock face will likely be struck by a vehicle after gating through the EAT.

Avoid placing objects just upstream of an EAT (about 75 feet). Objects upstream of an EAT can (the list is not all-inclusive):

- Funnel vehicles towards the EAT
- Cause a crash into multiple objects
- Cause a non-tracking crash into the EAT

Non-tracking crashes into an end treatment are more likely to have negative results. Figure 30.29 has a breakaway sign too close to the EAT.

Figure 30.29 Fixed Object may Funnel Vehicle into EAT

In some situations, (e.g. urban areas, low speed), the area that AASHTO shows free of fixed objects and traversable grading may be difficult to achieve.

Review placement of objects near EAT before PS&E. If there are conflicts, adjust the location of the object or EAT, or use different hardware.

EATs, like many other end treatments, are designed to work independently. Avoid placing two EATs, or other end treatments, near each other (See Figure 30.30). Crashes like Figure 30.31 can have less than desirable

outcomes.

Figure 30.30 End Treatment Placed Near Each Other[lxxix]

Figure 30.31 Results of Placing End Treatments Near Each Other[lxxx]

Other end treatments are more suitable where there is little room between barrier systems. Examples are:

- Thrie beam bullnoses
- Crash cushions
- Special semi-rigid barrier end terminals

Coordinate with the WisDOT project manager and the regional design oversight engineer, early in the design process, when end treatments are close to each other (typically 25 feet or less). Provide additional engineering, special details, and special provisions.

30.4.1.3 EAT Grading

In 2004, FHWA released a memorandum that highlights the importance of advance, adjacent and run-out grading for EATs (see Figure 30.32).[lxxxi] Advance grading allows a vehicle to avoid hitting the EAT or allows the vehicle to engage the EAT properly. Adjacent grading provides stability for the vehicle during crash and provides structural strength to the whole barrier system. Run-out grading provides an area for a damaged vehicle to stop before hitting a fixed object. The tree in Figure 30.32 may be struck by a vehicle that hit the EAT, and then gates through the EAT.

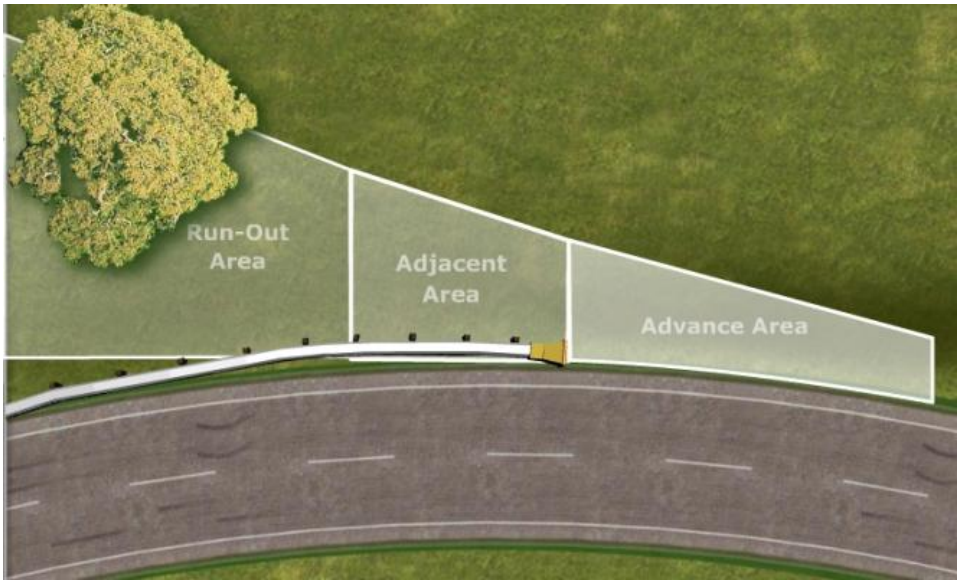


Figure 30.32 EAT grading Locations[lxxxii]

AASTHO suggests the desirable grading would be the yellow area in Figure 30.32. WisDOT does allow changes to the EAT grading (see SDD 14B24 and SDD 14B44). The area bounded by roadside clear zone, hinge point between posts 1 through 5 of the EAT and gradeline should conform to clear zone requirements. Grading for the additional area shown in the 2011 AASHTO Roadside Design Guide is not required (see Figure 30.32), but is a best practice.

Insert cross-sections at posts 1, 5, 9 and the beginning of approach taper into the plan. Review how various slopes blend into each other near EAT. Make transitions from one slope to another as smooth as practical. The blending of slopes will help minimize vehicle instability before and after hitting an EAT.

Removing or reducing earthwork at an end treatment may influence how the barrier system will work (see FDM 11-45-30.4.1.4 and FDM 11-45-30.4.1.5). Review FDM 11-45-30.3.1.3 to use grading and shaping barrier system item.

The soil outside the road's core may not be suitable. Consult with the Region's Soils Engineer. Review the need to bench the EAT's earthwork into existing road's slope. Remove unsuitable material before building EAT's fill. If benching existing slope, show benches in the cross-sections and add a note to construction details. Show the removal of unsuitable soils in the cross-sections as well.

Review drainage and right-of-way near EAT early in the scoping or design. See if more right-of-way is needed. If EAT grading interferes with ditch drainage, review installing a parallel culvert pipe (see FDM 11-45-30.6). Sometimes, a parallel culvert pipe may reduce the need for right-of-way and allow for proper grading near the EAT.

30.4.1.4 Extending Barrier Installation for EAT Grading

Minor shifts in EAT's location to account for transitions, and rounding up to get an even number of rail sections does not need documentation. Shielding of a secondary hazard, or to avoid having fixed objects within the area near the EAT needs documentation. Installing an EAT without grading needs a designer to evaluate and document moving the EAT to a different location.

If it is not possible to get the preferred grading, use the following options (in order of preference):

1. Provide alternative grading at first EAT location (See 2011 Roadside Design Guide Figure 8.3 for alternative grading).
2. Extend barrier to a location where desirable grading can be provided.
3. Extend barrier to a location where alternative grading can be provided.
4. Install EAT with substandard grading.

Flaring a barrier system may allow for a shorter overall barrier length and proper grading. See FDM 11-45-30.3.2.4 for information on flaring a barrier system.

When extending a barrier to allow grading, use one of the following methods (in order of preference):

1. Length Factor.
2. Cost Ratio.
3. Other Factors.

30.4.1.4.1 Length Factor

If it is not feasible to provide grading for the EAT near the end of barrier point (LON), multiply the length of barrier system by 1.6. This new value represents the maximum length the barrier system may be extended using the length factor method.[38]

Example:

Given:

Barrier run length is 312.5 FT

Extension factor 1.6

It is not feasible to provide grading at the desirable location.

Find:

Maximum distance designer may extend barrier to provide grading.

Max length of barrier run =312.5*1.6= 500.

Use any location between 312.5 to 500 FT in front of the hazard that allows for grading.

30.4.1.4.2 Cost Ratio

If grading for the EAT cannot be provided within the length factor range, extend barrier using the cost ratio method. If the total cost of EAT installation at the desirable location, divided by the total cost of extending the barrier to provide grading is greater than 6, extend the barrier to provide grading. The ratio uses the relative severity of hitting a barrier system versus hitting an EAT.[lxxxiii]

Example:

Given:

Barrier run length is 312.5 feet

Length Factor 1.6

It is not feasible to provide grading at the desirable location (i.e. 312.5 FT before the hazard).

The maximum length of the barrier using length factor method is 500 FT before the hazard.

It is not feasible to provide grading at any location from 312.5 to 500 FT before the hazard.

Find:

Does a location 650 FT before the hazard satisfy the cost ratio requirements?

The cost to provide more barrier and EAT measured from the desirable location (i.e. 312.5 feet before the hazard) to 650 feet before the hazard= $5,000

The cost of providing EAT and grading at desirable location (i.e. 312.5 feet before the hazard) = $15,000.

Cost Ratio= $15,000/$5,000=3

Cost Ratio is less than 6; it is not feasible to extend the barrier to a location 650 FT before the hazard.

30.4.1.4.3 Other Factors

There may be significant impacts preventing proper grading of a terminal. Consider how a terminal works with other needs of the road and its' surroundings.

Coordinate with the WisDOT project manager and the regional design oversight engineer early if using some other factor to justify not installing EAT grading. Show the scope of the impact of grading the EAT. Include an analysis of the other methods of altering an EAT's location.

Avoid aesthetic reasons to justify not designing the installation of an EAT accordingly. Review FDM 11-45-30.1.4.

The WisDOT project manager and the regional design oversight engineer may grant case-by-case DJ's to install EATs without grading.

30.4.1.5 Substandard Grading

The department does not want to install EATs without the proper grading. However, there may be situations where moving or providing proper grading for an EAT is not feasible. In these cases, providing a crashworthy end treatment with substandard grading is better than using a non-crashworthy end treatment.

Consider installing substandard grading for an EAT only after reviewing other EAT locations. Eliminate grading in the following order of preference:

---

[38] Length factor is based on the average ratio of L_r values in AASHTO's 2006 Roadside Design Guide divided by the L_r values in the FDM.

1. Reduce or remove EAT flare.
2. Reduce grading between EAT head and hinge point to 2 feet.
3. Review if installing a parallel culvert pipe with traversable grate and fill can reduce the need to flatten run out path slopes.
4. Reduce slope beyond the hinge line to 3:1.

See FDM 11-45-30.4.1.7 to reduce or remove EAT flare.

Reducing grading between the EAT head hinge point may make it more difficult for a vehicle to be stable during a crash. Reducing grading to less than 2 feet can weaken the entire semi-rigid barrier system.

Research conducted by Midwest Roadside Safety Facility (MwRSF) shows that recommended grading reduces the chances of rollover after hitting an EAT.[lxxxiv] The report also indicated 3:1 slopes could be used in the runout areas if the soil is firmly compacted[lxxxv]. Using 3:1 slopes may reduce flexibility for future projects. Review 3:1 slopes for a flat spot at the toe of slope and fixed objects on the slopes or at the toe of slope.

Approach taper may be steepened to 4:1.

30.4.1.6 Curb and Gutter near EAT

There has not been crash testing with an EAT installed near or behind curb and gutter. In areas with curb and gutter, it is desirable to install driveway curb 100 FT before the EAT head. In a constricted location, use a minimum of 25 feet before an EAT head[lxxxvi]. Extend driveway curb to post three of the EAT. Review drainage near EAT.

Locate driveway curb in the plan (i.e. individual construction detail). If providing paving details or curb and gutter details, locate driveway curb for EATs on these sheets. Typically, one contractor installs curb and gutter, and another contractor installs the EAT. There may be communication issues between contractors or project staff if this information is not in the plan.

30.4.1.7 Flare EAT

Install EATs tangent or flared from a road. The maximum flare rate for an EAT attached to tangent beam guard is on SDD 14B24 or SDD 14B44.

If beam guard is flaring away from the road, install the EAT without additional flare. For example, beam guard is flared 15:1 from the road. Flare the EAT at 15:1 from the road.

In urban and suburban/transitional areas, it can be difficult to get space for EATs. EAT offset from flow line of the curb can be reduced to 1 FT in these areas. Any offset less than 1 FT will more than likely lead to hits by snowplows. The EAT's head may extend beyond the flow line of the curb. Avoid reducing the flare rate in rural areas. Discuss with local government and regional maintenance staff before reducing the flare rate.

Provide information in the plan when no or reduced offset is used for an EAT.

30.4.1.8 Foundation/Soil Tubes for EATs

Review discussion in FDM 11-45-30.3.3.1.4 for more information on post rotation embedment.

EAT foundation/soil tubes are embedded nearly 6 FT into the ground. Designers may move EAT to accommodate tube installation (e.g. flare barrier system, install longer barrier system).

Where 6 FT of embedment is difficult, even if the designer relocates the end terminal, manufacturers may have special designs that could be used. If using a manufacturer's special design coordinate with the WisDOT project manager, the regional design oversight engineer, the manufacturer, and maintenance staff. Additional engineering, special provisions, special bid items, and drawings may be needed.

30.4.2 Downturned Ends, Blunt Ends, BCTs, MELTs, and Sloped Concrete End Treatments

Downturned end treatments (see Figure 30.64), sloped concrete end treatments (see Figure 30.74) blunt ends (see Figure 30.61, Figure 30.62), BCTs (Figure 30.63) and MELTs (Figure 30.65) are not crashworthy. These end treatments can launch vehicles into the air, decelerate a vehicle too quickly or spear into the cab. If considering their use, coordinate with the WisDOT project manager and the regional design oversight engineer.

30.4.3 Type 2 End Treatments

These end treatments are installed at locations where a vehicle cannot have a head-on crash or where it is unlikely to be hit. Some examples are:

- Downstream end of a beam guard installed in a wide median on a freeway or expressway
- Downstream end of a one-way road

See SDD 14B16 (Class A) and SDD 14B47 (MGS) for more information.

Computer modeling indicates that some crashes will gate through the MGS Type 2 (see Figure 30.48). Use this guidance for designing all Type 2 end treatments.

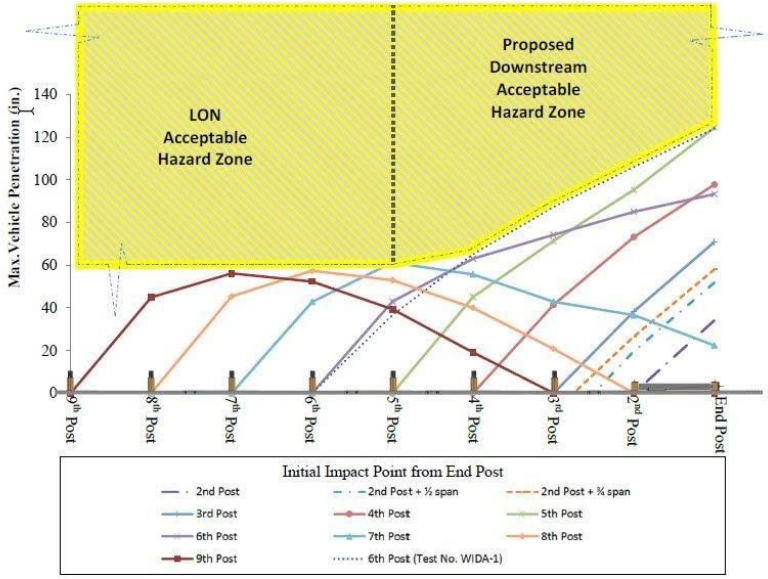


Figure 30.33 MGS Type 2 Computer Modeling

Options available to the designer are:

- If the hazard is close to the beam guard, extend beam guard 39.5 feet beyond the hazard and place a Type 2 end treatment.
- If the hazard is farther from the beam guard, the end treatment can have the same station as the hazard (see Figure 30.33).

For example, if a fixed object (e.g. pole) is 15 feet behind the beam guard. It is possible to have the end post of the Type 2 end treatment flush with the end of the fixed object hazard.

For some hazards, avoid installing a Type 2 end treatment within 39.5 FT of the hazard. Examples are (the list is not all-inclusive):

- Steep slopes
- Water
- Cliffs
- Areas of Concern for Pedestrians
- Areas with High Consequence of Collision

In general, avoid allowing a vehicle to gate through the Type 2 terminal and interact with a hazard.

Show the location of end post of a Type 2 end treatment in the plan.

Transition from curb and gutter to driveway curb and gutter between post 6 and 7 in Figure 30.33. Extend driveway curb and gutter 32 feet downstream of the end post.

Provide additional cross-sections for a Type 2 end treatment.

Provide grading behind the posts for the Type 2 end treatment. Lack of grading by the Type 2 end treatment may weaken barrier system. See FDM 11-45-30.3.3.1.3 and SDDs for more information about grading..

See discussion in FDM 11-45-30.4.1.8 for more information on foundation/soil tubes.

30.4.4 Crash Cushions and Sand Barrel Arrays

Where fixed objects cannot be removed, moved, made breakaway, or shielded by roadside barrier use a WisDOT approved crash cushion or sand barrel array. See approved product list for acceptable hardware. Use other barrier systems before using a crash cushion or sand barrel array. Sand barrel arrays and crash cushions are often the only effective ways to shield narrow, rigid hazards.

During a head-on crash, the crash cushion absorbs energy by deforming the components of the crash cushion. When a crash cushion is hit on the side, it will redirect a vehicle. Depending on crash severity and crash cushion, a crash cushion may have the potential to shield a second crash or be put back into service quickly.

An array is a series of barrels filled with a mixture of sand and salt. During a crash, the vehicle's momentum is dissipated by hitting various weighted drums in the array. Arrays do not allow for redirection of a vehicle. After a crash, an array has limited to no capacity to shield a second crash.

Arrays can have barrels from different manufacturers intermixed. Crash cushions cannot intermix parts from different manufacturers.

In work zones, shield temporary barrier ends within the clear zone when the posted speed is 30 mph or greater with a crash cushion or array.

Discuss the selection of permanent crash cushions or arrays with local maintenance staff. Proper maintenance is important for crash cushions to work correctly. Maintenance input may influence final design of a location or the selection of a system. Maintenance concerns should not be the only factor in selecting of a permanent crash cushion.

30.4.4.1 Design Criteria

Fundamental design criteria for crash cushions or arrays are:

- Crash test condition
- Area requirements
- Back width
- Grading
- System maintenance
- Object marking pattern
- Object being connected to
- Location of traffic
- Direction of traffic

Include this information in the miscellaneous quantities for each installation.

Length-of-need point for most crash cushions is within 2 feet of the crash cushion's nose or first metal diaphragm. Often, the length-of-need point of a crash cushion may not matter. For example, a crash cushion is protecting the blunt end of two barriers in a gore.

Length-of-need point for arrays is the first barrel.

Provide individual construction details for each crash cushion and array. Include the following (the list is not all-inclusive):

- Width and length available for installation
- What the array or crash cushion is shielding

Include cross-sections or contours near crash cushions and arrays in the plan.

Standard bid items show crash cushion system maintenance requirements.

Avoid using special provisions for crash cushions. In the past, some problems with special provisions for crash cushions have been (the list is not all-inclusive):

- Critical parts missing from contract documents
- Problems with consistency between special provisions
- Conflicts between standard bid items or other project's special provisions
- Specifying a product that is not required/allowed

These issues have caused delays, increases in project costs, and have led to less than desirable installations.

30.4.4.1.1 Sand Barrel Considerations

Department policy is to limit the use of permanent sand barrel arrays. Use arrays at locations where crash cushions cannot reasonably fit. Sand barrel arrays are typically more expensive to maintain, and in certain crashes not as safe as a crash cushion. For example, arrays allow vehicles to gate through, and vehicles can hit the heaviest barrel first. See system maintenance discussion.

The barrels typically vary in height based on design and manufacturer. An array may affect the sight distance of turning vehicles. Review sight distance near the array. State if the array is unidirectional (i.e. exposed to one-way traffic) or bidirectional (i.e. exposed to two-way traffic) in the miscellaneous quantities. In the Miscellaneous Quantities, state the crash test level for each array. See Chapter 8 in AASHTO Roadside Design Guide for more guidance on arrays.

Place arrays on asphalt or concrete pads. Show a pad for the array in the plan. The manufacturer is responsible for pad design. Provide enough room to install an array.

When providing space for an array use the following guidance:

- Provide minimum offset from last few rows of barrels and end of hazard (see Figure 8-40 of 2011 AASHTO Roadside Design Guide)
- 6 inches of space between barrels
- Barrels are 3 FT wide

Desirable new arrays would also include:

- For bidirectional arrays, install some barrels to reduce the severity of reverse direction crashes (see Figure 8-41 of 2011 Roadside Design Guide).
- Angle arrays toward traffic (see Figure 8-42 of 2011 Roadside Design Guide).

Show in the plan that additional barrels are being used to reduce reverse direction crashes or if the array is angled towards traffic.

30.4.4.1.2 Crash Test Level

Use Table 30.8 to select crash test levels for crash cushions and arrays. Put the crash test level in the plan for each crash cushion or array.

Table 30.8 Test Conditions

Speed (MPH)	Crash Test Level
≤25	NA –Sloped Concrete End Treatment
>25 to 45	TL-2
≥ 45	TL-3 *

*Most manufacturers use an 8-inch deep concrete pad to anchor a crash cushion. Some manufacturers allow the use of asphalt for temporary crash cushions. If the hazard is 4 or more feet in width, a temporary crash cushions needs a concrete pad. Confined locations, a TL-2 system may be used for speeds of 45 MPH.

30.4.4.1.3 Area Requirements

Figure 30.34 show the general components and the relationship of pad dimensions to the generic crash cushion. Most crash cushions on the Department's Approved Products list will fit within the dimensions of Table 30.9.

Crash cushions need to be anchored into the ground. Most manufacturers use a concrete or asphalt pad. Sometimes crash cushions use a backing block. Designers using the standard specifications do not need to provide details or payment items for pads or backing blocks.

Lack of room for the pad or backup block may hinder the operation of the crash cushion. Table 30.9 an estimate of the concrete pad's width and length.

Review the pad's location for underground conflicts. It is difficult to install or maintain a crash cushion with limited room. Review manufacturers' information to verify that a system will fit.

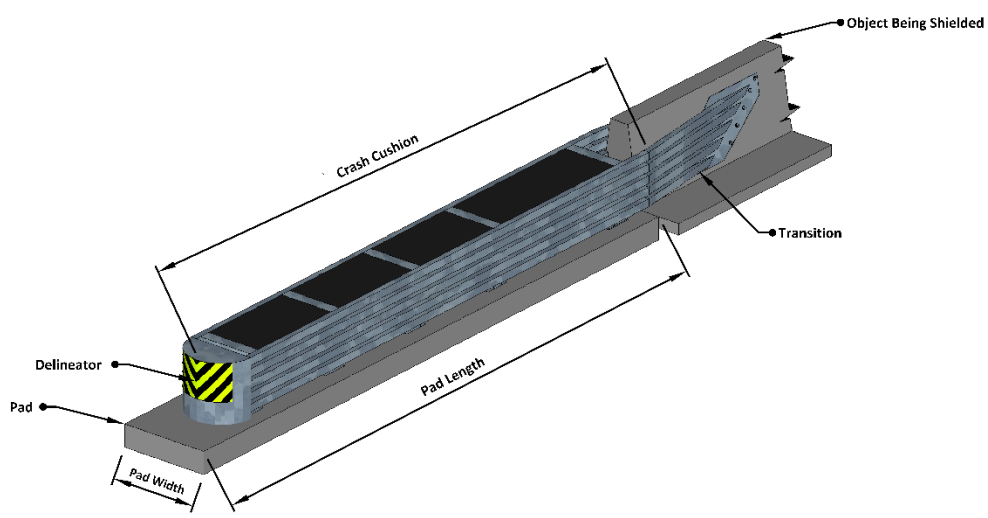


Figure 30.34 Area Requirements for Crash Cushions[lxxxvii]

Table 30.9 Area Requirements for Crash Cushions

	Pad Dimensions (FT)	
Test Level	**Width**	**Length**
TL-2	4	15
TL-3	4	26

Document when values less than the values in Table 30.9. Type of work, the amount of room for a crash cushion, or pad requirements may limit the effectiveness of a crash cushion. However, installing a crash cushion may be the best available option.

30.4.4.1.4 Back Width Requirements

Back width is the width of the hazard being shielded. Typically, crash cushions are as wide as or wider than the hazard, they are shielding.

Table 30.9 should allow most crash cushions to be installed. Objects that are 2 FT or wider may need an sand barrel array or be tapered to a narrower width. Wider crash cushions will cost more to repair than standard sized crash cushions. Also there are no wider crash cushions that are tested to MASH 16.

Limit the use of wider crash cushions to locations where it is not feasible to taper the back width of the hazard to the values in Table 30.9. Use concrete barrier that tapers to the widths in Table 30.9 to minimize the cost of future repairs. See FDM 11-45-30.3.6 for guidance on narrowing a hazard with a concrete barrier.[39] In addition, there are no MASH-16 wider crash cushions on the department's approved product list.

Typically, using beam guard or thrie beam to taper a hazard is acceptable when using beam guard or thrie beam to shield the hazard. Beam guard or thrie beam tapers will require more room than concrete barriers and may have other special requirements. Beam guard and thrie beam tapers may be more expensive to repair. Coordinate with the WisDOT project manager and the regional design oversight engineer when using beam guard or thrie beam to taper a hazard.

Typically, on retrofit projects, the back width may be larger and it may be more difficult to taper the hazard down. Manufacturers can provide wider crash cushions or use an array.

Use the outermost limits of the hazard to determine back width. If two barriers are near each other, use the distance from outside toes of the barriers for back width. If a hazard is near a barrier, use the distance from the outer toe of the barrier to the outside edge of the hazard for back width.

30.4.4.1.5 Grading

Provided 10:1 or flatter grading leading to, alongside, and under a crash cushion or array. Include grading items in the plan. Crash cushions may use the grading and shaping standard bid item. See FDM 11-45-30.3.1.3 for more information on the grading and shaping bid item.

Curb and gutter will make it more difficult for crash cushions or arrays to work as intended. Avoid installing curb and gutter leading to, or alongside of a crash cushion or array. If curb and gutter is needed by a crash cushion or array on a project that is not new construction or reconstruction, use 4-inch sloped curb.[lxxxviii]

30.4.4.1.6 Maintenance Requirements

Some crash cushions are designed specifically to be easier, faster, or less expensive to repair. These low-maintenance systems are typically installed in areas where there is a significant chance of the crash cushion being struck, difficulties in repairing the device, or significant user delay because of maintenance activities. Low-maintenance crash cushions are usually more expensive than a normal crash cushion.

If there is no crash data available, or the crash data indicates that there has been 4 or more years between crashes on a crash cushion, use (in order of preference):

1. Desirable maintenance criteria tables in Attachment 30.11.
2. Less than desirable maintenance criteria tables in Attachment 30.11.

If a crash cushion has experienced less than 4 years between crashes, use a low-maintenance crash cushion. Other issues may factor into the selection of a low-maintenance crash cushion. Some of the issues are (the list is not all-inclusive):

- User delay

[39] *Figure 2.47 indicates that a "12:1 taper (Min)". Flatter tapers (e.g. 20:1, 15:1) are acceptable.*

    - The road is at capacity, and it is not feasible to repair cushion during the off-peak time or at night.
  - Exposure to the traveling public or maintenance staff
    - Geometric or cross-section issues near the crash cushion (e.g. there is little to no shoulder, a high-volume ramp gore requires a crash cushion).
  - Violation of driver expectations
    - Geometric issues are present (e.g. left-hand off-ramp, curve hidden by hill…).

Look for locations that have high crash frequency and it is difficult to maintain the crash cushion. Using a crash cushion with some residual capacity may be suitable. Locations like this have one or more crashes within a week. Coordinate with the WisDOT project manager and the regional design oversight engineer for assistance. Special provisions may be needed.

30.4.4.1.7 Object Marking Pattern

Show in the miscellaneous quantities the object marking pattern required for a given installation. Manufacturers will provide the marking on the front of their crash cushion.

For permanent installations:

- When the installation is on the left side of a one-way road, use marking pattern OM-3L (W5-58L sign plate).
- When the installation is on the right side of a one-way or two-way road, use marking pattern OM-3R (W5-58R sign plate).
- When the installation is in the median or a gore between a ramp and the mainline, use marking pattern OM-3C (W5-58M sign plate).

For temporary work zone installations:

- When the installation is on the left side of a one-way road, use marking pattern OM-3L (WO5-58L sign plate).
- When the installation is on the right side of a one-way or two-way road, use marking pattern OM-3R (W05-58R sign plate).
- When the installation is in the median or a gore between a ramp and the mainline, use marking pattern OM-3C (W05-58M sign plate).

Include correct WisDOT sign plates in the plan.

30.4.4.1.8 Direction of Travel

There are two traffic directions: unidirectional (e.g. outside shoulder of a one-way road, gores between the ramp and mainline...) or bidirectional (e.g. temporary barrier divides north and southbound traffic, narrow median installation in a freeway or expressway). Provide direction of travel in the plan.

Different hardware or different layouts are used depending on traffic direction. For example, bidirectional traffic needs a transition from temporary barrier to the crash cushion. Lack of this information in the plan may cause a crash cushion not to function adequately.

30.4.4.1.9 Traffic Location

Traffic can be on one side (e.g. temporary barrier is on the outside shoulder) or have traffic on both sides (e.g. gore between ramp and mainline, gore between east bound and west bound mainline). Traffic location may influence crash cushion hardware.

30.4.4.1.10 Object Crash Cushion Shields

Type of object can influence crash cushion or crash cushion’s layout. Typical hazards are the blunt ends of the temporary barrier and permanent barrier. There may be some other hazards as well. Identify what to shield and the crash cushion’s location in the plan.

30.4.4.2 Miscellaneous Quantities Sheet

Below is a sample miscellaneous quantity sheet for crash cushions and sand barrel arrays.

Table 30.10 Crash Cushion Miscellaneous Quantity Sheet

Location	614.0800 Crash Cushions Permanent	614.0805 Crash Cushions Permanent Low-Maintenance	614.0905 Crash Cushions Temporary	Back Width FT	Object Marking Pattern	Crash Test Level	Traffic Direction	Traffic location	Crash cushion shields
354+13, 30' R	--	1	--	4	OM-3C (W5-58M)	TL-3	Unidirectional	L and R	permanent concrete barrier in ramp gore
50 "c"+67 10' L	1	--	--	2	OM-3C (W5-58M)	TL-2	Bidirectional	L and R	permanent concrete barrier in median
10 "temp"+15 R	--	--	1	4	OM-3R (W05-58R)	TL-3	Bidirectional	L and R	gore between temporary lanes single temporary barrier
357+80 45 L	1	--	--	2	OM-3L (L5-58L)	TL-3	Unidirectional	L	permanent concrete barrier on shoulder
Total	2	1	1						

30.4.4.3 Other Crash Cushion Considerations

Occasionally, a crash cushion must be left in place and a future project will remove it. Typically, this is because of traffic staging on large multi-contract projects. It is recommended that permanent crash cushion items are used.

The temporary crash cushion bid item uses some older crash cushions. These crash cushions may have high repair costs. During the time between projects, county forces will be responsible for maintenance. Repair crews are more familiar with the crash cushions on the permanent crash cushion list. It is also easier to get replacement parts. The future project can remove the crash cushion.

Standard specifications require the contractor to attach the crash cushion to the object being shielded. Sometimes it is not proper to attach a crash cushion to an object. For example, traffic is temporarily closer to a metal pole during construction. Use a special provision to modify standard specifications for these locations.

Avoid placing crash cushions near each other or having a fixed object installed near a crash cushion (see discussion in FDM 11-45-30.4.1.2).

Do not add bid items to repair crash cushions during construction. In most cases, the department does not pay for repairing temporary crash cushions. Standard specification 614 already requires the contractor to "immediately" repair a damaged crash cushion. In part 1 of the Standard Specification, the contractor is responsible for maintaining the safety of the traveling public.

30.5 Existing Barrier System Evaluation

A significant amount of research has been invested into making barrier systems reasonably safe. However, there can be crashes into a barrier system that have serious outcomes. Because of this, it is important to review the need and quality of existing barrier systems.

In September of 1994, a technical memo from FHWA indicated:

> "We [i.e. FHWA {emphasis added}] believe that roadside hardware selected by a highway agency to improve safety should do so and that agencies must provide due care in not allowing inappropriate devices to remain indefinitely. Consequently, we [FHWA {emphasis added}] expect the selection and maintenance of roadside safety hardware will be key elements of a State's safety management system, with the objective of assuring that current crashworthy designs will be employed where appropriate."[lxxxix]

The 2006 Roadside Design Guide states:

> "If the feature requiring shielding cannot be eliminated, the designer must assess the adequacy of the barrier installation. If the barrier is essentially non-functional (i.e., it cannot reasonably be expected to function satisfactory under most expected impacts) it should be upgraded to current standards."[xc]

The 2016 FHWA/AASHTO MASH Implementation Agreement states:

> "Agencies are urged to establish a process to replace existing highway safety hardware that has not been successfully tested to NCHRP Report 350 or later criteria."[xci]

The same FHWA/AASHTO agreement also states:

> "Agencies are encouraged to upgrade existing highway safety hardware to comply with the 2016 edition of MASH either when it becomes damaged beyond repair, or when an individual agency's policies require and upgrade to safety hardware."[xcii]

Document the following:

- The quantity of existing barrier systems,
  - Where are existing barrier systems located?
  - What barrier systems are on the project?
- The need for the existing barrier systems:
  - Can the use of other roadside design methods reduce the severity or frequency of crashes?
- The quality of barrier systems:
- What hazard does the barrier system shield?
  - Is the barrier crashworthy?
  - How does this barrier system compare to the current standards?
- What is the past performance of the barrier system?

Without this information, it is difficult to determine what action to take (e.g. remove the hazard, spot improvement of barrier, or replace existing barriers systems). Except for certain projects (see FDM 3-5-5), not reviewing existing barrier systems requires a DJ.

After deciding that a barrier system is needed, analyze the existing barrier system. Use Attachment 20.1, Table 30.1, and guidance provided in this subsection to decide if spot improvements or full replacement is needed.

Roadway Design Standards Unit (RDSU) recommends:

- Installing barrier systems as shown in SDDs and FDM.
- Fully replace barrier systems instead of performing a significant amount of spot improvements.
- Flexibility for existing barrier system does not apply to newer installations. Examples are:
  - Existing beam guard has a range of acceptable heights. It is not correct to use this range of heights for new beam guard installations.
  - Retrofitting a sloped concrete end treatment to shield an existing blunt end has more flexibility than installing a new sloped concrete end treatment for a new blunt end.
- Remove barrier systems that are no longer needed[40].
- Remove or modify curb on approaches to, or alongside an existing barrier systems.[41]
  - Do the following (in order of preference)[42]:
    - Remove curb and gutter
    - Use driveway curb and gutter
    - Use 4-inch sloped face curb
- Shorten barriers that are longer than needed.[43]

[40] Barriers are hazards and require maintenance.
[41] Some modifications may allow a barrier system to be installed by curb. See SDDs and FDM for details.
[42] Contractors have access to equipment that makes removal of the head of curb easier to do.
[43] This assumes that the barrier was not lengthened to shield other hazards or to allow for proper grading for the EAT.

Some of the design guidance for new barrier systems can be used on existing barrier systems. Some examples are length-of-need, grading, and working width. More guidance on existing barrier systems is in the following subsections. Guidance in this subsection applies to roadside barriers systems. Guidance may apply to parapets on structures. Contact BOS for guidance on existing parapets.

A significant number of crashes occur in work zones. Replace or do spot repairs on existing barrier systems before shifting traffic closer to or increasing traffic near existing barrier systems.

Document the following:

- Not reviewing existing barrier systems.
- Leaving a barrier system that is no longer needed in-place.
- Leaving a "modified" barrier system in-place.[44]
- Not applying spot improvements or replacing a substandard barrier system.
- Not reviewing Length-of-Need
- Not modifying existing curb or installing 4-inch sloped face curb near a barrier system.

Other issues within this subsection may need additional documentation in the DSR.

When needed, provide individual construction details to retrofit existing barrier systems.

Barrier systems may have parts that can be salvaged. Coordinate with regional maintenance staff. Provide local unit of government contact within the plan.

Both removal and salvage items have language telling the contractor to restore the site. No additional bid items are needed to fill holes left by the contractor removing posts. If installing a new barrier at the same location, earthwork items may be needed.

30.5.1 Flexible Barriers

Replace low-tension cable barrier systems installed in non-median locations (See Figure 30.35). Typically, these systems are not crashworthy, have fixed objects within a barrier's working width, or have grading issues.

Coordinate with the WisDOT project manager, the regional design oversight engineer and maintenance personnel before removing or working near median cable barrier. Review grading, cable barrier placement, drainage structures, and soil conditions. Those items can influence performance.

Review FDM 11-45-30.3.2 for more information on cable barrier.

Desirably, remove curb and gutter near cable barrier systems.

Figure 30.35 Strong Post Low-Tension Cable Barrier to be Replaced

30.5.2 Semi-Rigid Barriers

Semi-rigid barriers include:

[44] The WisDOT project manager and the regional design oversight engineer may grant case-by-case design justifications (DJ) allowing modification of barrier system. Document the DJ in Design Study Report.

- Non-MGS beam guard (See SDD 14B15)
- MGS beam guard (See SDD 14B42)
- Transitions to rigid barrier[45]
- Bullnoses
- Curved beam guard

General guidance can be applied to almost all semi-rigid barriers systems and special applications of semi-rigid systems. Examples are (the list is not all-inclusive):

- Damaged parts
- Missing parts
- Washer between rail and bolt head
- Working width
- LON
- Grading

There are some differences between systems. Examples are (the list is not all-inclusive):

- Depending on speed, normal non-MGS beam guard needs adjustments and specific types of curb
- Normal MGS does not need adjustments or special types of curb
- Special application of beam guard may need a special curb or cannot use curb

What works for one barrier system may not work for another system. Know what barrier systems are within a project.

In many cases, specialty applications of a barrier system has more design requirements than normal barrier system. Examples are (the list is not all-inclusive):

- MGS long-span cannot have curb installed by it.
- Regardless of speed, non-MGS long span cannot have curb installed by it.

Some circumstances may need individual construction details.

CMM 6-25 has examples of semi-rigid barrier that need repair. Table 30.11 is an example of a miscellaneous quantity sheet for semi-rigid repair items. Use the limits of the barrier installation to identify where to use bid items. For example, show stationing from post number one of an EAT to post number one of an EAT in the plan.

Table 30.11 Example Miscellaneous Quantity Sheet

Location	204.0165 Removing Guardrail LF	614.0400 Adjusting Steel Plate Beam Guard LF	614.0920 Salvaged Rail LF	614.0950 Replacing Guardrail Posts and Blocks Each	614.0951 Replacing Guardrail Rail and Hardware LF
2+00 to 3+00 LT		35		--	25
3+00 to 7+35 RT		150		75	100
8+00 to 10+50 LT	250				
15+00 to 19+00 RT			600		
Total	**250**	**185**	**600**	**75**	**125**

30.5.2.1 Adjustment of Steel Rail Height

Top of rail for existing non-MGS beam guard is between 27 3/4 to 29 inches.[xciii] Top of rail for existing MGS beam guard is between 27 3/4 to 32 inches.[xciv,xcv] Top of thrie beam rail is plus or minus 1 inch of the rail height

[45] Rigid barriers includes bridge parapets and concrete road barriers.

in the applicable standard detail drawing. Standard Spec 614 provides guidance on adjusting rail height.

Verify top of rail's height once every 50 feet. Measure the rail's height at mid-span. Do not measure rail height on damaged rail sections or at locations where erosion or other grade abnormalities would cause errors in height measurements.

Use caution when the majority of a barrier system is using the maximum height adjustment.

Use adjustment item (614.0400) by itself or with other spot improvements.

30.5.2.2 Replacement of Steel Rail

Replace torn, dented, flattened, and kinked rails. Replace rails with additional holes punched into them or rails with structural rust (i.e. not small locations of surface rusting). Use steel rail replacement item (614.0951). Show in plan when replacing thrie beam with the replacement item. Provide radii in the plan when replacing bent rail (See FDM 11-45-30.5.2.12).

Review thrie beam bullnose rail replacements. These rails may be bent and have slots. Use rail number or rail number and letter to show what rail to replace.

Do not use steel rail replacement item on EATs. EATs are proprietary products and may need special rails.

30.5.2.3 Replace Posts and Block

Replace posts or blocks that are rotten or damaged. Replace or adjust blocks that are 1½ inch above or below the rail. Use replace block and post item (614.0950).

Posts in foundation/soil tubes are important for the entire semi-rigid system. Replace damaged post in soil tubes. Use replace block and post item (614.0950). Show in the plan that posts being replaced is in a foundation/soil tube for bullnoses and Type 2 end treatments. Include appropriate SDDs in plan so contractors can order the correct posts.

Do not use 'replace post and block' item on EATs. EATs are proprietary products. Use a special provision to replace blocks and posts in EATs.

Do not use 'replace post and block' item for anchor post assemblies.

30.5.2.4 Straightening Blocks or Posts

Straighten out of plumb blocks. Straighten posts 6 or more inches out of plumb.[xcvi] Use the adjust item (614.0400) for straightening blocks or posts.

30.5.2.5 Other Hardware Issues

The following issues need special provisions:

- Removing washers installed between the head of a bolt and traffic side of steel rail[xcvii,46]
- Replacing delineators that are missing
- Lapping rails in the correct direction (see SDD 14B15 or SDD 14B42) [47]
- Remove signs, mailboxes, and other objects mounted to beam guard

[46] A washer in this location can cause semi-rigid barrier to fail.

[47] In temporary conditions (e.g. a unidirectional road has become bidirectional), it is not necessary to change rail lap direction.

Figure 30.36 Sign Mounted on Beam Guard

30.5.2.6 Use of Salvage or Removal Bid Item

Use salvage and removal bid items separately. Use removal item (204.0165) if the contractor is to dispose of all parts.

Use salvage item (614.0920) to reclaim metal parts. The standard specification is not set up to reclaim wooden parts. Installing and cutting a post to proper height may make it difficult to reuse the post. Exposure to the elements may weaken wooden parts.

Use a special provision when (the list is not all-inclusive):

- Reclaiming all semi-rigid barrier parts (e.g. metal and wood)
- The contractor is to disassemble hardware. Others select what hardware they wish to have. Finally, the contractor is to dispose of the remaining hardware.

Removing a semi-rigid barrier can help other work or allow for a better-finished product. For example, an overlay project can add shoulder material. Removing the beam guard can allow proper compaction of the shoulder material.

30.5.2.7 Grading for Semi-Rigid Barriers

Review grading of existing semi-rigid barrier. Modify grading or semi-rigid barrier when grading is missing. See 11-45-30.3.1.3 for discussion of grading and shaping item. Review FDM 11-45-30.3.3.1 for more discussion on grading and other issues important to semi-rigid barriers and special applications of semi-rigid barriers. See grading options for semi-rigid barrier systems in other parts of 11-45-2, or on the SDDs.

Review grading near foundation/soil tubes. These tubes provide strength for the whole semi-rigid barrier system. Visual gaps between tube and soil reduces the amount of energy the anchors can absorb. Small gaps should have soil replaced and compacted around the tube. Replace foundation/soil tubes when a soil gap is one inch or more. Provide special provisions to reset foundation/soil tubes or replace soil around the post.

30.5.2.8 Beam Guard

Beam guard is the most often used barrier system. Use Excel spreadsheet (Attachment 30.6), Table 30.12, and Table 30.13 to decide if beam guard is to be replaced or have spot improvements. Install new beam guard for issues in Table 30.12. Other issues not in Table 30.12 may influence the decision to install new beam guard.

Table 30.12 Issues that Warrant New Barrier System

Situation	Issue	Discussion
Project	A new hazard needs shielding.	Install the current standard.
	Other work on the project needs the beam guard removed.	Install the current standard.
Beam Guard Installation	Current beam guard has 12-foot 6-inch post spacing.	This installation is not crashworthy.
	Beam guard has had poor past performance.	A new barrier system may have better performance.
	At the post, beam guard has a w-beam backup plate.[48]	The w-beam backup plate may prevent rail and post separation during a crash (see Figure 30.40).
	Beam guard has a washer installed between the bolt head and the front face of the rail (see Figure 30.42).	A washer may prevent rail post separation.[49]
	Top of steel rail is less than 24-3/4 inches tall.	It is not possible to adjust rail to an acceptable height.
	The cost of spot improvements is greater than the depreciated value of the existing barrier system (see Excel analysis program).	It is less expensive to install a new barrier system.
	Total installation length (end treatments plus beam guard) is 75 FT or less. [50]	Shorter lengths of beam guard have not been crash tested. Fixed objects that are shielded by short beam guard still can be hit (see FDM 11-45-30.3.1.4).
	Beam guard is being used as a barrier system and retaining wall	See Attachment 30.26 for examples
	Beam Guard Class B is installed	Connecting beam guard directly to a 6x8 wood post allow for too much tire snag during an crash. Post spacing for Class B is 12.5 FT, which is too far apart to be effective. Often Beam Guard Class B was installed at locations where a vehicle can have a 90-degree crash.

[48] The last time that the w-beam backup plate was included in a standard detail drawing was 1981.

[49] The last time that the washer was included in a standard detail drawing was 1985.

[50] This length of beam guard only applies to terminal, beam guard, and terminal designs. Other designs (e.g. EAT, thrie beam transition and bridge parapet; EAT, beam guard, long-span, beam guard and EAT…) have different length requirements.

Figure 30.37 W-Beam Backup Plate

Table 30.13 is a list of situations that need at least spot improvements and may need replacement. Replacement of beam guard depends on the size and collective influence of spot improvements. Other issues not in Table 30.13 may influence the decision to use spot improvements or to replace beam guard.

Table 30.13 Issues that Warrant Spot Improvements of Beam Guard

Situation	Issue	Discussion
Beam Guard Installation	Non-MGS beam guard has curb and gutter installed near it (see FDM 11-45-30.3.3.1.5).	Curb and gutter have a negative influence on beam guard performance.
	Beam guard posts cannot freely rotate in asphalt, millings, or concrete (see FDM 11-45-30.3.3.1.4).	Pinned posts increase the likelihood of beam guard not working as intended.
	Beam guard lacks working width (see Figure 30.38).	Beam guard can direct a vehicle into the fixed object (see Figure 30.37), or vehicle can lean over the barrier and strike a fixed object. See FDM 11-45-30.3.1.1
	Lack of grading behind beam guard with 6-foot 3-inch post spacing (See FDM 11-45-30.3.3.1.3).	Lack of soil behind posts increases the likelihood of beam guard failure.
	Steel rail or wooden planks are used to control erosion, water or right-of-way (see Figure 30.40)	Steel rail or wooden planks limit post rotation
	Improperly flared beam guard (see FDM 11-45-30.3.1.5)	Barrier flared improperly may not work as intended.
	Beam guard posts or blocks are missing, out of plumb, or damaged.	Missing, damaged, or out of placed hardware can influence barrier performance.
	Steel rail is Weathering or Cor-Ten steel.[51]	This steel makes it difficult to perform maintenance on.
	Total installation length (end treatments plus beam guard) is 175 FT or less. [52]	Beam guard is typically crash tested using 175 FT of barrier. Fixed objects shielded with shorter lengths of beam guard may be hit (see FDM 11-45-30.3.1.4). Review barrier for length-of-need.
	Beam guard is installed without anchorages	Beam guard uses anchorages to absorb energy.
	Steel rail is damaged.	Weakened rail may not work as intended.
	Lack of transition between beam guards with significantly different working widths (see FDM 11-45-30.3.1.1).	Beam guard may form a pocket when struck.
	Objects installed on top of beam guard (e.g. signs, mailboxes)	Beam guard is not tested with objects on top of it. These objects may penetrate the vehicle cab. Plastic delineators are acceptable when attached to block or post.

[51] Weathered or Cor-Ten steel is specially designed to have a stable rust surface that does not require painting. This type of steel was used for a while as an aesthetic treatment.

[52] This length of beam guard only applies to terminal-beam guard- terminal designs. Other designs (e.g. EAT, thrie beam transition and bridge parapet; EAT, beam guard, long-span, beam guard and EAT) have different length requirements.

Figure 30.38 Utility Pole placed within Working Width of Barrier

Figure 30.39 Beam Guard Directed Vehicle into Utility Pole[xcviii,53]

[53] More than likely, the beam guard was installed to shield the bridge pier. If the beam guard was not there the vehicle, more than likely, would have missed the utility pole.

Figure 30.40 Wood planks limit post rotation

The following situations need additional engineering to decide what action to take (this list is not all-inclusive):

- Beam guard is on slopes steeper than 10:1.
- Beam guard is over a drainage feature (e.g. bridge, box culverts, culverts, pipes).[54]
- Beam guard is shielding a vehicle from going over the top of a retaining wall or other structure.[55]
- Most of a barrier installation needs the maximum height adjustment.
- If a project has a service life greater than 15 years (see duration discussion in Attachment 20.1).

30.5.2.9 MGS Attaching to Existing Class A

Although it is possible, BPD does not recommend intermixing of MGS and Non-MGS systems. There has been no crash testing of this connection.

30.5.2.10 Treatments Near Rigid Barrier-Transitions

There are three types of treatments near the beginning and end of existing rigid barriers:

- Unconnected beam guard (see Figure 30.41)
- Beam Guard Transition to Rigid Barrier (See Figure 30.42)
- Thrie beam transitions (See SDD 14B20, SDD 14B45 and Figure 30.43)

[54] A previous construction project may have installed shorter posts, used other methods to mount the beam guard to the drainage structure, or used a long-span beam guard design.

[55] The consequences of a collision (i.e. a vehicle goes over the beam guard) may require a different barrier system. Retaining wall may need to be designed to accommodate crash loads.

Figure 30.41 Unconnected Beam Guard[xcix]

Figure 30.42 Beam Guard Transition to Rigid Barrier

Figure 30.43 Thrie Beam Missing Posts

There are different choices to update barriers near a rigid barrier. The choices depend on (the list is not all-inclusive):

- Type of treatment (see Figure 30.41 through Figure 30.43)
- Direction of travel
- What deficiencies are present
- Speed
- Crashworthiness of the rigid barrier

Approach transitions (i.e. transition from a more flexible barrier to a rigid barrier) are more critical than departure transitions (i.e. transition from a more rigid barrier to a more flexible barrier).

Review parapets on, or connected to, a bridge, retaining wall or other structure. Coordinate with the WisDOT project manager, the regional design oversight engineer and BOS if parapet is not shown in:

- Standard detail drawings
- LRFD Bridge Manual
- BOS's standard detail drawings

The parapet may have crashworthiness issues. For example, a parapet designed before 1964 may lack the strength to contain a crash.[c] Parapets designed after 1964 may have enough strength, but the parapet may have other issues (e.g. snagging, pocketing...).

Provide additional engineering to evaluate the parapet or develop alternative retrofit designs. Coordinate with the WisDOT project manager and the regional design oversight engineer and BOS early in the design or scoping. Crashworthiness of a parapet can have a significant influence on a project's scope.

Review location for other hazards besides the blunt end of the rigid barrier. If possible, remove the other hazards and focus on shielding or delineating the blunt end of the rigid barrier[56].

If an existing installation does not have at least 2 feet of grading behind the existing posts, options are (in order of preference):

1. If there is enough right-of-way, provide 2 feet of grading behind the posts.
2. Extend rigid barrier to a location that would allow for proper grading for the transition.
3. If there is not enough right-of-way or there is a restriction preventing the use of the right-of-way, install a retaining wall.

Provide individual construction details.

Use standard semi rigid barrier adjustments bid items to provide spot improvements. Special SDDs have been developed to retrofit transitions to rigid barriers when posts are missing and cannot be reinstalled (SDD 14B48, SDD 14B49, SDD 14B50 and SDD 14B51). These special SDDs are designed for class A thrie beam

[56] Delineating a roadside hazard is the least desirable roadside design treatment and requires documentation in Design Study Report.

transitions.

Transitions to rigid barrier may also use the grading shaping item.

Figure 30.44 Problematic Thrie Beam Transition to Rigid Barrier

Figure 30.45 New Thrie Beam Transition with Drainage Problems

Figure 30.38 has a thrie beam transition to a rigid barrier. This transition has the following issues: post pinned into position by asphalt, lack of grading behind posts and inadequate post embedment.

Transitions were not designed to be curved or flared away from the road. Coordinate with the WisDOT project manager and the regional design oversight engineer when there are curved or flared installations. Provide additional engineering and special bid items.

Some older parapets were constructed with a notch in the parapet (see Figure 30.46). Approach transition SDDs have had notes on them telling contractors to install a wood block. In many cases, the block has not been installed. Use the ‘replace block’ bid item, appropriate transition SDD, and add a note in the plan pointing to the location needing a block.

In Figure 30.47, the existing combination rail has a horizontal crack, that should be discussed with BOS.

Figure 30.46 Missing Wood Block is a Snag Point

Figure 30.47 Damage to Parapet and Height of Parapet Issues

30.5.2.10.1 Unconnected Beam Guard

Unconnected beam guard near a rigid barrier is a significant hazard (i.e. Figure 30.41). The beam guard near the blunt end is a concern. Unconnected beam guard is an issue on the approach and departure ends of a rigid barrier.

All beam guard end treatments installed like Figure 30.41 will allow a vehicle to hit the blunt end of a rigid barrier. An example of an end treatment allowing a vehicle to hit a blunt end of a rigid barrier is in Figure 30.48.

The end treatment in Figure 30.41 is a potential spearing hazard for a vehicle traveling in the opposite direction. An end treatment, like the one pictured in Figure 30.41**,** may not provide the beam guard enough strength to contain a vehicle. Review FDM 11-45-30.3.3.1.2, FDM 11-45-30.4.4, and 11-45-30.3.5.

Figure 30.48 Unconnected Beam Guard Gated or Directed Vehicle into Blunt End[ci]

If there is no other object to shield, but the blunt end, review using a crash cushion or sand barrel array. A sloped end treatment may be used on low speed roads (see FDM 11-45-30.5.6). If beam guard is needed to shield other hazards, use a thrie beam transition to a rigid barrier. In certain circumstances, a beam guard transition to rigid barrier may be used (see FDM 11-45-30.5.2.10.2).

30.5.2.10.2 Beam Guard Connected to Rigid Barrier

Beam guard connections may experience pocketing (see Figure 30.10 and Attachment 30.21) or other failures during a crash.

Figure 30.49 Pocket Formed by Vehicle Hitting Beam Guard Connected to Parapet[cii]

There may be situations where a special beam guard transition to rigid barrier could be used.

A beam guard transition to a rigid barrier is not as desirable as installing a thrie beam transition to the rigid barrier. BPD is trying to balance between allowing minor projects to advance, and providing an improvement to roadside safety.

Coordinate with the WisDOT project manager and the regional design oversight engineer if considering the use of a beam guard transition to rigid barrier.

30.5.2.10.3 Thrie Beam Transitions

Since 1990, thrie beam transitions to rigid barriers have been installed by the Department. The thrie beam transition drawings have had various changes. The preferred method is to install a thrie beam transition to rigid

barrier as shown in standard detail drawings.

Existing non-MGS installations that have the following may remain in-place:

- Posts:
  - Quarter post spacing (i.e. 1 foot 6 3/4 inches) for the first 6 posts upstream of the rigid barrier.
  - Half post spacing (i.e. 3 foot 1 1/2 inches) for the next 4 posts upstream of the quarter post spacing).
- Steel thrie beam:
  - 12 1/2 feet of nested thrie beam rail upstream of the rigid barrier.
  - A minimum of 12 1/2 feet of standard thrie beam rail following the nested thrie beam rail.

It is typical to replace missing posts within the thrie beam transition. Posts may conflict with drainage structures. Move drainage structures to allow for post installation. Review discussion about approach transition retrofits in FDM 11-45-30.5.2.10.

Existing curb and gutter may remain in-place. Review guidance provided in FDM 11-45-30.3.5.

Some thrie beam transitions to single slope barrier are missing the connector plate detailed in SDD 14B45. Without these plates installed, a tire may snag on the blunt end of the thrie beam anchorage. To install plates, use a special provision and SDD 14B45. Write special provision to install the connector plate and reset approach transition.

If using the 'replace rail' item, note that a thrie beam rail or thrie beam transition piece is being replaced in the miscellaneous quantities.

30.5.2.11 Bullnoses

WisDOT has utilized at least three different bullnose designs. Only the thrie beam bullnose design has been successfully crash tested to NCHRP 350. The three systems are:

- Downturned end treatment bullnose (See Figure 30.50)
- Bent beam guard bullnose (See Attachment 30.7)
- Thrie beam bullnose (SDD 14B26)

Replace downturned end treatment bullnoses and bent beam guard bullnoses.

Thrie beam bullnoses may remain in-place if they are installed correctly and are in good working order. Review thrie beam bullnose installations for other issues that may influence performance (e.g. grading, working width, curb and gutter, fixed objects too close to rails 1 and 2 of bullnose, missing or damaged components).

Remove curb on the approach to, and along the side of bullnoses. 'Grading at Bullnose' drawing in SDD 14B26 sheet A has the approximate area where curbs should be removed. If curb cannot be removed follow guidance in the beginning of FDM 11-45-30.5 discussion on curb.

Figure 30.50 Downturned Bullnose Design

Vehicles hitting the nose of the bullnose need the area behind the rail to stop. Figure 30.51 and Figure 30.52 show the final resting place of some crash test vehicles.

SDD 14B26 shows where objects should not be placed within a thrie beam bullnose. Remove objects, even if they are breakaway, from this area. The trees in Figure 30.53 will cause a bullnose not to work correctly.

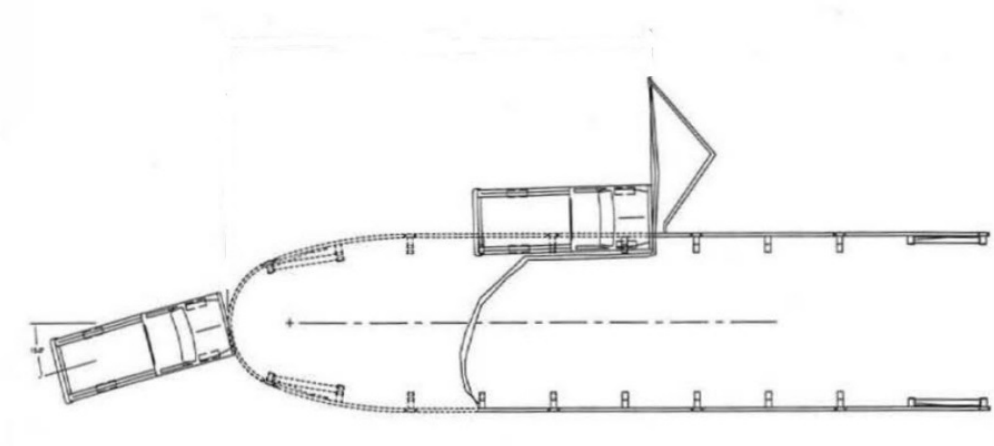


Figure 30.51 Offset Nose Crash Test with Pick-up Truck[ciii]

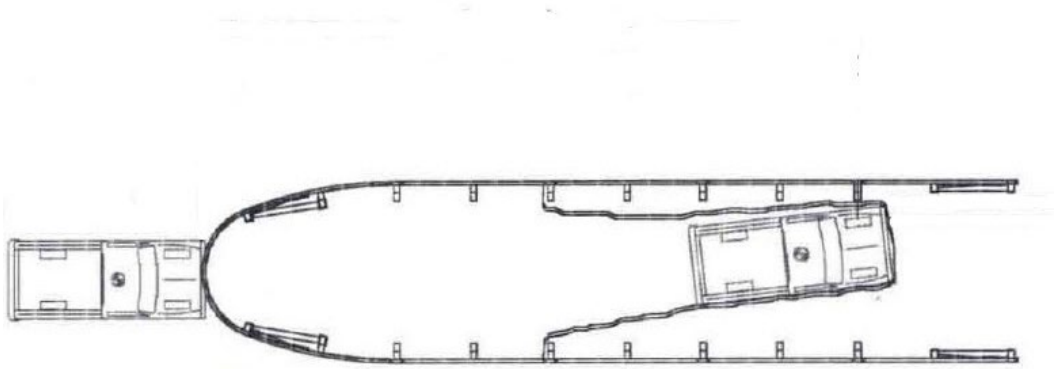


Figure 30.52 Head-on Crash Test with Pick-up Truck[civ]

Figure 30.53 Trees placed within Bullnose

Remove objects that are within the working width of the sides of the thrie beam bullnoses.

30.5.2.12 Curved Beam Guard

Curved beam guard is any beam guard that is bent to a radius.[57] In general, WisDOT does not want to use curved beam guard because of cost, longer repair time, and crashworthiness issues. However, site specific or project related issues may allow the use of a curved beam guard. For example, crashing into curved beam guard may be more desirable than crashing into a different hazard.

Review curved beam guard with radiuses 150 feet or less. Use SDD 14B27, SDD 14B53, and 11-45-30.3.3.2 to review existing hardware. Implement spot improvements or full replacement of curved beam guard sections that do not match SDDs or FDM. Replace short radiuses that are less than 8 FT with a larger radius system or other hardware.

Provide individual construction details.

The short radius system may need more right-of-way. Review right-of-way early in design.

Figure 30.54 Problematic Short Radius with installation Problems

The installation in Figure 30.54 has the following issues:

- Not using CRT post in radius

[57] Radii 150 feet or less require shop bending.

- Not enough beam guard along the low volume road
- Wrong end treatment
- curb and gutter

30.5.3 Concrete Barriers

WisDOT has used various shaped concrete barriers (See FDM 11-45-30.3.6). Issues in Table 30.14 require a new concrete barrier. Other issues not in Table 30.14 may influence the decision to install a new concrete barrier.

Table 30.14 Issues that Warrant New Concrete Barrier

Situation	Issue	Discussion
Project	Shielding a new hazard.	Install the current standard.
	Other work requires the removal of a whole run of concrete barrier.	Install the current standard.
	Structural protection is needed (FDM 11-35-1).	LRFD crash loads need special barrier designs.
Concrete Barrier	The barrier is GM shaped.	GM shaped barrier has not passed NCHRP 350 testing.
	Concrete barrier does not match NJ, F, single slope or vertical shapes (See FDM 11-45-30.3.6).	Barrier shape is a non-crash tested design.
	A concrete barrier flare rate is too steep. See FDM 11-45-30.3.1.5.	Barrier flared too steep may not work as intended.
	Overlays greater than 3 inches adjacent to a NJ, or F shaped barrier (see Figure 30.55).	NJ and F shaped barriers can allow up to 3 inches of overlays.[cv]
	Single slope barrier with a height less than 32 inches (see Figure 30.55).	Shorter single slope barriers may have difficulties redirecting larger vehicles.

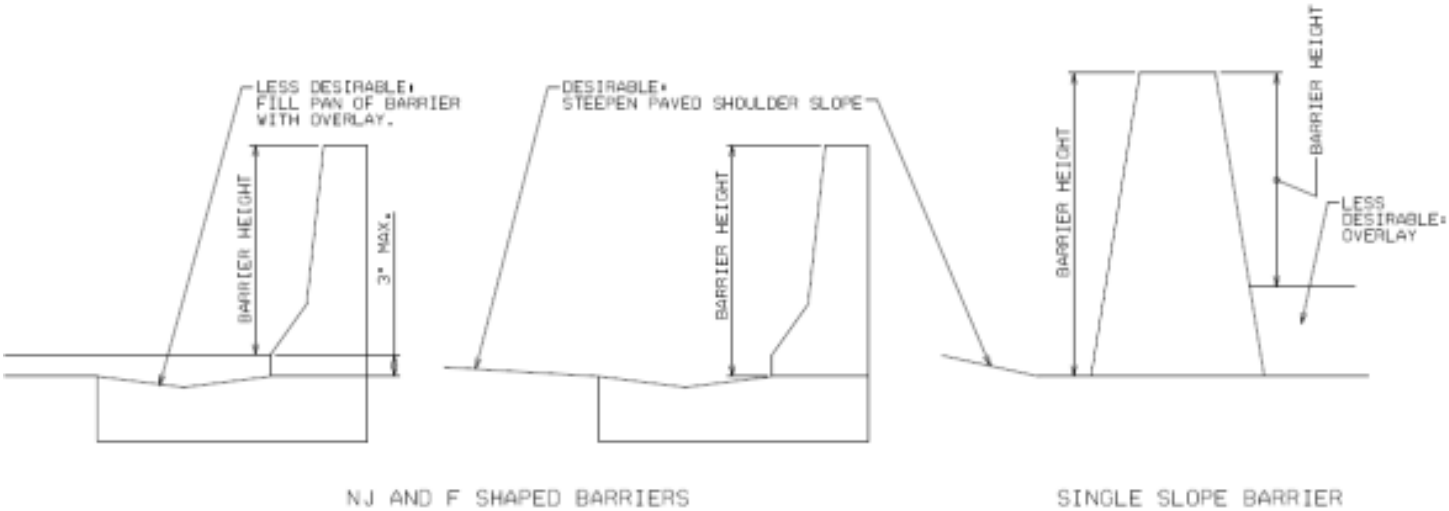


Figure 30.55 Overlays near NJ, F, and Single Slope Barriers

Vehicles can vault over or hit objects just behind shorter concrete barrier. From a roadside design perspective, it is more desirable to steepen paved shoulder slopes when overlaying near concrete barrier. Steepening the

shoulder slopes can maintain the height of the barrier.[58] Sometimes combining milling with steeper shoulders will minimize or prevent reducing the height of concrete barrier. It may not be possible to steepen shoulder slope to avoid reducing concrete barrier height. Overlays alongside the barrier (Left side of Figure 30.55) may cause drainage issues.

The minimum height for single slope concrete barrier on freeways or expressways with design speeds greater than 45 mph is 36 inches. Single sloped concrete barriers with a height of 32 inches may be acceptable on other roads.

Avoid reducing barrier height in the following locations:

- Fixed objects are close to the barrier
- Consequences of a collision is severe
- Pick-up trucks or smaller vehicles have ridden on top of, hit fixed objects on the barrier or vaulted over the barrier
- Crash history of large vehicle crashes into a barrier

Table 30.15 is a list of situations that would need at least spot improvements and may need the concrete barrier to be replaced. Replacement of concrete barrier depends on the size and collective influences of spot improvements. Other issues not in Table 30.15 may also influence the decision to use spot improvements or fully replace concrete barrier.

Table 30.15 Issues that Warrant Spot Improvements

Situation	Issue	Discussion
Project	The project needs to partially remove concrete barrier to make repair work easier.	Shorter sections of concrete barrier can be replaced in kind
Concrete Barrier Installation	Police reports show that vehicles are vaulting over, riding on top of, or striking objects behind, on top of the barrier.	See discussion below.
	Concrete barrier has open cracks that extend through the barrier (see Figure 30.59 through Figure 30.61).	Concrete barrier with open cracks may fail during a crash or launch projectiles at other vehicles or pedestrians.
	A concrete barrier has exposed or rusted reinforcement.	The concrete barrier is structurally weak and may fail during a crash.
	A concrete barrier is tipping over or faulting (see Figure 30.56).	The concrete barrier may snag a vehicle during a crash.
	Sections are more than 2 inches offset from each other (See CMM 1-45.12.5.9 for examples).	The concrete barrier may snag a vehicle during a crash
	A concrete barrier has an opening greater than 4 inches long (See CMM 1-45.12.5.9 for examples).	The concrete barrier may snag a vehicle during a crash.
	A concrete barrier has open gaps (see Figure 30.58).	The concrete barrier may snag a vehicle during or fail during a crash.
	A concrete barrier has abrupt changes in cross-sectional area (see Figure 30.57).	The concrete barrier may cause rapid deceleration or launch vehicle into opposing lanes.
	Curb and gutter is in front of a concrete barrier.	Concrete barrier may not work as intended when curb is in front of it.
	A concrete barrier has a blunt end.	Blunt ends not a crashworthy.

Issues like Figure 30.56, will need limited engineering effort (i.e. remove the barrier and replace with new). Other issues, like Figure 30.57, Figure 30.58, Figure 30.59 and barrier openings (see CMM 1-45.12.5.9), will

[58] Review other sections of FDM about maximum shoulders slopes and maximum algebraic difference in slopes.

need more engineering effort. Coordinate with the WisDOT project manager and the regional design oversight engineer early in design.

Review FDM 11-45-30.5 for guidance on curb. Review FDM 11-45-30.3.6 for guidance on concrete barrier design.

Special provisions and construction details may be needed.

Use bid item 204.0157 to remove the concrete barrier. Use this bid item to remove transitions, standard sections of concrete barrier and concrete anchorages.

Acceptable repairs to concrete barrier depend on (the list is not all-inclusive):

- Extent of the repair
- What part of the concrete barrier system needs work
- Type of barrier

The extent of repairs may be minor. For example, repairing cracks on the concrete barrier (damage like Figure 30.59 through Figure 30.61), may not provide structural strength for critical crashes. Repairing cracks may help reduce future deterioration of the barrier, limit snag, limit the size of barrier fragments from a crash, and provide some shielding for less than critical crashes.

Issues like Figure 30.59 through Figure 30.61 may be only a few feet of repair. Other issues, such as Figure 30.56 may be hundreds of feet long.

Issues like Figure 30.57 can cause excessive deceleration, damage to object on barrier, and abruptly redirect a vehicle back into the lanes of travel. Modification to situations similar to Figure 30.57 will need more engineering.

Repairs near the end of a concrete barrier, transition, or bridge parapet may need vertical steel. Not providing vertical reinforcement near the end of the barrier may lead to barrier failure. Not adjusting the shape of a barrier could lead to wheel snag, excessive deceleration, or vehicle rollover. Situations like this may require removal of an end or transition.

Review FDM 11-45-30.3.6.4 and SDD 14B32 to SDD 14B41 when repairing single slope barrier and transitions.

Single slope barrier, SDD 14B32 sheet E provides guidance on how to repair or replace sections standard single slope barrier.

Use details like Attachment 30.22 to fully replace middle sections of older safety shaped concrete barrier designs.

Provide additional engineering, special details, individual construction details, special provisions when doing improvements to existing concrete barrier. Coordinate with the WisDOT project manager and the regional design oversight engineer early in the design.

Figure 30.56 Concrete Barrier Tipping Over

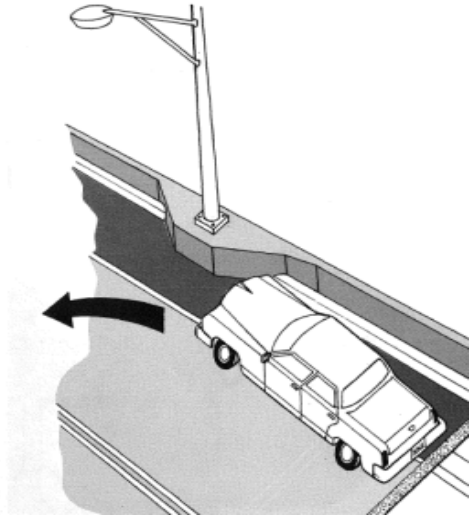


Figure 30.57 Cross-Sectional Changes in Barrier[cvi]

Figure 30.58 Opening in barrier that can snag a vehicle[cvii]

Figure 30.59 Cracked Concrete Barrier Needing Repair

Figure 30.60 Cracked Concrete Barrier Needing Repair

Figure 30.61 Cracked Concrete Barrier Needing Repair

30.5.4 End Treatments

Review guidance in FDM 11-45-30.4.

Replace existing downturned (Figure 30.65) or blunt terminal ends (see Figure 30.62 and Figure 30.63), including breakaway cable terminals (BCTs) (see Figure 30.64) and modified eccentric loader terminal (MELT) systems (see Figure 30.66), with appropriate anchorages.

SRT-350 terminals (Figure 30.67) may remain in-place if they are in good working order and installed correctly.

Figure 30.62 Blunt Ends

Figure 30.63 Blunt Ends[59]

Figure 30.64 BCT terminal[cviii]

[59] Besides the blunt ends the beam guard also has the following issues: improper steel posts, overall barrier length is not sufficient to protect hazard and utility pole is a hazard.

Figure 30.65 Downturned End Treatment

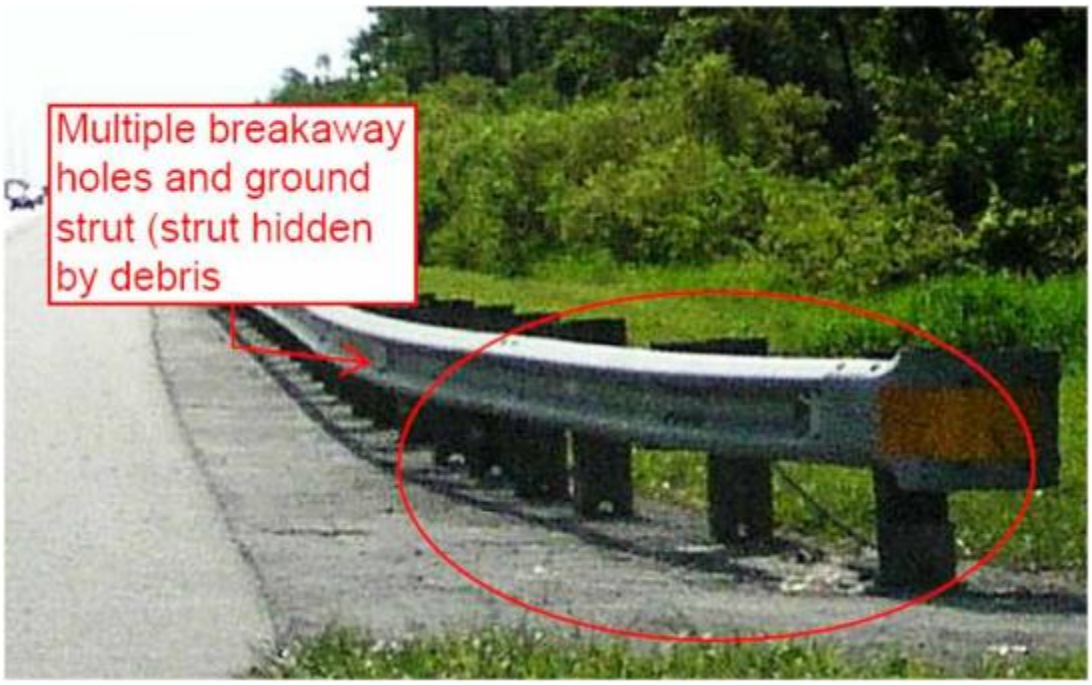


Figure 30.66 MELT[cix]

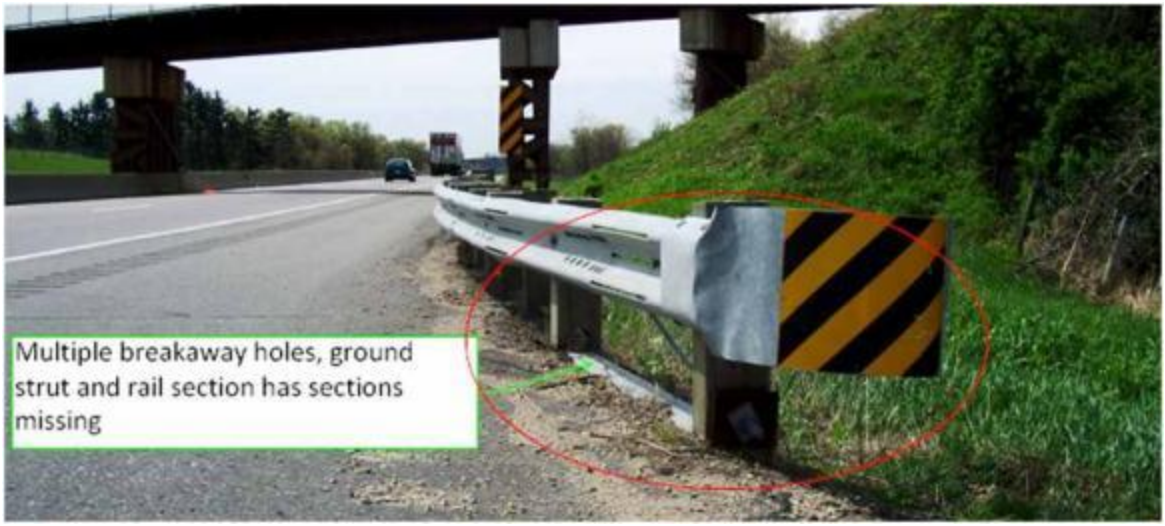


Figure 30.67 SRT-350[cx]

Older NCHRP 350 crashworthy EATs may remain in-place if they are in good working order:

- ET-2000 (See Figure 30.68)
- SKT-350 (See Figure 30.69)
- ET-Plus (See Figure 30.70)

Figure 30.68 ET-2000

Figure 30.69 SKT-350

Figure 30.70 ET-Plus

If an older EAT is not in working order, replace with a newer crashworthy terminal.

Review existing terminals for proper grading, hardware, and rail height, reflective sheeting and EAT. The terminals uses the same height and height tolerance as the semi-rigid barrier it is attached to. Provide appropriate grading. See appropriate section of FDM for guidance on grading. Coordinate with the WisDOT project manager and the regional design oversight engineer if there is an issue with grading.

Replace existing beam guard end terminals that are too close to one another (see Figure 30.30).

Beam guard end terminals are not designed for backside hits.

Review FDM 11-45-30.4.1.6 for guidance on curb and gutter placement near existing beam guard end terminals. Consider sawing the head of the curb, if full removal is not necessary.

Provide individual construction detail drawings for beam guard end terminals retrofits.

Extend beam guard far enough downstream to prevent a vehicle from gating through Type 2 end terminal and hitting a hazard (see FDM 11-45-30.4.3).

A broken post in an end treatment may limit the effectiveness of a barrier system. Review end treatments for broken posts and replace these posts. Use special provisions, special detail drawings of the post, and indicate

where a post is to be replaced. Note that posts within the EAT are proprietary. These post need to come from the manufacturer. A project may need to have multiple special provisions to replace posts for various beam guard end treatments.

Remove objects attached to beam guard end terminals (e.g. signs, mailboxes…). An object attached to beam guard end terminal could penetrate into the vehicle cab.

Figure 30.71 Sign Mounted to Post 2 of and EAT

Beam guard end terminals using a cable attached to a foundation/soil tube need to review cable tension. The cable transfers crash forces to soil tubes. Slack cables may allow too much rail movement during a crash.

Visual gaps between foundation/soil tubes and soils around the tube reduces the amount of energy the beam guard system can absorb. Small gaps should have soil replaced around the tube and compacted. Replace foundation/soil tubes when a soil gap is one inch or more. If there are issues with gaps around foundation/soil tubes, provide special provision fix the foundation/soil tube problem.

30.5.5 Crash Cushions and Sand Barrel Arrays

Issues in Table 30.16 need new crash cushions or sand barrel arrays. Other issues not in Table 30.16 may also influence the decision to install a new crash cushion or sand barrel array.

Table 30.16 Issues that Warrant New Crash Cushion or Sand Barrel Array

Situation	Issue	Discussion
Project	A new hazard needs shielding.	Install the current standard.
	Other work needs the crash cushion or array removed.	Install the current standard.
Crash Cushion or Sand Barrel Array Installation	The crash cushion is a GREAT (see Figure 30.72 and Figure 30.73).	GREAT does not meet the current crash test standard.
	Crash cushion or array was installed before October 1, 1998.	Systems installed before this date do not meet current crash test standards.
	Crash cushion or array has had poor past performance.	A newer crash cushion or array may perform better.

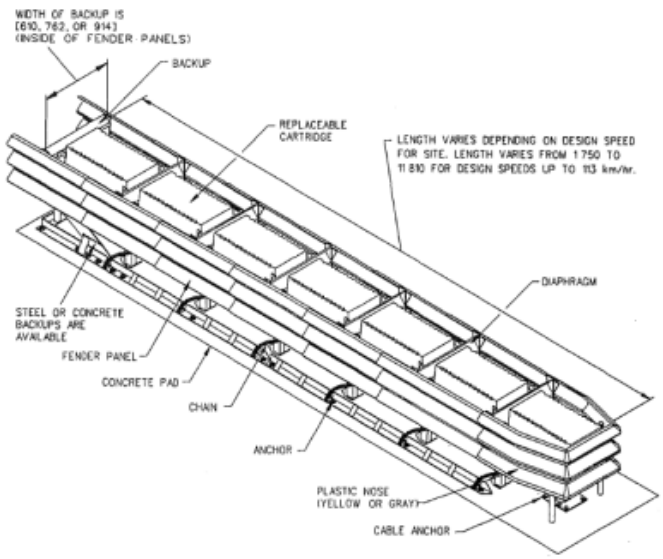


Figure 30.72 GREAT Crash Cushion[cxi]

Figure 30.73 Photo of GREAT installation

Table 30.17 is a list of situations that would need at least spot improvements and may need replacement. Replacement depends on the size and collective influence of spot improvements. Other issues not in Table 30.17 may also influence the decision to provide spot improvements or fully replace a crash cushion or array.

Table 30.17 Issues that Warrant Spot Improvements Crash Cushion or Array

Situation	Issue	Discussion
Crash Cushion or Sand Barrel Array Installation	Cushion or array is not on a paved surface.	A paved surface anchors the crash cushion. The crash cushion may not work without a paved surface.
	Paved surface is in poor condition	A paved surface anchors the crash cushion. The crash cushion may not work without a paved surface.
	The crash cushion is not anchored into a paved surface.	If the crash cushion is not anchored into a paved surface the crash cushion may not work.
	Curb and gutter is on the approach or alongside the crash cushion or array.	Curb can have negative influences on performance.
	Grading from the edge of lane to the crash cushion or array is steeper than 10:1. Grading under the array or crash cushion is 10:1 or flatter.	A vehicle may not engage the crash cushion or array correctly.
	The array is 10 or more years old.	Older barrels are likely to fail because of exposure to UV rays. (e.g. yellow barrels look more like gray barrels or barrels are brittle)
	Connections between the object being shielded and crash cushion are missing.	Lack of a transition may allow the object that crash cushion is shielding to be hit. Transitions are needed on both sides of the crash cushion.
	Crash cushion or array has missing, improperly installed, or damaged parts.	The system may not work.

Review FDM 11-45-30.4.4 for more guidance on crash cushions or arrays.

Remove curb and gutter before and along arrays and crash cushions. Use driveway curb. If driveway curb cannot be used, use a 4-inch mountable curb.[cxii]

Review existing arrays using procedures in 2011 Roadside Design Guide, or manufacturer's most current array information. Replace arrays that are not to the NCHRP 350 crash test standard. If it is not possible to fit a new array into an existing location, review the use of a crash cushion.

Review arrays for:

- Minimum distance between barrels
- Minimum distance from barrels to object being shielded
- Correct number of barrels
- Correct weight of sand at the correct location
- Rock salt is mixed with sand

Existing barrels warp over time and may not accept new lids. Replace older warped barrels. If most of the barrels in an array need replacement, replace the whole array.

If feasible, adjust existing arrays using the following guidance:

- For bidirectional, arrays install some barrels to reduce the severity of reverse direction crashes (see Figure 8-41 of 2011 Roadside Design Guide).
- Angle arrays toward traffic (see Figure 8-42 of 2011 Roadside Design Guide).

.

Figure 30.74 Problematic Sand Barrel Array

Figure 30.74 is a problematic array. The array has the following issues: curb and gutter, no pad, and a damaged barrel.

Use special provisions to refurbish crash cushions. Include the name of the manufacturer, the name of the specific crash cushion. Point out what work the crash cushion needs in the special provisions. If multiple systems are within a project, use different special provisions for each crash cushion. Provide individual construction details when grading, installing a pad or a back-up block, or adjusting curb near a crash cushion.

Use special provision to repair individual barrels within an array. Provide individual construction details showing which barrel to replace and its' weight. Reference WisDOT's Product Approval List for arrays when using a special provision.

Use standard bid item to replace the whole array. Provide individual construction details when grading, installing a pad, or adjusting curb near array.

30.5.6 Sloped Concrete End Treatments

Replace approach sloped concrete end treatments with a crashworthy option. As previously stated, the Department does not want to install or leave sloped end treatment in areas where crashworthy treatments are feasible.

There could be existing site specific issues that may allow a sloped end treatment to be retrofitted at a location (i.e. slope end treatment is better than an exposed blunt end and sight restriction prevent installing a crashworthy option). Coordinate with the WisDOT project manager and the regional design oversight engineer when retrofitting a sloped end treatment.

Retrofitting in a new sloped end treatment into an existing location when all the following criteria exist:

- Design speeds are 40 mph or less
- Other road features prevent the proper installation of crash tested hardware
- Barrier has LON to protect roadside hazards
- 10:1 or flatter grading is present leading to and alongside the sloped end treatment

Sloped concrete end treatment will require additional engineering, special details and special provisions. See FDM 11-45-30.3.6.4.6 and Attachment 30.8 for guidance. Attachment 30.8 has an acceptable sloped concrete end section. Other "sloped" concrete sections that do not match the barrier design in Attachment 30.8 (such as Figure 30.75 or SDD 14B20 sheet c) are considered blunt ends.

Attachment 30.8 is a sloped concrete end treatment designed to match into a 32-inch F shaped barrier. To match into a taller barrier, extend slope to reach correct height. To match into a different shaped barrier, use similar geometry and transition to shape needed. The length of the sloped concrete end treatment will be 20 feet or longer. The length of the sloped concrete end treatment depends on the height of barrier matching into it.

Flare the sloped concrete end treatment. Extend slope concrete end treatments to limit the likelihood that a vehicle will ride up the sloped end treatment and interact objects nearby.

No curb or gutter should be leading into or alongside the sloped concrete end treatment. See FDM 11-45-30.5 for guidance on curb and gutter.

Figure 30.75 A "Sloped" End Treatment that Needs Replacement

Provide individual construction detail drawings and special provisions.

30.6 Drainage Features and Cattle Passes

Drainage features like culverts, bridges, large drainage conduits, and similar features have unique challenges. These challenges can make it difficult to select a roadside treatment. Cattle passes or similar features can have the same roadside design challenges. This section will discuss common challenges and potential roadside design treatments for these features.

Drainage features or cattle passes can be a hazard depending on orientation, the number of drainage features, and size. Drainage features or cattle passes with diameters greater than the value listed in the table below are hazards.

Table 30.18 Drainage Feature or Cattle Pass Size [cxiii]

Pipe Orientation to Road	Number of Culverts	Culvert diameters or box culvert opening width (inches)
Perpendicular	1	36
	2 or more	30
Parallel	1	24
	2 or more	All multi-culvert runs are hazards

If a part of the structure snags the undercarriage of a vehicle or the vehicle's bumper can hit the structure, the culvert is a hazard. The culvert is a hazard regardless of the opening size. Examples are (the list is not all-inclusive):

If a vehicle can fall into the culvert opening and hit the inside of a wing wall (see Figure 20.5)

If a headwall can snag the undercarriage of a vehicle (see Figure 20.6 and Figure 20.34)

Drainage features that are equal to or smaller than the values listed in Table 30.18 are not roadside hazards. However, consider treating smaller parallel drainage features. Treating smaller parallel drainage features is a best practice.

Also, other objects near a drainage feature or cattle pass can be considered a hazard (refer to Figure 30.77 and Figure 30.78). Examples are (the list is not all-inclusive):

- Water [60]
- Slopes

[60] Water 2 feet or deeper.

    - Leading to and departing from drainage feature.
    - Slopes that blend into drainage feature.
- Ditches
    - Non-traversable road's ditches.
    - Drainage ditches' slopes (i.e. non-road ditches).
    - Blending slopes:
        - Road backslopes and drainage ditch slopes.
- Other fixed object hazards.
- Overall drop from structure to ditch bottom.[61]

Other hazards typically increase the traveling public's crash exposure (refer to Figure 30.76) and may influence what treatments are used near the culvert. Some examples are (the list is not all-inclusive):

- Shielding may be a better option if there is deep water present
- A traversable grate may be a better option than extending a culvert if there is adequate existing grading

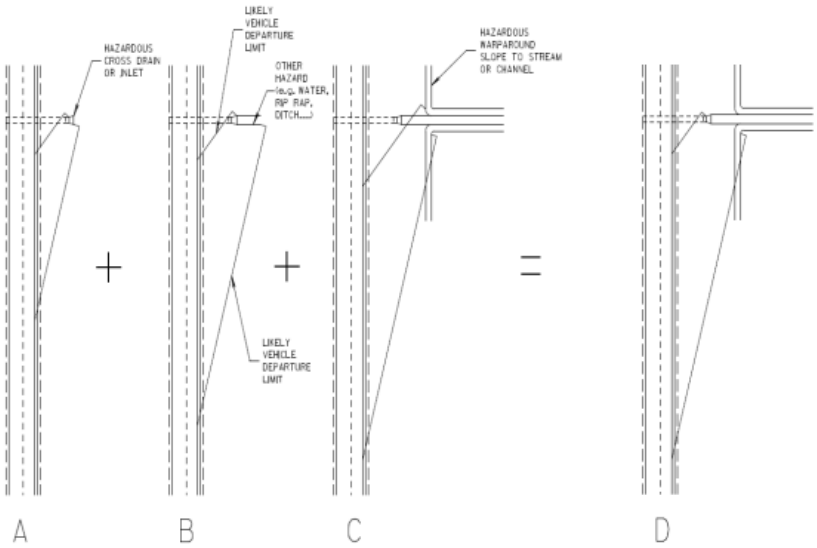


Figure 30.76 Likely Exposure Limits for Vehicles to Hazards (one direction of travel only)

[61] Vertical drops of 8 feet or more are hazardous. Vertical drops of 6 feet or more combined with other hazards (e.g. riprap or water) are hazardous.

Figure 30.77 Water and Culverts are Hazards

Figure 30.78 Overall height of this box culvert would need shielding. Edge of box culvert is just beyond clear zone.

Some of the alternatives to treat drainage features and cattle passes may need hydraulic analysis. See FDM Chapter 13 for more information.

Provide individual construction details for barrier systems or safety hardware near drainage features or cattle passes.

Use FDM 11-45-30.6 on perpetuation, rehabilitation and modernization projects. Guidance may apply to some Preventive Maintenance (PM) projects. The type of work within the PM project influences what roadside treatment is used. Some examples are in Table 30.19 and it is not all-inclusive.

Table 30.19 Roadside Treatment for Drainage Features or Cattle Pass on PM Projects

Type of PM Project or Work Being Performed	Traversable Grate	Extend, Remove or Move	Shield	Delineate
Drainage Restoration Project	X	X	X	X
Restoring grading near drainage feature or cattle pass	X	X	X	X
Restoring or installing riprap			X	X
Removing a barrier system for a culvert and installing a traversable grate	X			
Project is crack sealing and upgrading signage				X

Coordinate early with the WisDOT project manager and the regional design oversight engineer to decide on a roadside treatment. If a drainage feature or cattle pass cannot be addressed within a PM project, program a future project to address the issue.

The following subsections assume that the drainage feature or cattle pass is in good structural condition. When reviewing structural condition, it is important to review where safety hardware or a barrier system will attach to drainage feature or cattle pass. If there are questions about the structural condition of the drainage feature or cattle pass, contact BOS.

30.6.1 Perpendicular Drainage Features (Cross Drains) and Cattle Passes

This subsection deals with drainage features and cattle passes that are perpendicular or skewed to the direction of mainline travel. Treatments available are (in order of preference):

1. Traversable grates
2. Extending removing or moving cross-drain
3. Installing a barrier system
4. Delineate

30.6.1.1 Traversable Grates

From a roadside design perspective, traversable grates are the recommended treatment. In general, traversable grates have lower installation and crash costs than other treatments. Traversable grates can have a lower maintenance cost than a barrier system.

Do not install traversable grates on cross-drains for navigable waterways.

Review hydraulic capacity of cross-drains before installing traversable grates.

Refer to FDM 11-45-30.2.10 for a warrant on using traversable grates for perpendicular drainage features (cross drains).

See SDD 8F8 for traversable cross drain culvert grates. Steel traversable culvert grates can be used with concrete culverts. SDD8F8 has a “Steel Adapter Sleeve for Concrete Pipe” drawing.

It is not possible to mix traversable cross-drain culvert grates of SDD 8F8 with traversable parallel grates of SDD 8F7. The number of bars, bar orientation, and bar spacing is different.

Traversable grates in SDD 8F8 have a wide bar spacing that minimizes the likelihood of a drainage feature being clogged by small objects. To minimize the risk of a large object clogging a drainage feature, install a traversable grate on the upstream end of the drainage feature. Install a traversable grate on the upstream end of a pipe even if it is beyond the clear zone.

Document the decision, in the DSR, not to install a traversable grate from SDD 8F8 because of maintenance concerns.

Traversable grates on SDD 8F8 are not appropriate for cross-drains or similar features with significant skew. Provide additional engineering, special details and special provisions. Contact the WisDOT project manager and the regional design oversight engineer for more information.

Significantly larger drainage features can have specially designed traversable grades similar to what is in SDD 8F8. Provide additional engineering, special details and special provisions. Coordinate with the WisDOT project manager and the regional design oversight engineer early in design.

Figure 30.79 Larger Traversable Grate[62]

Inlets with appropriate inlet covers could also be used to make a drainage feature traversable. Normal inlet covers may be more prone to clogging. A number of different inlet types could be used to make a drainage feature traversable. Median inlets can be used along a roadside to make a drainage feature traversable. Slopes may need to be adjusted similar to what is in SDD 8C8.

Mortar rubble masonry endwalls (older standard), or concrete masonry endwalls (SDD 8F10), may need special provisions, and individual construction drawings to use a traversable grate. Coordinate with the WisDOT project manager and the regional design oversight engineer.

Provide grading for traversable grates. On projects with significant grading, match the new traversable foreslope.

For projects doing spot improvements, a traversable grate may need individual construction detail drawings and cross-sections. Attachment 30.9 shows typical grading limits for a culvert extension, but can be used as a guide to define the area that needs grading for a traversable cross-drain.

Do not rely on a generic drawing like Attachment 30.9 as the sole source of grading information for installing a traversable grate.

30.6.1.2 Extend, Remove or Move Perpendicular Drainage Features (Cross Drains) or Cattle Pass

In general, extending cross-drains or cattle passes will have higher construction costs and will result in lower crash costs than placing traversable grates. Extending a smaller drainage feature is simpler and less costly than extending a larger feature. Extending a large cross-drain or cattle pass is more likely to need coordination with BOS, environmental work, review of hydraulic capacity, right-of-way, and grading.

Review using a traversable grate before extending a cross-drain. Extending a culvert or cattle pass may be the best treatment when installing a new cross-drain or cattle pass, or performing a significant amount of work on an existing cross-drain or cattle pass.

Other hazards may limit the effectiveness of extending a cross-drain or cattle pass (e.g. overall drop, water, riprap...). In some case, shielding may be a better treatment than extending a cross-drain or cattle pass.

If extending a cross-drain or cattle pass use the desirable clear zone value adjusted for AADT, speed, and curvature. See FDM 11-15 Attachment 1.9 and 1.10.

Provide grading for cross-drain or cattle pass extensions. For projects doing spot improvements, pipe extension may need individual construction detail drawings and cross-sections. Attachment 30.9 shows typical grading limits for a culvert extension. Do not rely on a generic drawing like Attachment 30.9 as the sole source of grading information. Check drainage. Avoid making a non-traversable “hump” of soil over pipe extension (see

[62] Final grading by grate not completed. Bottom of grate has a hinge to allow for easier maintenance.

FDM 11-45-30.6.2.1).

Remove unnecessary cross-drains or cattle passes. FDM 11-55-10 addresses unnecessary cattle passes. Installing a drop inlet can “remove” a cross-drain.

Occasionally, cross-drains or cattle passes can be moved. For example, moving a cattle pass out of a curve to a tangent section will reduce crash frequency. When relocating a cross-drain or cattle pass, extend the new cross-drain or cattle pass to the desirable clear zone distance.

30.6.1.3 Barrier Systems

Review using more desirable treatments before shielding.

Barrier systems can shield other roadside hazards near cross-drains or box culverts. Previous roadside design treatments may not be able to address other hazards.

Refer to FDM 11-45-30.2.12 for warrants to shield larger culverts.

Some difficulties with installing barrier systems are (the list is not all-inclusive):

- Lack of cover over the cross-drain or cattle pass.
- Lack of room between posts for drainage feature or cattle pass.
- Lack of room before or after the cross-drain or cattle pass to install a barrier system.
- Lack of room to get proper grading for barrier system.
- Structural issues with cross-drain or cattle pass.
- Maintaining a barrier system
- Barrier system may make a structure too narrow

Lack of soil cover can limit barrier alternatives available (see FDM 11-45-30.3.3.1.4). Treatments for a low fill situation are:

- Long-Span Beam guard
- Attaching to the structure
- Rigid barrier system

Barrier systems need length up station and down station to shield hazards. If there are driveways or side roads within 125 feet of the cross-drain, or a cattle pass, it may be difficult to install a barrier system. Options are:

- Move driveway or cross street
- Move cross drain or cattle pass
- Taper semi-rigid barrier (see FDM 11-45-30.3.1.2 and FDM 11-45-30.3.1.5)
- Install a short radius system

Figure 30.80 Culvert by Driveway

The cattle pass in Figure 30.80 has both a driveway very close, little cover over the culvert and little to no room on top to install a barrier system. These issues combine to make it difficult to install a barrier system. It is likely that without some extension of the cattle pass, a barrier system may be difficult to install.

All barrier systems need some grading. Grading near the cross-drain or cattle pass may prevent using a given barrier system. For example, existing location may not have the room to install grading per typical MGS design.

If these options cannot fit a location, coordinate with the WisDOT project manager and the regional design oversight engineer. Additional engineering, individual construction details, and special provisions may be needed.

Coordinate with BOS when attaching a barrier to a box culvert or cattle pass. Some examples of why coordination is needed are (the list is not all-inclusive):

- Barrier system influences structural rating
- Attaching to box culvert or cattle pass needs structural analysis
- Condition of box culvert or cattle pass may influence hardware selection.

Provide additional engineering. Special provisions and individual construction details may be needed.

Discuss with maintenance staff and BOS before bolting through a box culvert with permanent water in it.. See SDD 14B51 to attach beam guard to a shallow fill box culvert.

30.6.1.4 Delineate

If other roadside design treatments are not feasible, delineate a hazardous cross-drain or cattle pass within the clear zone. Use SDD 15A7. Refer to MUTCD 2C.63 and 2C.65.

Use flexible marker post for culvert pipe (SDD 15A3) for non-hazardous cross-drains and cattle passes.

30.6.2 Parallel Drainage Features

Parallel drainage features are typically access points to the highway (e.g. driveway, side road, median crossover).

Options for parallel drainage features are (in order of preference):

1. Traversable Grates
2. Move or remove structure
3. Installing a barrier system
4. Delineate

30.6.2.1 Traversable Grates

Installing traversable grates for parallel drainage features is the preferred roadside treatment. Parallel traversable grates have the same benefits and issues as traversable cross-drain grates.

Do not install traversable grates on parallel drains for navigable waterways.

Review hydraulic capacity of parallel drains before installing traversable grates.

Review FDM 11-45-30.2.11 for a warrant to install traversable grates on parallel culverts.

Refer to SDD 8F7 for information on traversable grates for parallel culverts. Steel traversable culvert grates can be used with concrete culverts. SDD 8F7 has a “Steel Adapter Sleeve for Concrete Pipe” drawing.

It is not possible to mix traversable cross-drain culvert grates of SDD 8F8 with traversable parallel grates of SDD 8F7. The number of bars, bar orientation, and bar spacing is different.

In general, parallel drainage features are less likely to clog than cross-drains. Grates in SDD 8F7 are less likely to be clogged by small objects. To minimize the risk of a large object clogging a drainage feature, install a traversable grate on the upstream end of the drainage feature.

Inlets with appropriate inlet covers could also be used to make a drainage feature traversable. Normal inlet covers may be more prone to clogging. A number of different inlet types could be used to make a drainage feature traversable. Median inlets can be used to make a parallel drainage feature traversable. Slopes may need to be adjusted similar to what is in SDD 8C8.

Mortar rubble masonry endwalls (older standard), or concrete masonry endwalls (SDD 8F10), may need special provisions, and individual construction drawings to use a traversable grate. Coordinate with the WisDOT project manager and the regional design oversight engineer.

Provide grading for traversable grates. Provide individual construction details and cross-sections for traversable grate. See Attachment 30.10 for example. Do not rely on a generic drawing like Attachment 30.10 as the sole source of grading information. Select traversable grate and transverse slope using the following table:

Table 30.20 Maximum Parallel Slope to the Direction of Travel [cxiv] [cxv]

Posted Speed (mph)	Maximum Parallel Slope to the Direction of Travel
<35	4:1
≥ 35 to <60 *	6:1
≥60 *	10:1

* 20:1 is more desirable for freeways, expressways, and divided highways.

Flatter slopes are acceptable. Inlets using 10:1 or flatter slopes may have to be cast-in-place. Drop inlets may be a more desirable option.

Flatter slopes are recommended in the medians of freeway, expressways and other divided highways. Vehicle trajectory after hitting steeper slopes in median slope could launch vehicle into opposing traffic.

Other locations may have slopes perpendicular to the direction of travel. Examples are (the list is not all-inclusive):

- a parallel drainage feature sticking out of the foreslope
- median berm near a thrie beam bullnose installation.

These locations may need flatter slopes than what is in the table above.

30.6.2.2 Remove or Move Structure

Remove parallel drainage features that are no longer needed. One possible way of "removing" a parallel drainage features is to combine closely spaced parallel drainage features into one feature.

Installing a culvert and inlet between driveways or side roads can remove a drainage feature and associated slope.

It may be possible to move a parallel drainage feature to a location where run off the road crashes are less frequent. Review Figure 3-11 of 2011 Roadside Design Guide.

30.6.2.3 Barrier Systems

It can be difficult to install a barrier system to protect a parallel drainage feature and associated slopes. Use a short radius system to wrap beam guard around the parallel drainage feature and associated slopes.

In some situations a structure is too close to install any barrier system. In other cases, project staff may have to use hardware that they wouldn't "normally" use. Coordinate with the WisDOT project manager and the regional design oversight engineer.

If a short radius system does not fit, designer may put a "break" in the barrier system[63]. A break may allow some vehicles to hit a hazard.

30.7 Safety Edge

Safety edge is a wedge of pavement added to the outside edge of a lane with no paved shoulder or outside edge of a paved shoulder. See Figure 30.81.

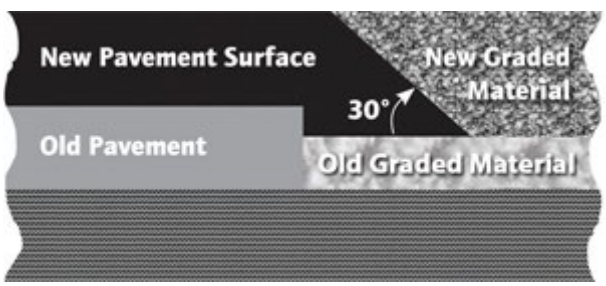


Figure 30.81 Cross-Section of Safety Edge[cxvi]

Safety edge can mitigate run off the road crashes caused by edge drop between the paved surface and gravel shoulder. An edge drop as little as 2.5 inches can cause a driver to oversteer when they try to reenter the pavement.[cxvii] Eventually, when the vehicle's tires climb the edge, the vehicle will shoot abruptly across its' lane and strike oncoming traffic.

[63] Instead of designing one continuous barrier system, there would be two independent barrier systems with a gap between them.

Many states are reporting better pavement performance near a safety edge. Some of the pavement benefits are a decline of edge line cracking, better compaction, and less damage from construction traffic.

Safety edge can be installed on HMA and concrete pavements. WisDOT is installing safety edge on HMA projects. Safety edges are created by adding a wedge maker to the paver.

CMM 6-70 has more information about safety edge.

30.7.1 Policy

Install safety edge on HMA pavements with 0 to 3 feet of paved shoulder. Install safety edge on temporary roads that are in-service over the winter or will be in-service for a year or more.

. Avoid using concerns about “gravel dropping away from safety edge” as justification for not installing safety edge.

It is optional to provide safety edge on wider HMA shoulders.

30.7.2 Design Information

Standard Spec 450.3.2.11 contains language on where to install safety edge. SDD 14B29 contains information on how to build safety edge. Use special provisions for safety edge on wider paved shoulders. If not installing a safety edge on a roadway that matches the criteria use a special provision.

Calculate HMA quantities for safety edge and add to the overall quantities. Typically, safety edge adds less than 1 to 2% to the overall HMA quantities.

30.8 Cross-Median Crash (CMC)

A cross-median crash (CMC) is when a vehicle travels through a median and enters or passes beyond the lanes of the opposing direction of travel. A CMC crash can involve single or multiple vehicles.

Review methods to limit median encroachments before installing a barrier system. Potential methods to reduce the severity and frequency of a median encroachment are (the list is not all-inclusive):

- Widen shoulders
- Widen median*
- Flatten median slopes
- Change ditch from a “V” to trapezoidal ditch
- Minimize the use of horizontal curves with a radius 3,000 FT or less*
- Minimize the use of grades 4% or steeper*
- Increase separation between on- and off-ramps between interchanges
- Increase decision sight-distance
- Simplify or remove weaving areas*
- Lengthening speed-change areas
- Improve merge and diverge areas*
- Limit or remove left hand on and off-ramps*
- Edge line improvements
- Install or update shoulder rumble strips
- High friction treatment
- Improve delineation
- Improve visibility at ramps
- Speed reduction techniques
- Repairing edge drops from lane to paved shoulder and shoulder to gravel
- Safety Edge

* These methods are typically only available for new or reconstruction projects.

If a significant number of CMCs occurs during wet weather, ice, or snowy conditions, review:

- Superelevation
- Pavement cross slope
- Faulting pavement
- Pavement ruts
- Standing water on road
- Maintenance activities in poor weather

Review the mitigation methods for CMC crashes. Use mitigation methods with barrier system..

Review NCHRP 790 Appendix D for the effectiveness of the some of the potential mitigation methods.

The department has two methods to decide if a segment has potential CMC issues:

- Locations where CMC crash are statistically likely (See FDM 11-45-30.8.1)
- Locations where existing crash history shows CMC are happening (See FDM 11-45-30.8.2)

30.8.1 Likely CMC Locations

Cross-median crashes are most likely to occur at the following locations[cxviii, cxix]:

- Downstream of bridge*
- Downstream of on-ramps*
- Curves with radius of 3,000 FT or less
- Curves to the right*
- Downgrades of 4% or greater
- Closely spaced on and off-ramps between interchanges

* Locations are statistically significant based on Wisconsin data. Other locations are from NCHRP Report 790

Install median barrier systems at locations above on perpetuation and rehabilitation projects. Providing barriers at these locations is a proactive measure to prevent future CMC.

Attachment 30.17 and Attachment 30.18 has information on common barrier systems installations for CMC.

It is likely that other run off the road crashes are happening at CMC locations. Avoid placing fixed objects, or other hazards in locations were CMC is likely.

30.8.2 Department's CMC Hotspot Analysis or CMC Warrants

CMC crash rate may identify a hotspot. Use warrant in FDM 11-45-20.3.5.7.3 or the Department's CMC Hotspot Analysis. See Regional Safety Engineer for more information for Department's CMC Hotspot Analysis.

It can be difficult to identify where to stop treating CMC. Use the following methods to decide where to end treating CMC.

30.8.2.1 Logical Termini

Logical termini are highway features such as:

- Interchanges
- Grade separations
- Median openings
    - Median intersections
    - Maintenance crossovers
    - Permanent crossovers
- Road transitions to urban lower speed road
- Medians wider than 70 feet and AADT is less than 90,000 AADT*.

* If the median is 70 feet or wider and has CMC history (see FDM 11-45-30.8.2), install a median barrier. If the existing AADT is greater than 90,000 and the location has CMC (see FDM 11-45-30.8.2) install a median barrier.

Extend barrier system to logical termini when:

- Next segment has CMC history (see FDM 11-45-30.8.2)
- Within 2,000 feet of logical termini

30.8.2.2 Road Similarity

Extend barrier systems into areas where the road has similar road characteristics. Road segments with similar characteristics share (the list is not all-inclusive):

- Number of lanes
- Lane width
- Shoulder width
- Traffic characteristics
- Median width

30.8.3 Median Opening

Review existing median openings or crossings where CMC is likely to occur, or there is a history of CMC crashes. Each median opening left in-place can allow a CMC crash. Avoid placing new median openings in locations where there is a history of CMC, or CMC is likely to occur.

See Figure 6.16 in the 2011 AASHTO Roadside Design Guide to design an opening in barrier systems. Attachment 30.19 shows a median opening design for cable barrier.

30.8.4 Barrier Systems for CMC

Many of the attachments listed in FDM 11-45-30.8 use a single run of cable barrier to prevent CMC. Other barrier systems or other layouts of standard barrier could be used.

There are a few double-faced barrier systems that can be installed as a single run in the median. These systems typically have lower working widths and may fit into narrower medians. Double faced barrier systems can be hit from both directions. One drawback of these double-faced systems is that grading to the barrier needs to be 10:1 or flatter. Many of the double-faced barrier systems will need additional engineering, special details, and special provisions.

A design team may decide to install two barrier system in the median because (the list is not all-inclusive):

- Grading for one barrier system disrupts median drainage too much.
- Excessive grading
- Fixed object density and placement

LIST OF ATTACHMENTS

Attachment 30.1	Example Problem 1: West Side of Structure
Attachment 30.2	Example Problem 2: Rock Wall
Attachment 30.3	Example Problem 3: Outside of Curve Cattle Pass
Attachment 30.4	Example Problem 3: Inside of Curve Cattle Pass
Attachment 30.5	Example Beam Guard Plan Sheet
Attachment 30.6	Beam Guard Analysis
Attachment 30.7	Beam Guard Bullnose
Attachment 30.8	Sloped Concrete End Treatment
Attachment 30.9	Grading Area for Hazardous Cross-Drain
Attachment 30.10	Grading Area for Hazardous Parallel Drain
Attachment 30.11	Crash Cushion Selection Tables
Attachment 30.12	Length of Barrier and Working Width Examples
Attachment 30.13	Barrier Working Width Table
Attachment 30.14	Barrier Length Examples
Attachment 30.15	Minimum Barrier Length Table
Attachment 30.16	Shielding Large Fixed Objects in a Median with Cable Barrier and Other Barrier Systems
Attachment 30.17	Median Cable Barrier on a Curve
Attachment 30.18	Median Cable Barrier by an Interchange or Bridge
Attachment 30.19	Median Cable Barrier by a Maintenance Cross Over
Attachment 30.20	Underground Obstructions and Shifting Beam Guard
Attachment 30.21	Crash Test Photos Sequence Beam Guard Attached to Rigid Barrier
Attachment 30.22	Thrie Beam Transitions to Rigid Barrier Installations
Attachment 30.23	Partial Removal of a Middle Section of an Older Barrier Section Details
Attachment 30.24	Short Radius
Attachment 30.25	Long-Span
Attachment 30.26	Beam Guard Retaining Wall
Attachment 30.27	Beam Guard Terminal Earthwork

FDM 11-45-40 Fencing

February 18, 2020

40.1 General

Fencing along a highway serves primarily to prevent vehicles, people and animals from entering onto highway right-of-way where they may cause a hazard to traffic. Fencing is especially important along freeways where drivers are traveling at high speeds and expect complete protection from all forms of roadside interference. Fencing is used in urban areas to separate pedestrians from vehicle traffic in special situations where there would be a safety benefit such as along school grounds and parks or to channel pedestrians to pedestrian structures.

Fencing may be deferred until needed or possibly eliminated at locations where access to the highway is blocked by rough topography, dense vegetation, or a natural barrier such as a body of water or a river.

Fencing is normally not required along the outside of frontage roads unless the abutting property was fenced prior to highway construction. Such fencing would normally be part of right-of-way negotiations.

If an adjacent property owner requests the installation of a fence, for example to contain domestic animals or to keep multi-use path users off private property, it is the property owner's responsibility to construct and maintain the fence on their property. Unless the property owner's fence already existed, it is unlikely that WisDOT would participate in the cost of the fence. If WisDOT does participate in the cost of any fence constructed on private property, the designer shall coordinate with the Region Real Estate Section to include fencing in the right-of-way negotiations.

It may be appropriate, such as meeting a compelling safety need or addressing a demonstrated land encroachment issue, to construct a second fence on the outside of a multi-use path but on WisDOT right-of-way.

Note: Refer to FDM 11-35-1 for guidelines for protective screening of overpass structures. This is technically a fence but does not serve the same purpose as the fencing discussed in this procedure.

Refer to FDM 11-55-5 for barriers on top of retaining walls.

40.2 WisDOT Policy for Freeways

Department policy is to fence along freeways, designated and non-designated, except where such fencing would not be effective or essential for access control. The following guidelines are provided for application of this policy:

1. Fence along freeways with no multi-use path shall be located along the right-of-way line, generally 3 feet inside the right-of-way line.
2. Fence along freeways with multi-use paths adjacent to the facility shall be located between the roadway and the multi-use path. This fence shall be installed near the edge of the path shoulder and outside the clear zone of both the roadway and the multi-use path[64].
3. Fencing should be provided between frontage roads and the freeway, or ramps, unless other barriers are used to control access.
4. Fencing of planned freeways which will be built in stages and operate initially as a two-lane highway should be constructed to the extent possible with the construction of the first roadway

40.3 WisDOT Policy for Expressways

Department policy is to generally not fence expressways[65] including facilities designated as expressways under s. 84.295 stats, and expressways with multi-use paths., and to minimize fencing in those locations where fencing is deemed necessary. Expressways are generally defined as divided highways with at-grade intersections and usually having a posted speed of 50 mph or greater.

40.3.1 Department's Expressway Fencing Policy

While the Department's general policy is to not fence expressways, there may be some locations where fencing is needed:

1. Where there is a demonstrated history of right-of-way encroachment problems, or there is a strong expectation they will occur in the future. Typical problems include land use encroachment or illegal use of motorized vehicles.
2. Where there is a perceived or demonstrated potential for an unsafe condition related to the highway right-of-way. Generally, this potential is likely to occur in an urban or suburban setting, and may include the following conditions:

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[64] The clear zone for a multi-use path is normally 3 feet minimum beyond the edge of traveled way.

[65] Expressways are generally defined as divided highways with at-grad intersections and usually having a posted speed of 50 mph or greater.

- Existing residential areas or areas zoned residential where development is expected to occur within five years. As a general rule, fence should be evaluated where 20 or more residences exist or are clearly planned within 500 feet of the right of way for a distance of 500 feet along the highway.
- Along the entire frontage of abutting school property.
- Along sidewalks to channel pedestrians over pedestrian structures.
- Along the entire frontage of official city, county, state or federal parks or preserves with due consideration to aesthetics and the desires of local officials.
- Along steep embankments or drop offs such as a box culvert opening adjacent to a sidewalk.
- Other areas where pedestrian traffic is present or anticipated such as playgrounds, sports fields and golf courses.
- Where a local government requests the fence and participates in its funding.

The decision to provide fencing along an expressway whether it is separating the roadway from a multi-use path, a frontage road, a deterrent to land use encroachment, safety or other reasons should be made by the Region on a case-by-case basis.

40.3.2 Location of Expressway Fencing

To satisfy the WisDOT concerns identified above, there are two locations to install fence:

1. When there is not a multi-use path along the expressway, the fence shall be located along the right-of-way line, generally 3 feet inside the right-of-way line.
2. When there is a multi-use path along the expressway the fence may be located either along the right-of-way line, or between the multi-use path and the expressway. When the fence is installed between the expressway and the path it should be located adjacent to the path shoulder, and outside the clear zone of the highway and the multi-use path[66]. Fence location is determined as follows:
   - 2.1. Fence along the right-of-way line when there is a compelling safety need to control access or prevent encroachment to the path and the highway.
   - 2.2. It may be appropriate to fence between the highway and the multi-use path at locations where access to the path from the adjacent property is acceptable, such as:
     - A frontage abutting school property
     - Other areas where pedestrian traffic is present or anticipated such as playgrounds and sports fields
     - Steep embankments or drop offs such as a box culvert located between the path and the highway.

The fence may be alternately located at the right-of-way line for a certain section of a project; and then, located between the multi-use path and the highway at other sections. This discontinuity of the fence is considered acceptable.

40.4 Fencing Types

Selection of fence type depends primarily on the character and density of adjacent development and cost of installation and maintenance. In general, chain link fence should be installed in urban/suburban areas and woven wire or high-tensile fence in rural areas. Consideration may be given to improving the aesthetics of chain link fence by adding a colored epoxy coating.

40.4.1 Chain Link Fence

Chain link fence should be installed in urban and suburban areas. It should be considered where the following conditions exist adjacent to the highway right of way:

1. Existing residential areas or areas zoned residential where development is expected to occur within five years. As a general rule, chain link fence should be evaluated where 20 or more residences exist or are clearly planned within 500 feet of the right of way for a distance of 500 feet along the highway.
2. Along the entire frontage of abutting school property.
3. Along sidewalks to channel pedestrians over pedestrian structures.
4. Along the entire frontage of official city, county, state or federal parks or preserves with due consideration to aesthetics and the desires of local officials.
5. Along steep embankments or drop offs such as a box culvert opening adjacent to a sidewalk.

[66] The clear zone for a multi-use path is normally 3 feet minimum beyond the edge of traveled way.

6. Other areas where pedestrian traffic is present or anticipated such as playgrounds, sports fields and golf courses.

Chain link fence should not be used where it may restrict sight distance, particularly on curves. In addition, chain link fence can result in additional snow drifting in some locations and it is more of a trash and waste paper collector than the other fence types.

40.4.2 Woven Wire or High Tensile Wire Fence

Woven wire or high tensile wire fence should be installed where chain link fence is not warranted and where the following conditions exist:

1. Areas that are rural in character. Note: Standard woven wire and high tensile wire fence are not adequate to retain livestock. This application requires special fencing that should be provided by the property owner and subject to right of way negotiations.
2. Urban and suburban areas where improvements along the right of way are infrequent and future development is not anticipated.

Transitions between fence types may change within a relatively short length due to existing or planned land use. Transitions should be planned to occur at logical points such as at an interchange or bridge; for expressways the transition may also be at a cross road intersection.

40.5 Gates

Gates along freeways should be provided only where necessary to allow access by maintenance personnel. Each gate must be provided with a lock and keys in accordance with maintenance policy or preference. All gates on the Interstate system, including those for maintenance purposes, require FHWA approval.

Gates along expressways may be provided to allow access by maintenance personnel, at field entrances, and when requested by the property owner at the main entrance to the farm or residence.

40.6 Design Standards

Design details for each of the fence types are shown on standard detail drawings in Chapter 16.

The standard detail drawing for chain link fence and the standard specifications recognize a range of fence heights from four to eight feet. The desirable height is six feet because it is sufficient to discourage people from attempting to climb over the fence. Special circumstances may warrant installation of shorter fence. For example, a tall fence may reduce sight distance at interchanges or be objectionable to property owners for a variety of reasons.

High tensile wire fence is an effective rural fence that is economical to build. However, this fence requires periodic maintenance to assure wire tension and this may add to its life cycle cost. Also, the fence can be hazardous to deer, which can become entangled and trapped in the top wires as they try to leap over it.

Woven wire fence is a good general-purpose rural fence, which may be specified as an equal alternate to high tensile wire fence or specified exclusively.

40.7 References

For further reading on this subject, refer to the AASHTO publication; "An Informational Guide on Fencing Controlled Access Highways" dated November 1990. The laws relative to fencing are contained in Chapter 90 of the Wisconsin Statutes.

FDM 11-45-50 Bicycle Facilities

February 18, 2020

See FDM 11-46-15.

FDM 11-45-99 References *February 18, 2020*

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Guardrail Post Sampling Procedure used by BTS (Auger method)

1. <u>Equipment required:</u>

    a. Mid-sized track driven skid steer to work the best - due to the steep slopes and or soft ground encountered tracks provided more stability and maneuverability.

    b. A 5'x 4" continuous flight auger with a 4- tooth carbide tipped cutter head is preferred as to minimize soil disturbance around the posts.

    c. The auger, cutter head, and drive coupling to mate with the Bobcat auger attachment is available from Hole Products of Wausau.

    d. 8' rod with 90-degree hook on the bottom

    e. Tape measure

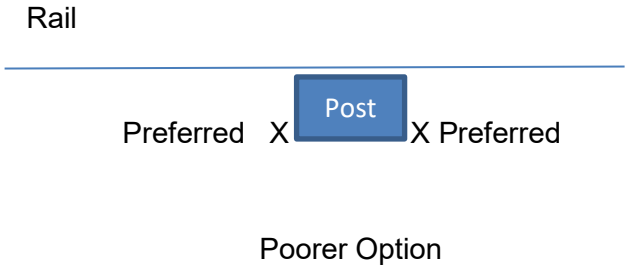
    f. 4' level

    g. Shovels and other clean up equipment

Equipment Used

2. <u>Process preferred</u>:

   a. The hole can be bored behind or next to the post and must extend beyond the embedment depth of the post. Note: Borings next to the post proved to be easier than behind the post, seeing as the drive attachment would sometimes bottom out on top of the post before reaching full depth.



Drilling adjacent to the post (preferred to behind)

   b. Starting the hole at a slight angle towards the post helps to keep it aligned but the operator needs to be careful not to cut into the post with the auger.

   c. Once the hole is drilled the auger should be pulled straight out without rotating to keep from filling the hole in.

A cleanly drilled hole

d. A rod at least 8’ long with a 90 degree hook bent at the bottom can then be used to clear away the bottom of the post, the bottom hooked and the embedment measured to the top of the post. Note, a clothes pin or some sort of clip on device to the rod at the top of the post can help improve the accuracy of the measurements.

Hooking the bottom of the post for measurement

e. If wanting to measure the embedment of the post, take a separate measurement using a 4’ level to get to the ground elevation.

Measuring Rod (clip or something would improve accuracy)

f. The hole can now be backfilled by first rotating the auger in reverse from the bottom of the hole then shovel in the remaining cuttings and compacting every 12” using the auger until full. This has proved very effective in backfilling the hole. The area should show little sign of disturbance once work is complete.

Cleaned up area (all these posts were drilled next to)

Roadside Design Factors to Consider

Some of the information below is specific to barrier systems. Some of the information below can apply to all aspects of roadside design.

Issue	Discussion
AADT	Typically, as AADT increases, there is an increase chance that hazard will be impacted. Usually, as the number of impacts increase, crash severity increases. Also, as the number of impacts increase it is more likely that a critical impact (i.e. high speed, high impact angle…) will occur.
Accumulative Effect of Spot Improvements	It may be more cost effective to fully replace verses performing multiple modifications to a barrier system.
Age of Barrier System	Replacing older barrier systems improves safety and reduces long term maintenance costs. Older crash tests used lighter vehicles with lower center of gravity and shallower impact angles. Because of these issues, it can be difficult for older barrier systems to interact with newer vehicles. Due to exposure to the elements, older barrier systems may be degraded.
Barrier Safety Performance	Barrier safety performance is broken into to two main categories: general and site specific. General performance is based on the average performance of each type of barrier systems (e.g. comparing beam guard verses concrete barrier). Site specific performance uses actual police crash reports for a given project or location. As working width of the barrier system decreases the probability of injury or fatality increases. From a general performance perspective, use barrier systems that use all available working width before using barrier systems with less working width (i.e. cable barrier over semi-rigid barrier, semi-rigid barrier over rigid barrier). If site specific data indicates that a barrier system is not performing, changes to the barrier system can be justified (e.g. a fixed object behind a barrier system is being impacted). Changes can range from spot improvements of the existing barrier to installing a different barrier system. Site or project conditions may assist in selecting appropriate action. For example, a fixed object is within the working width of an existing beam guard installation. Viable options are: relocate the object, reducing the working width of the beam guard or replacing beam guard with concrete barrier.
Collision Frequency	Some locations ROR crashes are more likely[1]. In these locations, it is likely that a severe crash will occur. It is also more likely that a critical impact (i.e. high speed, high impact angle…) will occur. Locations of concern are: projects that have segments with a metamanager ROR Flag, and locations that are more prone to ROR crashes[2]. Some examples of locations more prone to ROR are curves, weave sections, merge/diverge sections, or locations that violated driver expectation. Provide additional effort to improve roadside design in locations of high collision frequency. Efforts to improve roadside design include: clear zone improvements, hazard removals, use of breakaway hardware, modifying existing barrier systems, installing a new barrier system of the same type or installing a completely different barrier system.

[1] A simple definition of Run off the Road is: any non-intersection crash, where a vehicle has left its lane and has either struck a fixed object, traversed a slope, hit a vehicle in the opposing lanes of travel or rolled over.

[2] See Meta-Manager documentation for procedure to assign crash flags.

Collision Severity	Some locations may have low occurrence of ROR crashes, but high crash severity. For example, a grove of trees has been hit twice in 5 years (i.e. low frequency). But, each of the crashes has lead to a fatality (high severity). A review of the police reports may indicate a collision severity issue. There is a difference between collision severity and consequence of a collision. Collision severity can be traced to actual police reports (e.g. reports indicate that people are hitting a grove of tree) or physical evidence (e.g. tree has impact scars). Collision severity typically deals with frequently encountered roadside object that require high speed impacts to cause injury (e.g. bridge pier, beam guard, foreslopes…)[3]. Provide additional effort to improve roadside design in locations with high collision severity. Efforts to improve roadside design include: clear zone improvements, hazard removals, use of breakaway hardware, modifying existing barrier systems, installing a new barrier system of the same type or installing a completely different barrier system.
Consequence of a Collision	Consequence of collision deals with hazards that can generate serious crash outcomes. Many of the hazards that fall into this category are not frequently encountered along the roadway.[4] Consequence of a collision may not be associated with police crash reports. Some collisions, regardless of speed, will have dire consequences for vehicle occupants. Some examples are: vehicle falls off a cliff; vehicle hits a hazardous chemical tank. Some collisions may have negative consequences to others using a transportation network. Some examples are: dropping an overhead sign on to a roadway; dropping a light pole into an area of heavy pedestrian concentration. Some collisions may have negative consequences for a whole community. Some examples are: vehicle enters an electrical sub-station; vehicle hits a major gas valve. Provide additional effort to improve roadside design in locations where consequence of collision is severe. Efforts to improve roadside design include: clear zone improvements, hazard removals, use of breakaway hardware, modifying existing barrier systems, installing a new barrier system of the same type or installing a completely different barrier system. In some cases, consequence of a collision could lead a designer to install a barrier system when normally a barrier system would not be required.
Cost	Costs vary for different barrier systems. Consider installation, collision and maintenance costs when selecting a barrier system. Installation costs include the cost of providing grading, drainage, transitions, barriers and terminals. Collision costs are based on severity, consequences, and frequency of collision. Maintenance costs consist of repair costs (i.e. collision generated repairs), and the cost of maintaining systems (e.g. the periodic adjustments of a barrier system due to exposure to the elements). The decision to use a more rigid barrier system for a whole project because of maintenance concerns requires the analysis of collision costs. Costs and options on how to modify different barrier systems vary. What may be an easy modification for a barrier system (e.g. raising beam guard height), may to be a difficult task for another barrier system (e.g. concrete barrier). HSIP severity costs are not appropriate for this kind of analysis.

[3] High speed does not always equate to a design speed of 45 mph or greater. For example impacts on trees at 35 mph can cause serious injuries or fatalities.

[4] Overhead sign, sign bridges, and light poles would be the exception to this general rule.

Crash Tested Hardware	Impacts into crashworthy barrier systems can sometimes have undesirable results. Undesirable results are more likely with a non-crash tested barrier system. Avoid modifying existing SDDs to fit a give location or situation. In some situations, it may be desirable to provide a modified barrier system over no barrier system.[5] Two options present themselves at a given location or situation; option one would install a barrier system per SDD. Option two would modify a barrier system to fit a given location or situation. Option one is more desirable.
Duration	The longer a hazard is exposed to traffic the more likely it will be impacted or experience a critical impact. For example, in one year a one mile section of a roadway with 2,500 AADT will have on average 2.2 vehicles leaving the roadway. In 10 years the same stretch of roadway will have on average 22 vehicles leaving the roadway. Provide additional effort to improve roadside design on projects with an anticipated long service life. Service life is the time between the end of construction for the current project and next construction project. Projects with service life of 15 years or greater are considered long service life projects. Roadways that repeatedly receive minimum roadway improvement or maintenance should look to improve roadside design because of exposure. Efforts to improve roadside design include: clear zone improvements, hazard removals, use of breakaway hardware, modifying existing barrier systems, installing a new barrier system of the same type or installing a completely different barrier system.
Existing Site Conditions	Site conditions may limit what options are available. For example, a designer may have to install the short radius beam guard system.
Speed	As speed increases, collision severity increases. Consider speed of the errant vehicle when designing roadside features.[6] Speed of an errant vehicle may be higher or lower than the design speed or posted speed of a roadway. [7,8]
Type of Project	The scope of some projects allow for more effort to be placed on roadside design issues. For example, a project that is providing spot repairs on a bridge deck is less likely to remove a non-crashworthy bridge parapet.[9] If a bridge project was replacing the bridge's deck, a crashworthy bridge parapet should be installed.

[5] Limited project by project exceptions allowing modification of barrier system may be granted by Bureau of Project Development (BPD). However, these exceptions will be rare. Document the exception in DSR.

[6] 2006 AASHTO Roadside Design Guide

[7] 2006 AASHTO Roadside Design Guide

[8] Geometric features, time of day or traffic volumes may influence vehicle's impact speed.

[9] More than likely this project could provide some modifications to make parapet better than what it was. For example, the parapets could be delineated.

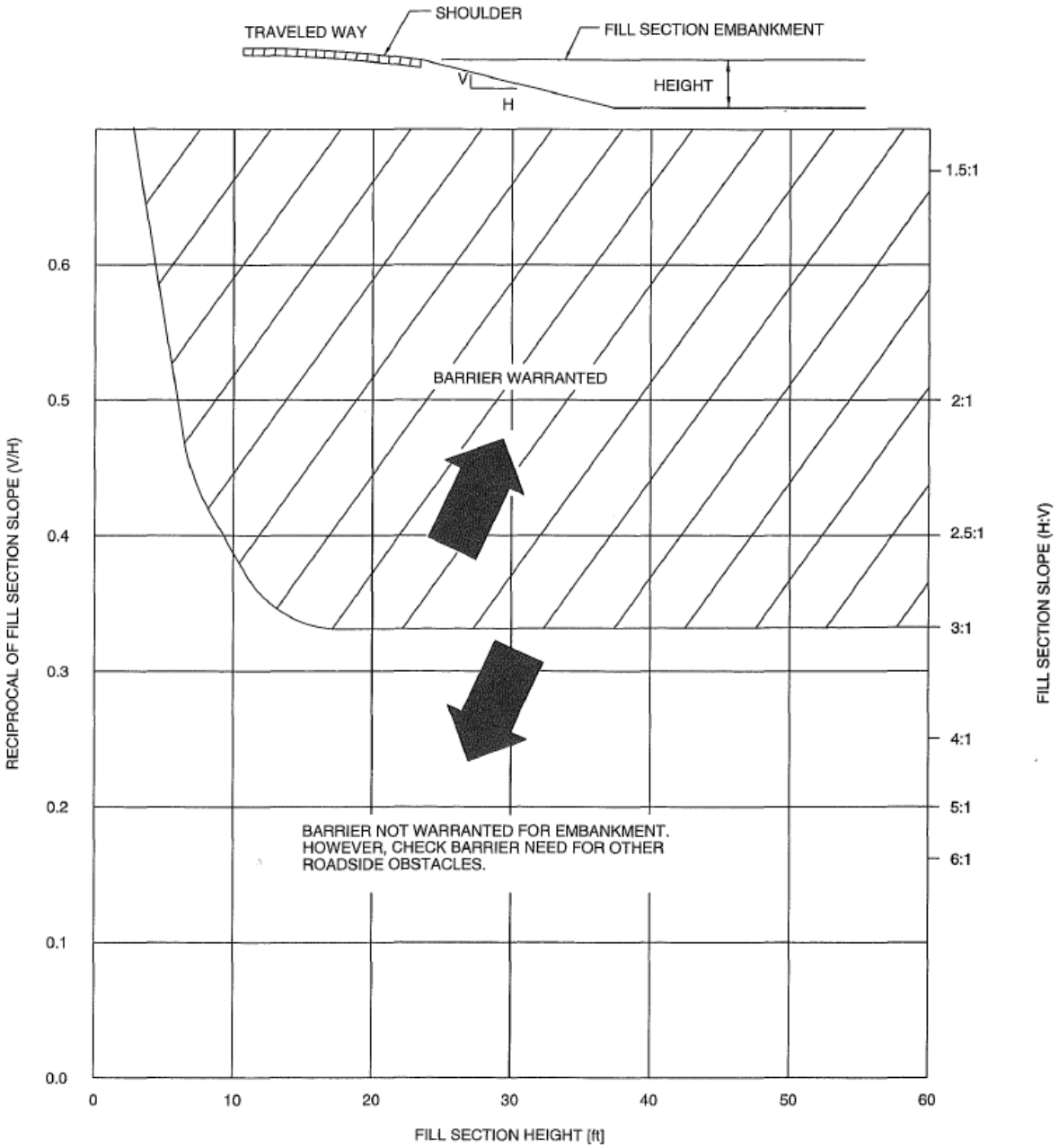


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Table A.1: Traffic Growth Adjustment Factor, TG

Annual Growth Factor	Adjustment Factor
0%	1.00
1%	1.10
2%	1.21
3%	1.34
4%	1.49
5%	1.65

Table A.2: Horizontal Curve Adjustment Factor, HC

Radius	Adjustment Factor (HC)	
	Hazard on Outside of Curve	Hazard on Inside of Curve
1,911 ft or greater	1.00	1.00
1,431 – 1,910 ft	1.50	1.25
1,151 – 1,430 ft	2.50	1.50
951 – 1,150 ft	3.50	1.75
950 ft or less	4.00	2.00

Table A.3: Down Grade Adjustment Factor, DG

Percent Down Grade	Adjustment Factor (DG)
0 – 2%	1.00
2.1% – 3.0%	1.10
3.1% – 4.0%	1.40
4.1% – 5.0%	1.70
5.1% – 6.0%	1.90
6.1% and larger	2.00

Source: FHWA Central Lands Publication

Table A.15: Barrier Warrants for 1V: 2H Foreslopes 13 Feet High X 100 Feet Long

Speed	Hazard Offset from Edge of Lane	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	**4 – 7 ft**	0 – 549	550 – 2,999	3,000 (+)
	8 – 11 ft	0 – 599	600 – 3,599	3,600 (+)
	12 – 15 ft	0 – 749	750 – 4,999	5,000 (+)
	16 – 17 ft	0 – 1,399	1,400 (+)	
	18 – 19 ft	0 – 3,999	4,000 (+)	
	20 (+) ft	All		
40 mph	**3 – 7 ft**	0 – 949	950 (+)	
	8 – 11 ft	0 – 1,049	1,050 (+)	
	12 – 13 ft	0 – 1,249	1,250 (+)	
	14 – 15 ft	0 – 1,499	1,500 (+)	
	16 – 17 ft	0 – 3,199	3,200 (+)	
	18 (+) ft	All		
30 mph	**2 – 7 ft**	0 – 2,149	2,150 (+)	
	8 – 10 ft	0 – 2,349	2,350 (+)	
	10 – 11 ft	0 – 3,399	3,400 (+)	
	12 (+) ft	All		
20 mph	**All**	All		

Source: FHWA Central Lands Publication

Table 4.17: Barrier Warrants for 1V: 2H Foreslopes 46 Feet High X 100 Feet Long

Speed	Hazard Offset from Edge of Lane	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	**4 – 7 ft**	0 – 149	150 – 649	650 (+)
	8 – 11 ft	0 – 199	200 – 749	750 (+)
	12 – 15 ft	0 – 249	250 – 899	900 (+)
	16 – 19 ft	0 – 399	400 – 1,599	1,600 (+)
	20 – 23 ft	0 – 899	900 (+)	
	24 (+) ft	All		
40 mph	**3 – 7 ft**	0 – 249	250 – 949	950 (+)
	8 – 11 ft	0 – 299	300 – 1,249	1,250 (+)
	12 – 15 ft	0 – 349	350 – 1,599	1,600 (+)
	16 – 17 ft	0 – 549	550 – 3,149	3,150 (+)
	18 – 19 ft	0 – 1,299	1,300 (+)	
	20 (+) ft	All		
30 mph	**2 – 7 ft**	0 – 599	600 – 3,199	3,200 (+)
	8 – 11 ft	0 – 749	750 (+)	
	12 – 13 ft	0 – 799	800 (+)	
	14 (+) ft	All		
20 mph	**2 – 7 ft**	0 – 3,799	3,800 (+)	
	8 (+) ft	All		

Source: FHWA Central Lands Publication

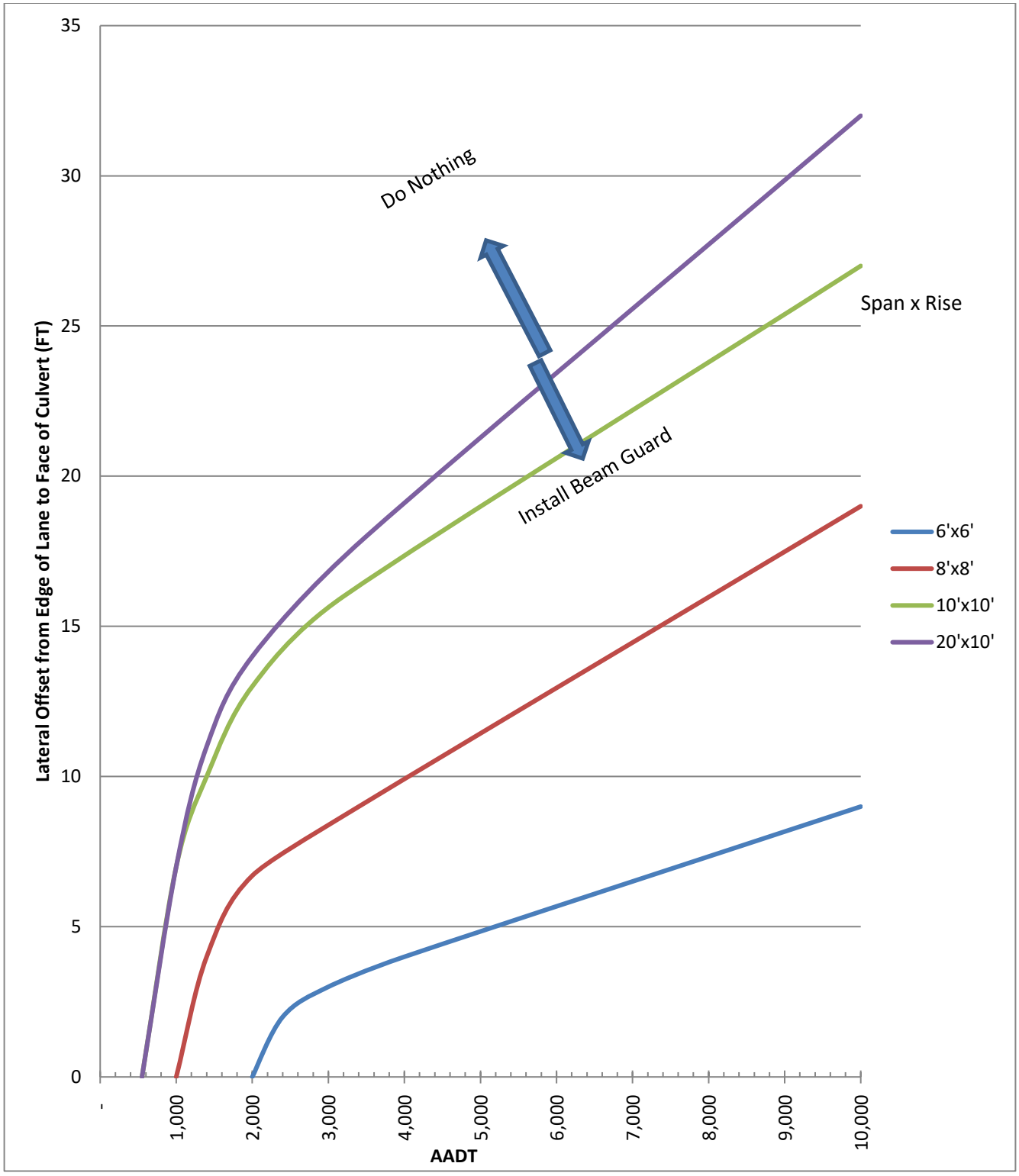

35
30
25
20
15
10
5
0
Lateral Offset from Edge of Lane to Face of Culvert (FT)
Do Nothing
Install Beam Guard
Span x Rise
6'x6'
8'x8'
10'x10'
20'x10'
-
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
AADT

Table A.23: Barrier Warrants for Water 2 Feet Deep X 100 Feet Long

Speed	Hazard Offset from Edge of Lane	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	**4 – 7 ft**	0 – 249	250 – 1,099	1,100 (+)
	8 – 11 ft	0 – 349	350 – 1,499	1,500 (+)
	12 – 15 ft	0 – 449	450 – 1,999	2,000 (+)
	16 – 19 ft	0 – 2,999	3,000 (+)	
	20 (+) ft	All		
40 mph	**3 – 7 ft**	0 – 249	250 – 1,099	1,100 (+)
	8 – 11 ft	0 – 349	350 – 1,499	1,500 (+)
	12 – 15 ft	0 – 449	450 – 1,999	2,000 (+)
	16 – 17 ft	0 – 2,999	3,000 (+)	
	18 (+) ft	All		
30 mph	**2 – 7 ft**	0 – 599	600 – 3,199	3,200 (+)
	8 – 11 ft	0 – 749	750 (+)	
	12 – 13 ft	0 – 799	800 (+)	
	14 (+) ft	All		
20 mph	**2 – 7 ft**	0 – 3,799	3,800 (+)	
	8 (+)	All		

Number of Vehicle Tree Collisions Per Year

	Rural U.S./State Roadways		Rural Local Roads	
AADT	Curved	Straight	Curved	Straight
100	0.12	0.06	0.79	0.12
200	0.15	0.08	1.04	0.15
300	0.17	0.1	1.23	0.17
400	0.19	0.11	1.39	0.19
500	0.21	0.12	1.53	0.21
600	0.22	0.12	1.66	0.22
700	0.23	0.13	1.77	0.24
800	0.25	0.14	1.88	0.25
900	0.26	0.14	1.98	0.26
1,000	0.27	0.15	2.07	0.27
1,100	0.28	0.15	2.16	0.28
1,200	0.29	0.16	2.25	0.29
1,300	0.29	0.16	2.33	0.3
1,400	0.3	0.17	2.41	0.31
1,500	0.31	0.17	2.49	0.32
1,600	0.32	0.17	2.56	0.32
1,700	0.33	0.18	2.64	0.33
1,800	0.33	0.18	2.71	0.34
1,900	0.34	0.19	2.77	0.34
2,000	0.35	0.19	2.84	0.35
2,100	0.35	0.19	2.91	0.36
2,200	0.36	0.2	2.97	0.36
2,300	0.36	0.2	3.03	0.37
2,400	0.37	0.2	3.09	0.38
2,500	0.38	0.21	3.15	0.38
2,600	0.38	0.21	3.21	0.39
2,700	0.39	0.21	3.27	0.39
2,800	0.39	0.21	3.32	0.4
2,900	0.4	0.22	3.38	0.4
3,000	0.4	0.22	3.44	0.41

	Rural U.S./State Roadways		Rural Local Roads	
AADT	Curved	Straight	Curved	Straight
3,100	0.41	0.22	3.49	0.41
3,200	0.41	0.23	3.54	0.42
3,300	0.42	0.23	3.59	0.42
3,400	0.42	0.23	3.65	0.43
3,500	0.43	0.23	3.70	0.43
3,600	0.43	0.24	3.75	0.44
3,700	0.44	0.24	3.80	0.44
3,800	0.44	0.24	3.85	0.45
3,900	0.45	0.24	3.89	0.45
4,000	0.45	0.24	3.94	0.46
4,100	0.45	0.25	3.99	0.46
4,200	0.46	0.25	4.03	0.47
4,300	0.46	0.25	4.08	0.47
4,400	0.47	0.25	4.13	0.47
4,500	0.47	0.26	4.17	0.48
4,600	0.47	0.26	4.22	0.48
4,700	0.48	0.26	4.26	0.49
4,800	0.48	0.26	4.31	0.49
4,900	0.49	0.26	4.35	0.49
5,000	0.49	0.27	4.39	0.5
5,500	0.51	0.28	4.60	0.52
6,000	0.53	0.28	4.81	0.53
6,500	0.54	0.29	5.00	0.55
7,000	0.56	0.3	5.19	0.57
7,500	0.57	0.31	5.37	0.58
8,000	0.59	0.32	5.55	0.6
8,500	0.6	0.32	5.72	0.61
9,000	0.61	0.33	5.89	0.62
9,500	0.63	0.34	6.05	0.64
10,000	0.64	0.34	6.21	0.65
10,500	0.65	0.35	6.37	0.66

	Rural U.S./State Roadways		**Rural Local Roads**	
AADT	Curved	Straight	Curved	Straight
11,000	0.67	0.36	6.52	0.68
11,500	0.68	0.36	6.67	0.69
12,000	0.69	0.37	6.82	0.7
12,500	0.7	0.37	6.97	0.71
13,000	0.71	0.38	7.11	0.72
13,500	0.72	0.39	7.25	0.73
14,000	0.73	0.39	7.39	0.74
14,500	0.74	0.4	7.52	0.75
15,000	0.75	0.4	7.66	0.76
15,500	0.76	0.41	7.79	0.77
16,000	0.77	0.41	7.92	0.78
16,500	0.78	0.42	8.05	0.79
17,000	0.79	0.42	8.18	0.8
17,500	0.8	0.43	8.30	0.81
18,000	0.81	0.43	8.43	0.82
18,500	0.82	0.43	8.55	0.83
19,000	0.83	0.44	8.67	0.84
19,500	0.84	0.44	8.80	0.85
20,000	0.84	0.45	8.91	0.86

Table A.21: Barrier Warrants for Group of Trees 8 Feet Wide X 100 Feet Long

Speed	Hazard Offset from Edge of Lane	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	**4 – 7 ft**	0 – 149	150 – 549	550 (+)
	8 – 11 ft	0 – 199	200 – 749	750 (+)
	12 – 15 ft	0 – 249	250 – 899	900 (+)
	16 – 19 ft	0 – 349	350 – 1,499	1,500 (+)
	20 – 23 ft	0 – 749	750 (+)	
	24 (+) ft	All		
40 mph	**3 – 7 ft**	0 – 249	250 – 999	1,000 (+)
	8 – 11 ft	0 – 299	300 – 1,249	1,250 (+)
	12 – 15 ft	0 – 349	350 – 1,649	1,650 (+)
	16 – 17 ft	0 – 599	600 – 3,199	3,200 (+)
	18 – 19 ft	0 – 799	800 (+)	
	20 (+) ft	All		
30 mph	**2 – 7 ft**	0 – 449	450 – 2,149	2,150 (+)
	8 – 11 ft	0 – 599	600 – 2,999	3,000 (+)
	12 – 13 ft	0 – 799	800 (+)	
	14 (+) ft	All		
20 mph	**2 – 7 ft**	0 – 2,599	2,600 (+)	
	8 – 9 ft	5,000 (+)		
	10 (+) ft			

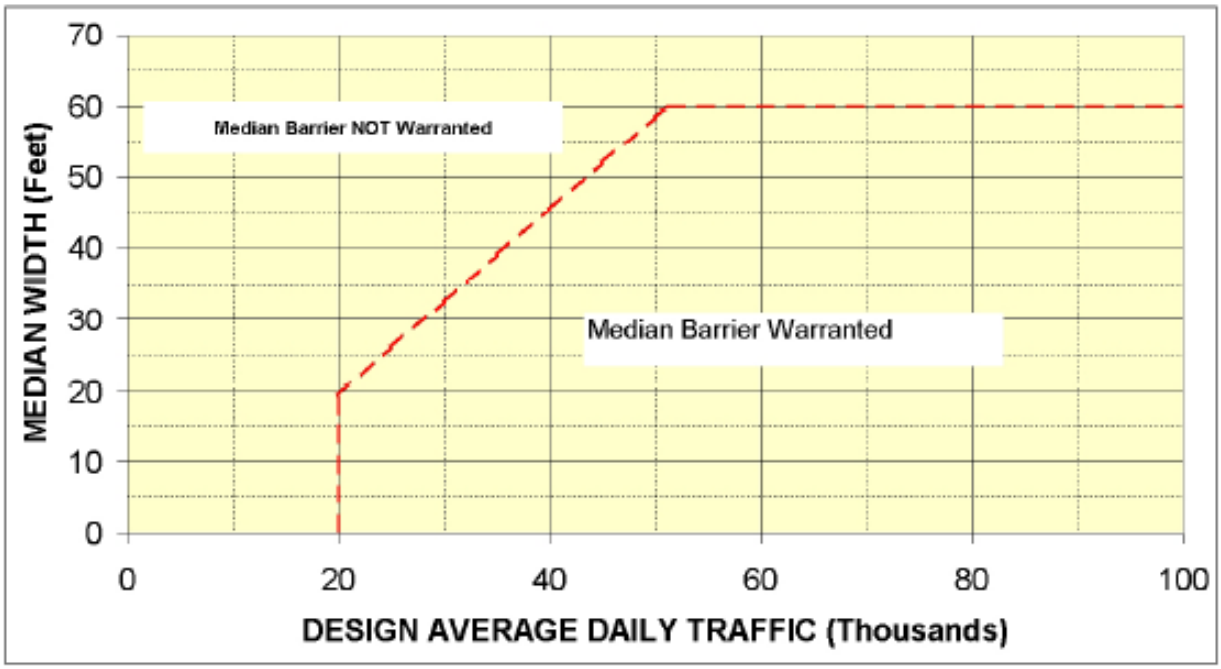

70
60
50
40
30
20
10
0
MEDIAN WIDTH (Feet)
Median Barrier NOT Warranted
Median Barrier Warranted
0
20
40
60
80
100
DESIGN AVERAGE DAILY TRAFFIC (Thousands)

Table A.7: Barrier Warrants for Fixed Objects 4 Feet X 4 Feet

Speed	Hazard Offset from Edge of Lane	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	**4 – 11 ft**	0 – 249	250 – 999	1,000 (+)
	12 – 15 ft.	0 – 349	350 – 1,399	1,400 (+)
	16 – 19 ft	0 – 499	500 – 2,399	2,400 (+)
	20 – 21 ft	0 – 1,199	1,200 (+)	
	22 – 23 ft	0 – 2,999	3,000 (+)	
	24 (+) ft	All		
40 mph	**3 – 7 ft**	0 – 299	300 –1,399	1,400 (+)
	8 – 15 ft	0 – 399	400 – 1,899	1,900 (+)
	16 – 19 ft	0 – 799	800 – 4,999	5,000 (+)
	20 – 23 ft	0 – 1,299	1,300 (+)	
	24 (+) ft	All		
30 mph	**2 – 5 ft**	0 – 799	800 – 4,999	5,000 (+)
	6 – 9 ft	0 – 999	1,000 (+)	
	10 – 11 ft	0 – 1,199	1,200 (+)	
	12 – 13 ft	0 – 1,299	1,300 (+)	
	14 ft (+)	All		
20 mph	**All**	All		

Scoping/Preliminary Roadside Hazard Design Review List:

Structures and Large Drainage Features:

If an answer to any of the following questions is yes, Contact Bureau of Structures or Bureau of Project Development prior to proceeding with scoping the project:

1. Parapet built prior to 1964?
2. Non-Standard Parapet on structure (See Bridge Manual for standard parapets designs)?
3. Parapet has snag points?
4. Parapet damaged or has missing components?
5. Barrier system is on top of retaining wall?
6. Is there brush or safety curb present?
7. Box culvert has beam guard attached to or installed on top of structure?
8. Are there structures that may need structural protection?
9. Are there unprotected blunt ends of the parapets?

If the answer to the following question is yes, additional review prior to proceeding with scoping the project:

1. Are there intersecting roadways or driveways within 125 feet of the structure or large drainage feature?

Barrier Systems:

If the answer to any of the following questions is yes, conduct additional review prior to proceeding with scoping the project:

1. Is the barrier system 15 years or older?
2. Does the barrier system have non-EAT end treatments that can be hit head on?
3. Is a transition from semi-rigid barrier to rigid barrier being used?
4. Are there non-standard barrier systems being used?
5. Is there sufficient grading for the barrier system and end treatments?
6. Is there rigid barrier with a height less than 32 inches on the project?
7. Is there a significant amount of barrier on the project or proposed to be on the project?

Grading:

If the answer to any of the following questions is yes, conduct additional review prior to proceeding with scoping the project:

1. Are there slopes steeper than 4:1?
2. Are ditches traversable?
3. Are slopes perpendicular to the direction of travel traversable?

Other Hazards:

If the answer to any of the following questions is yes, conduct additional review prior to proceeding with scoping the project:

1. Are there drainage features that are hazards?
2. Are there poles that are hazards?
3. Is there a vertical drop of 8 feet or more?
4. Is there water 2 feet deep?

Other Issues:

If the answer to any of the following questions is yes, conduct additional review prior to proceeding with scoping the project:

1. Are there segments with Metamanager ROR flags?
2. Are there areas that violate driver expectations?

3. Are there locations with high pedestrian concentrations?
4. Are there locations with severe consequence of collision?
5. Is the service life of the project 15 years or greater?

To obtain a working copy of this form go to: FDM 11-45 A20.11 File 1

Roadside Hazard Analysis

Project I.D. _____

Entered by: _____

Checked by: _____

Speed (MPH) = _____

AADT = _____

Alignment = _____

Hazard ID	Station or Stations	Offset (ft)	L/R	Total length of hazard (FT)	Description	Action	Discussion
1							
2							
3							
4							
5							
6							
7							
8							

Hazard ID	Station or Stations	Offset (ft)	L/R	Total length of hazard (FT)	Description	Action	Discussion
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							

Notes for Roadside Hazard Analysis Form:

Location information needs to only be accurate enough give a general location of the hazard. For example:

100+35 L 5 is better than 100+35.25 L 4.52

A general description of a hazard is acceptable. For example:

Sign is better than STH 73 shield with Left Turn Arrow

The “Discussion” section should provide a general outline of the actions to be taken, issues that cannot be address or mitigation being used. If detailed analysis was completed or there are other complexities, other sections of the Design Study Report may need to provide further discussion.

Avoid using construction cost to justify non-action. Other costs such as maintenance, and crash cost are to be considered as well as construction cost.

Avoid using aesthetics to justify non-action. AASTHO documentation indicates that crashworthiness is an important feature even in sensitive locations.

Add rows as needed. Change column and row heights to allow for discussion text to be read.

Roadside Hazard Analysis

Project I.D. _____

Entered by: _____

Checked by: _____

Speed (MPH) = _____

AADT = _____

Alignment = _____

Hazard ID	Station or Stations	Offset (ft)	L/R	Total length of hazard FT	Description	Action	Discussion	Notes
1	100+35	3	L	5	Overhead sign support	Shield Hazard	installing crash cushion	
2	101+23 to 101+33	9	R	10	Grove of trees	Remove Hazard	Trees average 10 to 8 ft from edge of lane. Average value 9 ft used	1
3	100+35 to 105+00	4	L	4.5	Light poles 2 ft behind curb	Relocate Hazard	Moving poles to back of sidewalk. Not using breakaway because of concerns of ped. and striking nearby buildings.	2
4	100+35	4	L	1.5	Light poles 2 ft behind curb	NA	Not possible to move light to behind sidewalk because of building. Not using breakaway because of concern of pole striking building or peds.	2
5	100+35 to 102+35	6	R	200	Steep slope	Make Traversable	Steep slopes and non-traversable ditch. Portions of ditch have water 2' deep. Seen hazard IDs 9 and 10.	3
6	101+01	4	L	3	Rock	Remove Hazard		4
7	101+23 to 101+33	5	L	5	Historical marker/pedestrian trail	NA	Removal, relocation, improving traversablility, or installing barrier not possible because these options will interfere with Ped. trail. Trimming trees and bushes to improve sight lines to Ped. trail. Providing delineation and signs	5

Hazard ID	Station or Stations	Offset (ft)	L/R	Total length of hazard FT	Description	Action	Discussion	Notes
8	101+99 to 102+74	4	R	75	Steep slopes on driveway	Make Traversable	Driveway slope needs to be flatten and a traversable culvert endwall installed.	
9	103+05	8	L and R	7	60" cross drain	Remove Hazard	Lengthen box culvert and Connecting it to a new storm sewer. Inlet of pipe will have traversable grate and grading. Other side will connect into a storm sewer system. See hazard IDs 10 and 5	3
10	103+05 to 104+05	8	R	100	Steep foreslope of ditch and water 2' deep	Remove Hazard	Installing storm sewer, flattening slopes See ID 5 and 9	3
11	104+08	7	L	1	Old plow being used as mail box	NA	Putting mail box information into hazardous mail box report.	6
12	104+05 to 104+40	6	L	35	Driveway	Make Traversable	Driveway slope needs to be flatten and a traversable culvert endwall installed.	
13	104+35	15	L	8	School sign	NA	Sign is just outside analysis area, but within Right-of-Way. Placing this sign on the encroachment list.	7
14	104+52 to 105+07	20	L	150	Playground	Shield Hazard	Playground is just beyond clear zone. However, consequence of errant vehicle getting to play ground severe enough to require barrier.	8
15	105+17	18	L	5	Gas valve	Shield Hazard	Gas valve near playground. Extending barrier for playground to protect gas valve. Consequence of collision very severe.	8
16	105+63	20	R	2.5	Survey Witness Tree	Delineate Hazard	Tree is a witness tree for section corner. Tree is on the inside of curve and there is no ROR history.	9
17	105+46 to 106+96	16	R	150	Grove of trees and bushes	Remove Hazard	Tree range from 12 to 20 from edge of roadway Average value 16 ft	10

Hazard ID	Station or Stations	Offset (ft)	L/R	Total length of hazard FT	Description	Action	Discussion	Notes
18	107+35 to 108+35	12	L	100	Effigy Mound	NA	Effigy mounds are culturally significant asset. Installing barrier and delineation not options because they would degrade the culturally significant asset.	11

Discussion of Notes in Example Roadside Hazard Analysis Form

Note 1:

Hazard ID 2 has similar hazards (trees) with similar offsets. These hazards are being treated the same and can be grouped within one entry.

Normally an individual hazard would not need discussion (see note 4), but because a group of similar hazards are being grouped together some discussion is provided to clarify that the designer intends on treating similar hazards with similar offsets as a group.

Note 2:

Hazard IDs 3 and 4 have similar hazards (light poles) with similar offsets. However, one pole cannot be moved and is entered in as hazard ID 4. Discussion provides information on why breakaway hardware was not used.

Note 3:

Hazards IDs 5, 9, and 10 are related because of the treatment being used to solve each hazard.

Note 4:

As stated in note 1, individual hazards that are being removed do not need additional discussion.

Note 5:

Hazard ID 7 provides some information on alternatives reviewed at a given location, why alternatives are not practical, and what it any methods are being used to mitigate risk.

Note 6:

Hazard ID 11's description indicates that hazardous mail boxes will follow the procedures in FDM 11-15-1.

Note 7:

Hazard ID 13's description indicates sign is will be identified as a right of way encroachment and will be treated as such.

Note 8:

Hazard IDs 14 and 15 deal with areas of concern. Hazard ID 14 deals with pedestrian areas of concern. Hazard ID 15 deals with a consequence of collision concern.

Notes 9 and 10:

Hazard IDs 16 and 17 deal with similar hazards with similar offsets. However, one hazard (Hazard ID 16) cannot be removed because it is a witness tree.

Notes 11:

Hazard ID 18 deals with a significant cultural artifact that prevents the proper use of roadside design principles.

Example Problem 1 –West side of Structure[10]

See Figure D for plan view; see Figure E for cross-section views of stations 2+00 and 3+00.

Given:

- AADT= 3500 (Always use larger of design or existing AADT)
- Design Speed = 45 MPH
- At station 4+00 and beyond: side slopes within the clear zone are recoverable; ditch within the clear zone is traversable
- Station 3+00 to 4+00: there is not a clear runout area beyond the toe of traversable but non-recoverable slope
- L_C = Clear Zone = 26' (from FDM 11-15-1, Attachment 10)
- L_R = 135' (from Table 1)
- L_2 = shoulder width = 6'

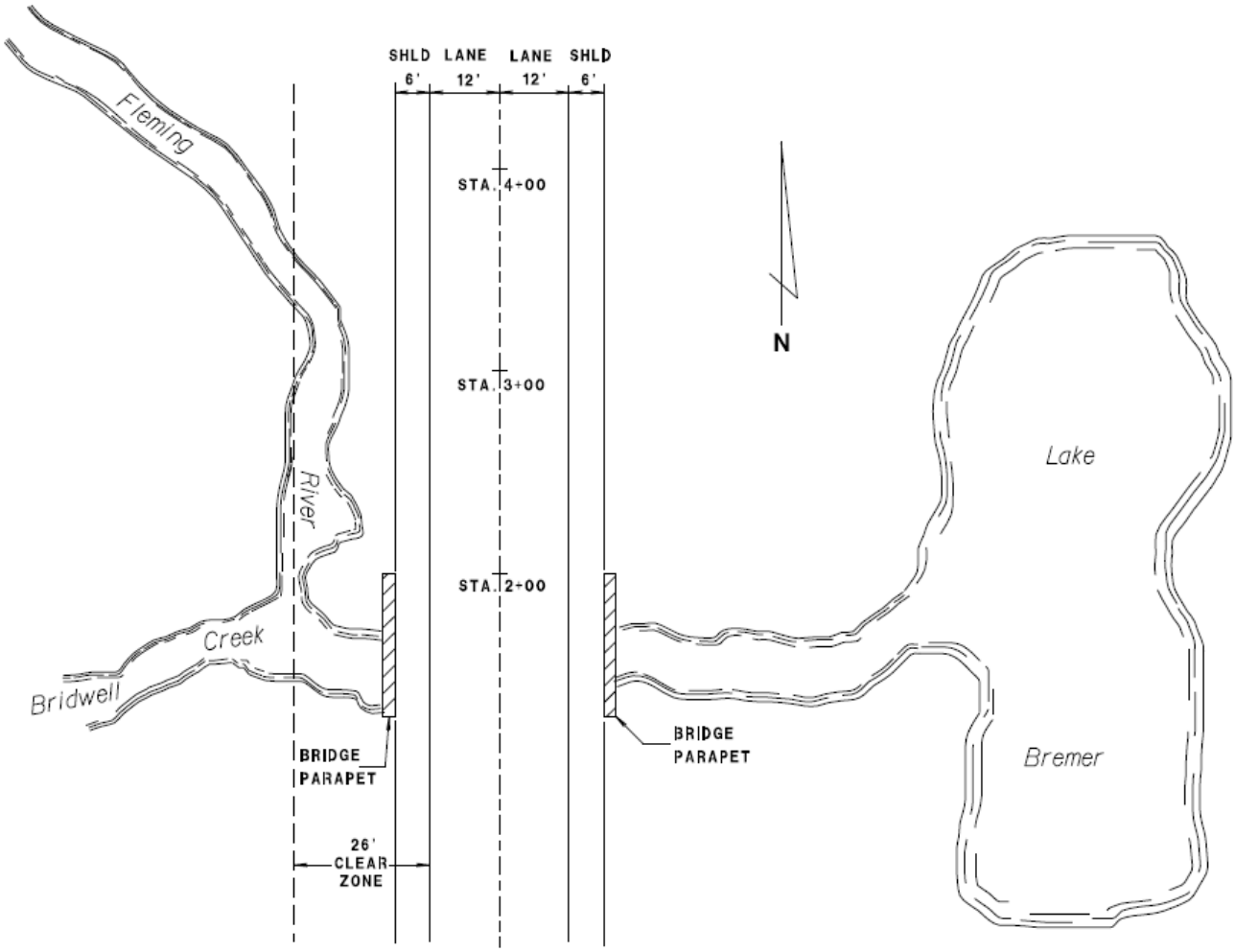


Figure D Example 1 Plan View

[10] FDM is only providing examples for one side of the roadway. Other side would also need to have calculations performed.

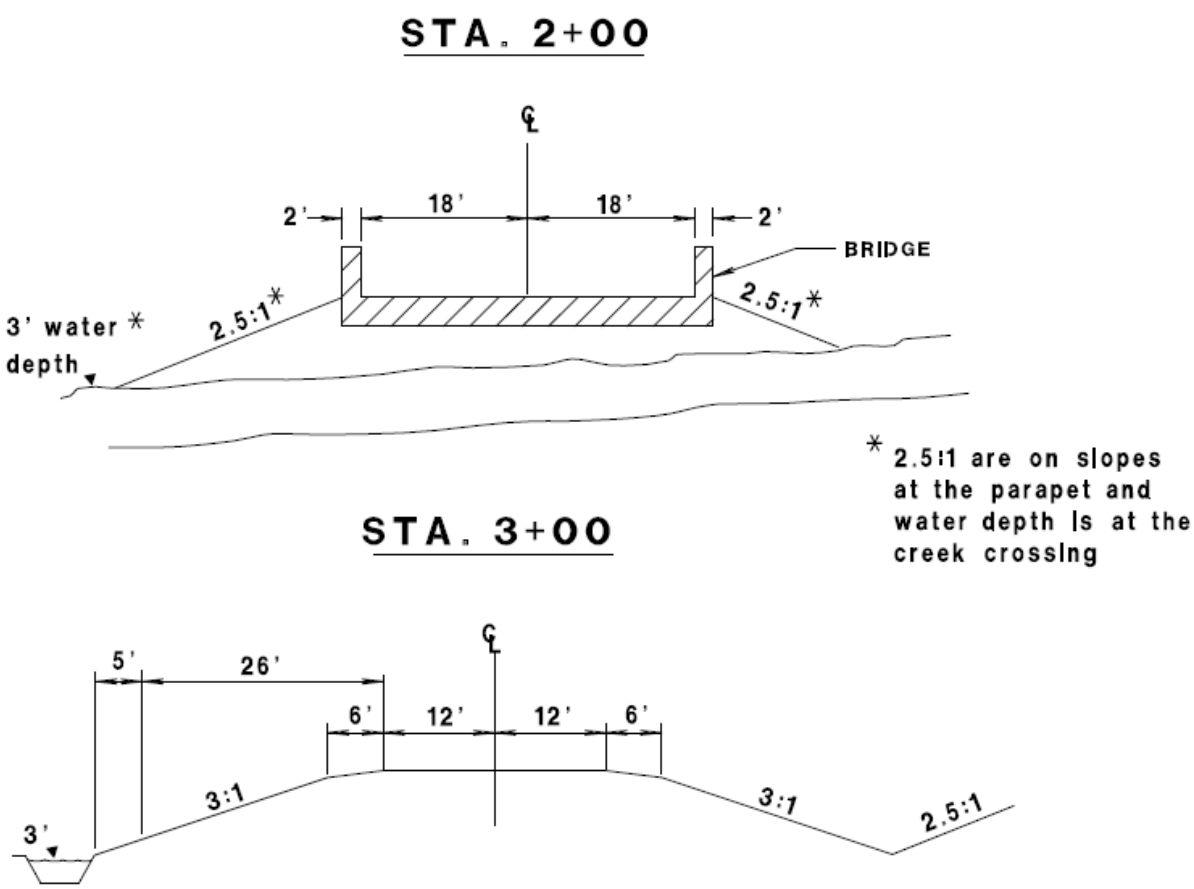


Figure E Example 1 Cross Section Views

Find:

1. Determine which hazards need to be shielded.
2. Calculate the LON for installation using equation 1.
3. Calculate the length of barrier from end of terminal to hazard that is needed to provide calculated LON.
4. Verify that the calculated length of barrier is greater than or equal to the minimum required length from end of terminal to hazard
5. Verify that there is adequate space for the required grading at the EAT terminal

Example 1 Part 1 Solution: Near-side Approach (Northwest Quadrant)

Hazards that need to be shielded:

- The north end of the west-side bridge parapet;
- Water within the clear zone that is deeper than 2'; and
- Traversable side slopes within the clear zone for which there is not a clear runout area and critical side slopes within the clear zone.

Calculate the length of beam guard needed to shield north end of the west-side bridge parapet

L_A = shoulder width + parapet width = 6' + 2' = 8'; L_R and L_2 are as given on the previous page.

$$X=\frac{(L_A-L_2)}{L_A/L_R}=\frac{(8-6)}{8/135}=33.75'$$

Note:

The calculated LON in this example is less than the minimum installation standard length for EAT and thrie beam structure approach (e.g. length of MGS EAT and MGS thrie beam transition is approximately 93').

However, there are other hazards at this location that need shielding: (e.g. the water has a depth of 2' or more within the clear zone, and the side slopes near the structure are non-traversable). Therefore, the length of need is calculated using full clear zone width (i.e., L_A=L_C).

Calculate the length of beam guard needed to shield the water within the clear zone that is deeper than 2-ft. This hazard extends from station 2+00 to station 4+00 because there is no clear recovery area between these stations. Therefore, the edge of clear zone at station 4+00 becomes the end of hazard that should be shielded. The length of need is calculated using full clear zone width (i.e., L_A=L_C=26')

$$X=\frac{(L_A-L_2)}{L_A/L_R}=\frac{(26-6)}{26/135}=103.8'\cong 104'$$

The LON equation places the "end point of barrier need" 104 feet upstream of station 4+00 (i.e. station 5+04). This represents the station of EAT post no. 3. EAT post no. 1 is at station 5+16.5, which is 116.5-feet from the hazard. The beam guard needs to shield the entire length of the hazard starting at station 2+00. Station 5+16.5 is a suitable location to install the EAT.

<u>Example 1 Part 2 Solution: Departure Side (Southwest Quadrant)</u>

Given:

AADT= 3500

Design Speed = 45 MPH

Clear Zone= 26' (See 11-15-1)

L_R= 135' (See Table 1)

Find:

Compute LON using LON equation

Verify that the required grading, minimum lengths for barrier system and terminals can be provided at the calculated location

Solution:

L_A=12' (lane width) +6' (shoulder width)+2'(2 parapet)=20' (However, use full clear zone 26'. See above discussion about water being a hazard)

L_2=12' (lane width)+6' (shoulder width)=18'

$$X=\frac{(L_A-L_2)}{L_A/L_R}=\frac{(26-18)}{26/135}=41.5'$$

The 41.5' length of the departure end of the bridge is a minimum length of barrier from the length of need equation. If there were other hazards (water, non-recoverable slopes, non-traversable slopes) the length of beam guard on the departure end would need to be extended, or other roadside design methods would need to be deployed (e.g. remove, make traversable…).

In this example (i.e. two-way traffic), the minimum installation length would be the length of EAT plus thrie beam structure approach (e.g. length of MGS EAT and MGS thrie beam transition is approximately 93').

Typically, the downstream end of a bridge on a one-way road does not need additional barrier. However if there are other hazards to shield (e.g. sign bridge, steep slopes…), a thrie beam transition to beam guard (see SDD 14B45 see sheet b), beam guard (if needed), and a type II terminal (see SDD 14B47) should be installed.

Example 2 Rock Wall

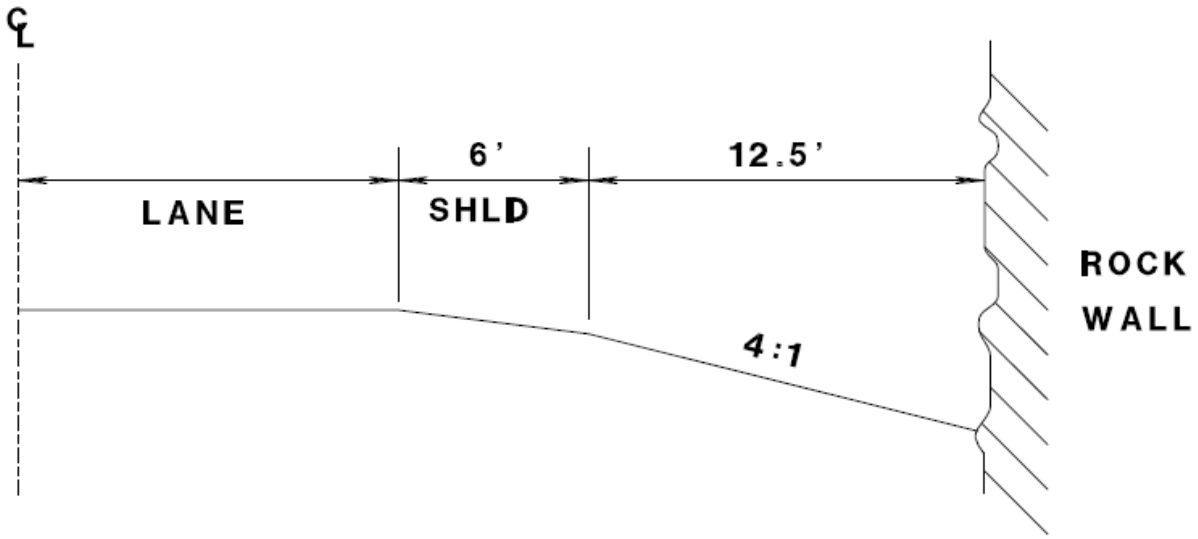


Figure F Example 2 Outside Of Curve Cross Section

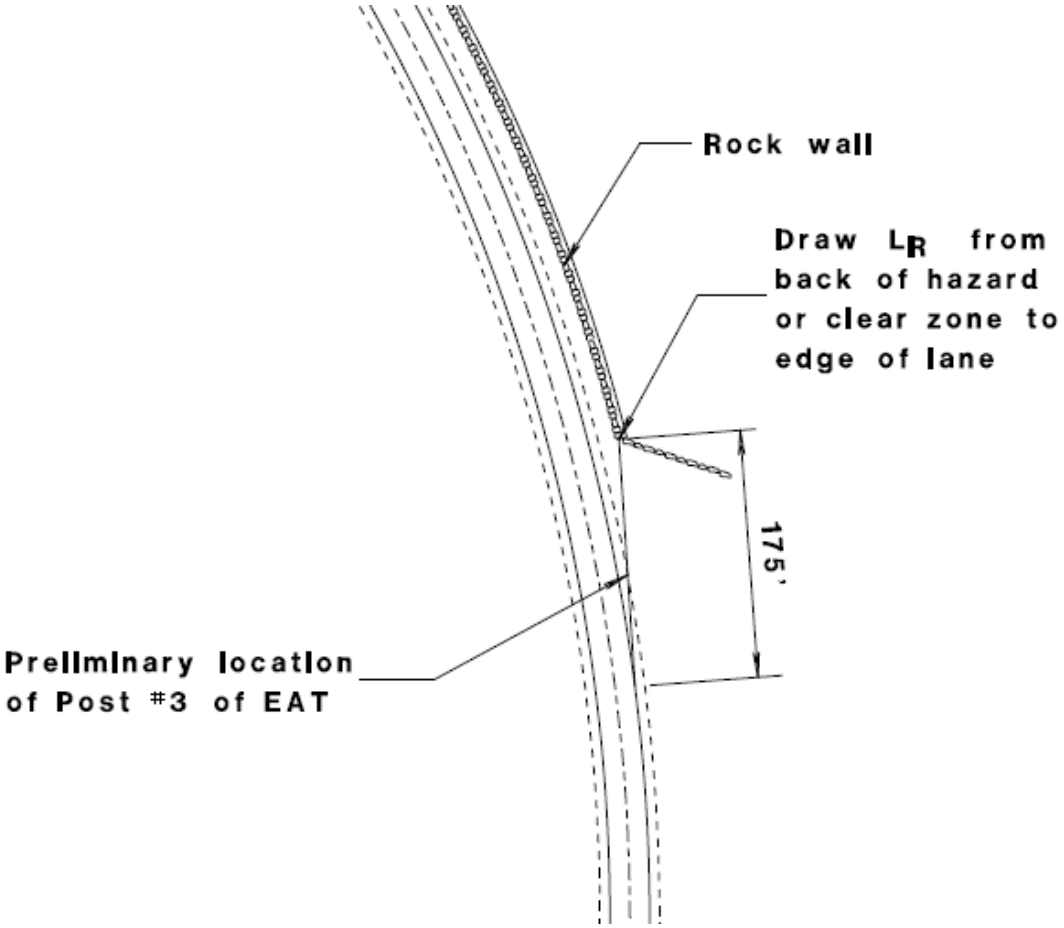


Figure G Example 2 Outside of Curve Plan View (Runout Length)

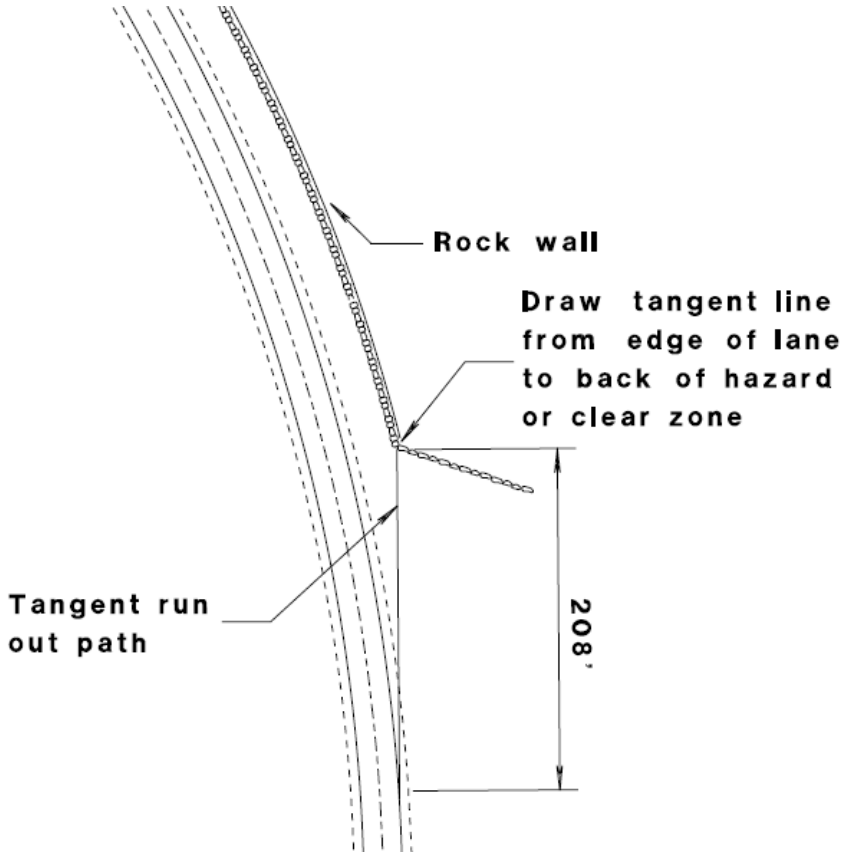


Figure H Example 2 Outside of Curve Plan View (Tangent Path)

Given:

Design AADT= 750

Design Speed = 55 MPH

Curve Radius = 1150'

Clear Zone: 14' (from As-built plans 3R construction)

L_R= 175' (See Table 1)

Find:

Adjusted clear zone value for curve.

Is rock wall within the adjusted clear zone?

Is the rock wall a hazard?

LON for installation compensating for curve.

Solution:

K_{CZ}=1.3 (See 11-15-1)

Adjusted Clear Zone=14 X 1.3 = 19.6'

Distance from edge of lane to edge of rock wall =6' (shoulder width)+12.5 (distance to rock wall)=18.5'

Rock wall is within adjusted clear zone install barrier.

L_R is less than drawn tangent runout of 208' (see **Figures G and H**). Use L_R to locate LON point for barrier system.

Example 3 Outside of Curve Cattle Pass

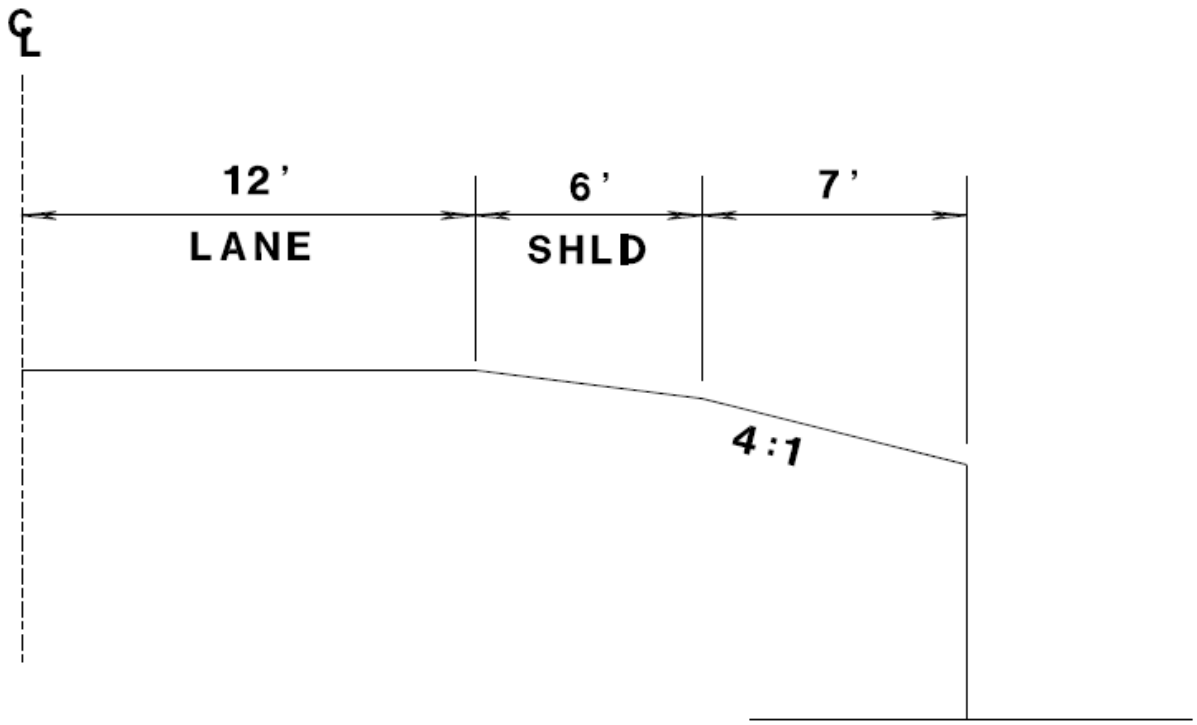


Figure I Example 3 Outside of Curve Cross Section View

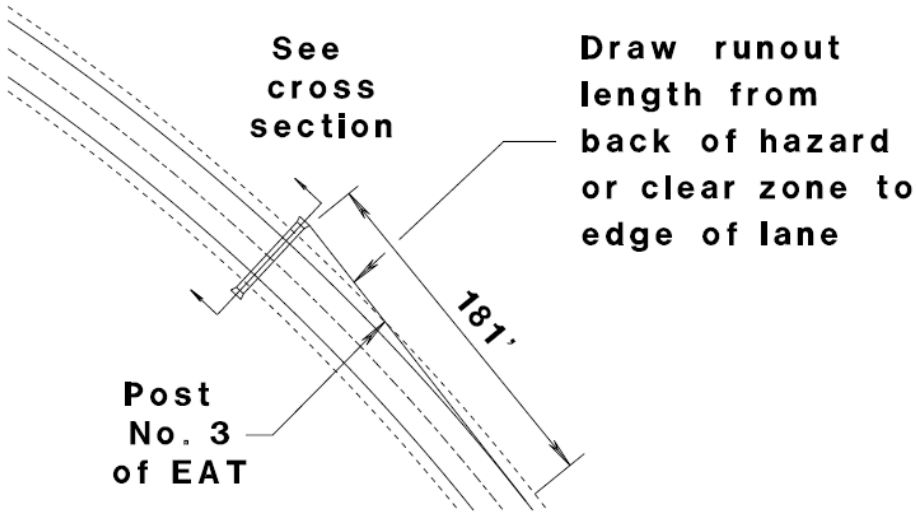


Figure J Example 3 Outside Of Curve Plan View (Tangent Runout Length)

Given:

Design AADT: 5130

Design Speed = 55 MPH

Curve Radius = 1150'

Clear Zone: 24-30' (See 11-15-1)

L_R= 220’ (See Table 1)

Find:

Adjusted clear zone value for curve.

Is the cattle pass within the clear zone?

Is the cattle pass opening a hazard?

What is LON for installation compensating for curve?

Solution:

K_{CZ}=1.4 (See 11-15-1)

Adjusted Clear Zone=30 X 1.4 = 42’

Distance from edge of lane to back of cattle pass =6’ (shoulder width)+7’(distance to back of cattle pass)=13’

Cattle pass is within adjusted clear zone and is a hazard; therefore install barrier.

Assuming that all slopes around the cattle pass are traversable and there are no other hazards to shield, L_R is greater than tangent runout of 181’ (see **Figure J**). Use drawn tangent runout length of 181’ to locate LON point for barrier system on the outside of curve.

Use desirable clear zone values for new installation, or if the cattle pass required reconstruction. Structures like cattle passes can become future pinch points for future road projects. If a barrier system is needed to shield these new or reconstructed structures the “end point of the barrier” should be based off of the desirable clear zone.

Example 4 Inside of Curve Cattle Pass

Use information provided in example 3.

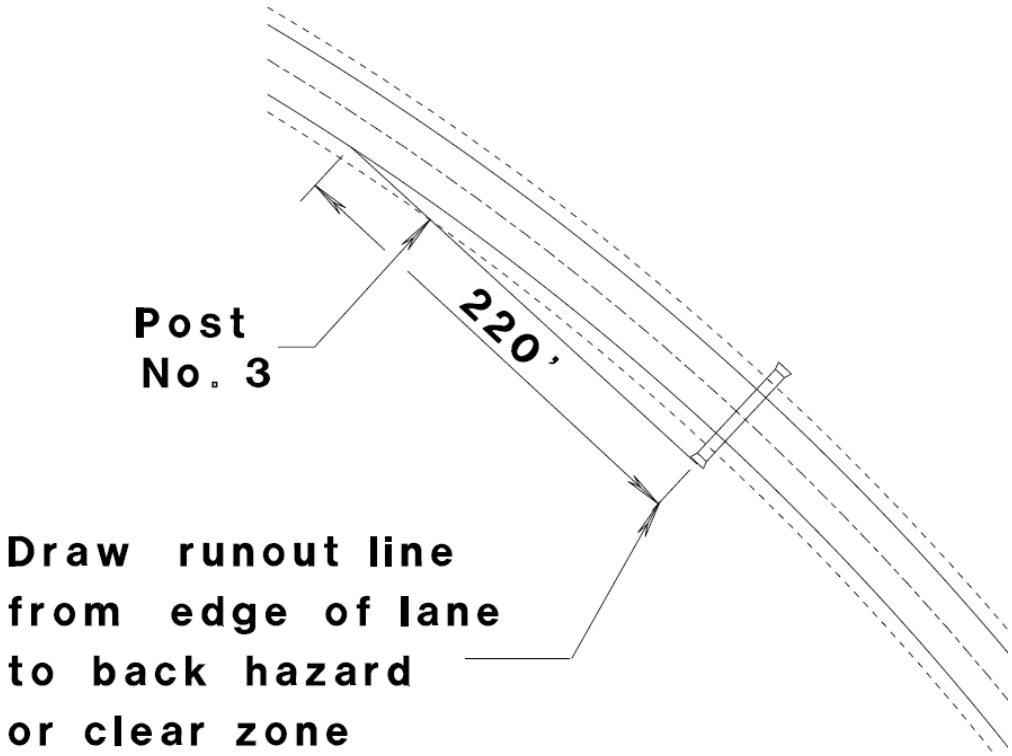
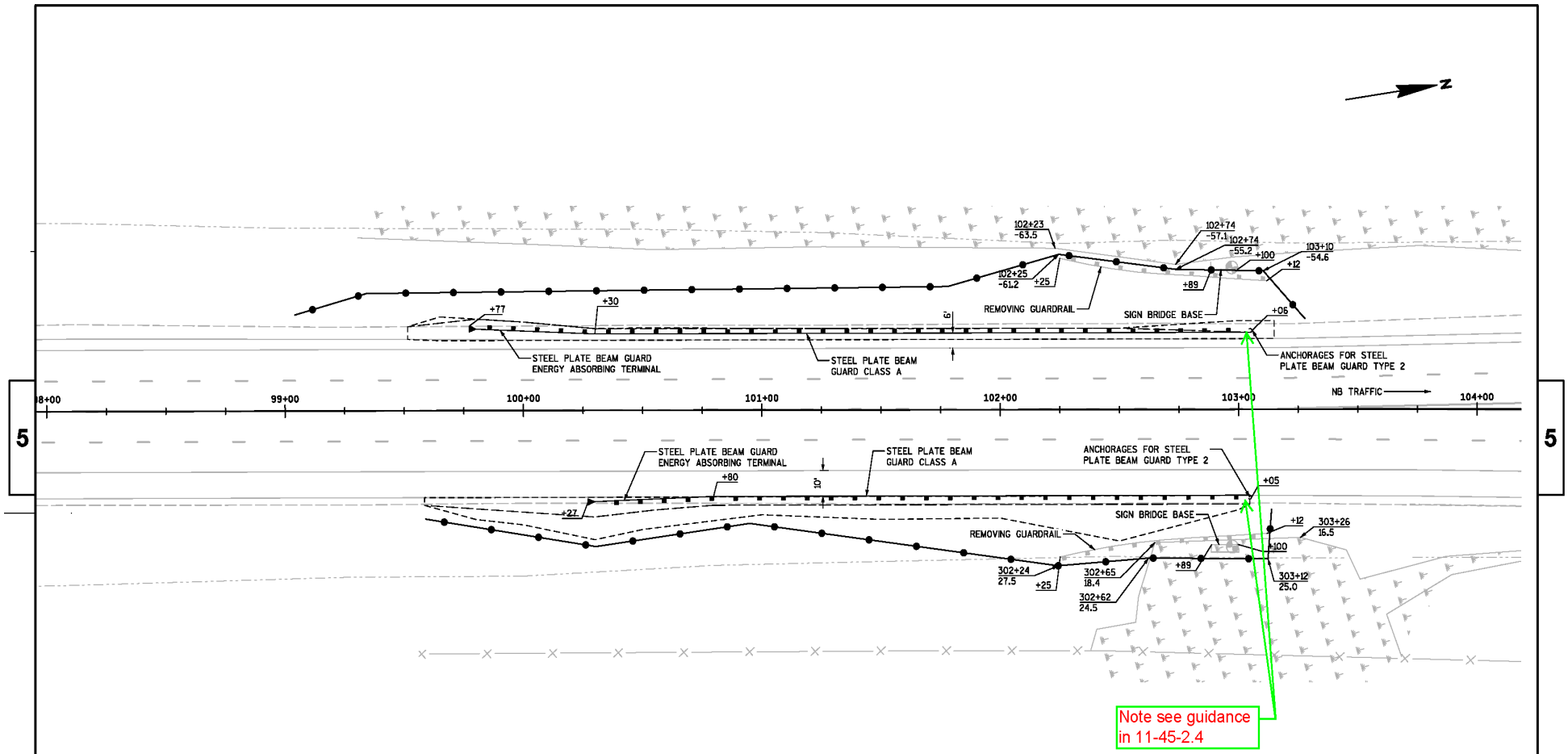


Figure K Example 4



BENCH MARKS

NO.	STATION	DESCRIPTION	ELEV.
160	99+17 LT	PK NAIL IN ASPHALTIC PAVEMENT	761.57
210	99+23 RT	PK NAIL IN ASPHALTIC PAVEMENT	761.38

LEGEND

TEMPORARY DITCH CHECKS

SILT FENCE

NOTES

USE INLET PROTECTION TYPE A ON ALL INLETS

Cross sections are not shown on this sheet.
Cross sections are available elsewhere in the plan.

0 20 40
SCALE, FEET

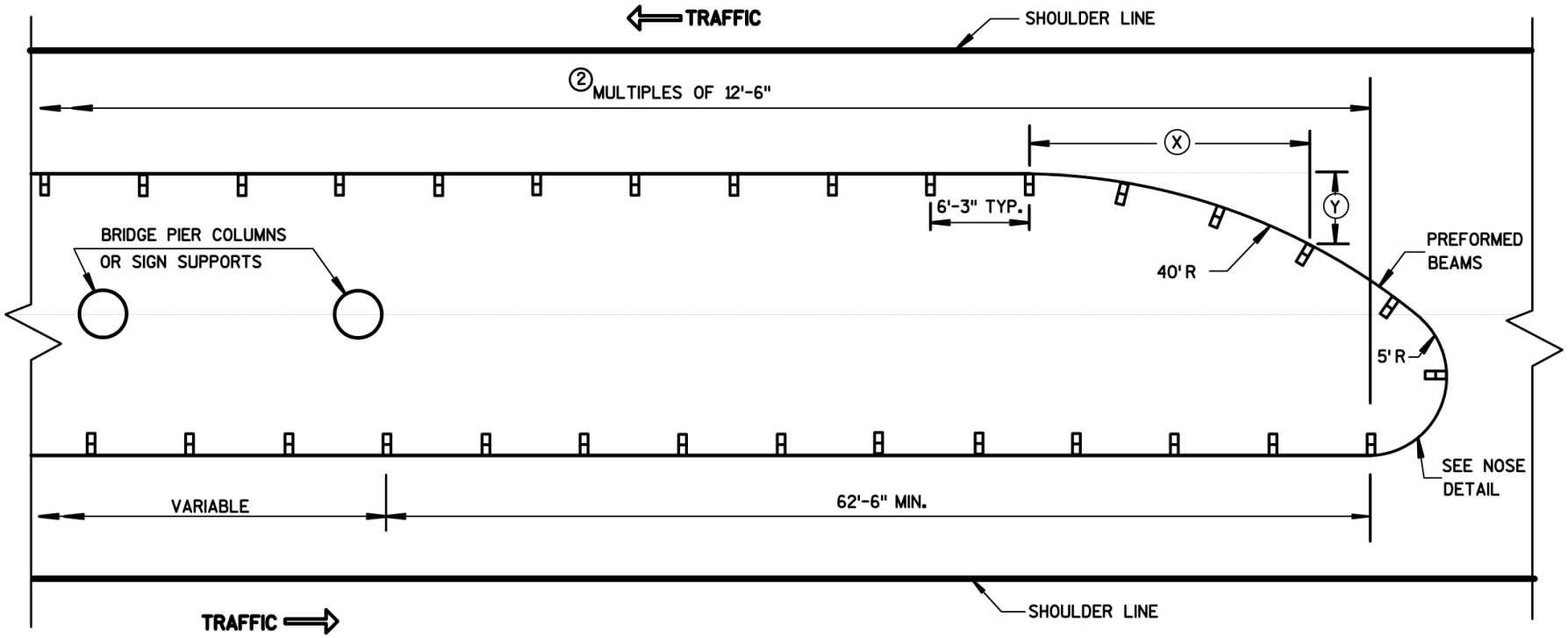
PROJECT NO: 1450-01-72	HWY: IH 43	COUNTY: OZAUKEE	STH 57 SIGN BRIDGE (LOCATION 009)	SHEET 19	E

FILE NAME : X:\20000S\20005\20005.05\Ozaukee_Cnty\OZA 043 009 STH 57 Sign Bridge\Engineering_Documents\OZA 043 009 pp_sheet.dgn PLOT DATE : 1/18/2011 PLOT BY : crutkowski PLOT NAME : PLOT SCALE : 1:40 WISDOT/CADDS SHEET 44

A working copy of this spreadsheet is available at: FDM 11-45 A30.6 File 1

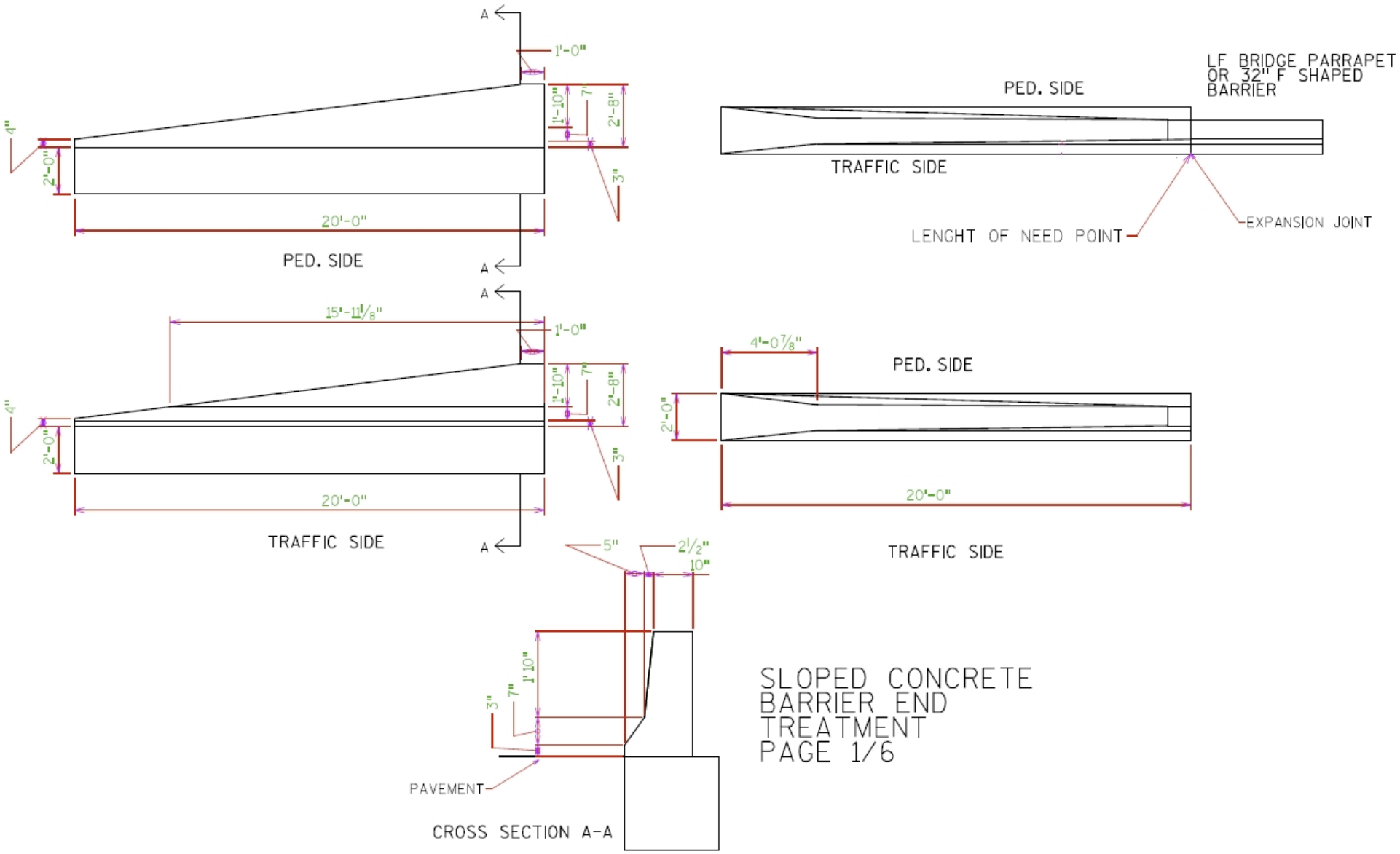
Beam Guard Analysis

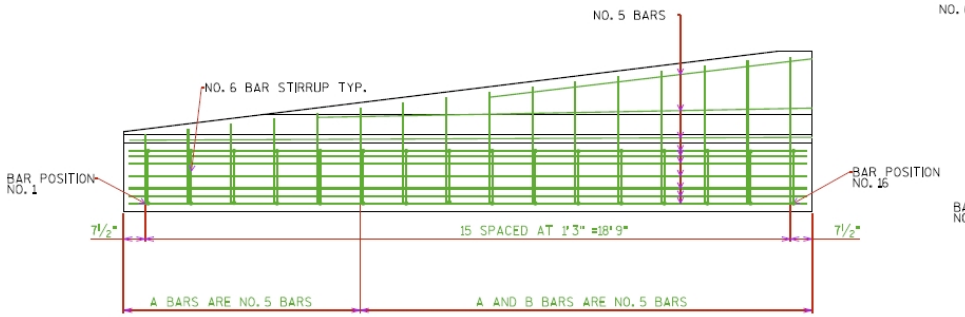
Project		
Location		
Length of Existing Beam Guard Run		ft
Additional Beam Guard Length Needed		ft
Length of Beam Guard to Remove		ft
Number of Blocks and Post that need Adjustment or Replacement		each
Length of rail that needs height adjustment		ft
Length of Rail that needs Replacement		each
Age of System		years
Number of Years to Next Project in Area		years
Average Item Costs		
Install Beam Guard		per ft
Remove/salvage Beam Guard		per ft
Replace/adjust Block and Post		each
Adjust Beam Guard		per ft
Replace Rail and Hardware		per ft
Depreciated Value (assuming removal of whole system)	$ -	
Barrier Modification Cost		
Additional Beam Guard needed	$ -	
Removal/salvage of Beam Guard	$ -	
Adjust or Replace Block and Post	$ -	
Adjust Beam Guard height	$ -	
Replace Rail and Hardware	$ -	
Total Cost of Modification	$ -	
Depreciated Value-Cost of Modifications	$ -	
Useful Service Life- Planned Barrier Life	25	



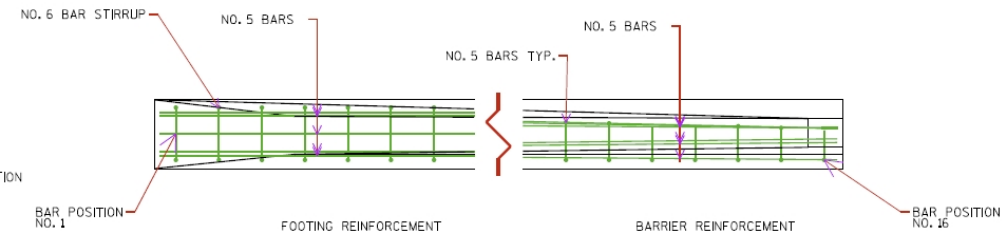
PLAN VIEW

TYPICAL LAYOUT AT PIERS AND SIGN SUPPORTS


A
1'-0"
1'-10"
7"
2'-8"
4"
2'-0"
3"
20'-0"
PED. SIDE
A
LF BRIDGE PARRAPET OR 32" F SHAPED BARRIER
PED. SIDE
TRAFFIC SIDE
LENGHT OF NEED POINT
EXPANSION JOINT
A
15'-11 1/8"
1'-0"
1'-10"
7"
2'-8"
4"
2'-0"
3"
20'-0"
TRAFFIC SIDE
A
4'-0 7/8"
PED. SIDE
2'-0"
20'-0"
TRAFFIC SIDE
5"
2 1/2"
10"
1'10"
3"
7"
PAVEMENT
CROSS SECTION A-A
SLOPED CONCRETE BARRIER END TREATMENT PAGE 1/6



PROFILE VIEW OF REINFORCEMENT



PLAN VIEW OF REINFORCEMENT

STAGGER LAPPING OF LONGITUDINAL STEEL. MINIMUM OVERLAP OF STEEL 2 FEET. BARS AT LAPS TO BE FIRMLY TIED OR CONNECTED.

4000 PSI CONCRETE AIR ENTRAINMENT PER STANDARD SPECIFICATION 501.

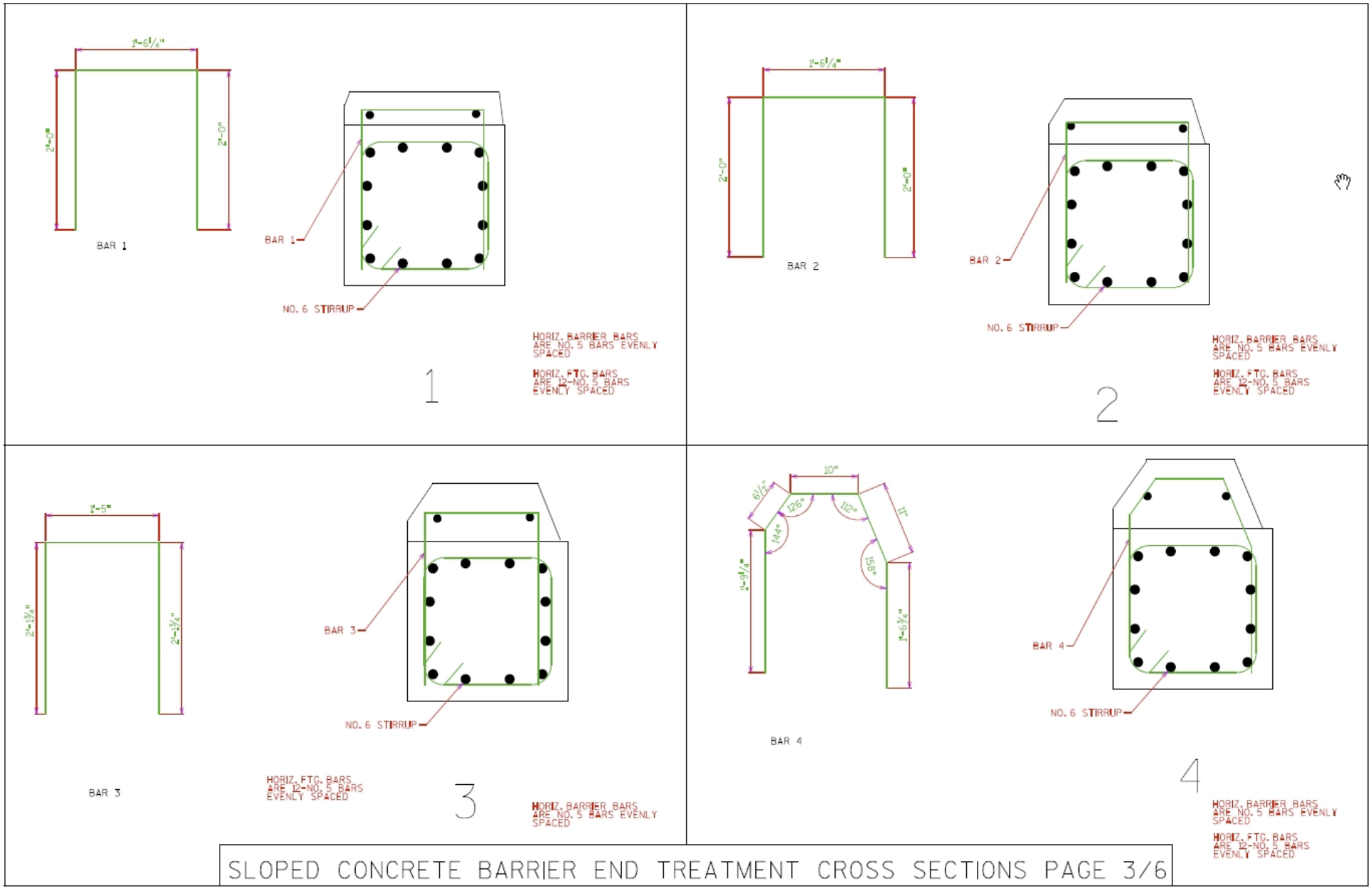
USE ¾" BEVEL OR 1" RADIUS ON ALL EXPOSED SHARP EDGES UNLESS OTHERWISE NOTED.

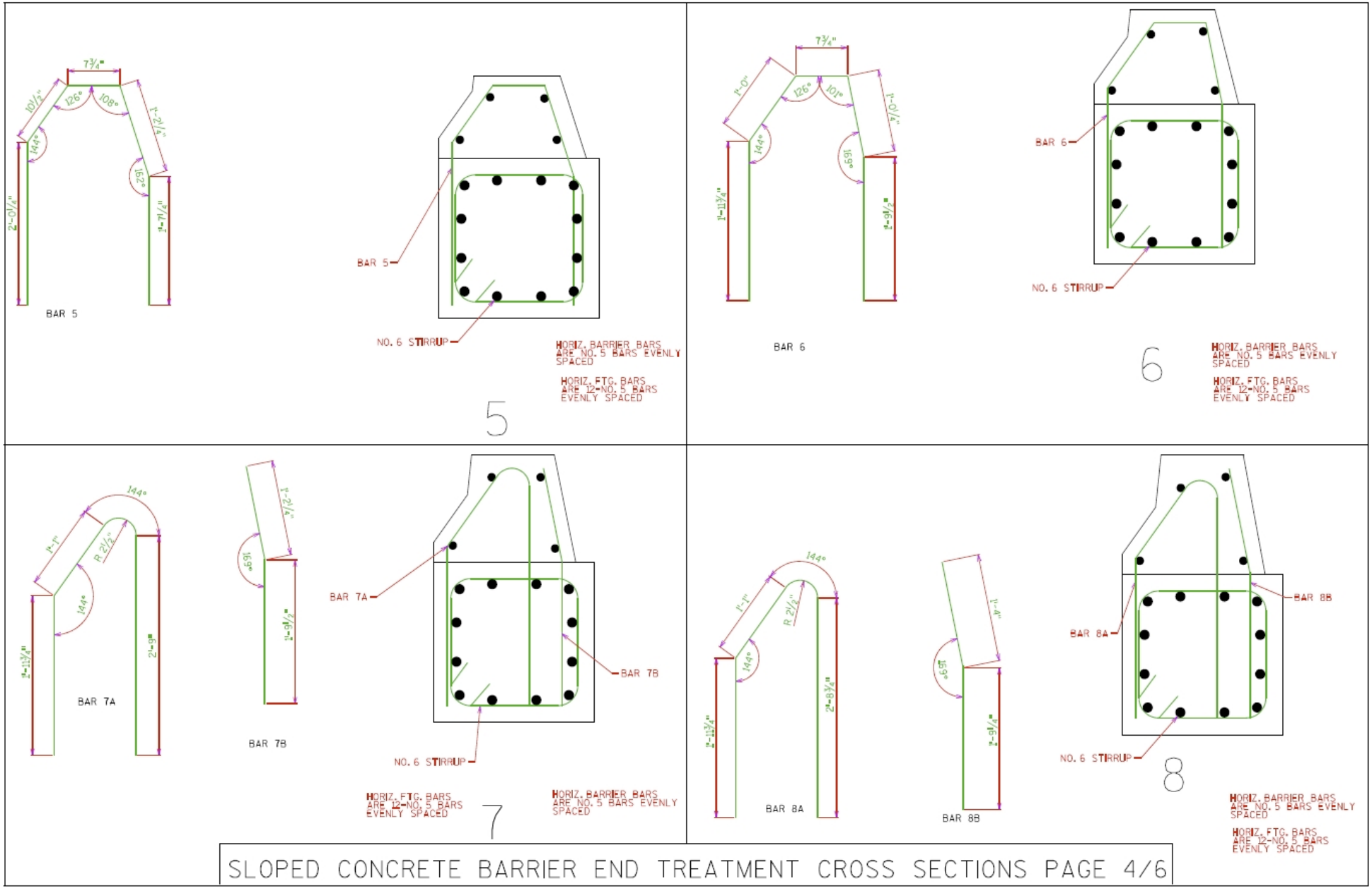
2" CLEAR COVER TYPICAL. 1½" MIN CLEAR COVER.

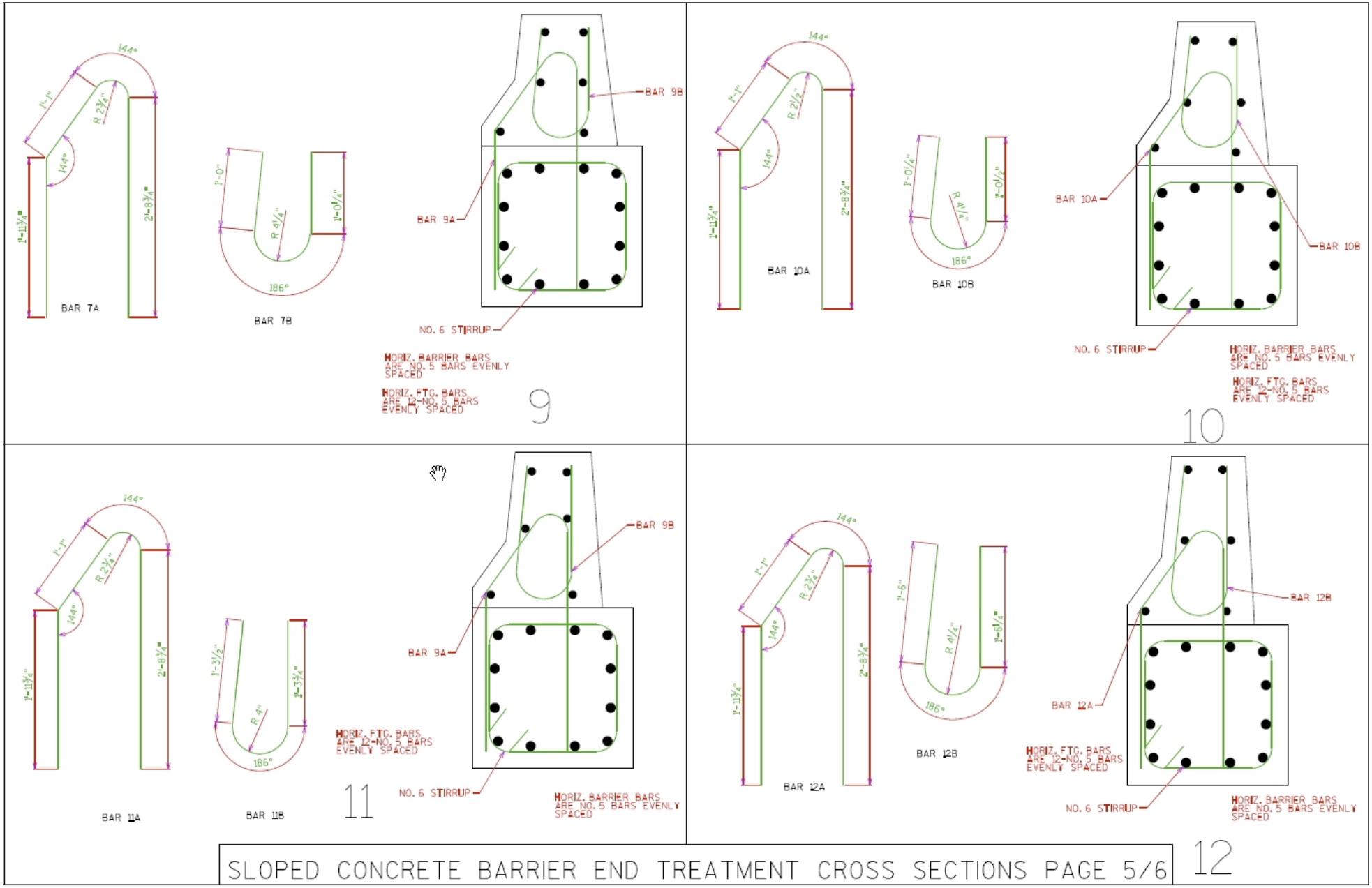
CONSTRUCT PER STANDARD SPECIFICATION 603.

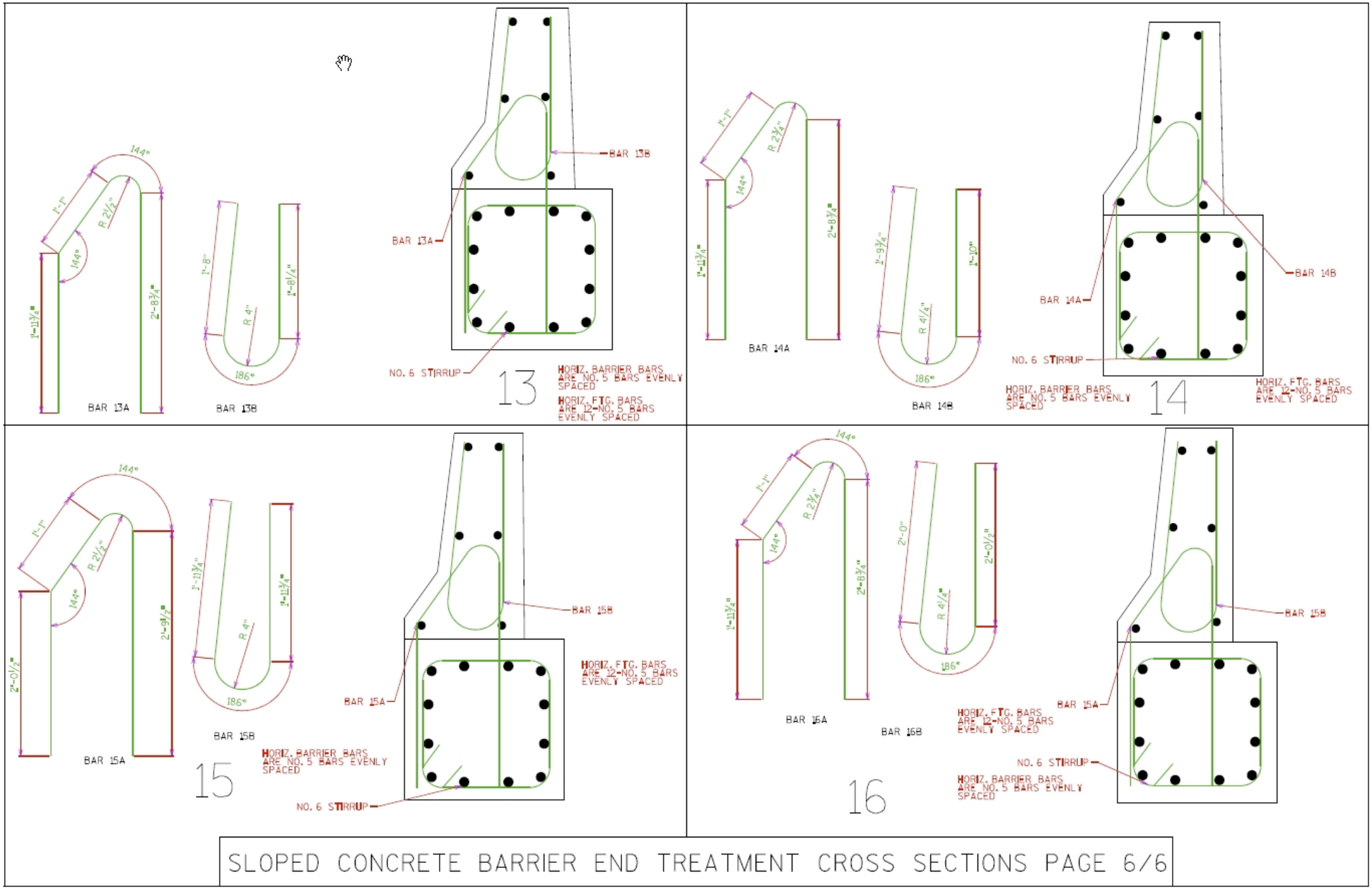
PLACE BARRIER PERPENDICULAR TO SHOULDER GRADE, UNLESS INDICATED IN PLAN.

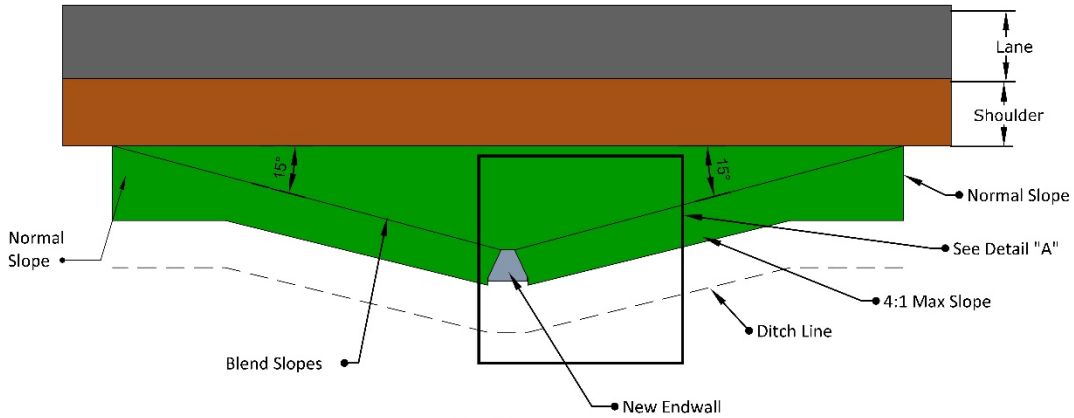
SLOPED CONCRETE BARRIER END TREATMENT PAGE 2/6


1'-6¼"
2'-0"
2'-0"
BAR 1
BAR 1
NO. 6 STIRRUP
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
1
1'-6¼"
2'-0"
2'-0"
BAR 2
BAR 2
NO. 6 STIRRUP
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
2
1'-5"
2'-1¾"
2'-1¾"
BAR 3
BAR 3
NO. 6 STIRRUP
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
3
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
10"
6½"
126°
112°
11"
144°
156°
1'-9¼"
1'-6¾"
BAR 4
BAR 4
NO. 6 STIRRUP
4
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
SLOPED CONCRETE BARRIER END TREATMENT CROSS SECTIONS PAGE 3/6

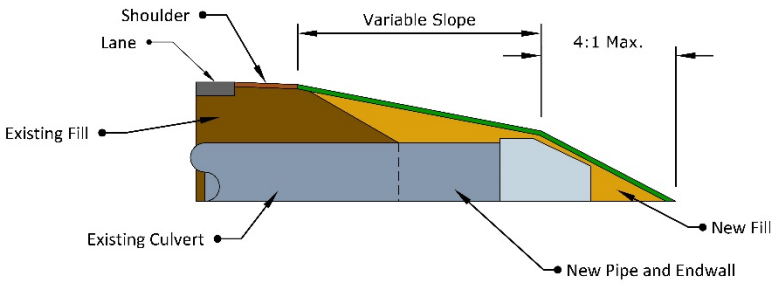

7¾"
10½"
126°
108°
1'-2½"
144°
162°
2'-0½"
2'-7¼"
BAR 5
BAR 5
NO. 6 STIRRUP
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
5
7¾"
1'-0"
126°
101°
1'-0¼"
144°
159°
1'-11¾"
2'-9½"
BAR 6
BAR 6
NO. 6 STIRRUP
6
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
144°
1'-1"
R 2½"
144°
1'-11¾"
2'-9"
BAR 7A
1'-2¼"
159°
2'-9½"
BAR 7B
BAR 7A
BAR 7B
NO. 6 STIRRUP
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
7
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
144°
1'-1"
R 2½"
144°
1'-11¾"
2'-8¾"
BAR 8A
1'-4"
159°
2'-9¼"
BAR 8B
BAR 8B
BAR 8A
NO. 6 STIRRUP
8
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
SLOPED CONCRETE BARRIER END TREATMENT CROSS SECTIONS PAGE 4/6


144°
1'-1"
R 2¾"
144°
1'-11¾"
2'-8¾"
BAR 7A
1'-0"
R 4¼"
1'-0¼"
186°
BAR 7B
BAR 9B
BAR 9A
NO. 6 STIRRUP
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
9
144°
1'-1"
R 2½"
144°
1'-11¾"
2'-8¾"
BAR 10A
1'-0¼"
R 4¼"
1'-0½"
186°
BAR 10B
BAR 10A
BAR 10B
NO. 6 STIRRUP
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
10
144°
1'-1"
R 2¾"
144°
1'-11¾"
2'-8¾"
BAR 11A
1'-3½"
R 4"
1'-3¾"
186°
BAR 11B
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
11
BAR 9B
BAR 9A
NO. 6 STIRRUP
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
144°
1'-1"
R 2¾"
144°
1'-11¾"
2'-8¾"
BAR 12A
1'-6"
R 4¼"
1'-6¼"
186°
BAR 12B
BAR 12B
BAR 12A
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
NO. 6 STIRRUP
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
SLOPED CONCRETE BARRIER END TREATMENT CROSS SECTIONS PAGE 5/6
12

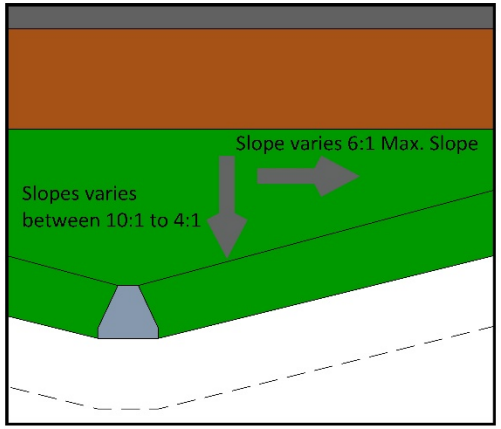

144°
1'-1"
R 2½"
144°
1'-11¾"
2'-8¾"
BAR 13A
1'-8"
R 4"
1'-8¼"
186°
BAR 13B
BAR 13B
BAR 13A
NO. 6 STIRRUP
13
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
1'-1"
R 2¾"
144°
1'-11¾"
2'-8¾"
BAR 14A
1'-9¾"
R 4¼"
1'-10"
186°
BAR 14B
BAR 14B
BAR 14A
NO. 6 STIRRUP
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
14
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
144°
1'-1"
R 2½"
144°
2'-0½"
2'-9½"
BAR 15A
1'-11¾"
R 4"
1'-11¾"
186°
BAR 15B
BAR 15B
BAR 15A
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
NO. 6 STIRRUP
15
144°
1'-1"
R 2¾"
144°
1'-11¾"
2'-8¾"
BAR 16A
2'-0"
R 4¼"
2'-0½"
186°
BAR 16B
HORIZ. FTG. BARS ARE 12-NO. 5 BARS EVENLY SPACED
BAR 15B
BAR 15A
NO. 6 STIRRUP
HORIZ. BARRIER BARS ARE NO. 5 BARS EVENLY SPACED
16
SLOPED CONCRETE BARRIER END TREATMENT CROSS SECTIONS PAGE 6/6



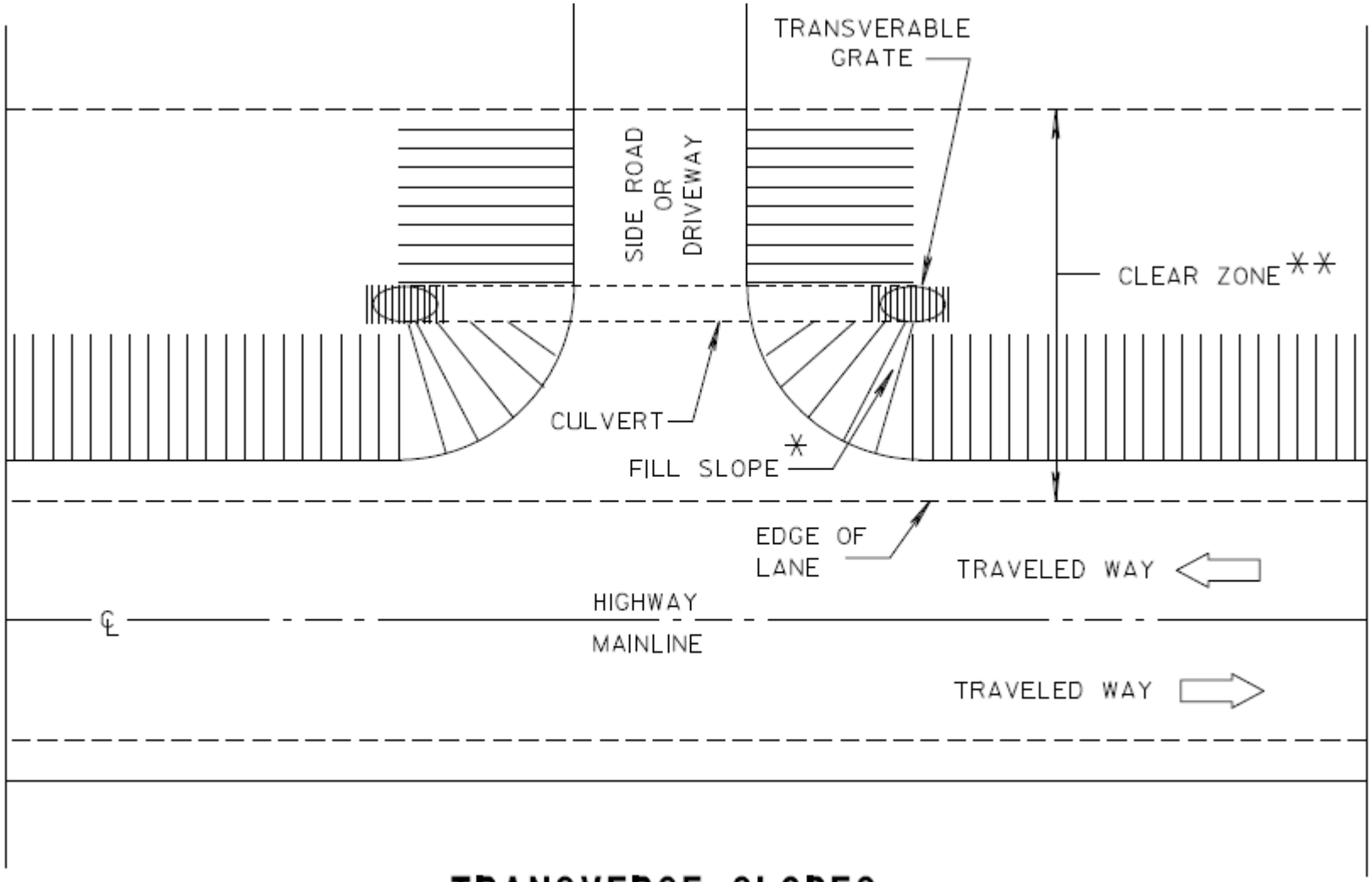
Plan View



Cross Section View



Detail A



TRANSVERSE SLOPES
ON 2-LANE, 2-WAY ROADWAYS

* Fill slopes may need to vary for blending purposes in select locations. Refer to FDM 11-45-30 for more guidance on transverse slopes.

** In some spot location existing Right of Way may limit how far from the roadway grading can be provided. Documentation these locations in DSR.

Crash Cushion Selection Tables

Crash Cushion Table Abbreviations:

CCP = Crash Cushions Permanent (Item 614.0800)

CCPL = Crash Cushions Permanent Low Maintenance (Item 614.0805)

OS = Other system should be used (e.g. EAT with thrie beam…) prior to using crash cushion

Table Notes:

1. Charts are based on Guidelines for Crash Cushion Selection MWRSF Report TRP-03-252-12
2. Initial analysis included sand barrel arrays. However, analysis did not indicate that sand barrel arrays were a cost effective alternative.
3. The desirable charts have a benefit cost ratio of 4 or more. The less than desirable charts had a benefit cost ratio of 2 or more.
4. Original charts used Degree of Curve to define curvature. Degree of curve has been converted into a radius value in feet and rounded to the nearest whole number.

Table A - Desirable Crash Cushion Selection Table for Freeway

	Radius (ft)		
AADT	**0**	**2865**	**1432**
5,000	CCP	CCP	CCP
10,000	CCP	CCP	CCP
25,000	CCP	CCP	CCP
50,000	CCP	CCP	CCP
75,000	CCP	CCP	CCP
100,000	CCPL	CCPL	CCPL
	All		
	Offset (ft)		

Table B - Desirable Crash Cushion Selection Table for Divided Rural Arterials or Expressways

	Radius (ft)					
AADT	**0**	**1910**	**955**	**0**	**1910**	**955**
1,000	CCP	CCP	CCP	OS	OS	OS
5,000	CCP	CCP	CCP	CCP	CCP	CCP
10,000	CCP	CCP	CCP	CCP	CCP	CCP
20,000	CCP	CCP	CCP	CCP	CCP	CCP
30,000	CCP	CCP	CCP	CCP	CCP	CCP
	<15 ft			≥15 ft		
	Offset (ft)					

Table C - Desirable Crash Cushion Selection Table for Undivided Rural Arterials

	Radius (ft)					
AADT	**0**	**1910**	**955**	**0**	**1910**	**955**
1,000	OS	OS	OS	OS	OS	OS
5,000	CCP	CCP	CCP	OS	OS	OS
10,000	CCP	CCP	CCP	OS	OS	OS
20,000	CCP	CCP	CCP	OS	OS	OS
30,000	CCP	CCP	CCP	OS	OS	OS
	<20 ft			≥20 ft		
	Offset (ft)					

Table D - Desirable Crash Cushion Selection Table for Undivided Rural Local

	Radius (ft)								
AADT	**0**	**1146**	**573**	**0**	**1146**	**573**	**0**	**1146**	**573**
200	OS	OS	OS	OS	OS	OS	OS	OS	OS
500	OS	OS	OS	OS	OS	OS	OS	OS	OS
1,000	OS	CCP	CCP	OS	OS	OS	OS	OS	OS
3,000	CCP	CCP	CCP	CCP	CCP	CCP	OS	OS	OS
	≤10 ft			≤20 ft			≤35 ft		
	Offset (ft)								

Table E - Less than Desirable Crash Cushion Selection Table for Freeway

	Radius (ft)		
AADT	**0**	**2865**	**1432**
5,000	CCP	CCP	CCP
10,000	CCP	CCP	CCP
25,000	CCP	CCP	CCP
50,000	CCP	CCP	CCP
75,000	CCPL	CCPL	CCPL
100,000	CCPL	CCPL	CCPL
	All Offset (ft)		

Table F - Less than Desirable Crash Cushion Selection Table for Divided Rural Arterials or Expressways

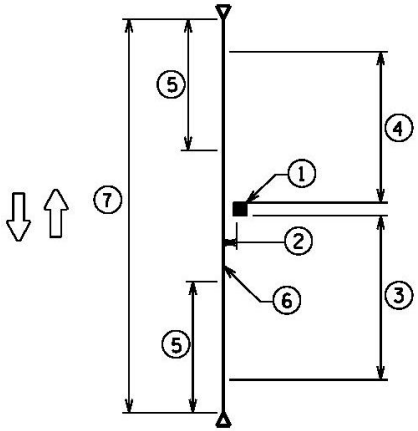
	Radius (ft)		
AADT	**0**	**1910**	**955**
1,000	CCP	CCP	CCP
5,000	CCP	CCP	CCP
10,000	CCP	CCP	CCP
20,000	CCPL	CCPL	CCPL
30,000	CCPL	CCPL	CCPL
	All		
	Offset (ft)		

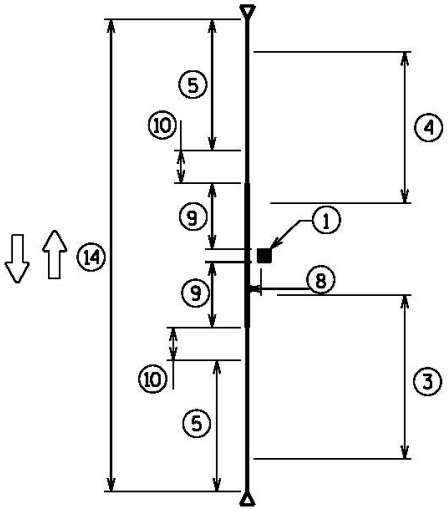
Table G - Less than Desirable Crash Cushion Selection Table for Undivided Rural Arterials

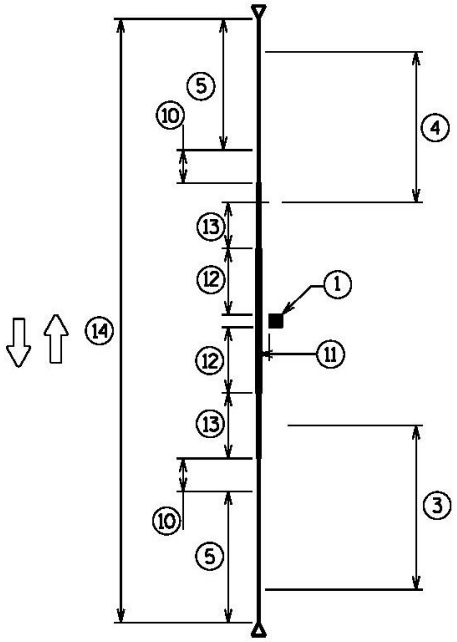
	Radius (ft)											
AADT	**0**	**1910**	**955**	**0**	**1910**	**955**	**0**	**1910**	**955**	**0**	**1910**	**955**
1,000	OS	OS	OS	OS	OS	OS	OS	OS	OS	OS	OS	OS
5,000	CCP	CCP	CCP	CCP	CCP	CCP	CCP	CCP	CCP	OS	OS	OS
10,000	CCP	CCP	CCP	CCP	CCP	CCP	CCP	CCP	CCP	OS	OS	OS
20,000	CCP	CCP	CCP	CCP	CCP	CCP	CCP	CCP	CCP	OS	OS	OS
30,000	CCP	CCP	CCPL	CCP	CCP	CCP	CCP	CCP	CCP	OS	OS	OS
	5 ft			10 ft			15 ft			≥20		
	Offset (ft)											

Table H - Less than Desirable Crash Cushion Selection Table for Rural Local

	Radius (ft)								
AADT	**0**	**1146**	**573**	**0**	**1146**	**573**	**0**	**1146**	**573**
200	OS	OS	OS	OS	OS	OS	OS	OS	OS
500	OS	OS	CCP	OS	OS	OS	OS	OS	OS
1,000	CCP	CCP	CCP	CCP	CCP	CCP	OS	OS	OS
3,000	CCP	CCP	CCP	CCP	CCP	CCP	OS	OS	OS
	≤5 ft			≤20 ft			≤35 ft		
	Offset (ft)								

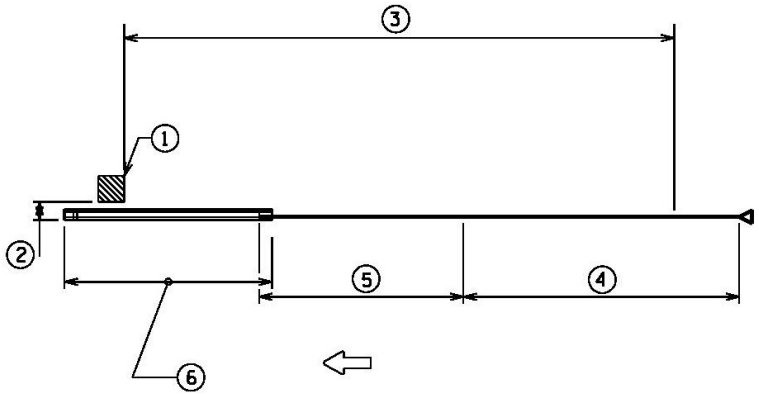


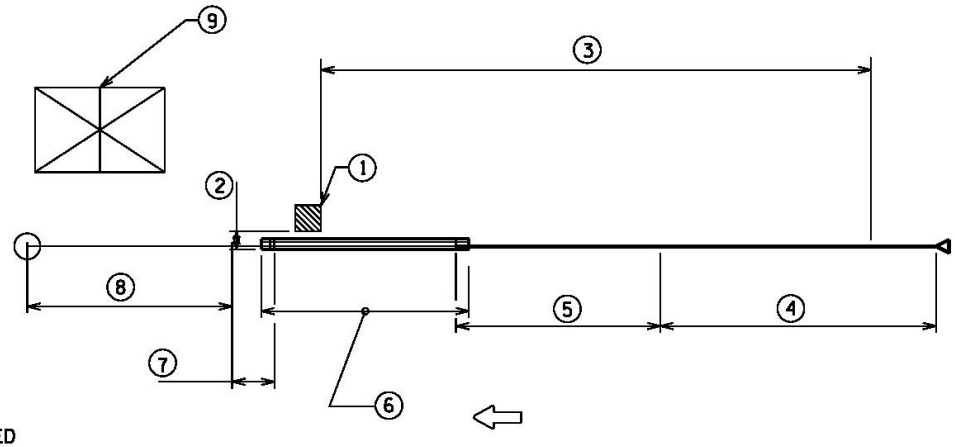




1. FIXED OBJECT BEING SHIELDED
2. APPROPRIATE WORKING WIDTH FOR OBJECT BEING SHIELDED
3. APPROACH LENGTH OF NEED (LON)
4. FAR SIDE LENGTH OF NEED (LON)
5. EAT LENGTH (SEE OTHER SECTIONS OF 11-45-2)
6. STANDARD POST SPACING FOR BEAM GUARD
7. TOTAL BARRIER SYSTEM LENGTH FOR NORMAL APPLICATIONS
8. HAZARD WITHIN THE WORKING WIDTH OF STANDARD BEAM GUARD
9. 25' OF HALF POST SPACING PRIOR HAZARD FOR BOTH DIRECTIONS OF TRAVEL
10. MIN. OF 12.5' OF STANDARD POST SPACING BETWEEN END OF TERMINAL AND START OF HALF POST SPACING.
11. BEAM GUARD QUARTER POST SPACING IS REQUIRED BECAUSE OF WORKING WIDTH OF NORMAL BEAM GUARD AND HALF POST SPACING BEAM GUARD IS TOO LARGE
12. 25' OF QUARTER POST SPACING PRIOR TO HAZARD FOR BOTH DIRECTIONS OF TRAVEL
13. 25' OF HALF POST SPACING PRIOR TO QUARTER POST SPACING
14. OVERALL LENGTH OF BARRIER SYSTEM MAY CHANGE DUE TO THE NEED FOR SMALLER WORKING WIDTHS

DRAWINGS NOT TO SCALE
DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS.
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.





1. FIXED OBJECT BEING SHIELDED
2. APPROPRIATE WORKING WIDTH FOR OBJECT BEING SHIELDED
3. APPROACH LENGTH OF NEED (LON)
4. EAT LENGTH (SEE OTHER SECTIONS OF 11-45-2)
5. APPROACH TRANSITION TO RIGID BARRIER
6. SINGLE SLOPE CONCRETE BARRIER WITH APPROPRIATE ANCHORAGES
7. DOWN STREAM THRIE BEAM TRANSITION
8. TYPE 2 BEAM GUARD TERMINAL
9. FIXED OBJECT HAZARD THAT IS OUTSIDE GATING AREA OF TYPE 2 END TERMINAL

DRAWINGS NOT TO SCALE
DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS.
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.

Barrier Sub-Type	Bid Items		Working width			Post Spacing	Nested rails	Grading		Curb and Gutter	Notes
			Measured from	Testing Criteria	Distance			Approach	Back of barrier		
	Bid Number	Name			FT	FT					
Low-Tension Cable Barrier	NA	NA	Impact face of Cable	NCHRP 230	12.00	Varies	NA	NA	NA	No	Not installed any more
High-Tension Cable Barrier	613.1100.S 613.1200.S	Cable Barrier Type 1 Cable Barrier End Terminal Type 1	Impact face of Cable	NCHRP 350	Initial Distance 12' See manufacturer's data	Varies	NA	6:1 or flatter	6:1 or flatter	No	Median Applications
Class A	614.0305	Steel Plate Beam Guard Class A	Face of Rail	NCHRP 350 TL-3	4.75'	6.25	No	10:1 or flatter	2' of flat grading behind post	Yes-See FDM	--
	Special Provision	Steel Plate Beam Guard Class A	Face of Rail	NCHRP 350 TL-3	3.75'	3.125	No	10:1 or flatter	2' of flat grading behind post	No	Need Special provision and special details
	Special Provision	Steel Plate Beam Guard Class A	Face of Rail	NCHRP 350 TL-3	3.33'	1.5625	No	10:1 or flatter	2' of flat grading behind post	No	Need Special provision and special details
	614.0340	Steel Plate Beam Guard Over Low-Fill Culverts A	Face of Rail	NCHRP 350 TL-3	5'	See SDD	Yes	10:1 or flatter	2' of flat grading behind post	No	Spanning short culverts that are up to 25' wide
	614.0510	Guardrail Stiffened NW	Face of Rail	NCHRP 350 TL-3	5.25'	6.25	Yes	10:1 or flatter	2' of flat grading behind post	Yes-See FDM	--
	614.0515	Guardrail Stiffened LHW	Face of Rail	NCHRP 350 TL-3	3.75'	3.125	No	10:1 or flatter	Use when there is less than 2' of flat grading behind post	No	Uses longer post at half post spacing to accommodate grading

Barrier Sub-Type	Bid Items		Working width			Post Spacing	Nested rails	Grading		Curb and Gutter	Notes
			Measured from	Testing Criteria	Distance			Approach	Back of barrier		
	Bid Number	Name			FT	FT					
MGS	614.2300	MGS Guardrail 3	Face of Rail	MASH TL-3	5.00’	6.25	No	10:1 or flatter	2’ of flat grading behind post	No	Normal Barrier system installed
	614.2300	MGS Guardrail 3	Face of Rail	NCHRP 350 TL-3	9.00’	6.25	No	10:1 or flatter	2’ of flat grading behind post	No	5:1 flare rate Need individual construction details
	614.2300	MGS Guardrail 3	Face of Rail	NCHRP 350 TL-3	8.33’	6.25	No	10:1 or flatter	2’ of flat grading behind post	No	7:1 flare rate Need individual construction details
	614.2300	MGS Guardrail 3	Face of Rail	NCHRP 350 TL-3	6.66’	6.25	No	10:1 or flatter	2’ of flat grading behind post	No	13:1 flare rate Need individual construction details
	614.2300	MGS Guardrail 3	Face of Rail	NCHRP 350 TL-3	5.50’	6.25	No		2’ of flat grading behind post	Yes	MGS installed 6” behind curb flow line
	614.2300	MGS Guardrail 3	Face of Rail	MASH TL-2 (Computer Model)	4.25’	6.25	No	10:1 or flatter	2’ of flat grading behind post	Yes	MGS installed 6” behind curb flow line at design speed 45 mph or less
	614.2300	MGS Guardrail 3	Face of Rail	MASH TL-2	3.83’	6.25	No		2’ of flat grading behind post	Yes	MGS installed 4’ to 8’ behind curb flow line at design speed 45 mph or less Need individual construction details

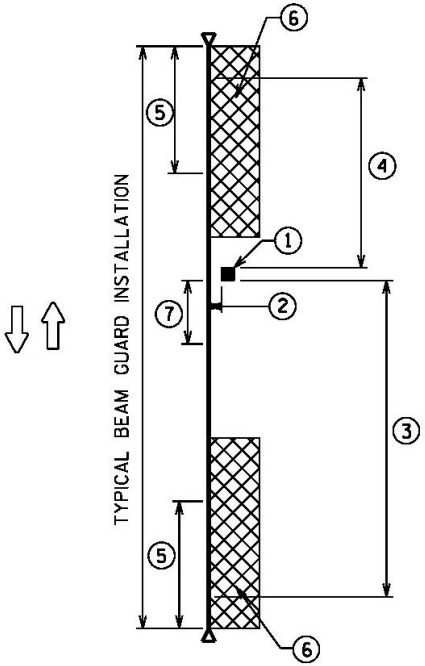
Barrier Sub-Type	Bid Items		Working width			Post Spacing	Nested rails	Grading		Curb and Gutter	Notes
			Measured from	Testing Criteria	Distance			Approach	Back of barrier		
	Bid Number	Name			FT	FT					
MGS	614.2300	MGS Guardrail 3	Face of Rail	MASH TL-1 (Computer Model)	3.33’	6.25	No		2’ of flat grading behind post	Yes	MGS installed 6” behind curb flow line at design speed 30 mph or less
	614.2300	MGS Guardrail 3	Face of Rail	MASH TL-2 (Computer Model)	5.00	6.25	No	10:1 or flatter	2’ of flat grading behind post	No	MGS installed without curb design speed 45 mph or less
	614.2300	MGS Guardrail 3	Face of Rail	MASH TL-1 (Computer Model)	4.00	6.25	No	10:1 or flatter	2’ of flat grading behind post	No	MGS installed without curb design speed 30 mph or less
	614.2310	MGS Guardrail 3 HS	Face of Rail	NCHRP 350 TL-3	4.50’	3.125	No	10:1 or flatter	2’ of flat grading behind post	No	Half Post Spacing
	614.2320	MGS Guardrail 3 QS	Face of Rail	NCHRP 350 TL-3	3.83’	1.5625	No	10:1 or flatter	2’ of flat grading behind post	No	Quarter Post Spacing
	614.2330	MGS Guardrail 3 K	Face of Rail	NCHRP 350 TL-3	5.50’	3.125	No	10:1 or flatter	Use when there is less than 2’ of flat grading behind post	No	Uses longer post at half post spacing to accommodate grading
	614.234	MGS Guardrail 3 L	Face of Rail	MASH TL-3	7.83	See SDD	No	10:1 or flatter	2’ of flat grading behind post	No	Spanning short culverts that are up two 25’

Barrier Sub-Type	Bid Items		Working width			Post Spacing	Nested rails	Grading		Curb and Gutter	Notes
			Measured from	Testing Criteria	Distance			Approach	Back of barrier		
	Bid Number	Name			FT	FT					
Single Faced Thrie Beam	614.0230	Steel Thrie Beam	Face of Rail	NCHRP 350 TL-3	4.10’	6.25	No	10:1 or flatter	2’ of flat grading behind post	No	Typically installed with Thrie beam Bullnose
	Special Provision	Steel Thrie Beam Modified Steel Block	Face of Rail	NCHRP 350 TL-4	4.50	6.25	No	10:1 or flatter	2’ of flat grading behind post	No	Modified Steel Block Design Individual construction details and other drawings Need BPD approval
	Special Provision	Steel Thrie Beam Half Post Spacing	Face of Rail	NCHRP 350 TL-3	3.25	3.125	No	10:1 or flatter	2’ of flat grading behind post	No	Half Post spacing Individual construction details and other drawings Need BPD approval
	Special Provision	Steel Thrie Beam Quarter Post Spacing	Face of Rail	NCHRP 350 TL-3	3.00	1.5625	No	10:1 or flatter	2’ of flat grading behind post	No	Quarter Post spacing Individual construction details and other drawings Need BPD approval
Double Faced Thrie Beam	Special Provision	Steel Thrie Beam Modified Steel Block	Face of Rail	NCHRP 350 TL-4	5.00	6.25	No	10:1 or flatter	10:1 or flatter	No	Modified Steel Block Design Individual construction details and other drawings Need BPD approval

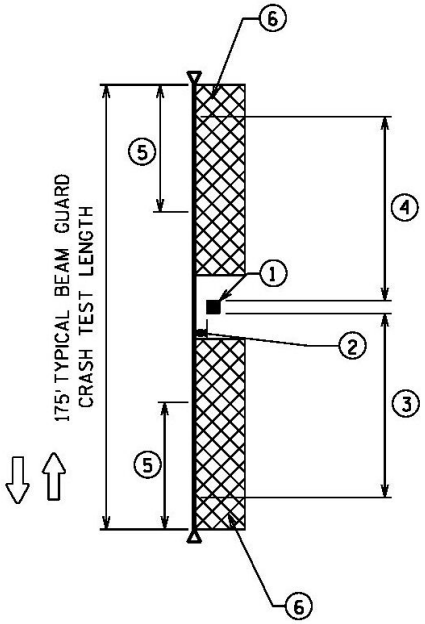
Barrier Sub-Type	Bid Items		Working width			Grading		Notes
			Measured from	Testing Criteria	Distance	Approach	Back of barrier	
	Bid Number	Name			FT			
Safety Shape Concrete Barrier Permanent	603.0105	Concrete Barrier Single Faced 32-Inch	Toe of barrier impact side	NCHRP TL-3	2.5	10:1 or flatter	1' of flat grading behind back of barrier on fill slopes. Median application may vary	Typically not installed unless for spot repairs, or extending safety shaped barrier
	603.0205	Concrete Barrier Double Faced 32-Inch	Toe of barrier impact side	NCHRP TL-3	2.5	10:1 or flatter	NA	Typically not installed unless for spot repairs, or extending safety shaped barrier
Single Slope	603.1132	Concrete Barrier Type S32	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2.25	10:1 or flatter	1' of flat grading behind back of barrier on fill slopes. Median application may vary	Standard barrier design
	603.1232	Concrete Barrier Type S32A	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2.25	10:1 or flatter	NA	Median Retaining wall
	603.1332	Concrete Barrier Type S32B	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2.25	10:1 or flatter	1' of flat grading behind back of barrier on fill slopes. Median application may vary	Short section of barrier
	603.1136	Concrete Barrier Type S36	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2.00	10:1 or flatter	1' of flat grading behind back of barrier on fill slopes. Median application may vary	Standard barrier design
	603.1236	Concrete Barrier Type S36A	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2.00	10:1 or flatter	NA	Median Retaining wall
	603.1336	Concrete Barrier Type S36B	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2.00	10:1 or flatter	1' of flat grading behind back of barrier on fill slopes. Median application may vary	Short section of barrier

Barrier Sub-Type	Bid Items		Working width			Grading		Notes
			Measured from	Testing Criteria	Distance	Approach	Back of barrier	
	Bid Number	Name			FT			
Single Slope	603.1436	Concrete Barrier Type S36C	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2	10:1 or flatter	NA	Roadside Retaining wall
	603.1142	Concrete Barrier Type S42	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2	10:1 or flatter	1' of flat grading behind back of barrier on fill slopes. Median application may vary	Standard barrier design
	603.1242	Concrete Barrier Type S42A	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2	10:1 or flatter	NA	Median Retaining wall
	603.1342	Concrete Barrier Type S42B	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2	10:1 or flatter	1' of flat grading behind back of barrier on fill slopes. Median application may vary	Short section of barrier
	603.1442	Concrete Barrier Type S42C	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2	10:1 or flatter	NA	Roadside Retaining wall
	603.1156	Concrete Barrier Type S56	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2	10:1 or flatter	1' of flat grading behind back of barrier on fill slopes. Median application may vary	Standard barrier design
	603.1256	Concrete Barrier Type S56A	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2	10:1 or flatter	NA	Median Retaining wall
	603.1356	Concrete Barrier Type S56B	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2	10:1 or flatter	1' of flat grading behind back of barrier on fill slopes. Median application may vary	Short section of barrier

Barrier Sub-Type	Bid Items		Working width			Grading		Notes
			Measured from	Testing Criteria	Distance	Approach	Back of barrier	
	Bid Number	Name			FT			
Single Slope	603.1456	Concrete Barrier Type S56C	Toe of barrier on impact side	MASH TL-3 (Computer Model)	2.0	10:1 or flatter	NA	Roadside Retaining wall
Vertical Barrier	Special Provision	Concrete Vertical Barrier 32-Inches	Toe of barrier on impact side	MASH TL-3	2.0	10:1 or flatter	1' of flat grading behind back of barrier on fill slopes. Median application may vary	Special Design Individual construction details and other drawings
Low Speed Barrier	Special Provision	Low Speed Permanent	Point of Beak	NCHRP 350 TL-2	1.50	10:1 or flatter	1' of flat grading behind back of barrier on fill slopes. Median application may vary	Special Design Individual construction details and other drawings Need BPD approval. For roadways with design speeds of 40 mph or less



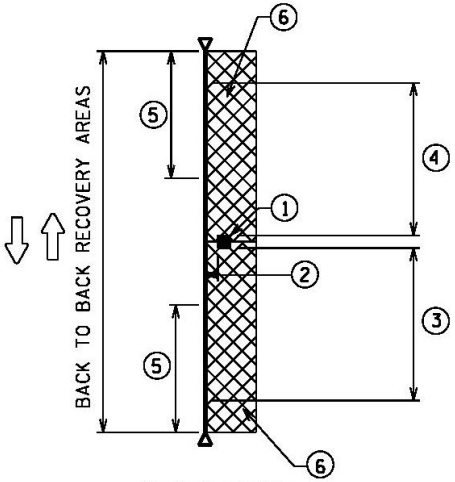
ACCEPTABLE



ACCEPTABLE

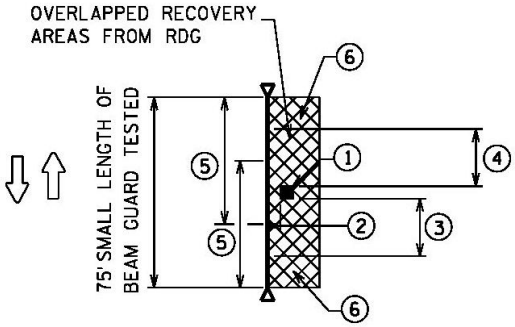
REQUIRES DOCUMENT IN DSR

1. FIXED OBJECT BEING SHIELDED
2. APPROPRIATE WORKING WIDTH FOR OBJECT BEING SHIELDED
3. APPROACH LENGTH OF NEED (LON)
4. FAR SIDE LENGTH OF NEED (LON)
5. EAT LENGTH (SEE OTHER SECTIONS OF 11-45-2)
6. 75' BY 20' RECOVERY AREA (SEE OTHER SECTIONS OF 11-45-2)
7. IF BEAM GUARD IS FLARED, A MINIMUM OF 25' OF TANGENT BEAM GUARD REQUIRED PRIOR TO HAZARD.



MINIMUM (AVOID)

REQUIRES DOCUMENTATION IN DSR

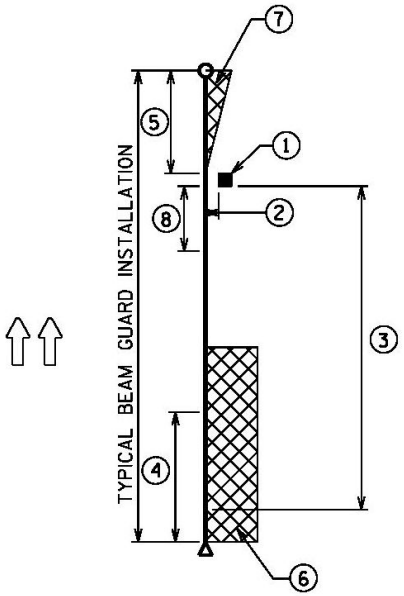


NOT ACCEPTABLE WITH BEAM GUARD TERMINALS

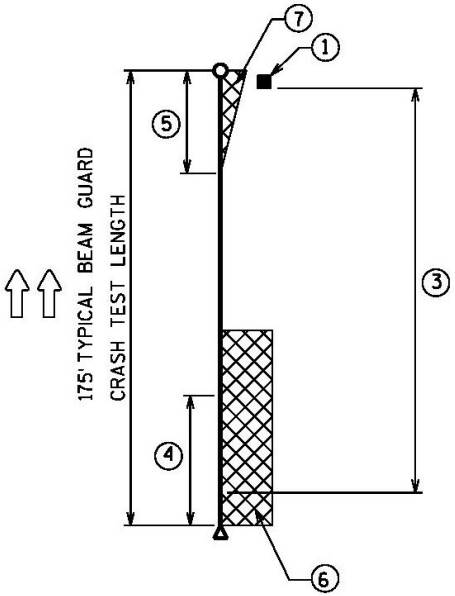
DRAWINGS NOT TO SCALE

DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS.

DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.

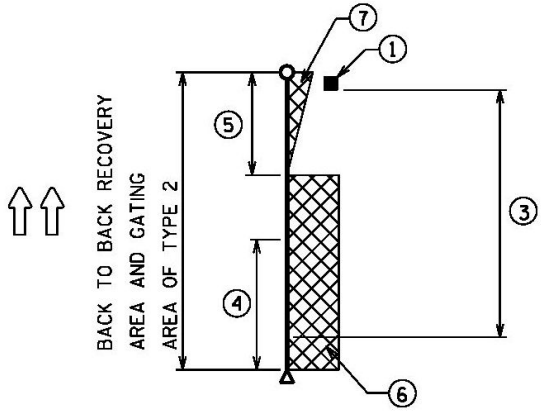


ACCEPTABLE

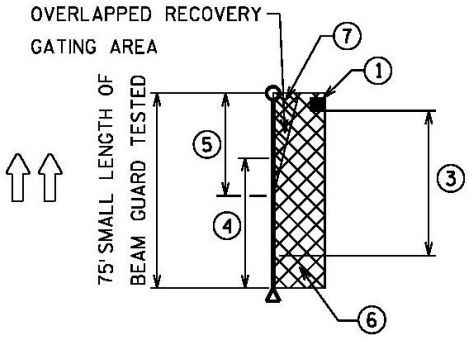


ACCEPTABLE
REQUIRES DOCUMENTATION IN DSR

1. FIXED OBJECT BEING SHIELDED
2. APPROPRIATE WORKING WIDTH FOR OBJECT BEING SHIELDED
3. APPROACH LENGTH OF NEED (LON)
4. EAT LENGTH (SEE OTHER SECTIONS OF 11-45-2)
5. TYPE 2 END TERMINAL (SEE OTHER SECTIONS OF 11-45-2)
6. 75' BY 20' RECOVERY AREA (SEE OTHER SECTIONS OF 11-45-2)
7. GATING AREA OF TYPE 2 END TERMINAL (SEE OTHER SECTIONS OF 11-45-2)
8. IF BEAM GUARD IS FLARED, A MINIMUM OF 25' OF TANGENT BEAM GUARD REQUIRED PRIOR TO HAZARD.



MINIMUM (AVOID)
REQUIRES DOCUMENTATION IN DSR



NOT ACCEPTABLE WITH BEAM GUARD TERMINALS

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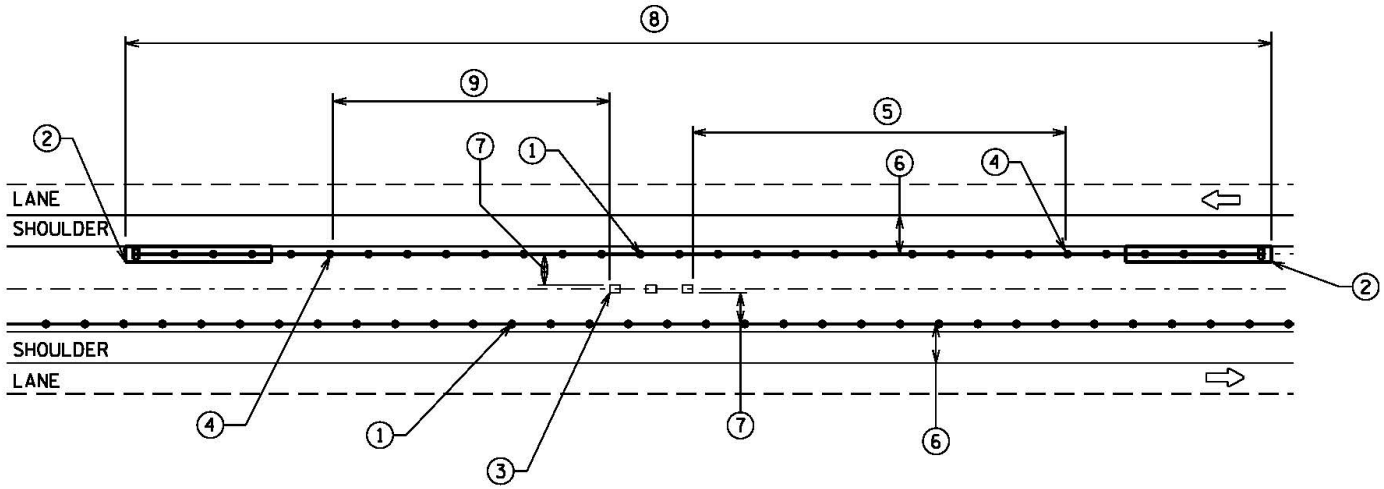
Barrier		Recommended Minimum Barrier Length (FT)	Comments
Cable Barrier		300	Excludes lengths of cable barrier anchorages
Beam Guard		175	Includes beam guard end treatments. On bidirectional roadways, avoid beam guard installations that are 150 ft or shorter. On unidirectional roadways, avoid beam guard installations that are shorter than 115 ft or shorter.*
Concrete Barrier Safety Shape	**Single Sided**	150	Includes concrete anchor section
	Double Sided (non-Retaining wall)	150	Includes concrete anchor section
	Median Retaining Wall	Structural review required to minimize movement of barrier during impact and overturning.	
Concrete Barrier Single Slope	**Regular**	40	Includes two Concrete Barrier Single Slope Anchorages (see SDD 14B33) or two end anchors (see SDD 14B32)
	Median Retaining Wall	Structural review required to minimize movement of barrier during impact and overturning.	
	Short Section of Wall	Bidirectional 31	Includes two Concrete Barrier Single Slope Anchorages (SDD 14B33)
		Unidirectional 21	Includes one Concrete Barrier Single Slope Anchorage (SDD 14B33)
		10	Short section of barrier installed between tightly spaced rigid hazards (e.g. bridge piers…)
	Roadside Retaining Wall	Structural review required to minimize movement of barrier during impact and overturning	

* For this length of barrier, proper placement of barrier relative to hazard is critical.



PIERS ARE NOT WITHIN WORKING WIDTH OF CABLE BARRIER

CABLE BARRIER IS PROVIDING VEHICLE PROTECTION FOR PIER

1. CABLE BARRIER
2. CABLE BARRIER END TERMINAL
3. PIER OR OTHER FIXED OBJECT
4. LENGTH OF NEED POINT OF CABLE BARRIER END TERMINAL
5. ADEQUATE APPROACH LENGTH OF NEED TO SHIELD PIERS
6. WORKING WIDTH OF CABLE BARRIER IS AT THE EDGE OF LANE (LESS DESIRABLE LOCATION TO MEASURE WORKING WIDTH BEING SHOWN)
7. PIERS ARE BEYOND WORKING WIDTH
8. PROVIDE MINIMUM LENGTH OF BARRIER
9. MINIMUM 100 FEET

DRAWINGS NOT TO SCALE
DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS AND ARE NOT INTENDED TO BE INSERTED INTO PLANS.
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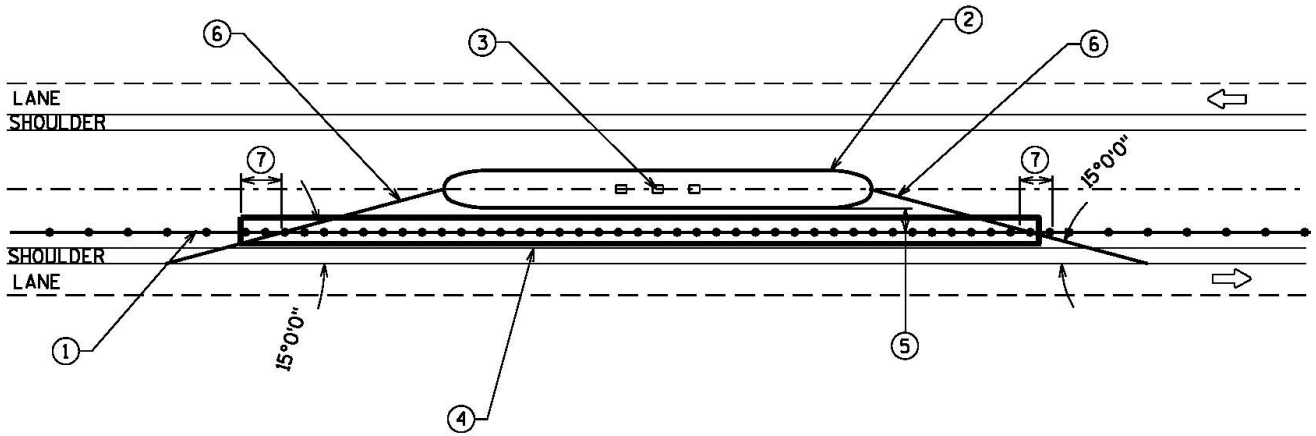

REDUCED CABLE BARRIER POST SPACING BY PIERS

BULLNOSE IS PROVIDING VEHICLE PROTECTION FOR PIER FOR ONE DIRECTION OF TRAVEL

1. CABLE BARRIER
2. THRIE BEAM BULLNOSE
3. PIER OR OTHER FIXED OBJECT
4. AREA WITH CABLE BARRIER WITH REDUCED POST SPACING (SHOW WORKING WIDTH IN PLAN)
5. WORKING WIDTH OF CABLE IS REDUCED TO MINIMIZE CABLE BARRIER AND THRIE BEAM BULLNOSE INTERACTION. SEE MANUFACTURER'S INFORMATION FOR MINIMUM WORKING WIDTH INFORMATION.
6. REDUCED POST SPACING LAYOUT LINE
7. PROVIDE REDUCED POST SPACING AT LEAST 1 SPACE BEYOND SPACING LAYOUT LINE

DRAWINGS NOT TO SCALE

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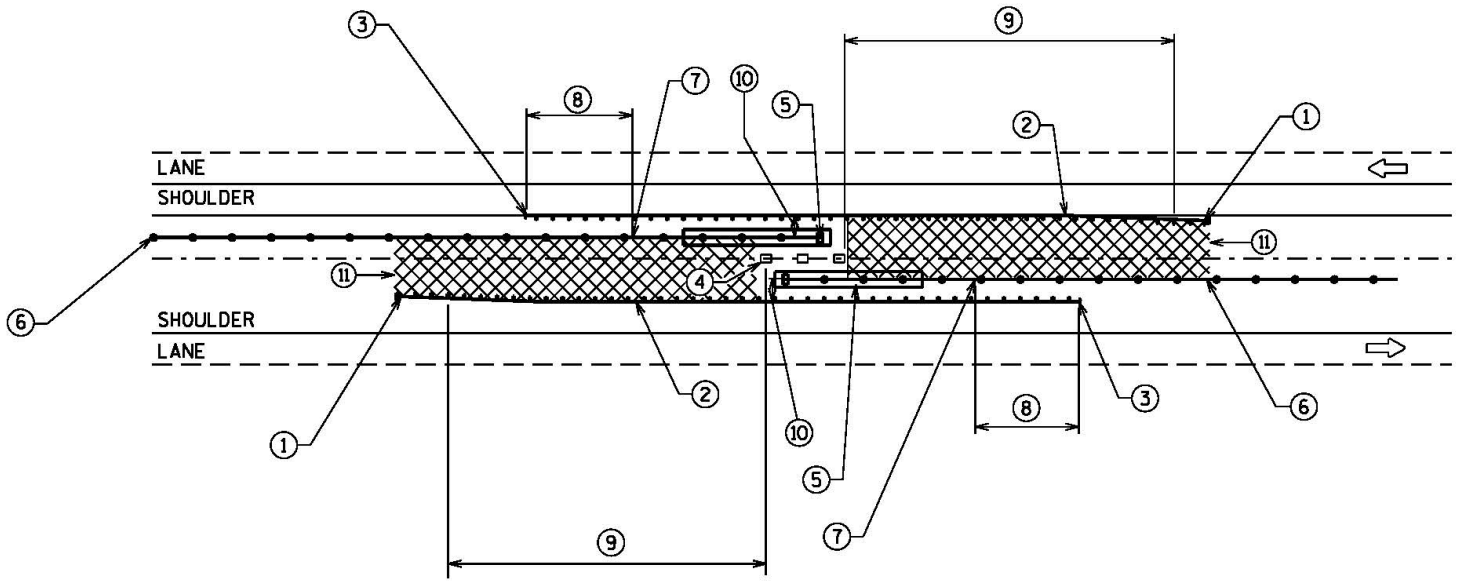
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.



PIERS ARE WITHIN WORKING WIDTH OF CABLE BARRIER

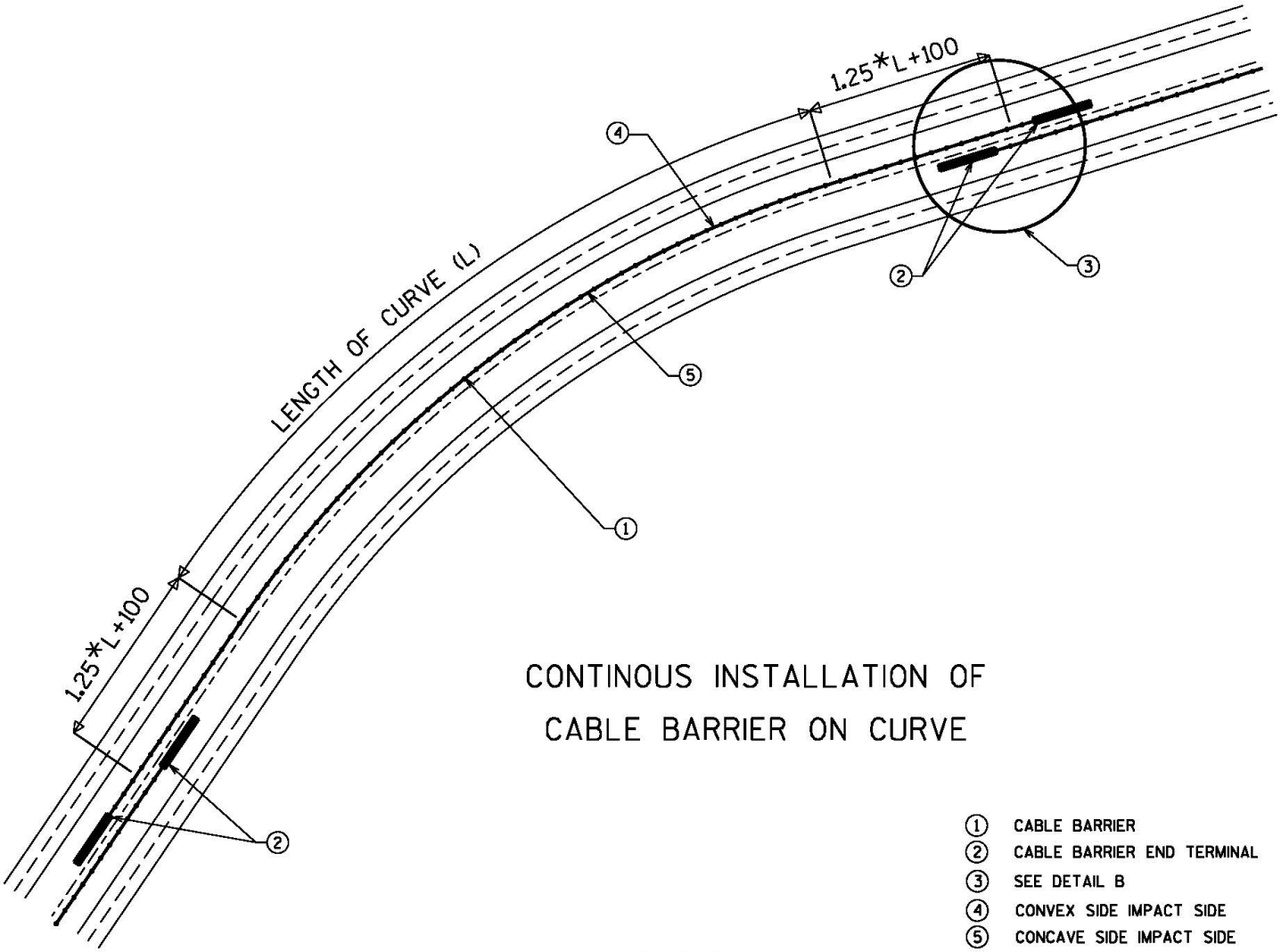
BEAM GUARD IS PROVIDING VEHICLE PROTECTION FOR PIER AND SHIELDING CABLE BARRIER END TERMINALS

1. EAT
2. BEAM GUARD
3. TYPE 2 END TREATMENT
4. PIER OR OTHER FIXED OBJECT
5. CABLE BARRIER END TERMINAL
6. CABLE BARRIER LINE POSTS
7. LENGTH OF NEED POINT FOR CABLE BARRIER END TERMINAL
8. MINIMUM 39.5 FEET OF BEAM GUARD BEYOND LENGTH OF NEED POINT OF CABLE BARRIER END TERMINAL
9. ADEQUATE APPROACH LENGTH OF NEED TO SHIELD PIERS
10. BEAM GUARD WORKING WIDTH
11. CABLE BARRIER IS PLACED TO MINIMIZE REBOUNDING OFF OF CABLE BARRIER AND INTO THE BACKSIDE OF BEAM GUARD

DRAWINGS NOT TO SCALE

DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS AND ARE NOT INTENDED TO BE INSERTED INTO PLANS.

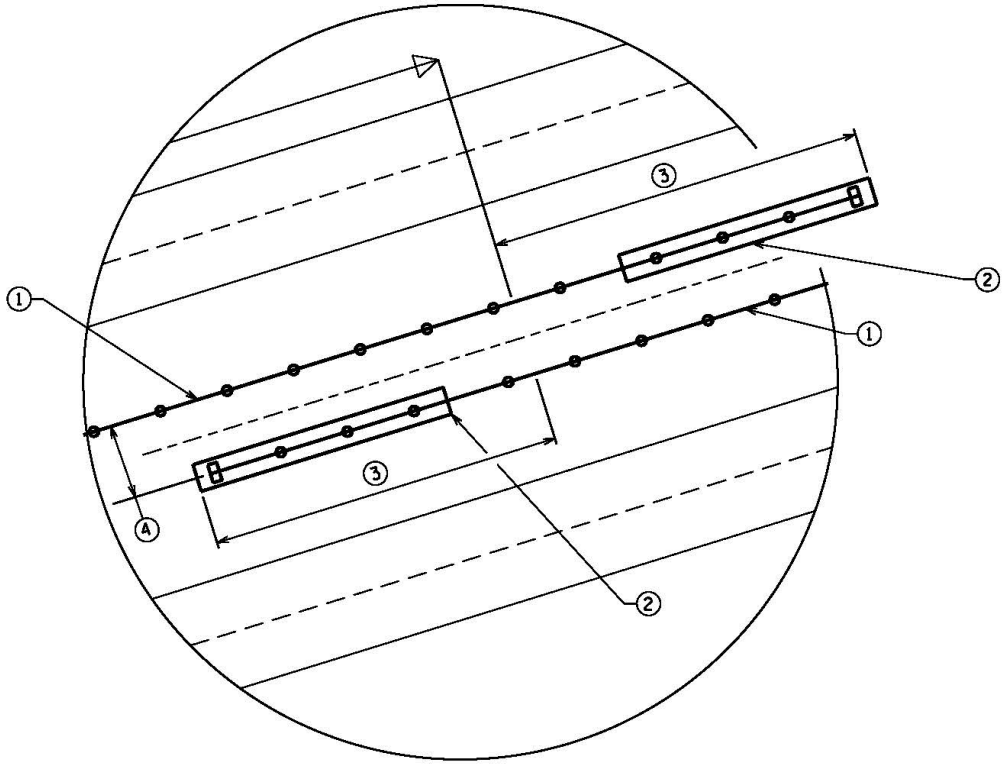
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.



CONTINOUS INSTALLATION OF
CABLE BARRIER ON CURVE

1. CABLE BARRIER
2. CABLE BARRIER END TERMINAL
3. SEE DETAIL B
4. CONVEX SIDE IMPACT SIDE
5. CONCAVE SIDE IMPACT SIDE

DRAWINGS NOT TO SCALE
DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS AND ARE NOT INTENDED TO BE INSERTED INTO PLANS.
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.



DETAIL B

1. CABLE BARRIER
2. CABLE BARRIER END TERMINAL
3. LENGTH OF NEED POINT OF CABLE BARRIER END TERMINAL
4. ADEQUATE WORKING WIDTH BETWEEN CABLE BARRIERS

DRAWINGS NOT TO SCALE
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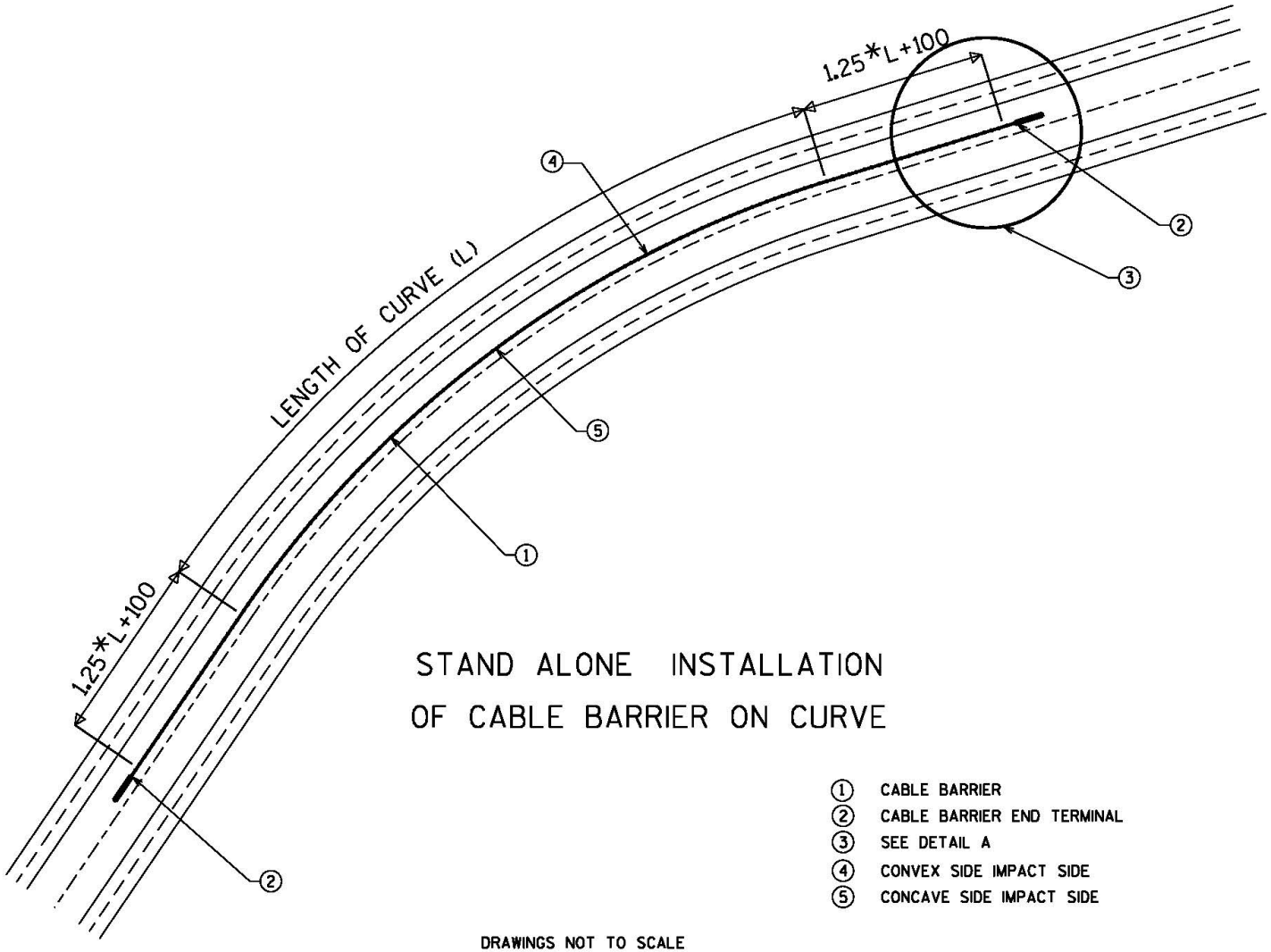
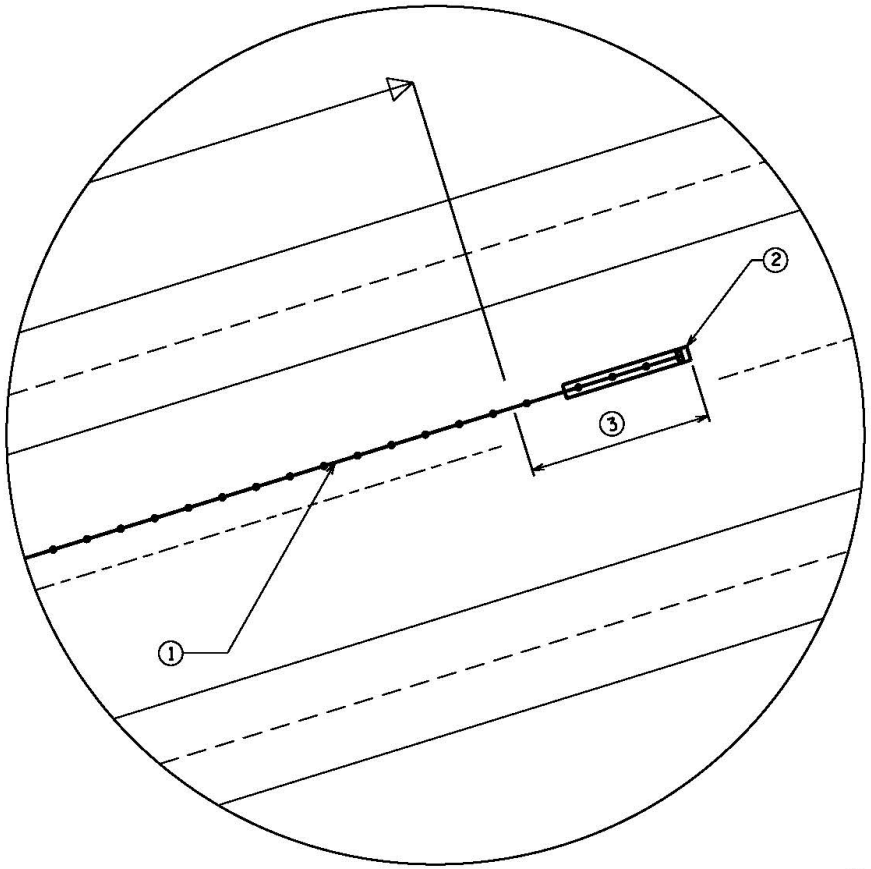
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.



STAND ALONE INSTALLATION
OF CABLE BARRIER ON CURVE

1. CABLE BARRIER
2. CABLE BARRIER END TERMINAL
3. SEE DETAIL A
4. CONVEX SIDE IMPACT SIDE
5. CONCAVE SIDE IMPACT SIDE

DRAWINGS NOT TO SCALE
DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS AND ARE NOT INTENDED TO BE INSERTED INTO PLANS.
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.



DETAIL A

1. CABLE BARRIER
2. CABLE BARRIER END TERMINAL
3. LENGTH OF NEED POINT OF CABLE BARRIER END TERMINAL

DRAWINGS NOT TO SCALE
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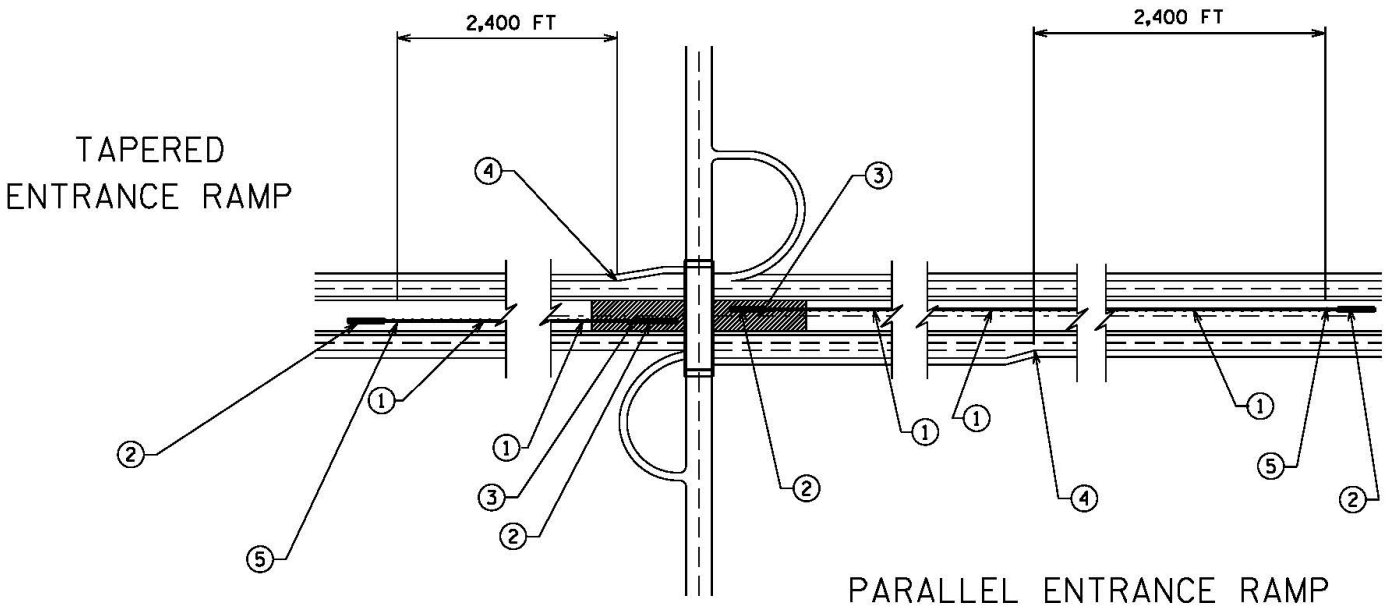
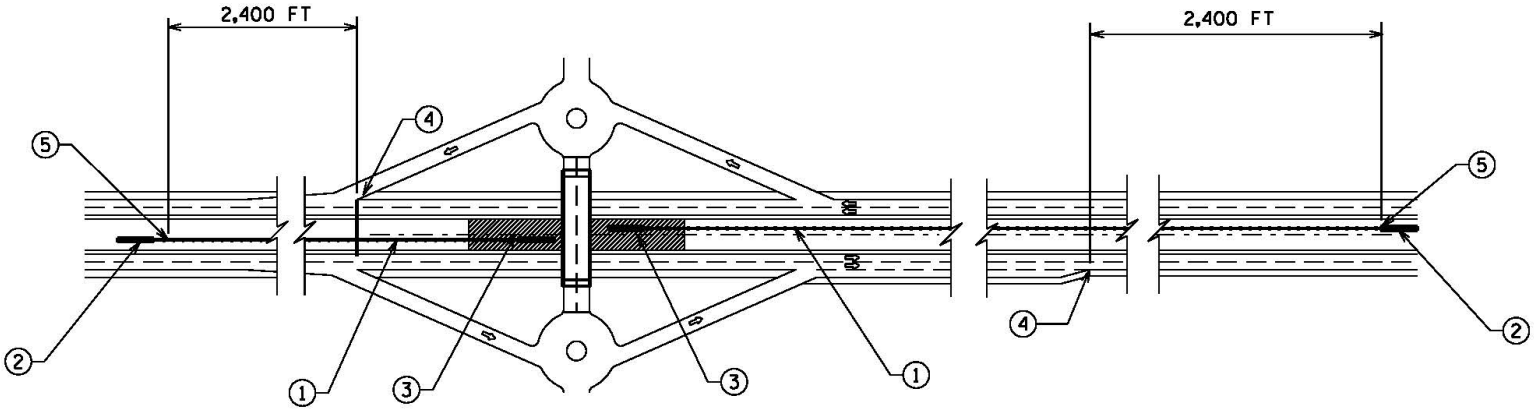


CABLE BARRIER INSTALLATION AT LOOP RAMPS

1. CABLE BARRIER
2. CABLE BARRIER END TERMINAL
3. SEE OTHER DETAILS FOR CABLE BARRIER NEAR BRIDGE PIERS OR OTHER LARGE FIXED OBJECTS
4. INTERSECTION OF RAMP EDGE OF LANE AND MAINLINE EDGE OF LANE
5. LENGTH OF NEED POINT OF CABLE BARRIER END TERMINAL

DRAWINGS NOT TO SCALE
DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS AND ARE NOT INTENDED TO BE INSERTED INTO PLANS.
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.



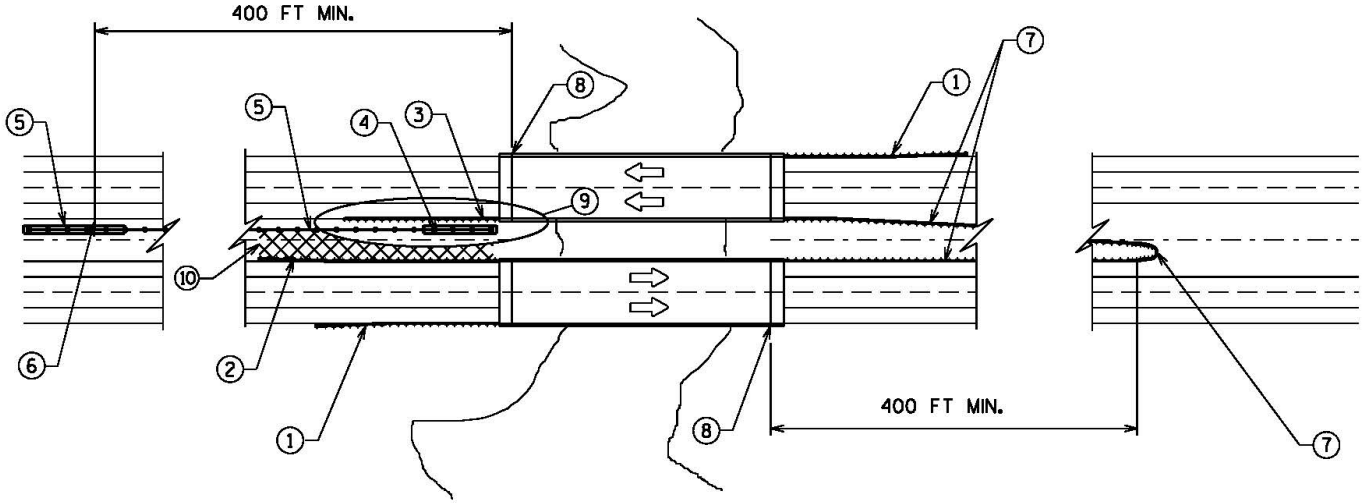
TAPERED ENTRANCE RAMP

PARALLEL ENTRANCE RAMP

CABLE BARRIER INSTALLATION AT DIAMOND INTERCHANGE

1. CABLE BARRIER
2. CABLE BARRIER END TERMINAL
3. SEE OTHER DETAILS FOR CABLE BARRIER NEAR BRIDGE PIERS OR OTHER LARGE FIXED OBJECTS
4. INTERSECTION OF RAMP EDGE OF LANE AND MAINLINE EDGE OF LANE
5. LENGTH OF NEED POINT OF CABLE BARRIER END TERMINAL

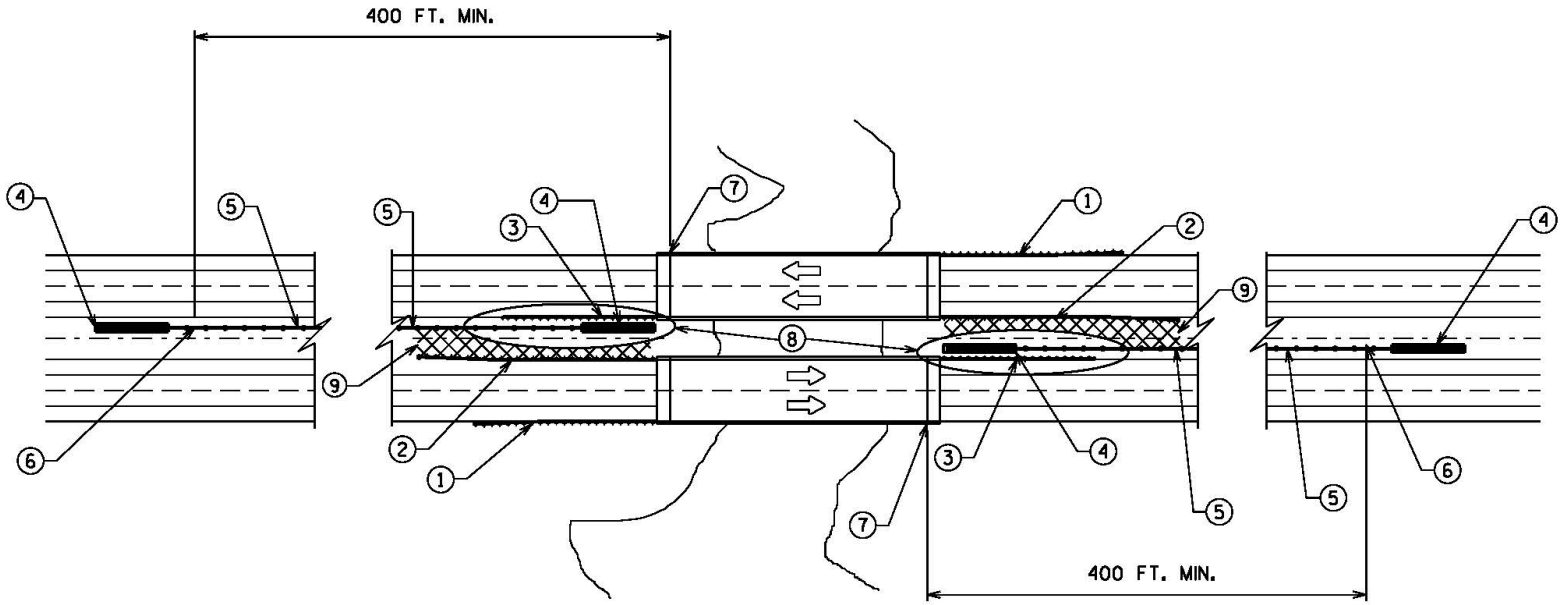
DRAWINGS NOT TO SCALE
DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS AND ARE NOT INTENDED TO BE INSERTED INTO PLANS.
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.



CABLE BARRIER AND THRIE BEAM BULLNOSE INSTALLATION
WHEN MAINLINE GOES OVER ROADWAY OR STREAM

1. EAT, BEAM GUARD AND THRIE BEAM APPROACH TRANSITION WITH APPROPRIATE LON FOR HAZARDS PRESENT
2. EAT, BEAM GUARD AND THRIE BEAM APPROACH TRANSITION WITH APPROPRIATE LON TO SHIELD CABLE BARRIER END TERMINAL AND OTHER HAZARDS PRESENT
3. THRIE BEAM DOWNSTREAM TRANSITION, BEAM GUARD AND TYPE 2 END TREATMENT WITH APPROPRIATE LENGTH TO PREVENT VEHICLE INTERACTION WITH CABLE BARRIER END TERMINAL
4. CABLE END TERMINAL
5. CABLE BARRIER
6. LENGTH OF NEED POINT OF CABLE BARRIER END TERMINAL
7. THRIE BEAM BULLNOSE WITH THRIE BEAM AND THREI BEAM APPROACH TRANSITION
8. EDGE OF BRIDGE DECK
9. SEE DETAIL C
10. CABLE BARRIER IS PLACED TO MINIMIZE VEHICLE REBOUNDING OFF OF CABLE BARRIER AND INTO BACK SIDE OF BEAM GUARD.

DRAWINGS NOT TO SCALE
DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS AND ARE NOT INTENDED TO BE INSERTED INTO PLANS.
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.



CABLE BARRIER INSTALLATION WHEN MAINLINE GOES OVER ROADWAY OR STREAM

1. EAT, BEAM GUARD AND THRIE BEAM APPROACH TRANSITION WITH APPROPRIATE LON FOR HAZARDS PRESENT
2. EAT, BEAM GUARD AND THRIE BEAM APPROACH TRANSITION WITH APPROPRIATE LON TO SHIELD CABLE BARRIER END TERMINAL AND OTHER HAZARDS PRESENT
3. THRIE BEAM DOWNSTREAM TRANSITION, BEAM GUARD AND TYPE 2 END TREATMENT WITH APPROPRIATE LENGTH TO PREVENT VEHICLE INTERACTION WITH CABLE BARRIER END TERMINAL
4. CABLE END TERMINAL
5. CABLE BARRIER
6. LENGTH OF NEED POINT OF CABLE BARRIER END TERMINAL
7. EDGE OF BRIDGE DECK
8. SEE DETAIL C
9. CABLE BARRIER IS PLACED TO MINIMIZE VEHICLE REBOUNDING OFF OF CABLE BARRIER INTO BACK SIDE OF BEAM GUARD. ADDITIONAL BEAM GUARD IS INSTALLED DOWNSTREAM OF THE BRIDGE TO SHIELD CABLE BARRIER END TERMINAL FROM BEING STRUCK.

DRAWINGS NOT TO SCALE

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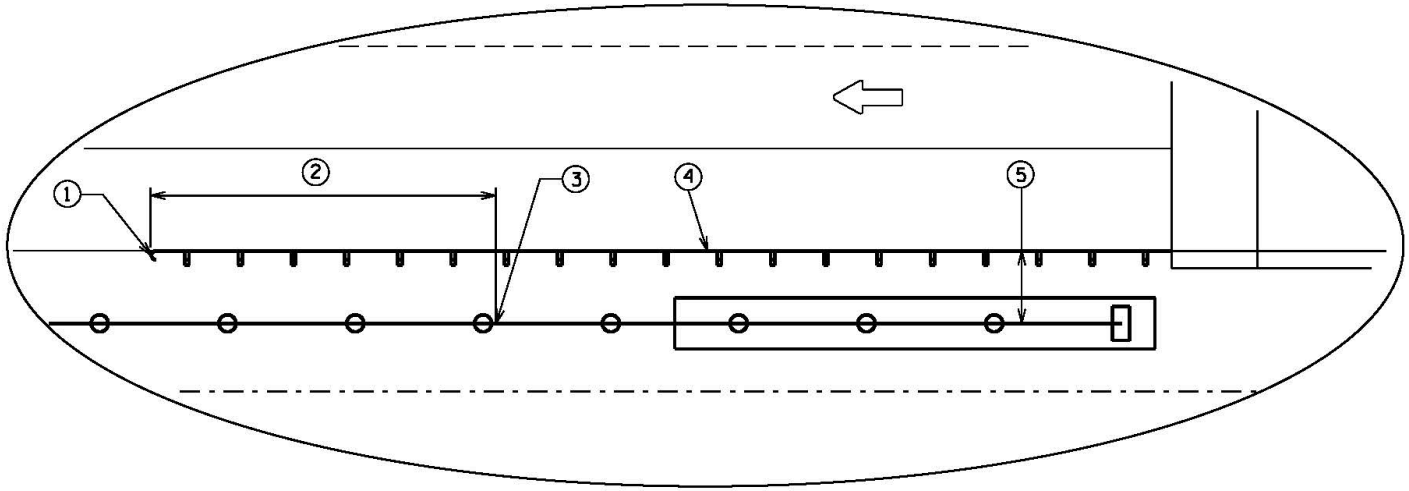
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.



DETAIL C

1. TYPE 2 END TERMINAL
2. 39.5 FEET BEYOND LENGTH OF NEED POINT
3. LENGTH OF NEED POINT OF CABLE BARRIER END TERMINAL
4. THRIE BEAM DOWNSTREAM TRANSITION AND BEAM GUARD
5. WORKING WIDTH OF BEAM GUARD

DRAWINGS NOT TO SCALE
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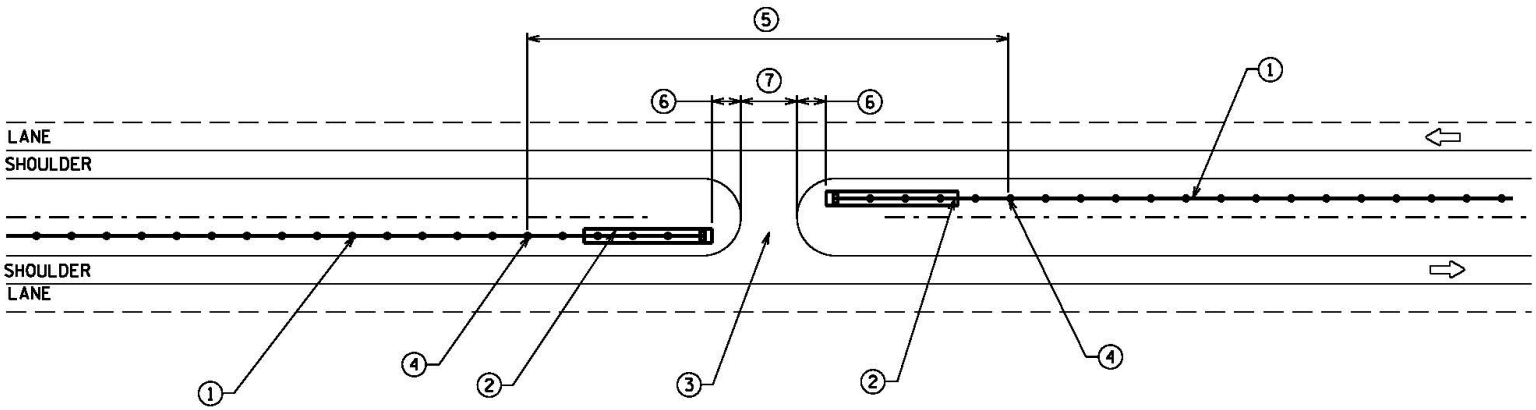

CABLE BARRIER LAYOUT BY MAINTENANCE CROSSOVER

1. CABLE BARRIER
2. CABLE BARRIER END TERMINAL
3. MAINTENANCE CROSSOVER
4. LENGTH OF NEED POINT OF CABLE BARRIER END TERMINAL
5. LENGTH OF ROADWAY UNSHIELDED FROM CROSS MEDIAN CRASH
6. OFFSET FROM PAVED MAINTENANCE CROSS OVER AND 1ST CABLE BARRIER END TERMINAL ANCHOR
7. WIDTH OF MAINTENANCE CROSS OVER (SEE SDD 11A1)

MINIMIZE AMOUNT OF MEDIAN THAT IS LEFT UNSHIELDED TO CROSS MEDIAN CRASHES, BY HAVING CABLE BARRIER SWITCH SIDES OF MEDIAN.
DISCUSS OFFSET FROM PAVED MAINTENANCE CROSS OVER AND 1ST ANCHOR OF CABLE BARRIER MEDIAN ANCHOR WITH MAINTENCE STAFF.

DRAWINGS NOT TO SCALE
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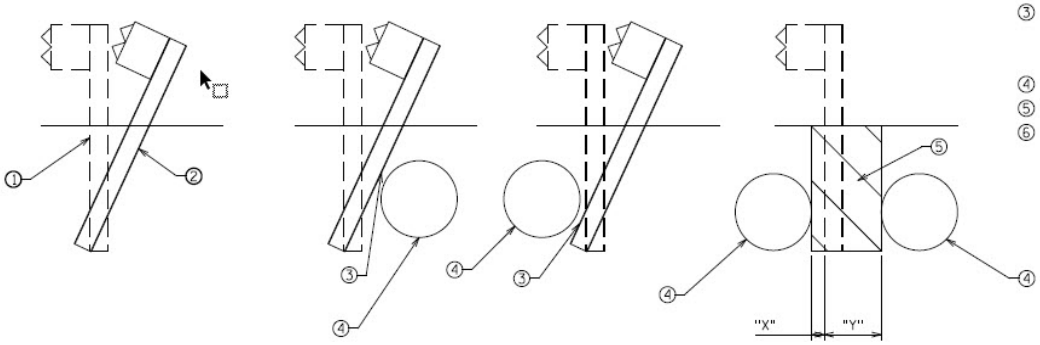
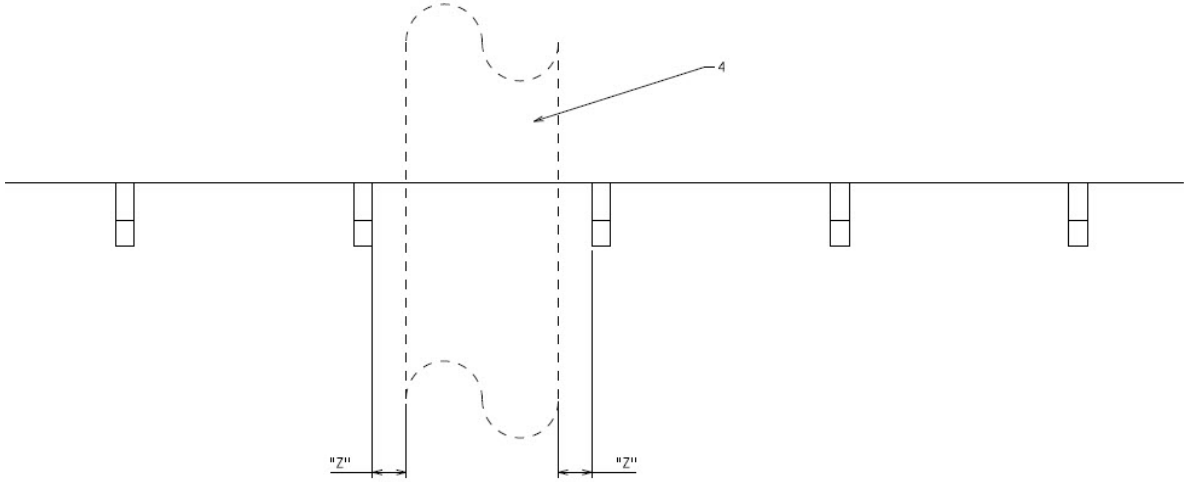


CROSS SECTION VIEW

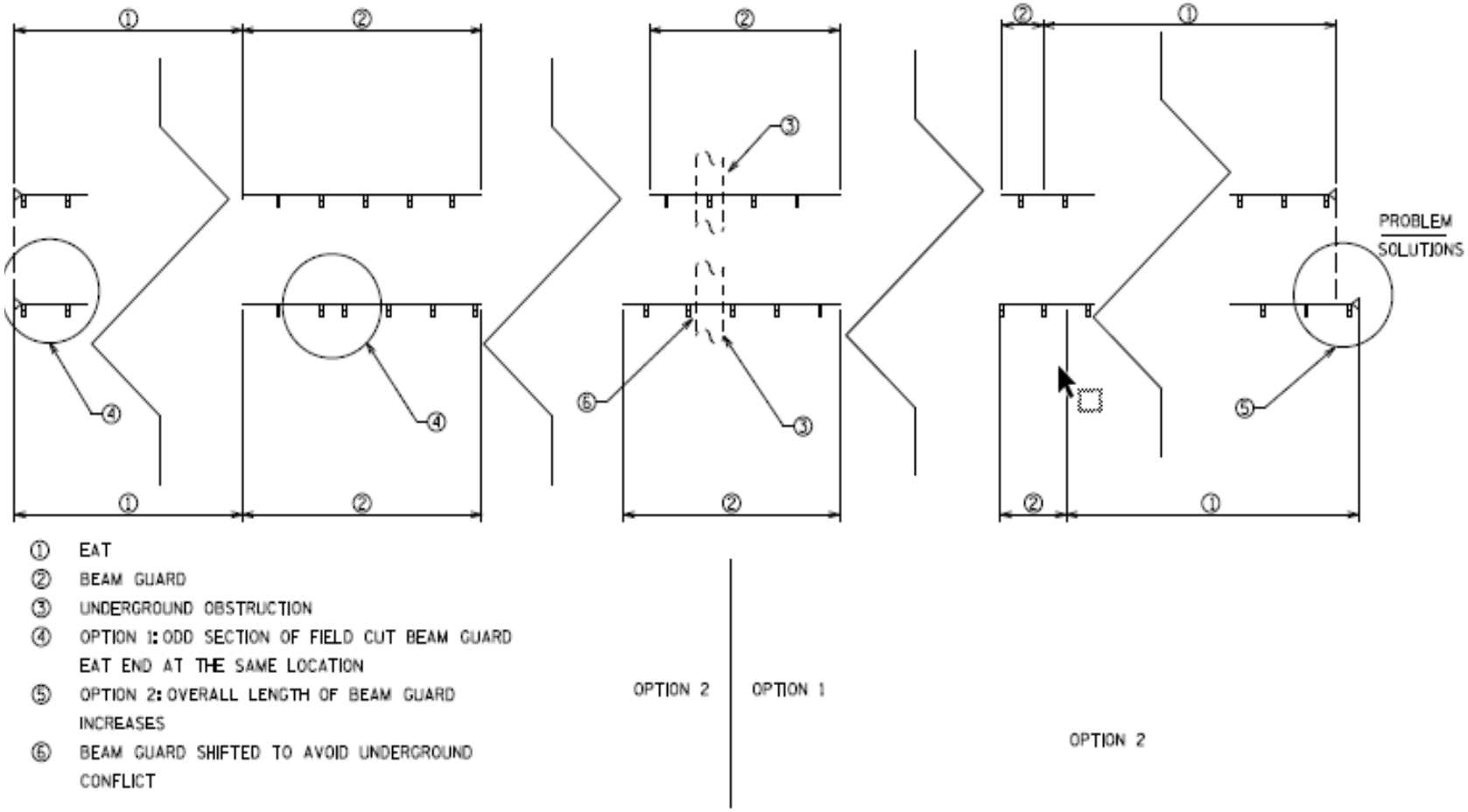
1. INITIAL POSITION OF BEAM GUARD
2. FINAL POSITION OF BEAM GUARD
3. LIKELY LOCATION WHERE POST WILL FAIL DUE TO UNDERGROUND OBSTRUCTION OR UTILLITY MAY BE DAMAGED
4. UNDERGROUND OBSTRUCTION
5. OBSTRUCTION FREE AREA
6. MINIMUM VALUE IS BASED ON MOW STRIP RESEACH. DEPENDING ON SOME UNDERGROUND OBSTRUCTION MAY BE DAMAGED USING MINIMUM VALUE. UTILITY LOCATION CAN VERY SIGNIFICANTLY. USING MINIMUM VALUE IN DESIGN MAY CAUSE CONSTRUCTION ISSUES.



PLAN VIEW

	MINIMUM (6)	DESIRABLE
X	4"	1'
Y	1'-6"	2'-6"
Z	1'	2'

DRAWINGS NOT TO SCALE
DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS AND ARE NOT INTENDED TO BE INSERTED INTO PLANS.
DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.



① EAT
② BEAM GUARD
③ UNDERGROUND OBSTRUCTION
④ OPTION 1: ODD SECTION OF FIELD CUT BEAM GUARD EAT END AT THE SAME LOCATION
⑤ OPTION 2: OVERALL LENGTH OF BEAM GUARD INCREASES
⑥ BEAM GUARD SHIFTED TO AVOID UNDERGROUND CONFLICT

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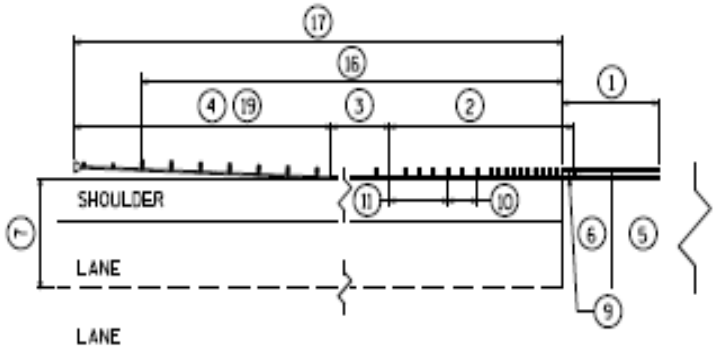
Initial Impact into Beam Guard

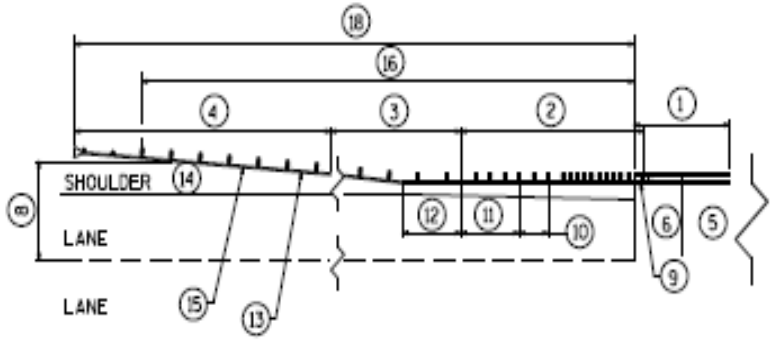
Initial Impact into Blunt End of Rigid Barrier

Last Frame of Video- Significant damage to vehicle compartment

THRIE BEAM APPROACH TRANSITION LAYOUT
BRIDGE WIDTH EQUAL TO ROADWAY WIDTH
OR
ROADWAY WIDTH BY CONCRETE BARRIER IS THE SAME
AS THE ROADWAY WIDTH BY BEAM GUARD



THRIE BEAM APPROACH TRANSITION LAYOUT
BRIDGE WIDTH IS LESS THAN ROADWAY WIDTH
OR
ROADWAY WIDTH BY CONCRETE BARRIER IS LESS
THAN ROADWAY WIDTH BY BEAM GUARD



1. BRIDGE PARAPET OR CONCRETE BARRIER.
2. THRIE BEAM APPROACH TRANSITION. (SEE SDD 14B45).
3. BEAM GUARD. (SEE SDD 14B42).
4. EAT. (SEE SDD 14B44).
5. BRIDGE DECK IS SHOWN, BUT COULD BE ROADWAY.
6. IF BRIDGE SEE SDDS FOR BRIDGE APPROACHES. OTHERWISE ROADWAY
7. FULL ROADWAY WIDTH ACROSS THE BRIDGE DECK OR ROADWAY WIDTH BY RIGID BARRIER IS THE SAME AS ROADWAY WIDTH BY BEAM GUARD.
8. FULL ROADWAY WIDTH ACROSS THE BRIDGE DECK OR ROADWAY WIDTH BY RIGID BARRIER IS NOT THE SAME AS ROADWAY WIDTH BY BEAM GUARD.
9. THRIE BEAM TERMINAL CONNECTOR AND ASSOCIATED CONNECTION. (SEE SDD 14B45).
10. ASYMMETRICAL W-BEAM TO THRIE BEAM TRANSITION. (SEE SDD 14B45).
11. BEAM GUARD INCLUDED IN THRIE BEAM TRANSITION. (SEE SDD 14B45).
12. 12.5' OF ADDITIONAL TANGENT BEAM GUARD IS REQUIRED.
13. SEE FDM FOR FLARE RATES OF MGS.
14. GRADING FROM EDGE OF LANE TO BEAM GUARD AND EAT IS 10:1 OR FLATTER.
15. INSTALL EAT TANGENT TO FLARED BEAM GUARD. NO ADDITIONAL EAT FLARE.
16. ADEQUATE LENGTH OF NEED FOR HAZARDS PRESENT.
17. MINIMUM INSTALLATION LENGTH IS EAT LENGTH AND THRIE BEAM APPROACH TRANSITION.
18. MINIMUM INSTALLATION LENGTH IS EAT LENGTH, 12.5' OF BEAM GUARD AND THRIE BEAM APPROACH TRANSITION.
19. EAT SHOWN WITH STANDARD FLARE (SEE SDD 14B44). EAT MAY BE INSTALLED TANGENT TO ROADWAY. SEE FDM 11-45-2.4.1.7.

GENERAL NOTE

SEE 11-45-2.3.1.4 FOR GUIDANCE ON INDIVIDUAL CONSTRUCTION DETAILS.

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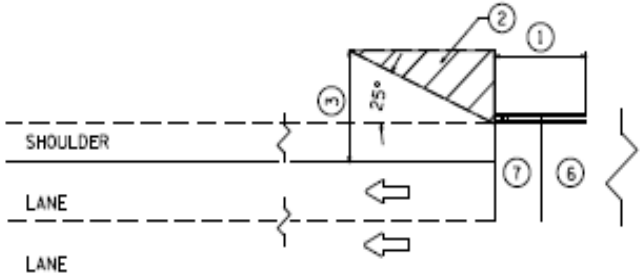
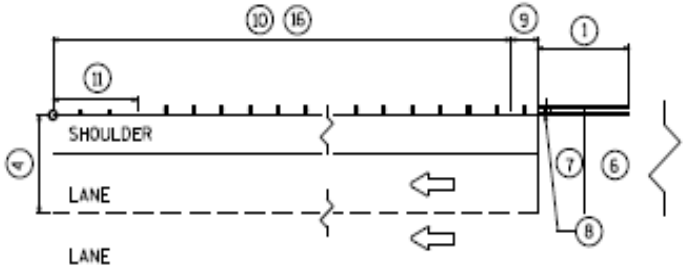
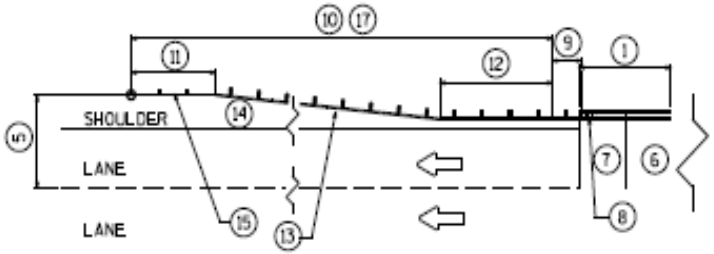
DOWNSTREAM OF PARAPET OR CONCRETE BARRIER
NO ADDITIONAL BARRIER REQUIRED



DOWNSTREAM OF PARAPET OR CONCRETE BARRIER
BRIDGE WITDH EQUAL TO ROADWAY WIDTH OR ROADWAY WIDTH BY THE CONCRETE BARRIER IS EQUAL TO ROADWAY WIDTH BY BEAM GUARD



DOWNSTREAM OF PARAPET OR CONCRETE BARRIER
BRIDGE WITDH LESS THAN ROADWAY WIDTH OR ROADWAY WIDTH BY THE CONCRETE BARRIER IS LESS THAN ROADWAY WIDTH BY BEAM GUARD



1. BRIDGE PARAPET OR CONCRETE BARRIER.
2. AREA TYPICALLY SHIELDED BY RIGID BARRIER OR PARAPET.
3. CLEAR ZONE.
4. FULL ROADWAY WIDTH ACROSS THE BRIDGE DECK OR ROADWAY WIDTH BY RIGID BARRIER IS THE SAME AS ROADWAY WIDTH BY BEAM GUARD.
5. FULL ROADWAY WIDTH ACROSS THE BRIDGE DECK OR ROADWAY WIDTH BY RIGID BARRIER IS NOT THE SAME AS ROADWAY WIDTH BY BEAM GUARD.
6. BRIDGE DECK IS SHOWN, BUT COULD BE ROADWAY.
7. IF BRIDGE SEE SDD 13B2 FOR BRIDGE APPROACHES, OTHERWISE ROADWAY.
8. THRIE BEAM TERMINAL CONNECTOR AND ASSOCIATED HARDWARE (SEE SDD 14B45)
9. ASYMMETRICAL W-BEAM TO THRIE BEAM TRANSITION (SEE SDD 14B45)
10. BEAM GUARD (SEE SDD 14B42)
11. MGS TYPE 2 END TERMINAL (SEE SDD 14B47)
12. 25' OF TANGENT MGS REQUIRED.
13. SEE FDM FOR FLARE RATES OF MGS.
14. GRADING FROM EDGE OF LANE TO BEAM GUARD AND MGS TYPE 2 IS 10:1 OR FLATTER.
15. INSTALL MGS TYPE 2 PARALLEL TO ROADWAY.
16. MINIMUM INSTALLATION LENGTH IS ASYMMETRICAL W-BEAM TO THRIE BEAM TRANSITION AND 12.5' BEAM GUARD FOR THE MGS TYPE 2 TERMINAL. NOTE THAT MINIMUM DESIGN WILL LIKELY NOT PROVIDE EFFECTIVE SHIELDING FOR HAZARDS NEAR ROADWAY. (SEE 11-45-2.4.3).
17. MINIMUM INSTALLATION LENGTH IS ASYMMETRICAL W-BEAM TO THRIE BEAM TRANSITION, 12.5' BEAM GUARD FOR THE MGS TYPE 2 TERMINAL, 25' OF TANGENT MGS BEAM GUARD AND WHATEVER AMOUNT OF BEAM GUARD NEEDED FOR THE TAPER.

GENERAL NOTE

SEE 11-45-2.3.1.4 FOR GUIDANCE ON INDIVIDUAL CONSTRUCTION DETAILS.

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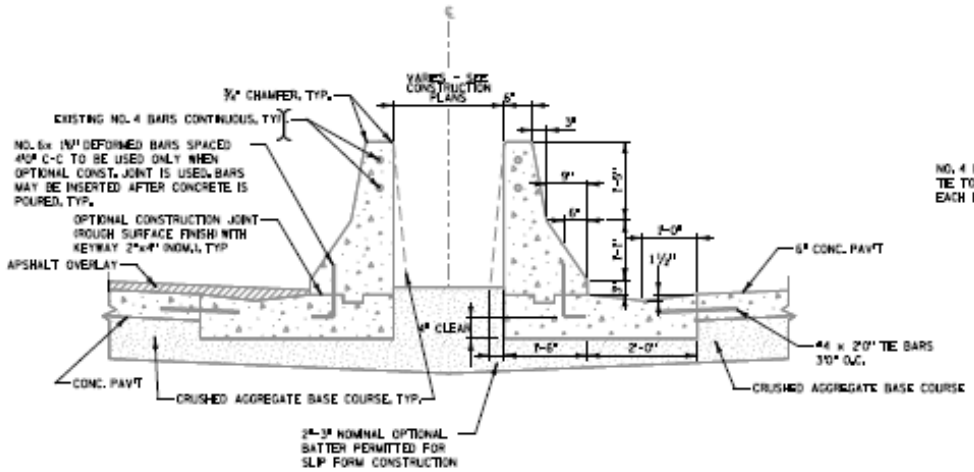
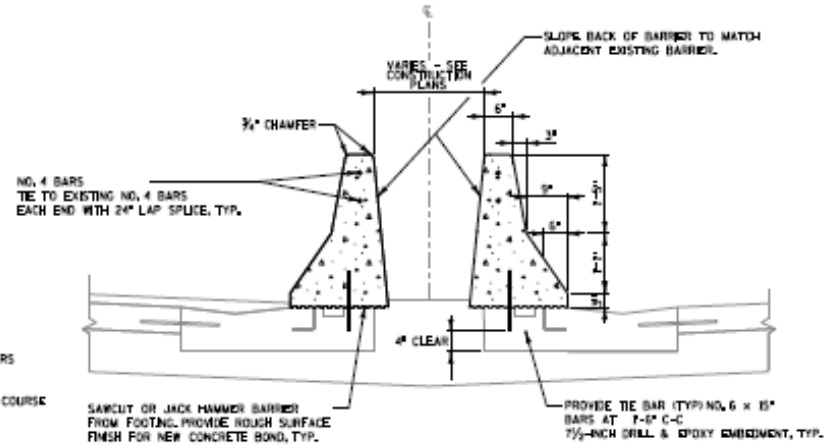


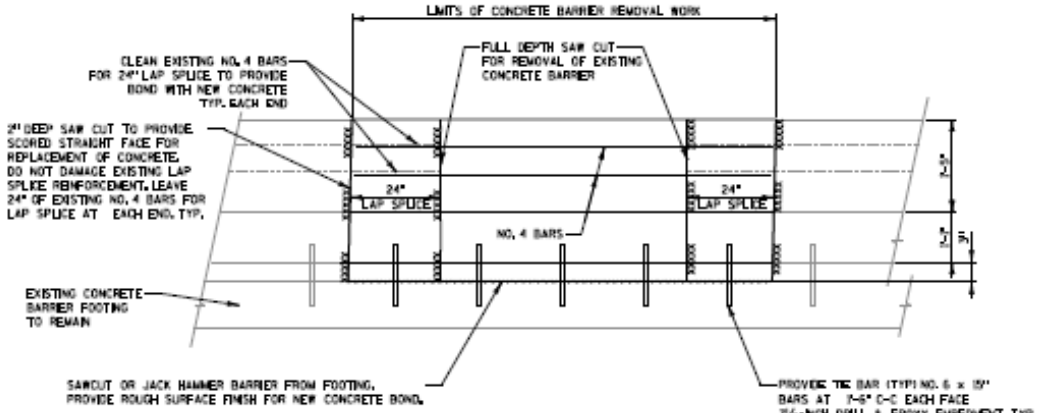
EXISTING CONCRETE BARRIER SINGLE-FACED 32-INCH, MODIFIED

TRANSVERSE SECTION THRU MEDIAN



CONCRETE BARRIER SINGLE-FACED 32-INCH, SPECIAL

TRANSVERSE SECTION THRU MEDIAN



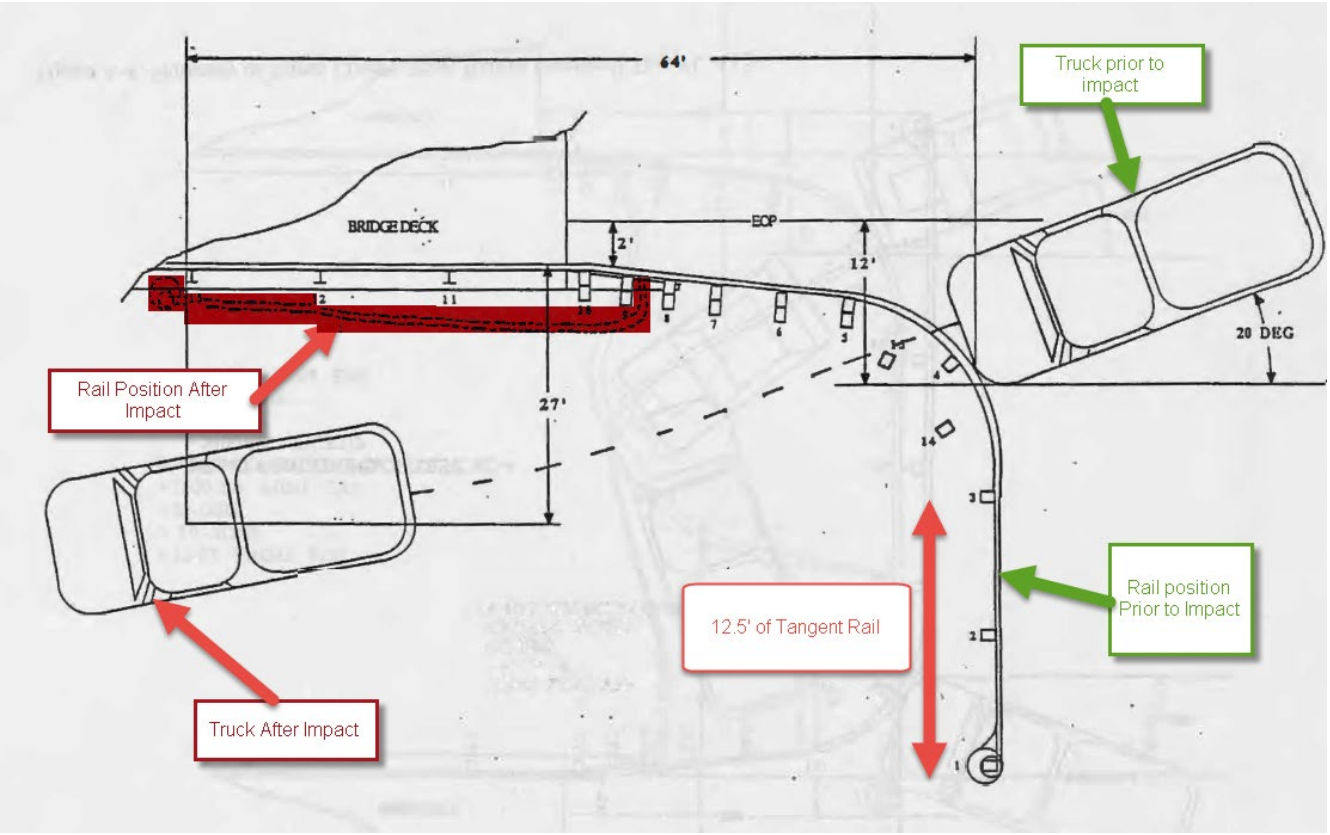
ELEVATION

LONGITUDINAL SECTION THRU MEDIAN

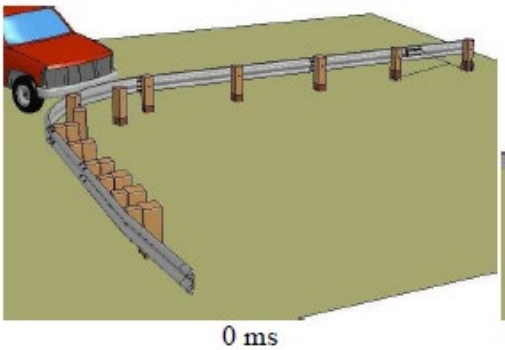
PROJECT NO: 1100-20-60	HWY: USH 45	COUNTY: MILWAUKEE	CONSTRUCTION DETAILS	SHEET 19	E

PLOT DATE = 13-OCT-2014 16:52 PLOT BY = dwilger PLOT NAME = PLOT SCALE = 20.00:1 WISDOT/CADDS SHEET 42

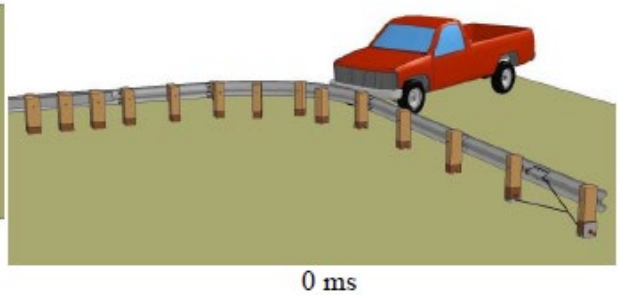
Figure below is from Mayer, J.B, *Full-Scale Crash Testing of Approach Guardrail for Yuma County Public Works Department*, Final Report, Project No.06-2111, Southwest Research Institute, San Antonio, Texas, 1989. In this test the pickup truck passed through the barrier system. A later test passed when there was 25' of tangent rail along the side road.



Computer Simulated Crash sequence photos from research report title “Extending TL-2 Short-Radius Guardrail to Larger Radii” (TRP-03-296-14) by Cody Stolle, John Reid, Robert Bielenberg, Ron Faller, Dean Sicking, and Karla Lechtenberg.



0 ms



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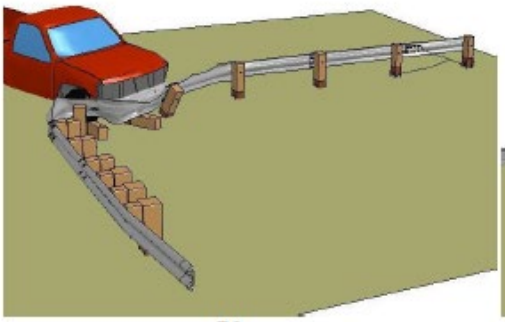
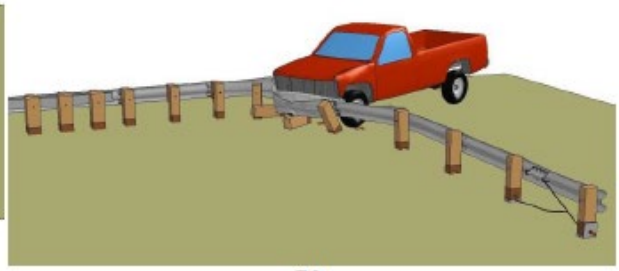


70 ms



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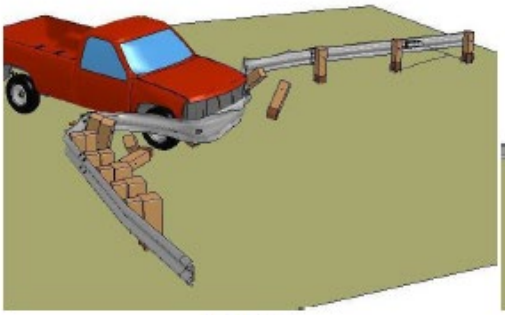
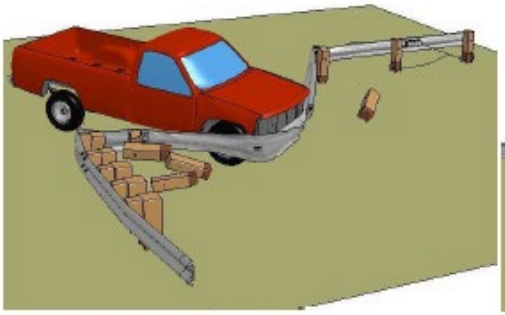


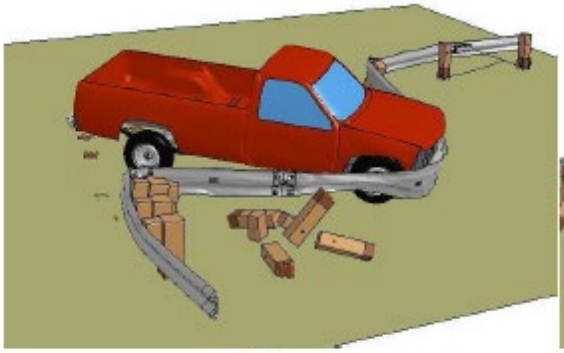
190 ms

190 ms

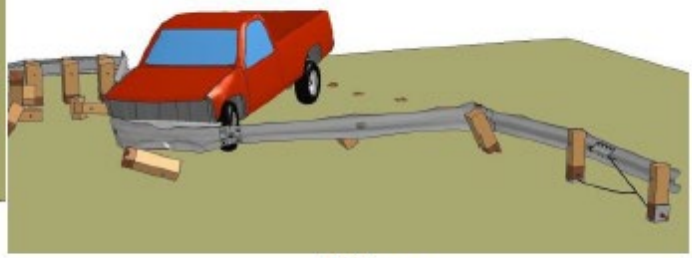


280 ms

280 ms



430 ms



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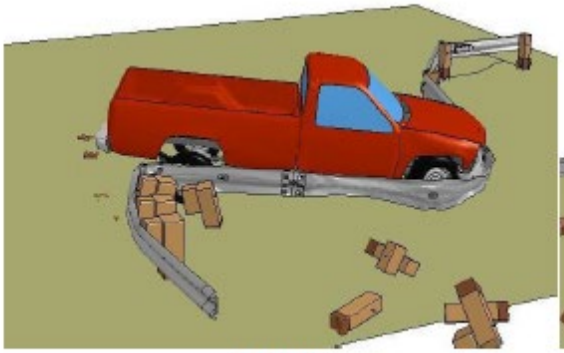
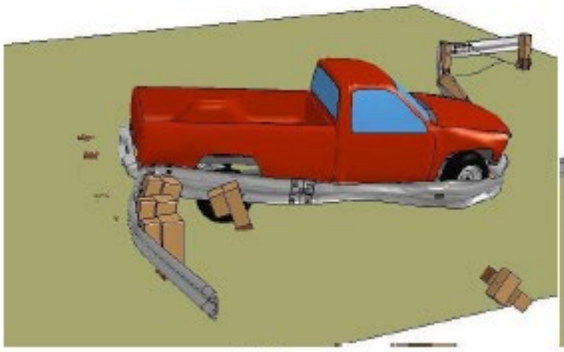


550 ms

550 ms



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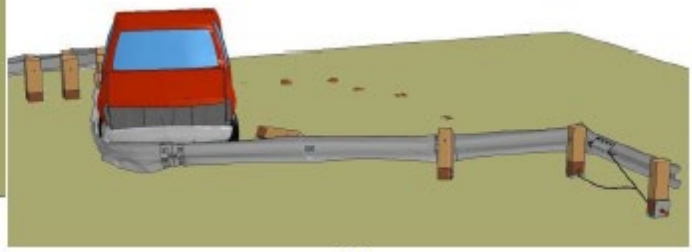

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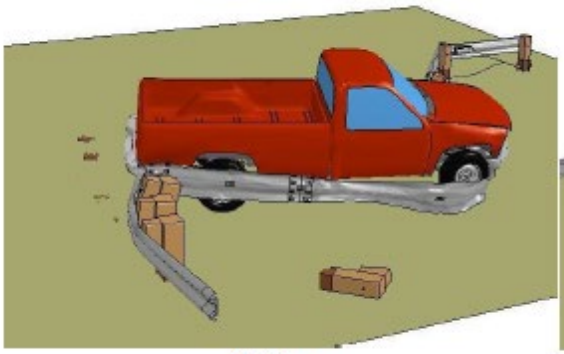
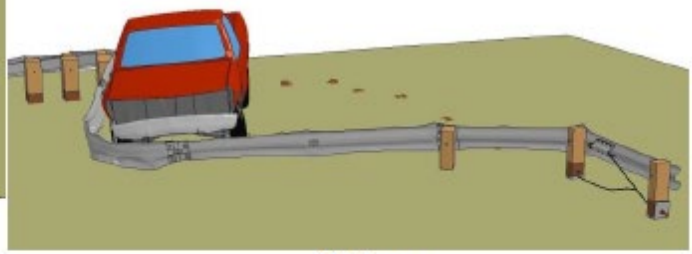


950 ms



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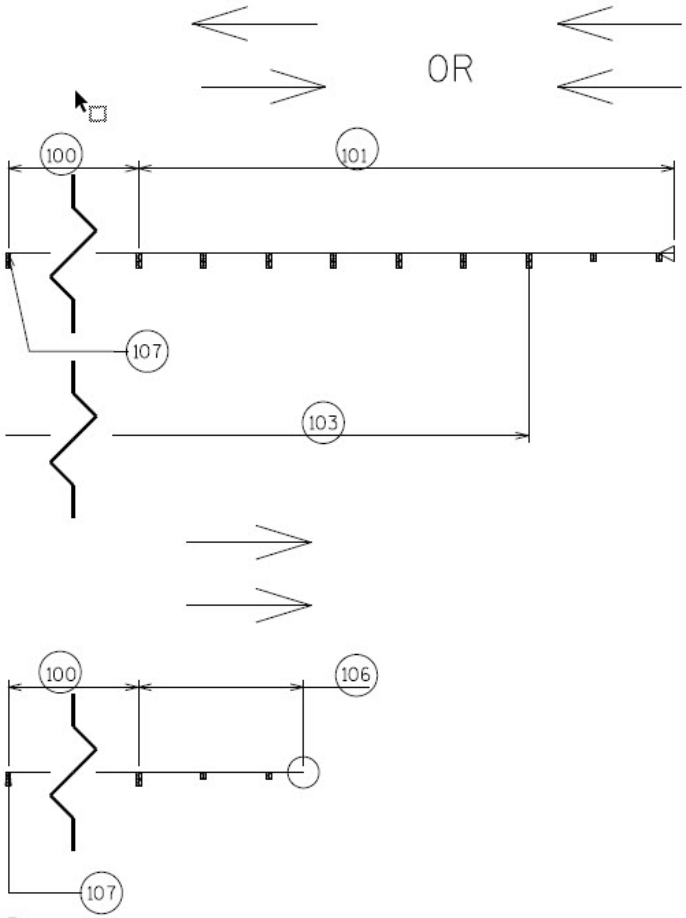

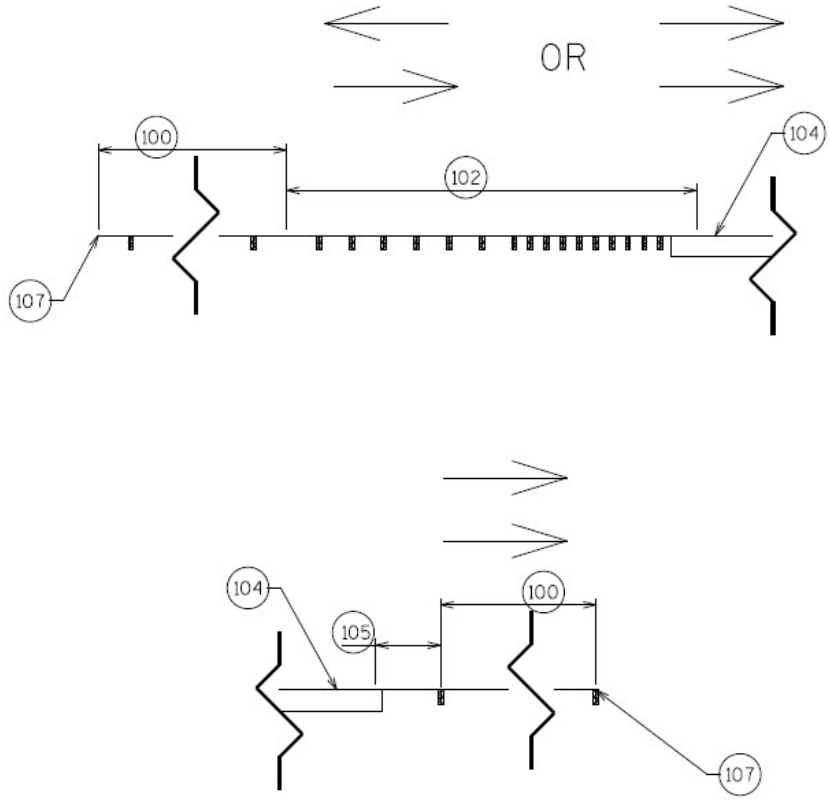

MAIN ROAD OPTIONS

100. MIN. 25' OF NORMAL BEAM GUARD (SDD 14B42)

101. EAT (SDD 14B44)

102. THRIE BEAM STRUCTURAL APPROACH TRANSITION-UPSTREAM (SDD 14B45)

103. ADEQUATE LENGTH OF NEED TO HAZARD(S)

104. RIGID ROADWAY BARRIER OR BRIDGE PARAPET (SDD 14B45 AND PLAN)

105. THRIE BEAM STRUCTURAL APPROACH TRANSITION-DOWNSTREAM (SDD 14B45)

106. TYPE 2 END TERMINAL (SDD 14B47)

107. BEGIN OF SHORT RADIUS (14B53 AND PLAN)

DRAWINGS NOT TO SCALE
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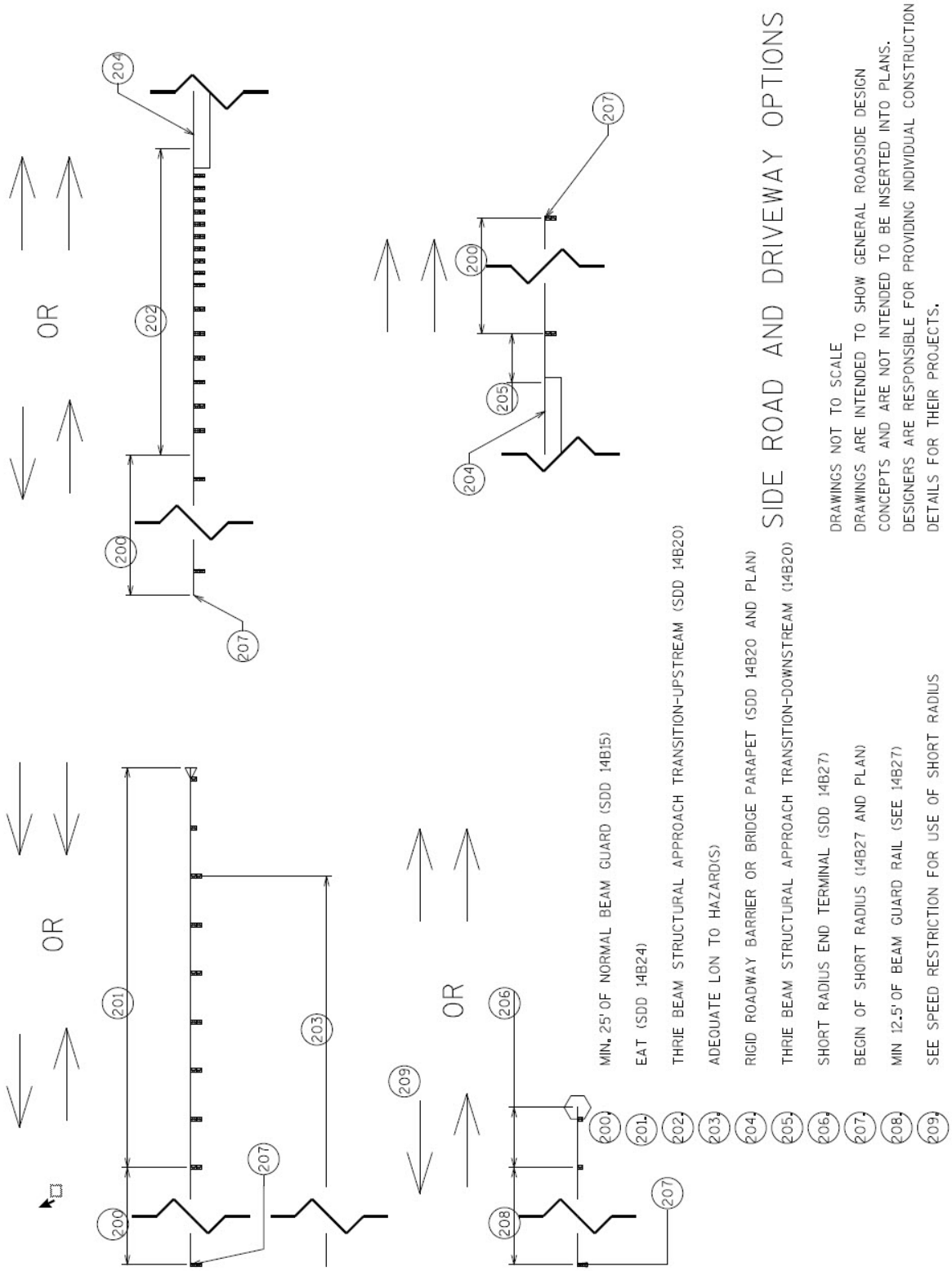

SIDE ROAD AND DRIVEWAY OPTIONS

DRAWINGS NOT TO SCALE
DRAWINGS ARE INTENDED TO SHOW GENERAL ROADSIDE DESIGN CONCEPTS AND ARE NOT INTENDED TO BE INSERTED INTO PLANS. DESIGNERS ARE RESPONSIBLE FOR PROVIDING INDIVIDUAL CONSTRUCTION DETAILS FOR THEIR PROJECTS.

200. MIN. 25' OF NORMAL BEAM GUARD (SDD 14B15)
201. EAT (SDD 14B24)
202. THRIE BEAM STRUCTURAL APPROACH TRANSITION-UPSTREAM (SDD 14B20)
203. ADEQUATE LON TO HAZARD(S)
204. RIGID ROADWAY BARRIER OR BRIDGE PARAPET (SDD 14B20 AND PLAN)
205. THRIE BEAM STRUCTURAL APPROACH TRANSITION-DOWNSTREAM (14B20)
206. SHORT RADIUS END TERMINAL (SDD 14B27)
207. BEGIN OF SHORT RADIUS (14B27 AND PLAN)
208. MIN 12.5' OF BEAM GUARD RAIL (SEE 14B27)
209. SEE SPEED RESTRICTION FOR USE OF SHORT RADIUS END TERMINAL

PLAN VIEW SHORT RADIUS INDIVIDUAL CONSTRUCTION DETAIL LAYOUT EXAMPLE

DRAWINGS NOT TO SCALE
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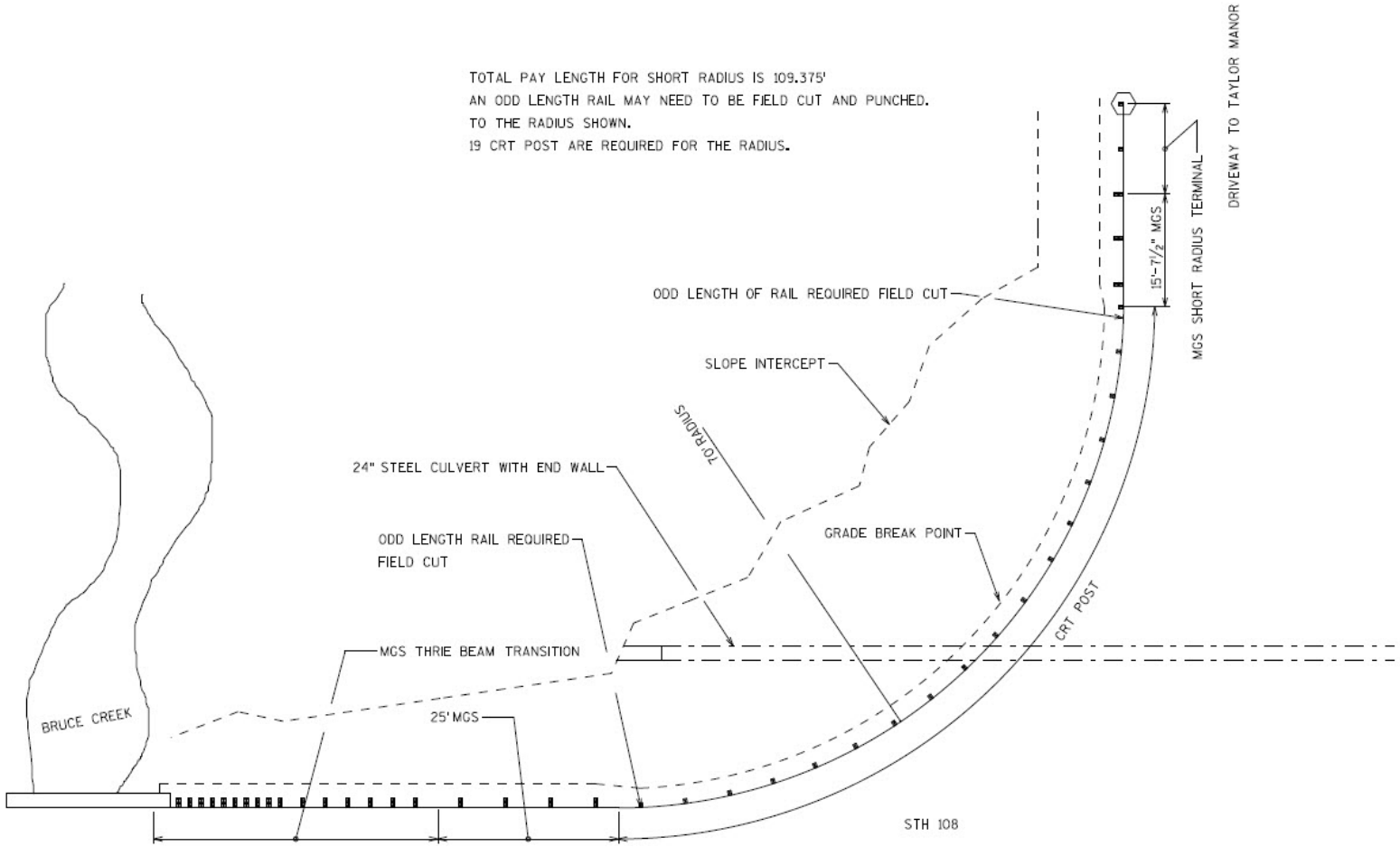
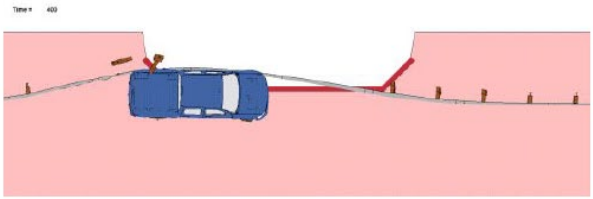
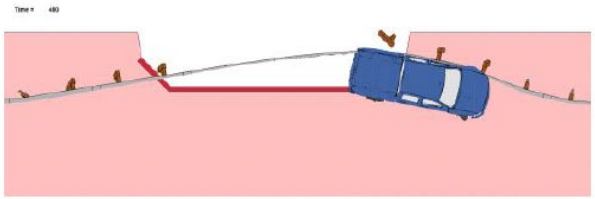


Computer Simulated Crash sequence photos from research report title Increased Span Length for the MGS Long-Pan Guardrail System" (TRP-03-310-14) by Nicholas A. Weiland, Ronald K. Faller, John D. Reid, Robert Bielenberg , and Karla Lechtenberg.

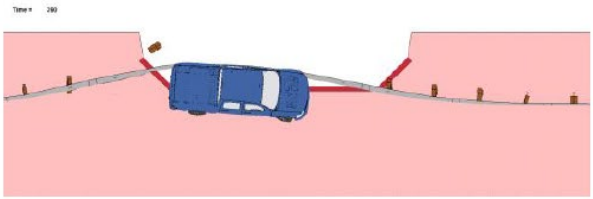
Plan view of multiple impact points along the MGS Long-span. In all impact scenarios run at least a portion of the vehicle is over the culvert opening. Rail tension is preventing the truck from falling into the culvert opening.



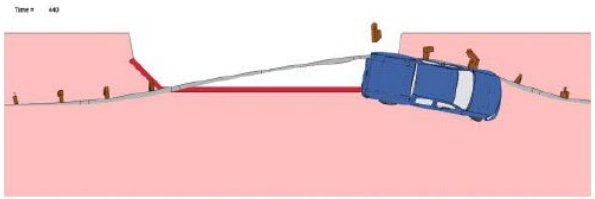
US-P4



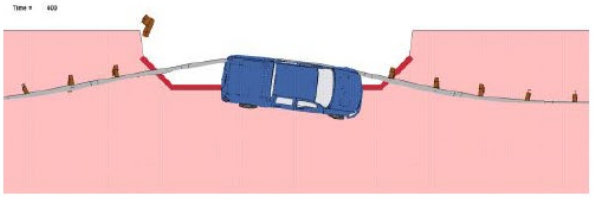
MP1



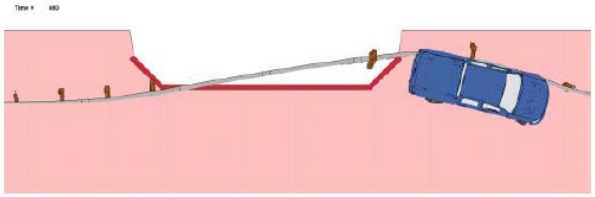
US-P3



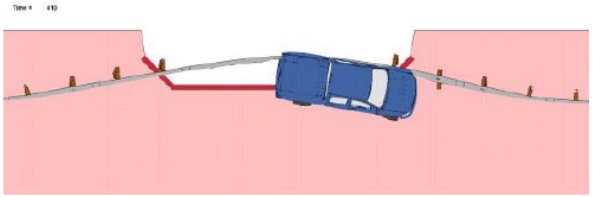
MP2



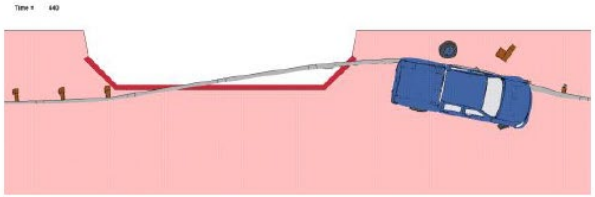
US-P2



MP3



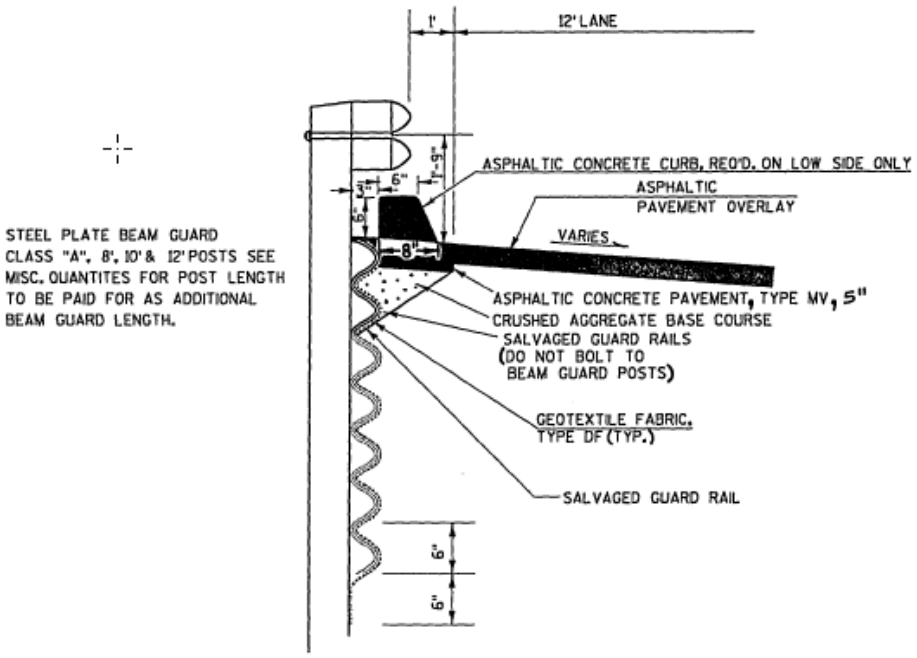
US-P1



MP4

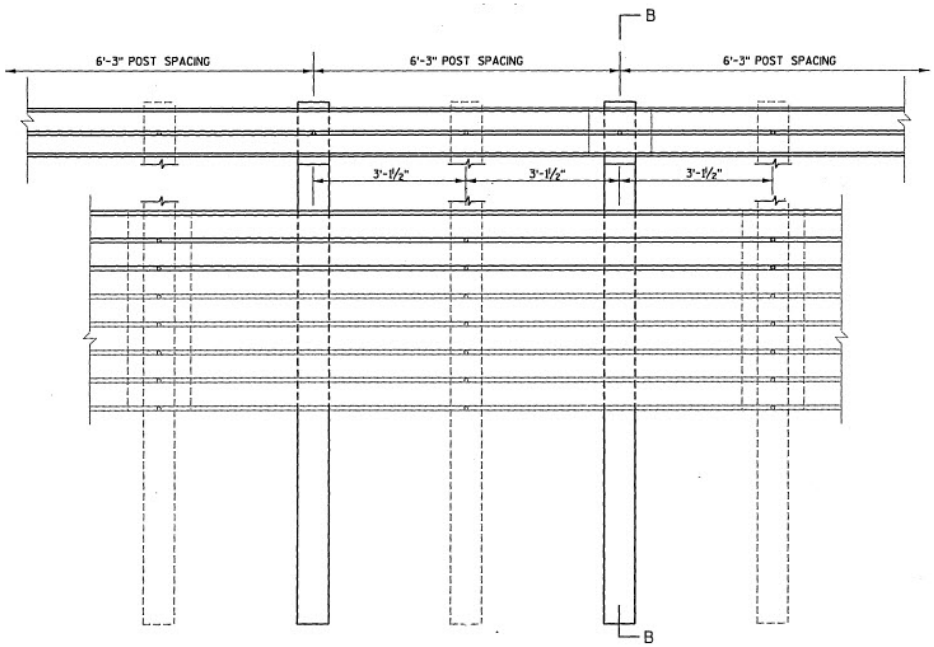
Crash Test sequence and Culvert photos below are from research report title "Midwest Guardrail System for Long-Span Culvert Applications" (TRP-03-310-14) by Robert Bielenberg, John Rohde, Dean Sicking, Erin Allison, Ronald K. Faller, John D. Reid, Robert Bielenberg , and Karla Polivka.

Photos shows portions of crash test vehicle over the culvert opening. There is some drop in vehicle height. As shown by the tire marks on culvert due to the vehicle redirection.

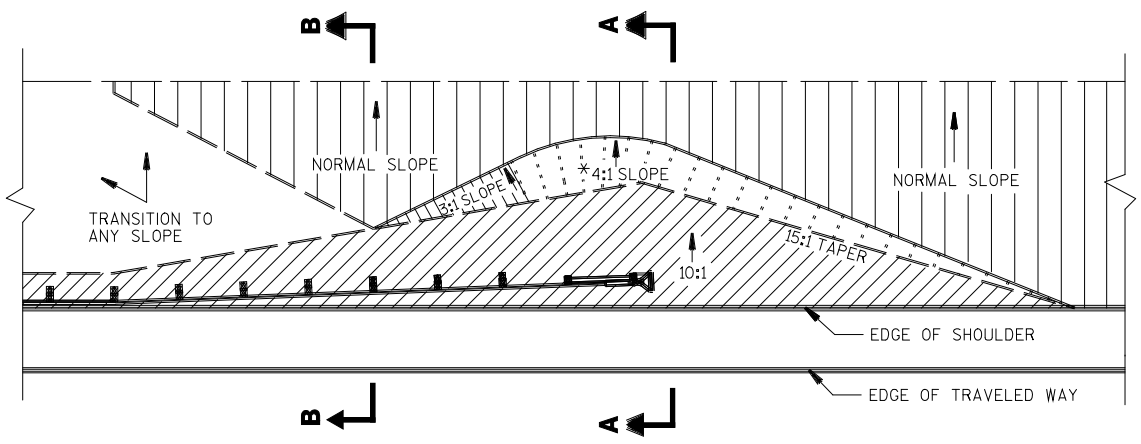


SEC B-B

STEEL PLATE BEAM GUARD POST DETAIL AND
(ASPHALTIC CONCRETE CURB DETAIL)

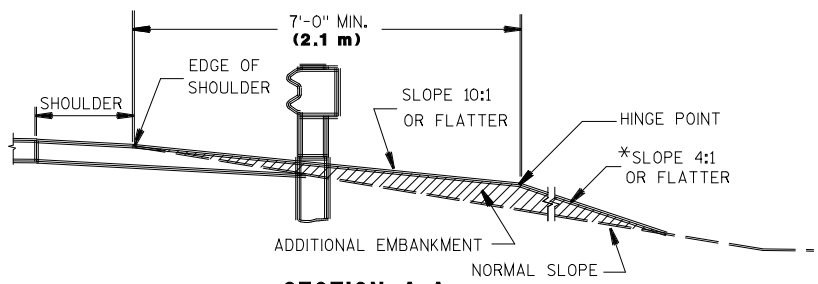


Small Beam Guard Retaining Wall Example

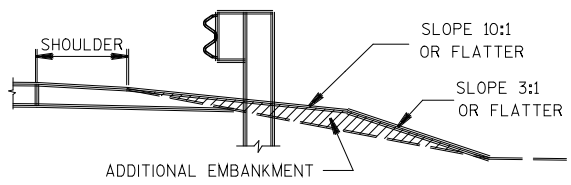


PLAN VIEW

*A 3:1 MAXIMUM SLOPE MAY BE USED FOR INSTALLATIONS ON EXISTING HIGHWAYS.



SECTION A-A



SECTION B-B

NOTE:

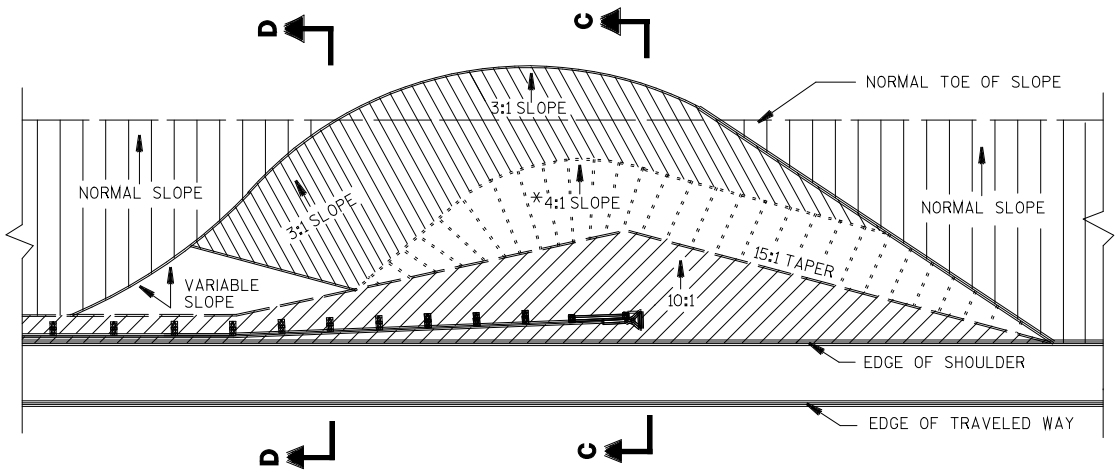
THIS DETAIL IS AVAILABLE AS A CELL FOR INCLUSION IN CONTRACT PLANS.

CADD'S DIRECTORY: DE_HWYS_STD

ENGLISH: DETAILS4.CEL
CELL NAME: CASE1

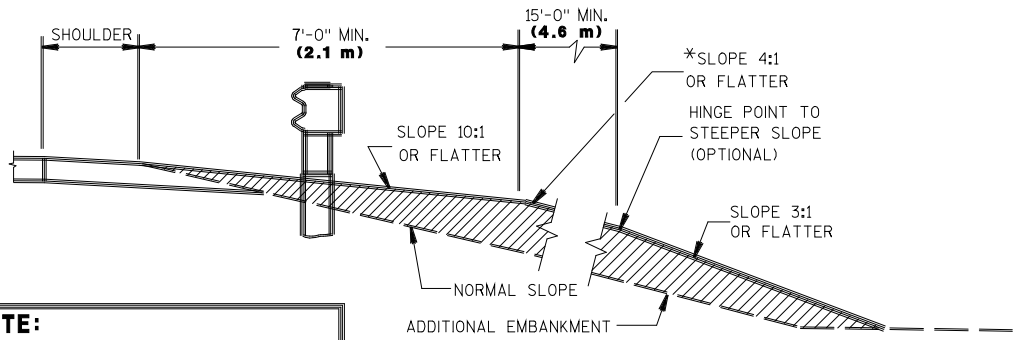
METRIC: MDETAILD.CEL
CELL NAME: D11

CASE 1



PLAN VIEW

*A 3:1 MAXIMUM SLOPE MAY BE USED FOR INSTALLATIONS ON EXISTING HIGHWAYS.



SECTION C-C

NOTE:

THIS DETAIL IS AVAILABLE AS A CELL FOR INCLUSION IN CONTRACT PLANS.

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ENGLISH: DETAILS4.CEL
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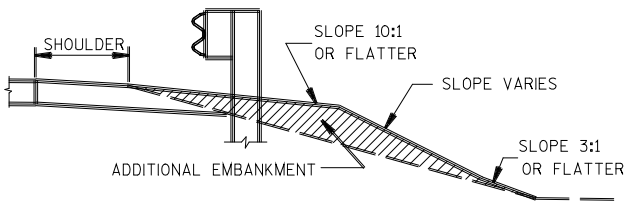
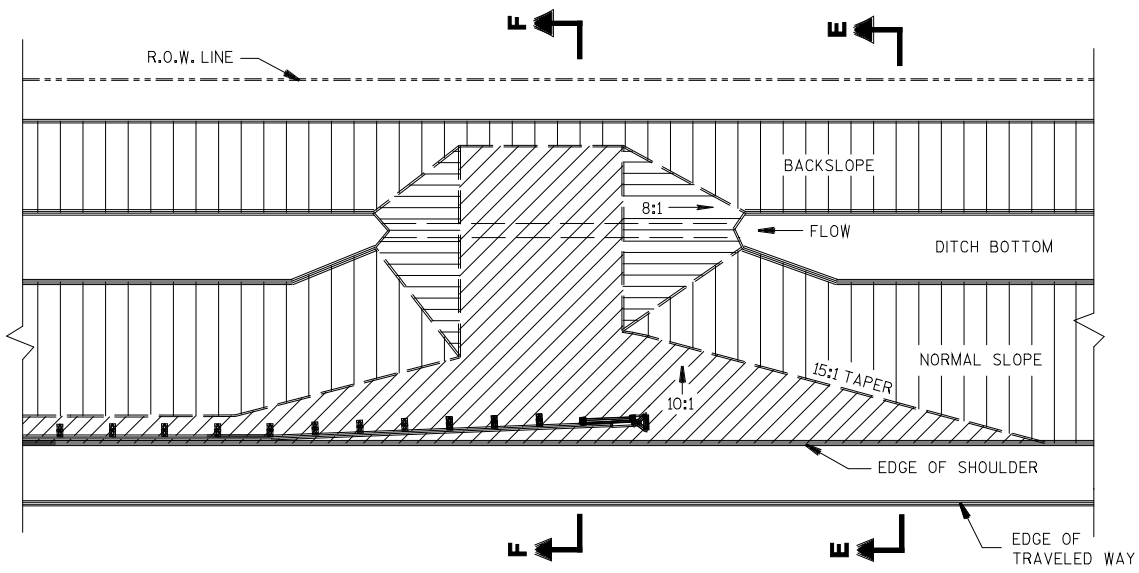
METRIC: MDETAILD.CEL
CELL NAME: D12



SECTION D-D

CASE 2



PLAN VIEW

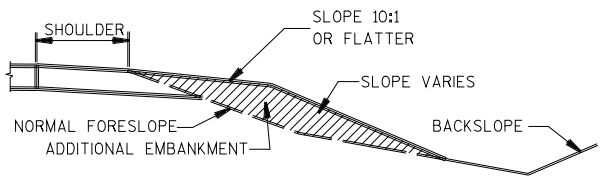
NOTE:

THIS DETAIL IS AVAILABLE AS A CELL FOR INCLUSION IN CONTRACT PLANS.

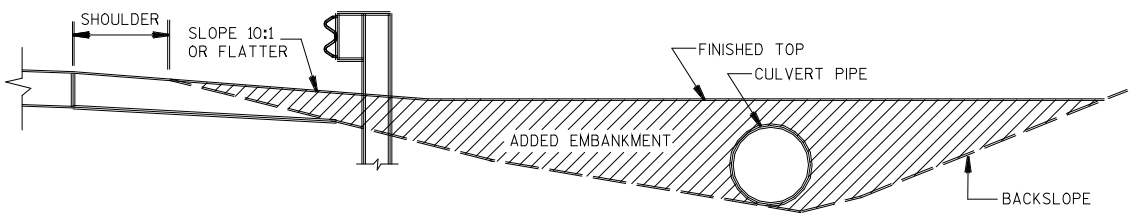
CADD'S DIRECTORY: DE_HWYS_STD

ENGLISH: DETAILS4.CEL
CELL NAME: CASE3

METRIC: MDETAILD.CEL
CELL NAME: D13



SECTION E-E



SECTION F-F

CASE 3

FDM 11-46-1 Bicycle and Pedestrian Elements Affecting Complete Streets

February 18, 2020

1.1 Introduction, Purpose, Definitions, Overview

"Complete streets" are broadly defined as roadways designed and operated to enable safe, convenient, and comfortable access and travel for all users. Pedestrians, bicyclists, motorists, and public transport users of all ages and abilities can move along and across a complete street with safety and comfort.

Federal policy for providing bicycle and pedestrian accommodation - per the 2010 "US DOT Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations" (Memorandum) *(1) - is as follows:*

"The DOT policy is to incorporate safe and convenient walking and bicycling facilities into transportation projects. Every transportation agency, including DOT, has the responsibility to improve conditions and opportunities for walking and bicycling and to integrate walking and bicycling into their transportation systems. Because of the numerous individual and community benefits that walking and bicycling provide — including health, safety, environmental, transportation, and quality of life — transportation agencies are encouraged to go beyond minimum standards to provide safe and convenient facilities for these modes."

Federal legislation currently requires that bicycle and pedestrian needs must be given due consideration under Federal Surface Transportation law (23 U.S.C. 217(g)(1)), and this should include, at a minimum, a presumption that bicyclists, pedestrians, and persons with disabilities will be accommodated in the design of new and improved transportation facilities. In the planning, design, and operation of transportation facilities, bicyclists, pedestrians, and persons with disabilities should be included as a matter of routine, and the decision to not accommodate them should be the exception rather than the rule. There must be exceptional circumstances for denying bicycle and pedestrian access (23 U.S.C 217(g)(1)). Federal Highway Administration (FHWA) policy requires the inclusion of bicycle and pedestrian accommodation on all modernization projects, with three exceptions:

1. Bicyclists and pedestrians are prohibited by law from using the roadway.
2. The cost of establishing bikeways would be excessively disproportionate to the need or probable use. Excessively disproportionate is defined by FHWA and state statutes as bicycle and pedestrian facilities together exceeding 20 percent of the cost of the larger transportation project.
3. Sparsity of population or other factors indicate an absence of need.

The FHWA Wisconsin Division Office directs that WisDOT shall follow federal policy on all projects on the National Highway System (NHS), and should follow federal policy on all federally funded projects off that system.

WisDOT policy, in conformance with Federal laws and policy, State Statute Section 84.01(35), and Connections 2030 *(2) (3)*, requires that projects must give due consideration to establishing bicycle accommodations and pedestrian facilities on all modernization and most rehabilitation (i.e. pavement and bridge replacement) highway projects funded in whole or in part from state or federal funds. After giving due consideration, if WisDOT determines that bike and pedestrian facilities are required on a project funded in whole or in part from state funds, then WisDOT is authorized to include those facilities only if each municipality[1] in which the project is located adopts a resolution authorizing WisDOT to establish a bikeway or pedestrian way. The state statute also states that the need for WisDOT to obtain a municipal resolution(s) does not apply if FHWA provides written notice that establishment of a bikeway or pedestrian way, as part of a project, is a condition of the use of federal funds for that project (s.84.01(35)(d)(2), Wis. Statutes.)

FHWA has indicated that when the results of due consideration show that bicycle and pedestrian facilities are to be provided, the signed final National Environmental Policy Act (NEPA) decision document is FHWA's written notice to WisDOT that establishment of a bikeway or pedestrian way as part of the project, is a condition of the use of FHWA funds, consistent with State Statute 84.01(35)(d). Therefore, for projects with any federal funding and those on the NHS, WisDOT's compliance with the FHWA written notice provision are satisfied by receipt of a completed environmental document from FHWA. However, even if the project does not require a resolution, the planning and design processes will still provide opportunities for public input and to evaluate environmental impacts of project alternatives that may include bike and pedestrian facilities. Municipalities may adopt

[1] Municipality is defined as a city, village, or town (Wis. Statutes Section 990.01(22).

resolutions that authorize the inclusion of facilities on the NHS or federal funded projects where WisDOT does not need to obtain them. These resolutions will be included in the environmental document.

Department policy on perpetuation and rehabilitation (i.e. reconditioning) project types is described in FDM 11-46-1.1.2 and 1.1.3.

The purpose of this procedure is to explain the requirements and applications of the state statute, WisDOT policy and federal laws and policies as they pertain to highway projects in Wisconsin.

1.1.1 State Statute

State Statute 84.01(35) was originally created in 2009 and was modified in 2014. The modifications to the state statute became effective on July 14, 2015. Projects with approved environmental documents as of July 14, 2015 will follow through on the commitments identified during the public involvement and environmental processes including bike and pedestrian commitments [2]. The state statute requires that WisDOT shall give due consideration to establishing bikeways, as defined in State Statute 84.60(1)(a), and pedestrian ways, as defined in State Statue 346.02(8)(a), on modernization projects funded in whole or in part from state funds or federal funds. The statute also states that the WisDOT may not establish bicycle and pedestrian ways if any of the following apply:

1. Bicycles and pedestrians are prohibited by law from using the highway; or
2. The project is wholly or partially funded with state funds, unless the governing body of each municipality within the project has adopted a resolution authorizing the department to establish the bikeway or pedestrian way. This subdivision does not apply if the federal government provides written notice to the department that establishment of a bikeway or pedestrian way as a part of a project is a condition of the use of federal funds for that project.

If after giving due consideration it is determined that establishment of bicycle and pedestrian facilities are proposed on a pavement replacement or modernization improvement project that is not part of the NHS system and has no federal funding, then WisDOT cannot establish those facilities unless each municipality[3] involved in the modernization project adopts an official resolution authorizing the establishment of those facilities as part of the improvement project. This requires consensus amongst all the governing bodies in which a portion of the project will occur. For this situation, WisDOT will not finalize an environmental document that recommends providing a bike or pedestrian accommodation unless the municipal resolutions have been adopted.

As stated previously in FDM 11-46-1, for projects with any federal funding and those on the NHS, WisDOT compliance with the FHWA written notice provision are satisfied above by receipt of a completed environmental document from FHWA. Therefore, WisDOT will not seek municipal resolutions on these types of projects (NHS or federal funded).

Further, a resolution is not required when bicycle and pedestrian facilities already exist and are to be replaced as part of the modernization improvement project.

For stand-alone bike and pedestrian projects funded using federal or state funding programs it is presumed that bike and pedestrian facilities are incorporated on the project and geometric design criteria applied accordingly.

Lastly, State Statute 32.015 provides condemnation authority limitations on establishing or extending a recreational trail, or bicycle or pedestrian way. However, this is not a limitation for evaluating bike and pedestrian accommodations as part of projects or from establishing within existing right-of-way, or through other land acquisition methods. It is expected that all projects will be evaluated for accommodations.

1.1.2 Asset Management

WisDOT has established a project delivery methodology focused on preserving and restoring existing facilities along the State Trunk Network (STN). Asset management provides the mechanism to meet these goals.

Projects consist of three (3) improvement strategies. These are perpetuation, rehabilitation and modernization. See FDM 3-5-1.1 for definitions of these Improvement strategies.

WisDOT has also adopted Performance Based Practical Design (PBPD) that assumes a perpetuation improvement strategy. Regardless of this strategy, all projects will be evaluated for bike and pedestrian accommodations as part of project development.

1.1.3 Construction Definition

As stated above, State Statute 84.01(35) is required on modernization and most rehabilitation (i.e. pavement and bridge replacement) projects.

However, that does not mean only modernization and most rehabilitation (i.e. pavement and bridge replacement) projects are reviewed for bike or pedestrian issues. All projects must go through the WisDOT Scope Certification process described in FDM 3-1 and FDM 11-4. It is the Scope Certification process which determines

whether a project will be designed to a perpetuation, rehabilitation, or modernization standard.

As part of PBPD, the Safety Certification Process (SCP) will validate if there are safety concerns warranting an increased strategy of rehabilitation or greater. A single bike or pedestrian crash of any type on a highway segment will trigger a project crash flag, and require a SCP review to be completed, and may result in an expanded design strategy. See FDM 11-38 for more details on SCP. If there are no bike or pedestrian crashes on the project, the Risk-Based Environmental Screening Template (RBEST) requires a discussion on presence of any bike or pedestrian concerns or conflicts. Both the SCP and RBEST are part of the Scope Certification process and lead to the following determinations:

1.1.3.1 If neither the SCP nor the RBEST identify any bike or pedestrian improvements, the perpetuation concept is validated by Scope Certification at LC 11, and no further evaluation is necessary during the final delivery phase.

1.1.3.2 If either the SCP or RBEST identify a bike or pedestrian improvement that can be accommodated within the perpetuation design strategy, that is noted in the Scope Certification documentation and further evaluation occurs during final design.

1.1.3.3 If either the SCP or RBEST identify a bike or pedestrian improvement that cannot be accommodated within a perpetuation design strategy, a rehabilitation design strategy may be necessary. Also, a rehabilitation design strategy may be necessary for issues other than bike and pedestrian needs. Regardless of how a rehabilitation consideration is prompted, a rehabilitation requires an evaluation of bike or pedestrian accommodations is those areas where S-2 design standards are applied.

Most rehabilitation designations occur because of spot safety or operational issues within a larger project segment. The spot locations where the rehabilitation need occurs is where S-2 design standards are applied and evaluation during final design required. The remaining portion of the project outside of the spot rehabilitation locations would still be considered a perpetuation where S-1 standards are applied. These perpetuation sections of the project are evaluated according to the preceding 1.1.3.1 and 1.1.3.2. The S-1 and S-2 standards may affect the extent and type of bike and pedestrian accommodations included within the scope of the project.

FDM 3-1 provides more on scoping phased deliverables for scope certification, including SCP and RBEST.

FDM 11-4-3 provides more information on the Scope Certification requirements.

Pursuant to sections in FDM 11-46-10 and FDM 11-46-15 certain bicycle and pedestrian design standards such as curb ramps and bicycle-acceptable grates are required on perpetuation or rehabilitation design strategies regardless of presence of crashes.

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[2] FAQs to Bicycle & Pedestrian State Statute 84.01(35); http://wisconsindot.gov/Documents/projects/multimodal/bike/8401-faq.pdf

[3] Municipality is defined as a city, village, or town (Wis. Stats. Section 990.01(22).

1.1.4 Asset Management and ADA Curb Ramp Compliance

Asset Management projects that are defined as an "alteration" per USDOJ and USDOT joint technical assistance memo and glossary of terms (See Attachment 1.2 and Attachment 1.3) are required to install or update curb ramps. This may include installing new curb ramps at locations if none previously existed or upgrading curb ramps to meet the applicable design criteria.

1.1.5 ADA Curb Ramp Compliance and Right-of-Way Requirements

If sufficient right-of-way is not owned and additional right-of-way is needed to install an ADA compliant curb ramp or to upgrade an existing curb ramp to full ADA compliance or to the maximum extent feasible, it is WisDOT's policy for state highways to acquire the necessary real estate to allow the curb ramp work to be constructed. The acquisition could be additional right-of-way or a temporary limited easement (TLE). See FDM 12-1-1 and FDM 12-1-15 for guidance to help determine the process to follow for real estate acquisition. A project is not exempt from ADA curb ramp compliance if no right-of-way is acquired.

These right-of-way requirements will apply to projects that have an environmental document that is signed on January 2, 2019 or later. For projects with an environmental document signed prior to January 2, 2019 these right-of-way requirements are not mandatory, however, curb ramps must still be made compliant to the maximum extent feasible within the existing right-of-way. Technical infeasibility documentation will still need to be provided accordingly (see FDM 11-46-5.1.2 Technical Infeasibility).

1.1.6 Bikeways

Bikeways will be repaired or resurfaced on projects where they exist as part of the roadway. This will apply to Perpetuation, Rehabilitation and Modernization projects.

1.1.7 Sidewalks

1.1.7.1 Sidewalk Treatment - Pavement Treatment Service Life < 18-Years

Perpetuation - Typically sidewalk improvements would not be scheduled for these projects. Thus, existing sidewalk will be left in place. Re-evaluate sidewalk treatment(s) with the next improvement project.

Rehabilitation - Existing sidewalk would be typically left in place on portions of rehabilitation projects where S-1 application is applied. The designer should evaluate the improvement portions of these projects where S-2 application is applied for inclusion of bicycle or pedestrian facilities. Project scope, context and system continuity should be considered to help determine if inclusion of a bicycle or pedestrian facility makes sense or should be scheduled at a time when a longer-term pavement treatment project or a modernization project is scheduled.

See FDM 11-1-10 for information about S-1 and S-2 applications.

1.1.7.2 Sidewalk Treatment - Pavement Treatment Service Life ≥ 18-Years

Modernization - Existing sidewalk will typically be repaired or reconstructed on modernization projects where S-3 application is applied. Right-of-way (Fee or TLE) will be acquired if necessary to allow the sidewalk to be repaired or reconstructed.

See FDM 11-1-10 for information about S-3 application.

1.2 Bikeways and Sidewalks

The state statute requires that WisDOT shall give due consideration to establishing bikeways, as defined in State Statue 84.60(1)(a), and pedestrian ways, as defined in State Statue 346.02(8)(a), on modernization projects funded in whole or in part from state funds or federal funds.

See the following references for guidance on bikeways:

- FDM chapter 11 - primarily FDM 11-46-15, but also other procedures, including FDM 11-15-1 and FDM 11-20-1
- Wisconsin Bicycle Facility Design Handbook *(4)*
- WisDOT Rural Bicycle Planning Guidelines *(5)*

Sidewalks are a common feature for urban and suburban roadways and recognized as pedestrian ways. The main issues associated with providing sidewalks in an urban environment are:

- Location of the sidewalk (placement on one side or both sides of the roadway),

- Sponsorship and maintenance of the sidewalks,
- Expected sidewalk usage
- Trade-offs with bicycle accommodations and other roadway features when funding or space is limited

See the following references for guidance on sidewalks:

- FDM chapter 11 - primarily FDM 11-46-5 and FDM 11-46-10, but also other procedures, including FDM 11-20-1
- Wisconsin Guide to Pedestrian Best Practices *(6)*
- Wisconsin Bicycle Facility Design Handbook, Chapter 4, Shared-use Path *(4)*

1.2.1 Prioritization between Bikeways and Sidewalks

It is WisDOT policy to strive to provide both sidewalks and bikeways on all modernization projects, to the geometric design criteria described in the FDM and associated design manuals. In locations where space is limited, provide the maximum extent of accommodations possible. Before omitting any accommodation for either bicyclists or pedestrians, give due consideration reducing the width of travel lanes, medians, terraces and gutter sections - to minimums, if needed. Then consider the following measures, in order of priority:

1. Reduce the width of bikeways to the minimal level, i.e., 14-foot-wide outside lanes instead of bike lanes.
2. Place a 6-foot minimum sidewalk directly behind the curb, i.e., eliminate the terrace.

   This is only acceptable for very short distances because a terrace serves many important functions (consult with region maintenance or the local government).
3. Omit bicycle accommodations.

   It is acceptable to prioritize sidewalks over bicycle facilities if a choice must be made between these two modes.
4. Provide a sidewalk on only one side, especially if meeting any of the criteria in Table 4.1, “WisDOT Guidelines for Sidewalk Placement” of the February 2011 Wisconsin Guide to Pedestrian Best Practices *(6)*.

These strategies can be used in combination. For example, it may be possible to provide wide outside lanes for a section of a project as well as a short stretch of sidewalk placed behind the curb.

1.2.2 Shared-Use Paths

Bicyclists are legal users of roadways, and the first responsibility is to provide on-road accommodations for bicycles where appropriate. Shared-use paths should only replace on-road bicycle accommodations in exceptional situations (e.g. bicyclists and pedestrians prohibited). In certain situations, shared-use paths can supplement on-road bicycle accommodations, or be used in place of a sidewalk (on a given side of the road) as a pedestrian facility.

The decision to use shared-use paths along roadways must meet the guidelines found in FDM 11-46-15 and in the “Wisconsin Bicycle Facility Design Handbook *(4).*

1.3 Project Development / Scoping Process

Due consideration shall be given to establishing bikeways and pedestrian ways in all modernization projects and applicable rehabilitation projects, consistent with state law, beginning with the first scoping meeting. WisDOT Regional Bicycle and Pedestrian Coordinators shall be involved in evaluating all projects for compliance with the state law and provide guidance in planning and design processes related to bicycling and walking.

Include the Regional Bicycle/Pedestrian Coordinator in all phases of project development and in all project review meetings (scoping, 30%, 60%, 90% (pre-PSE), TMP, etc.). The need for input from the Regional Bicycle/Pedestrian Coordinator will continue through construction.

1.3.1 Evaluation Criteria

There must be exceptional circumstances for not including bicycle and pedestrian access either by prohibition or by designing highways that are incompatible with safe, convenient walking and bicycling (23 U.S.C. 217(g)(1)). FHWA design guidance outlines exceptional circumstances in a Policy Statement and Supplementary Design Guidance.

The following are circumstances that may be useful for evaluating and documenting decisions:

1. Bicycles or Pedestrians Prohibited (see FDM 11-46-1.3.1.1)

2. Excessively Disproportionate Costs (see FDM 11-46-1.3.1.2)
3. Constrained Environments (see FDM 11-46-1.3.1.3)
4. Absence of Need (see FDM 11-46-1.3.1.4)
5. Refusal to Maintain (see FDM 11-46-1.3.1.5)

Even where circumstances are exceptional, and bicycle use and walking are either prohibited or made incompatible, States, Metropolitan Planning Organizations (MPOs), and local governments must still ensure that bicycle and pedestrian access along the corridor served by the new or improved facility is not made more difficult or impossible (23 U.S.C. 109(m) and 217(g)).

1.3.1.1 Bicycles or Pedestrians Prohibited

Bicyclists and pedestrians are prohibited on freeways and sometimes expressways in Wisconsin. Where a new prohibition is put into effect, it is critical to maintain connectivity by defining an alternative route that will accommodate bicyclists and pedestrians within the same corridor. In some cases, a shared-use path in the freeway right-of-way is a viable solution for short distances as a matter of providing basic access; however, care must be taken to ensure that the shared-use path is well-separated or partitioned off from the freeway or expressway traffic. The alternative facility and the type of bicycle accommodation thereon must be identified in the documentation.

It is also important to maintain connectivity across freeway and expressway corridors so that freeways and expressways do not create a barrier to bicyclists and pedestrians. Provide bicycle and pedestrian accommodations on a road that passes under or over a freeway or expressway (including the non-freeway and expressway roads running through interchanges) unless other criteria apply or that road prohibits bicyclists or pedestrians.

Documentation of each existing and proposed crossing is needed for every crossing of the facility that prohibits bikes and pedestrians.

1.3.1.2 Excessively Disproportionate Cost

Cost is excessively disproportionate when it exceeds 20 percent of the estimated total project cost. Implementation of bicycle and pedestrian facilities up to 20 percent of project costs *is expected and required*. Therefore, this portion of the rule functions as a limit of how much must be spent on bicycle and pedestrian facilities.

Neither WisDOT nor FHWA policy limits the percentage of state or federal funds used on a project for bicycle and pedestrian facilities. It is acceptable to spend more than 20 percent if it is not reasonable to limit bicycle and pedestrian facilities, either in length or in type, within a project.

If pedestrian and bicycle accommodations cannot both be provided for 20 percent or less of the total project cost, and it is not possible to allocate more than 20 percent of total project cost for bicycle and pedestrian facilities, then priority can and should be given to pedestrian facilities.

Document if it is not possible to provide bicycle and pedestrian facilities to WisDOT design criteria for 20 percent or less of a project's costs and it is not possible to allocate more than 20 percent.

The documentation of decisions should include at least the following four sections:

1. Location and Type of Project

   Provide the existing typical section as well as the type of project considered (rehabilitation or modernization). Provide sheets that illustrate the roadway section; existing right-of-way; pertinent mapping features such as building and driveway locations, retaining walls, utility and light poles; and affected landscaping such as street trees. Provide average current and projected traffic volumes on the roadway. If certain roadway features/characteristics contribute to the high cost of implementing bicycle or pedestrian facilities, include photographs of those features.

2. Alternatives Considered for Bicycle and Pedestrian Facilities

   Develop and analyze bicycle and pedestrian alternative(s) that have the greatest potential to satisfy the state statute while staying within 20 percent of total project costs. Engage the Regional Bicycle/Pedestrian Coordinator and project manager to aid in establishing reasonable, viable alternatives that are sensitive to the context of the corridor. When circumstances apply regarding disproportionate cost for limiting total expenditures on bicycle or pedestrian facilities, it is expected that reasonable alternatives include lower-level accommodations instead of high-level accommodations. For example, while a 12-foot travel lane and 5-foot bike lane may exceed 20 percent of total project costs, a 14-foot- wide outside lane may fall under the 20 percent threshold. The alternatives should

also consider shifting the existing centerline when there are constraints or excessive costs on one side of the project corridor that may not exist on the other side.

Costs Calculation steps for Each Alternative

- Estimate the total project cost as described in FDM 11-46-1.3.1.2.1.1.
- Estimate the marginal construction cost of establishing new/expanded sidewalks or bikeways as described in FDM 11-46-1.3.1.2.1.2.
- Estimate the marginal real estate cost of establishing new/expanded sidewalks or bikeways as described in FDM 11-46-1.3.1.2.1.3. - Perform the 20 percent disproportionate cost calculation using the formula:

$$\frac{(\text{marginal construction cost} + \text{marginal real estate cost})}{\text{total project cost}}$$

3. Bicycle and Pedestrian Measures Incorporated up to the 20 Percent Limit

   Make the determination in consultation with the Regional Bicycle/Pedestrian Coordinator, project manager, or Region Local Program Manager (for projects on the local system). The report should show which pedestrian and bicycle facilities are being provided for 20 percent of the total project cost, with the intent of providing the most accommodation, with a priority given to pedestrian facilities.

1.3.1.2.1 Cost Calculations

Not all costs can be attributed to bicycle/pedestrian facilities. The following sections describe how costs are calculated.

1.3.1.2.1.1 Calculation of Total Project Cost

The total project cost includes estimated construction costs (including the estimated cost of bikeway and sidewalk construction) and real estate costs (including compensable utilities).

1.3.1.2.1.2 Calculation of Marginal Costs for Bikeway/Sidewalk Construction

The cost of establishing a bikeway or sidewalk shall consider only the marginal cost of establishing any new or expanded bikeway or sidewalk and may not include any cost to reestablish any existing bikeway or sidewalk. Costs shall include only construction costs and the cost to acquire any real estate needed for a bikeway or sidewalk. See example #1 and Figure 1.1, and example #2, and Figure1.2 for examples of calculating marginal costs for bikeway/sidewalk construction.

1.3.1.2.1.3 Calculation of Marginal Real Estate Costs for Bikeway/Sidewalk Construction

Case 1 Real Estate Costs - Only 20 percent of the cost to acquire real estate needed for a bikeway or sidewalk shall be considered a cost of the bikeway or sidewalk if all of the following apply:

- Existing right of way is sufficiently wide to establish the bikeway and sidewalk were the highway construction project to occur without any additional travel lanes.
- Additional real estate is needed to accommodate all needed travel lanes, bikeways and sidewalks.

See example #3 and Figure 1.3 for an example of Case 1 real estate costs.

Case 2 Real Estate Costs - If bicycle or pedestrian facilities currently do not exist on a highway, and right-of-way must be acquired solely for the provision of bicycle and pedestrian facilities, then 100 percent of the right-of-way acquisition costs can be attributed to the 20 percent disproportionate cost calculation. See example #4 and Figure 1.4 for an example of Case 2 real estate costs.

Handle compensable utility costs the same way as right-of-way costs. If utility relocation is needed solely for the addition of bicycle and pedestrian facilities and there currently is not room for these facilities within the existing right-of-way, 100 percent of the utility relocation costs can be allocated toward the 20 percent disproportionate cost calculation. If utility relocation is part of the whole right-of-way acquisition package needed to construct the roadway, only 20 percent of the utility relocation costs can be counted toward the 20 percent disproportionate cost calculation. Non-compensable utility costs are not included in the 20 percent calculation.

Handle the cost to acquire temporary and permanent limited easement the same way as right-of-way costs. If easements are needed solely for the provision of bicycle or pedestrian facilities and there is not enough room in the existing right-of-way for these facilities, 100 percent of the easement acquisition costs can be allocated toward the 20 percent disproportionate cost calculation. Otherwise, only 20 percent of the easement acquisition costs can be included in the 20 percent disproportionate cost calculation.

1.3.1.2.2 Examples

Example #1: Calculation of Marginal Construction Costs for New Bikeways– Rural Paved Shoulder

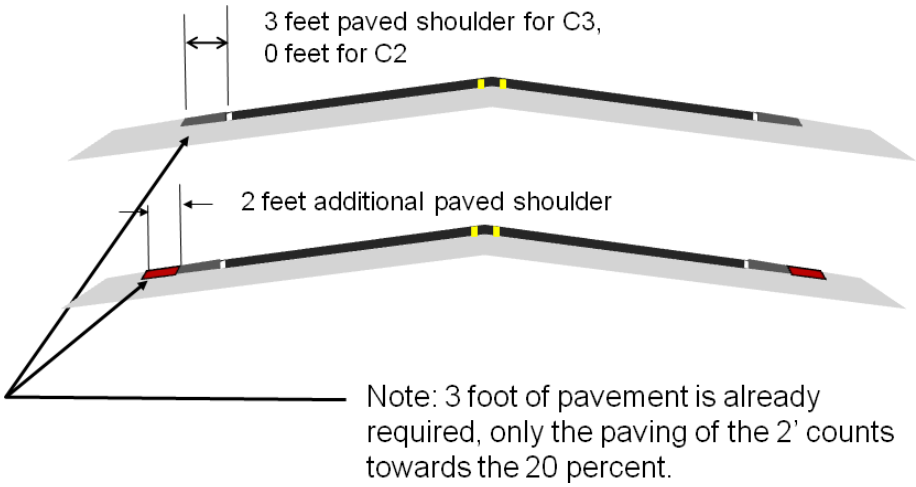

***Figure 1.1* Example 1: New Bikeways - Rural Paved Shoulder**

A rural state trunk highway carries 1500 vehicles per day (vpd) and has two 12-foot lanes and two 3-foot aggregate shoulders. The highway will be reconstructed to a C-3 classification with 5-foot paved shoulders to accommodate bicycles. The C-3 classification already requires a 6-foot shoulder of which 3 feet is paved. Therefore, the cost attributable to bicycle and pedestrian facilities is limited to the cost of the asphalt for 2 feet of each shoulder. The earthwork cost for widening of the shoulder to 6 feet, aggregate cost of the 6-foot shoulder, traffic control costs, and seeding costs cannot be included in the 20 percent disproportionate cost calculation because those costs would have been incurred even if no bicycle facility were provided.

Example #2: Calculation of Marginal Construction Costs for New Bikeways– Urban Street Widening

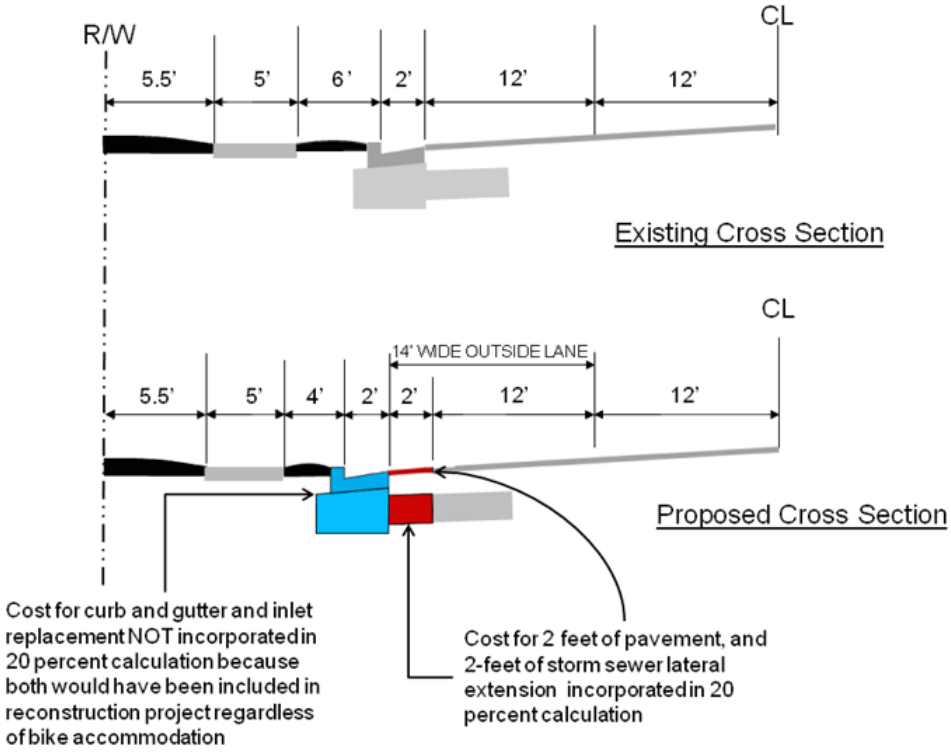

***Figure 1.2* Example 2: New Bikeways - Urban Street Widening**

An urban 4-lane undivided state highway carrying 10,000 vpd currently has four 12-foot lanes, 2-foot gutters, 6-

foot terraces, and 5-foot sidewalks. The project will reconstruct the roadway with two 12-foot inside lanes and two 14-foot outside lanes, while the terrace will be reduced from 6 feet to 4 feet. To accommodate bicycles, the curb line is moved, inlets are moved, and an additional 2 feet of pavement is provided. In this example, the cost for the 2-feet of pavement to create a wide outside lane, plus 2-feet of storm sewer lateral extensions associated with moving storm sewers are incorporated in the 20 percent disproportionate cost calculation since they are all required solely for the provision of bicycle facilities.

Example #3: Calculation of Marginal Construction & Real Estate Costs for Reestablishing Existing Sidewalks and Establishing New Bikeways– Urban Street Widening (Case 1 Real Estate Costs)

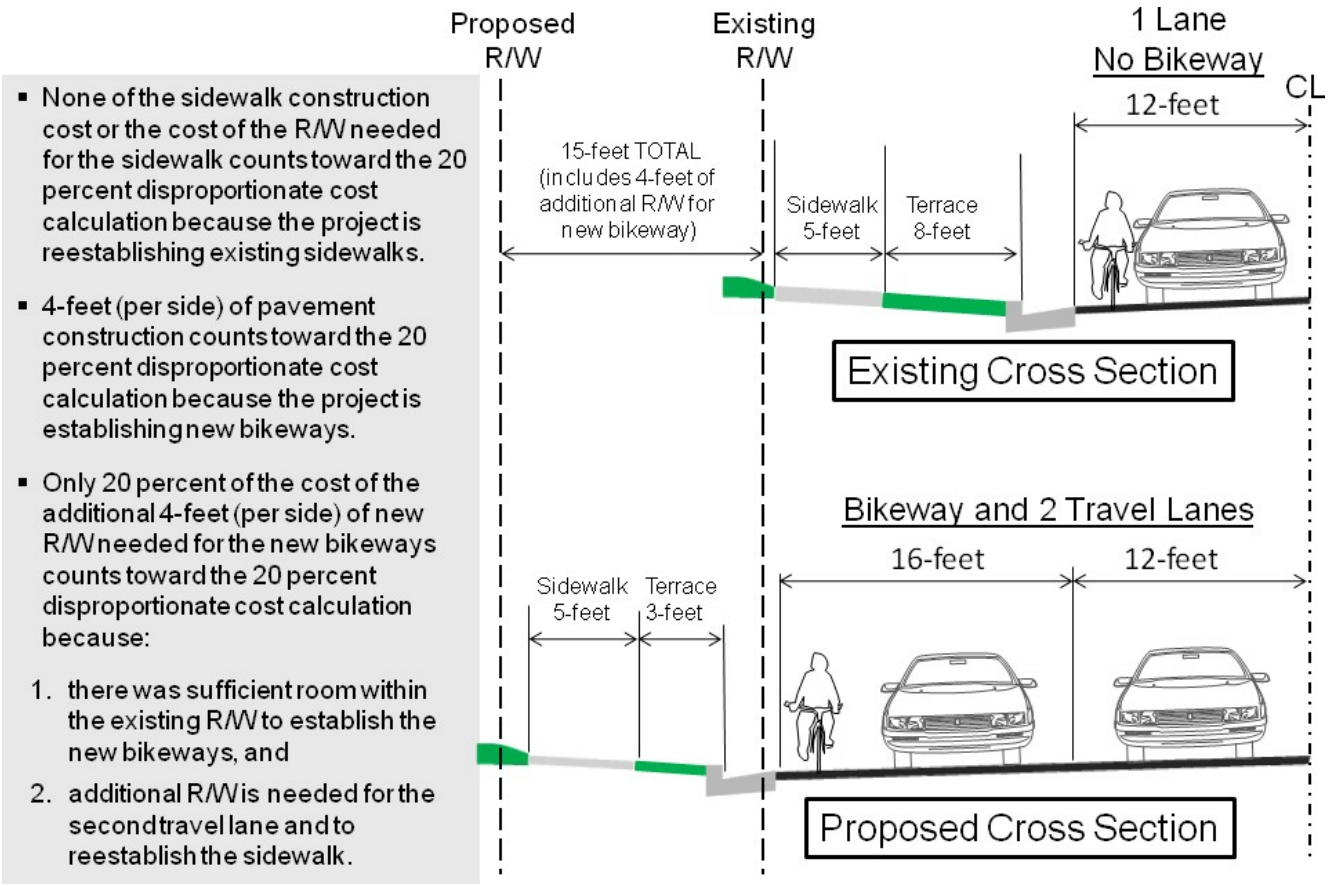

***Figure 1.3* Example 3: Reestablishing Existing Sidewalks and Establishing New Bikeways - Urban Street Widening (Case 1 Real Estate Costs)**

An existing 2-lane urban highway with sidewalks, but no bikeways, is expanded to four lanes with bikeways. The larger cross-section requires additional right-of-way, which needs to be wide enough to reestablish the existing sidewalks and to establish the new bikeways.

None of the sidewalk construction costs or sidewalk real estate costs counts toward the 20 percent disproportionate cost calculation because the project is reestablishig existing sidewalk.

Four feet of pavement are being added on both sides of the road for new bikeways. The construction cost for this additional pavement counts toward the 20 percent disproportionate cost calculation. An additional four feet of right-of-way is needed on both sides of the road to accommodate the new bikeways. Only 20 percent of the cost for this additional real estate counts toward the 20 percent disproportionate cost calculation because the project meets the Case 1 real estate criteria described in FDM 11-46-1.3.1.2.1.3.

Example #4: Calculation of Marginal Construction & Real Estate Costs for New Sidewalk (Case 2 Real Estate Costs)

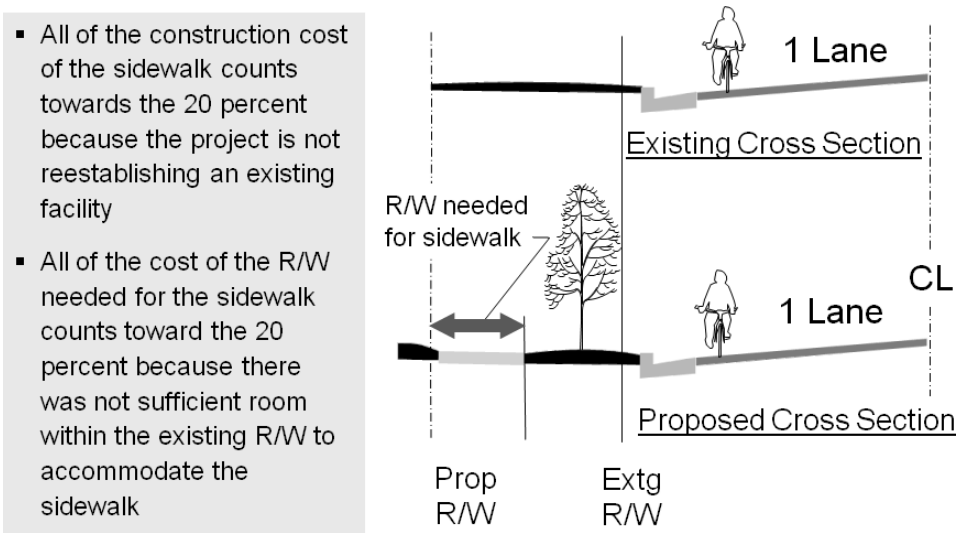

***Figure 1.4* Example 4: Establishing New Sidewalk (Case 2 Real Estate Costs)**

An existing two-lane urban highway without sidewalk is reconstructed to include a sidewalk and an 8-foot terrace. There is not enough existing right-of-way to accommodate either the sidewalk or terrace. The purchase cost of the right-of-way needed for the sidewalk counts fully toward the 20 percent disproportionate cost calculation because the project meets the Case 2 real estate criteria described in FDM 11-46-1.3.1.2.1.3. In addition, all sidewalk construction costs counts toward the 20 percent disproportionate cost calculation because the project is establishing new sidewalk.

The purchase cost of the right-of-way needed for the terrace does not count toward the 20 percent disproportionate cost because the terrace supports the roadway by providing room for snow storage, signage, and lighting.

1.3.1.3 Constrained Environments

Constrained environments may be used in due consideration evaluations. A May 21, 2010 letter (see Attachment 1.1) explains FHWA Wisconsin Division's position on this criterion.

> Until further guidance is developed, projects should consider this definition of constrained environment. A "constrained environment" is any area in which structures, improvements, natural resources, or historical or archaeological sites adjacent to the highway do not allow construction of all of the following on each side of the roadway unless the obstruction is eliminated:
>
> (a) A terrace at least 3 feet wide, including the width of the curb, and having no sidewalk.
>
> (b) A sidewalk that is either of the following:
>
> 1. Five feet wide, if adjacent to a terrace at least 3 feet wide.
> 2. Six feet wide, if adjacent to a curb or terrace less than 3 feet wide.
>
> (c) A bikeway.

In certain situations, it may not be possible to establish bikeways or sidewalks and they may be omitted from either or both sides of the roadway in a constrained environment where establishing them would have excessively negative impacts. However, those facilities shall be included to the greatest extent practicable and provide the highest level of accommodation while avoiding the constraint. This includes varying minimum widths, establishing bikeways or sidewalks using the amount of space remaining in the highway after the omission, and considering the establishment of omitted facilities nearby.

Impacts are considered excessively negative if:

- Constructing a sidewalk and bikeway or just a sidewalk reduces the terrace width to less than 3 feet for more than 50 percent of total project length.
- Constructing a sidewalk or bikeway requires eliminating structures or improvements adjacent to the highway that would dramatically reduce the aesthetic value or functionality of the remaining area.
- The environmental documentation process shows that providing bike or pedestrian facilities would result in loss or degradation of natural resources or has an adverse impact on historical or

archaeological sites potentially eligible for the National Register of Historic Places (NRHP).

This circumstance is likely to be most applicable in urban situations, often in traditional downtown districts where commercial buildings front the project roadway.

Bicycle and pedestrian facilities must be designed with sensitivity to the adjacent context. If bicycle or pedestrian facilities are not provided on a constrained corridor there would have to be substantial impacts on environmental resources, existing structures, or archaeological or historic sites potentially eligible for the NRHP. In most instances, this situation applies to traditional downtown districts where commercial buildings front the project roadway.

Because these locations often have existing sidewalks, this criterion most often applies to bicycle facilities. See Figure 1.5 for an example where providing bike accommodations would have a significant impact on both the outside use of the sidewalk and on the street trees. Explore a range of alternatives that have the greatest potential to satisfy the state statute and provide accommodations.

***Figure 1.5* Constrained Environment**

If possible, include sidewalks on both sides of the street. Consider installing a sidewalk on only one side of the street if limited by the constrained environment. See “WisDOT Guidelines for Sidewalk Placement” Table 4.1 of the February 2011 “Wisconsin Guide to Pedestrian Best Practices” *(6).*

Provide the highest level of accommodation while avoiding the constraint before omitting facilities. Evaluate various alternatives to create space for bicycle and pedestrian accommodations, including:

- Reduce the number of lanes and lane widths to the minimum necessaryto accommodate projected traffic volumes
- Shift the alignment of the roadway.
- Utilize a ‘road diet’, which converts a 4-lane undivided roadway into a 3-lane roadway with bikelanes
- Accommodate parking* needs in another fashion
- Eliminate parking* from one or both sides of the street
- Eliminate parking* in areas requiring a turn lane
- Eliminate the terrace for a short distance to avoid a particular constraint. This will require the use of a 6-foot sidewalk.
- Reduce the terrace width to less than 3-feet for not more than 25 percent of the overall project length in order to establish a bikeway. This will require the use of a 6-foot sidewalk.
- Include a narrower bikeway

It is acceptable to consider retaining parking on an urban section when evaluating a location for a “constrained environment” exception. However, it is necessary to consider the trade-offs and to explore all options for providing bikeways and sidewalks in a “constrained environment”. See FDM 11-46-15.3.1.2 for additional guidance.

Documentation of decisions that omit facilities due to a constrained environment should include:

1. Location and Type of Project

   Provide the existing typical section(s), the type of project considered (rehabilitation or modernization), and the average traffic volumes for the roadway. Provide drawings that illustrate the proposed roadway section(s); existing right-of-way; pertinent mapping features such as building and driveway

locations, retaining walls, utility and light poles; and affected landscaping such as street trees. Include pictures showing the resource(s) or structure(s) that must be avoided.

2. Alternatives Considered for Bicycle and Pedestrian Facilities

   As stated in the "excessive cost" text, the alternative development process is the most critical aspect of providing bicycle and pedestrian facilities. Some creativity may be necessary in developing reasonable bicycle and pedestrian alternatives that are sensitive to the corridor and that avoid buildings/resources to the extent possible. Review the bicycle and pedestrian alternatives considered with the Regional Bicycle/Pedestrian Coordinator and BPD Project Oversight Engineer. For example, using a single typical section may not be reasonable if it is necessary to avoid a structure on a corridor. It may be appropriate to eliminate the terrace and use a 6-foot sidewalk for 100 feet to preserve the structure and maintain continuous bicycle and pedestrian facilities.

   To accommodate bicycle and pedestrian facilities, narrower widths for travel lanes, medians, terraces, and gutters should be explored and incorporated when needed. For example, a 1-foot gutter pan with other lane width reductions may allow enough room for a bikeway to be added to the adjacent travel lane. If adding a 1-foot gutter pan, check drainage impacts on the project.

3. Type of Resource Being Avoided

   Describe the type of resource being avoided and the impact and magnitude that provision of bicycle (or pedestrian) facilities would cause. For example, eliminating 3 parking spaces from an 18-space parking lot is significantly different than eliminating 3 parking spaces from a 5-space parking lot. Similarly, removing three street trees is different than removing all trees from a half-mile corridor. Provide a cross section of the roadway with the minimum bikeway and pedestrian facility clearly showing how even the minimum cross section adversely impacts the resource or structure being preserved.

4. Bicycle and Pedestrian Measures Being Incorporated

   Describe the type of bicycle and pedestrian facilities being incorporated in the constrained environment. The project should include bicycle and pedestrian facilities to the greatest extent practicable. However, in a constrained environment, omitting a sidewalk or bikeway, or both, from either or both sides of the roadway, or varying the minimum widths may be necessary. If it is necessary to omit a bikeway or sidewalk for a portion of the project, state how bikeways or sidewalks are established after the omission for the remainder of the project. Consider establishing those omitted facilities nearby the constrained environment, such as along a parallel corridor, and document the details of this analysis.

This documentation can be in the form of a Technical Memo and should be referenced and added as an attachment in the DSR.

1.3.1.4 Absence of Need

For evaluating Absence of Need, both bikeway and sidewalk needs are associated with current and expected future residential/commercial land uses and land use densities. Bikeway needs are also associated with current and expected future traffic volumes. Criteria for this will vary depending on whether an area is an "Outlying District", "Rural Area", "Semi Urban District" or "Urban Area". Definitions for these areas are:

- (b) "*Outlying District" means the territory contiguous to and including any highway within the corporate limits of a city or village where on each side of the highway within any 1,000 feet along such highway the buildings in use for business, industrial or residential purposes fronting thereon average more than 200 feet apart*."
- (c) "*Rural area" means any area that is not an urban area or a semi urban district.*
- (d) *"Semi urban district" means the territory contiguous to and including any highway where on either side of the highway within any 1,000 feet along such highway the buildings in use for business, industrial or residential purposes fronting thereon average not more than 200 feet apart or where the buildings in use for such purposes fronting on both sides of the highway considered collectively average not more than 200 feet apart."* [4]
- (e) *"Urban area" means any area which is an urbanized area or urban place, as determined by the Department under 23 USC 101 (a) and regulations adopted under 23 USC 101 (a) and approved by*

[4] "Fronting thereon" or "fronting on" will include any portion of a property line that abuts the highway in question.

the appropriate federal authority." [5]

See FDM 11-46-1.3.1.4.1 for "Absence of Need" criteria for sidewalks. See section FDM 11-46-1.3.1.4.2 for "Absence of Need" criteria for bikeways.

Documentation of decisions where sidewalks and bikeways are not provided, should include:

Location, type of Project, and facility being excluded: Provide the existing typical section as well as the type of project considered (rehabilitation or modernization). Describe the bicycle or pedestrian facility that would not be established.

Basis for not establishing: Reasons for not establishing a facility will vary. One of the most common reasons for not providing a bikeway is a low volume roadway (under 750 for rural areas and under 1,500 for urban and semi urban areas). Similarly, sidewalks will rarely be built within rural areas.

Definition of the Area: Identify areas as urban, semi urban, outlying, or rural. If the highway or street project involves a town center or an outlying district, include a map or aerial photo that supports the low-density definition (on average, more than 200 feet between buildings over a length of 1,000 feet).

Attach pertinent portions of the community, county and regional land use plans and long-range transportation plans for projects within 3 miles of a community.

Mitigation: Describe the conditions that will remain for bicyclists and pedestrians. For example, a low volume roadway without paved shoulders may still be acceptable for the area given the types of cyclists that will be using the roadway. A short segment of wide paved shoulder may be acceptable for a town center with only eight homes spread over 2,000 feet. Discuss any mitigation efforts that will improve conditions for bicyclists or pedestrians short of complying with the design criteria in this procedure or in the FDM.

This documentation can be in the form of a Technical Memo and should be referenced and added as an attachment in the DSR.

1.3.1.4.1 Sidewalks

For sidewalks, adjacent land use and density determines "Absence of Need", not actual pedestrian counts or projected pedestrian counts. Conditions in which sidewalks should be established will vary depending on whether an area is an "urban area", "semi-urban district", "outlying district" or "rural area". See WisDOT classification maps for rural, urban, and urbanized areas, as well as other incorporated cities and villages meeting standards for small community criteria.

Urban Areas and Semi-Urban Districts: Sidewalks should be established in any urban area or semi-urban district. There are few areas within a city or village where it is not appropriate to include sidewalks.

Outlying Districts and Rural Areas: The usual practice is to omit sidewalks in an outlying district or rural area because the presumption is that sidewalk use will be too sparse to justify their inclusion. However, establishing sidewalks should be considered in any outlying district or rural area if, based on an official land use plan, there will be significant development within the outlying district within the next 10 years (i.e., the area will become a "Semi Urban District" or an "Urban Area").

Also, if land use is expected to change over the design life[6] of a project such that sidewalk would likely be needed by the end of a project's design life then give greater weight to the land use projected for the second half of the design life than for the first half. This does not necessarily mean including

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[5] 23 USC 101 (a): "(36) URBAN AREA.-The term ''urban area'' means an urbanized area or, in the case of an urbanized area encompassing more than one State, that part of the urbanized area in each such State, or urban place as designated by the Bureau of the Census having a population of 5,000 or more and not within any urbanized area, within boundaries to be fixed by responsible State and local officials in cooperation with each other, subject to approval by the Secretary. Such boundaries shall encompass, at a minimum, the entire urban place designated by the Bureau of the Census, except in the case of cities in the State of Maine and in the State of New Hampshire.

(37) URBANIZED AREA. -The term ''urbanized area'' means an area with a population of 50,000 or more designated by the Bureau of the Census, within boundaries to be fixed by responsible State and local officials in cooperation with each other, subject to approval by the Secretary. Such boundaries shall encompass, at a minimum, the entire urbanized area within a State as designated by the Bureau of the Census."

http://www.gpo.gov/fdsys/pkg/USCODE-2010-title23/pdf/USCODE-2010-title23-chap1-sec101.pdf

[6] For purposes of this evaluation, use a "design life" of 20 years for a roadway, and 75 years for a bridge

sidewalk as part of the project. It could mean designing the project to make it easier to install sidewalk in the future.

For example, on a structure project:

- If planned growth will affect the need for sidewalk in a 0 to 10-year period, add sidewalk to both sides of the structure and on the approaches.
- If planned growth will affect the need for sidewalk in a 10 to 20-year period, add sidewalk to one side of the structure and approaches. Design the other side of the structure and approaches to facilitate adding sidewalk in the future (e.g., construct a wider substructure for the bridge).
- If planned growth will not affect the need for sidewalk for over 20 years, do not add sidewalk but consider designing the structure and approaches to facilitate adding sidewalk in the future (e.g., construct a wider substructure for the bridge).

1.3.1.4.2 Bikeways

For bicycle accommodations, often few improvements are needed on low-volume roadways where a bicyclist can use a full travel lane or adequate roadway width already exists for a motorist to safely pass a bicyclist. Evaluating establishing a bikeway may be more involved and will vary depending on whether an area is an "urban area", "semi-urban district", "outlying district" or "rural area".

Urban Areas and Semi-Urban Districts: Bikeways are generally needed on highways with a design year ADT>=1,500 within an "Urban Area" or "Semi Urban District".

Outlying Districts and Rural Areas: It may not be necessary to provide additional roadway improvements in an outlying district or rural area if the highway that is the subject of the modernization project has, or upon completion will have, less than 750 ADT and any of the following applies:

(a) The average bicycle traffic volume[7] on the highway is or is expected to be less than 25 per day during the 10 most traveled days for bicycling of the year.

(b) The highway is not identified in part of a government bike transportation plan, in the Wisconsin Bicycle Transportation Plan *or in any other bicycle plan endorsed by or supported by WisDOT.*

(c) The highway does not provide a connection of one mile or less between any existing or planned bike routes, as defined in State Statue 340.01 (5m), Stats.

(d) The highway is not a short connection of one mile or less needed to connect an existing bikeway to the nearest local road."

Consider a bikeway on a highway with a design year ADT<750 if, based on an official land use plan, there will be significant development within the outlying district within the next 10 years, and establishing a bikeway will do any of the following:

- Complete a gap of one mile or less in an otherwise continuous bike route.
- Make a connection of not more than 3 miles from communities or urban areas to a town or county roadway network, excluding any dead-end roadway.

Also, if land use is expected to change over the design life[8] of a project such that a bikeway should be provided by the end of a project's design life, then give greater weight to the land use projected for the second half of the design life than the first half. This does not mean including a bikeway as part of the project. It could mean designing the project to make it easier to install a bikeway in the future.

1.3.1.5 Refusal to Maintain Sidewalks

In the past FHWA has indicated that it does not allow facilities to be omitted based solely on the lack of community support for the maintenance of sidewalks for urban and suburban sections of the NHS (see May 21, 2010 letter from FHWA Wisconsin Division office in Attachment 1.1). Currently, it is recommended to continue this approach on NHS roadways.

Often, one of the biggest issues related to the inclusion of sidewalks relates to their maintenance and

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[7] Volumes shown are two-way bicycle traffic. With respect to the criteria of 25 bicyclists per day, it may not be necessary to actually count the current number of bicyclists using a highway or to go through an involved methodology to project the anticipated number of bicyclists. For example, if a bicycle club uses the highway as an informal bicycle route, there are likely to be 25 cyclists using the roadway. Also, certain land uses on or near the highway can be used to estimate usage. For example, subdivisions, parks, schools and major businesses can all generate at least light to moderate numbers of bicyclists (on average, during the summer approximately 2 to 3 percent of all trips in the state are by bicycle). Assume that all roadways within 2 miles of an incorporated area meet these criteria unless counts specifically prove otherwise.

[8] For purposes of this evaluation, use a "design life" of 20 years for a roadway, and 75 years for a bridge

maintenance costs. Most municipalities in Wisconsin have passed ordinances that require landowners to clear snow, ice, and debris from sidewalks that are adjacent to their property. Even though, according to State Statute 66.0907(5) Wis. Stats, sidewalk maintenance is ultimately the municipality's responsibility, the initial burden falls on the adjacent landowners. [9] Objections to the placement of new sidewalks on a project often result from property owners' concerns regarding the future maintenance of the new sidewalks.

If a community considers not providing sidewalks it should be based on their inability to maintain them. Conditions for which a local unit of government (city, village, town, or county) can document their inability to maintain sidewalks on non-NHS highways, should include the following:

1. There are no existing sidewalks on the highway system[10] under the local unit of government's jurisdiction.
2. The local unit of government has no ordinance that requires the installation of sidewalks or that requires the removal of snow and ice from sidewalks.
3. The local unit of government lacks sufficient equipment for the efficient removal of snow and ice from sidewalks.

If it is determined to establish sidewalks as part of the roadway improvement project, the local unit of government must agree in writing to maintain any sidewalks added to the project when federal or state funds are used. Work with the local unit of government, to develop and execute a State-Municipal Agreement and, for STH projects, a Maintenance Agreement early in the planning and design process. This allows the local unit of government to decide early in a local road project whether to accept the maintenance of sidewalks or to forego the use of state or federal funds on the local road project. Similarly, the Department may put a STH project on hold until the local unit of government decides to accept the maintenance of sidewalks. Alternatively, for STH projects, the Department may decide to substitute a perpetuation project type, such as resurfacing, if pavement condition or other deficiencies require more immediate attention.

1.4 References

Refer to FDM 11-46-99 for list of references.

LIST OF ATTACHMENTS

Attachment 1.1	FHWA letter
Attachment 1.2	DOJ/DOT Joint Technical Assistance on the ADA Title II Requirements to Provide Curb Ramps when Streets, Roads, or Highways are Altered through Resurfacing
Attachment 1.3	Glossary of Terms for DOJ/FHWA Joint Technical Assistance on the ADA Title II Requirements to Provide Curb Ramps when Streets Roads or Highways are Altered through Resurfacing

FDM 11-46-5 Pedestrian Facilities

August 15, 2019

5.1 Introduction

In conformance with federal law and policy and pursuant to State Statute 84.01(35), the Department shall give due consideration to establishing bikeways and pedestrian ways on all modernization projects and applicable rehabilitation projects depending on the extent of work funded in whole or in part from state or federal funds. See FDM 11-46-1 for guidance.

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[9] Section 66.0907 (5), Wis. Statutes: Snow and ice. The board of public works shall keep the sidewalks of the city clear of snow and ice in all cases where the owners or occupants of abutting lots fail to do so, and the expense of clearing in front of any lot or parcel of land shall be included in the statement to the comptroller required by sub. (3) (f), in the comptroller's statement to the city clerk and in the special tax to be levied. The city may also impose a fine or penalty for neglecting to keep sidewalks clear of snow and ice.

[10] Section 340.01 (22) Wis Statutes. "Highway" means all public ways and thoroughfares and bridges on the same. It includes the entire width between the boundary lines of every way open to the use of the public as a matter of right for the purposes of vehicular travel. It includes those roads or driveways in the state, county or municipal parks and in state forests which have been opened to the use of the public for the purpose of vehicular travel and roads or driveways upon the grounds of public schools, as defined in s. 115.01 (1), and institutions under the jurisdiction of the county board of supervisors, but does not include private roads or driveways as defined in sub. (46).

Department policy for other project types, such as perpetuation and certain rehabilitation projects, may require an evaluation to include bicycle and pedestrian accommodations where possible/practical within the scope of the project.

Pedestrian facilities on roadways typically include sidewalks, shared-use paths, curb ramps and crosswalks. See the following FDM sections for guidance on pedestrian facilities:

- FDM 11-46-1 (Statutory requirements and policy)
- FDM 11-46-5.1 (Urban borders, sidewalks and terraces)
- FDM 11-46-10 (Curb Ramps and Crosswalks)
- FDM 11-46-15.6 (Shared-use paths and Roundabout sidepaths)
- FDM 11-46-20 (Publicly owned trail crossings of rural highways)
- FDM 11-20-1 (Urban cross sections)

Many of the guidelines in this procedure were developed using AASHTO, U.S. Access Board *(7)*, FHWA guides and design criteria *(20)* and WisDOT's *Wisconsin Guide to Pedestrian Best Practices (6)*. Collectively, these guidelines and design criteria are the most applicable for the design of pedestrian accommodations on state and federally funded projects.

FHWA memos *(19) and (19a)* encourage agencies to use other guides and resources that build upon the flexibilities provided in the AASHTO guides. These other guides and resources can provide useful information in project planning and development when used in context with AASHTO, U.S. Access Board, FHWA, and WisDOT design guidance. If a project proposes a pedestrian facility treatment(s) outside of Wisconsin guidelines, approval is required. Contact WisDOT regional bike and pedestrian coordinators to initiate this process. Use the WisDOT regional bike and pedestrian coordinators as a resource for planning and designing bike and pedestrian facilities on state and federally funded projects. Also, see the "references" section for additional documents and resource information.

5.1.1 ADA Compliance

When pedestrian facilities are provided, they are required to be accessible to people with disabilities.[11] Furthermore, there are Americans with Disabilities Act (ADA) design guidelines and standards that must be applied in roadway improvement projects with regards to pedestrian facilities within the public right-of-way.

All rehabilitation and modernization improvements that meet the ADA "alteration" definition will require curb ramp improvements. Most pavement strategies under perpetuation improvements meet the ADA "alteration" definition and will also require curb ramp improvements. Refer to FDM 3-5 Exhibit 5.1 for list of pavement strategies meeting the ADA "alteration" definition.

Newly constructed and altered facilities must be ADA-compliant. New construction is to provide the highest level of accessibility and meet current ADA accessibility standards. For altered facilities, there is some flexibility to work within existing conditions. The flexibility is provided to recognize that retrofits are different from new construction. When existing conditions alter portions of facilities and if it is technically infeasible to meet modernization design criteria, the facilities must meet current design criteria to the maximum extent feasible and the design decisions must be documented. Alterations must not decrease the accessibility of a facility.

The Department looks to meet the needs of all disabled users. To ensure that a project can meet accessibility requirements, a scoping of accessibility needs is required. During scoping, evaluate the existing right-of-way adequacy for bike and pedestrian facilities, particularly for accommodating full ADA-compliant curb ramps. At a minimum for ADA compliance, consider acquiring temporary limited easements if construction operations and final sloping requires access onto adjacent private property. Best practices may include working jointly with local units of governments to meet full curb ramp ADA requirements during an alteration-type project versus performing several partial curb ramp improvements with future projects, as this is the most cost-effective approach. If a public entity does not control sufficient right-of-way, it should seek to acquire the necessary right-of-way and document those efforts. If a complaint is filed, public entities will likely need to demonstrate that reasonable efforts were made to obtain access to the necessary right-of-way. Improvements must incorporate ADA accessibility standards to the maximum extent feasible within the existing right-of-way.

[11] Title II of the Americans with Disabilities Act (ADA) Accessibility Guidelines (ADAAG) and Section 504 of the Rehabilitation Act (49 CFR, Part 27) Act (49 CFR, Part 27).

5.1.2 Technical Infeasibility

Technical infeasibility is when there are existing physical or site constraints[12] that limit or restrict the ability to meet current minimum ADA accessibility standards to the full extent for new construction of facilities which are necessary to provide accessibility. Examples of existing physical or site constraints that may make it technically infeasible to make a facility fully compliant include but are not limited to the following:

- Right-of-way availability - If sufficient right-of-way is not owned, land acquisition (including easements) should be acquired to achieve full ADA compliance. Where right-of-way is not able to be acquired, improvements within the existing right-of-way must incorporate the ADA accessibility standards to the maximum extent feasible (see FDM 11-46-1.1.5). Technical infeasibility documentation will still need to be provided accordingly.
- Underground structures that cannot be moved without greatly expanding the project scope.
- Adjacent developed facilities, including buildings that would have to be removed or relocated to achieve accessibility.
- Drainage cannot be maintained if the feature is made accessible.
- Significant natural or historic features that would have to be altered in a way that lessens their aesthetic or historic value.
- Underlying terrain that would require significant expansion of the project scope to achieve accessibility.
- Street grades within the crosswalk exceeding the maximum cross slopes for pedestrian access route, if an engineering analysis has concluded that it cannot be done without greatly expanding the project scope (for example, changing from resurfacing an intersection to reconstructing the intersection).

Technically infeasible may also apply based on the project scope. Alterations of streets, roads, or highways include activities such as reconstruction, rehabilitation, resurfacing, widening, and projects of similar scale and effect. This requires curb ramps to be addressed.[13] The scope of an alteration project is determined by the extent the alteration project directly changes or affects the public right-of-way within the project limits. The public agency or municipality must improve the accessibility, to the maximum extent feasible, of only that portion of the public right-of-way changed or affected by the alteration. For example, if a project resurfaces the street, for accessibility purposes the curb ramps and pavement at the pedestrian crosswalk are in the scope of the project, but the sidewalk between intersections may not be in the scope of the project. Any of the features disturbed by construction must be replaced so that they are accessible. All remaining access improvements within the public right-of-way shall occur within the schedule provided in the public agency/municipality's planning process (FHWA Q&A about ADA, question 20. *(25)*. Unaltered, non-compliant facilities will then be improved to meet design criteria or to the maximum extent feasible with a stand-alone or future project. Implementation of the WisDOT transition plan may be used to prioritize, schedule and rectify the non-compliant facilities. At scoping, include any evaluation of the condition of existing sidewalks, shared use paths or other pedestrian facilities.

Document technically infeasible design decisions in the DSR. Tables summarizing the evaluation analysis for infeasible design decisions may be used as a DSR attachment to supplement conclusions. This documentation will serve to demonstrate the situation was evaluated and curb ramps improved to the maximum extent feasible. The documentation will also help address future concerns should they arise.

For modernization projects, technically infeasible should seldom be a factor. In projects that are an alteration per ADA, curb ramps are required to be installed or updated[14] within the project scope to the maximum extent feasible. Cost is not a reason to exclude improvements. At a minimum, if other pedestrian facilities are altered as part of the project, then those altered facilities must be improved or upgraded to meet current design criteria. Although additional work beyond curb ramp improvements may not be required, FHWA and WisDOT policy is to take the opportunity to evaluate and consider additional improvements to unaltered facilities where possible within the project scope to improve pedestrian access. It may be more efficient and beneficial to include

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[12] Existing physical constraints include, but are not limited to, underlying terrain, right-of-way availability, underground structures, adjacent developed facilities, drainage, or the presence of a notable natural or historic feature (i.e. aesthetic features such as stone walls, statues, or items with historical value or significance) or facility (generally a structure or something created to serve a certain function). Where existing physical constraints make it impractical for altered elements, spaces, or facilities to fully comply with new construction requirements, compliance is required to the maximum extent practicable/feasible within the scope of the project.

[13] https://www.fhwa.dot.gov/civilrights/programs/doj_fhwa_ta.cfm

[14] See FDM 11-46-1.1.3 and FDM 3-5-1.1.

improvements as part of the existing project.

5.2 Urban Borders and Zone System

An urban border is the area adjacent to a street, measured from the face of curb to the right-of-way line, and is described using the zone system, as shown in Figure 5.1. The zone system helps to better define the usage of space between the face of curb and the right-of-way line or property line, and consists of four distinct areas:

1. Curb zone
2. Planter/furniture zone
3. Pedestrian or sidewalk zone
4. Frontage or sidewalk clearance zone

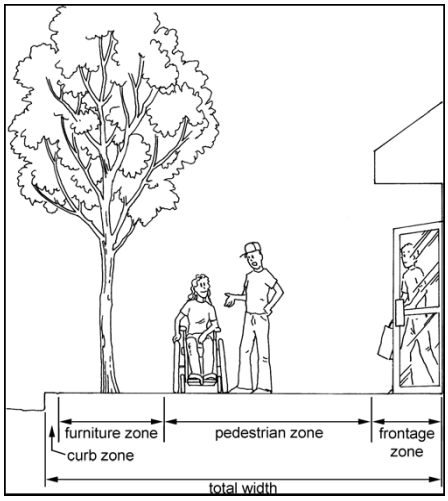

Figure 5.1 Zone System (7)(23)

See Attachment 5.1 for illustrations and descriptions of various scenarios for incorporating sidewalks into the project under the following conditions:

- Protruding objects and vertical clearance
- Elevation difference between street and building
- Sidewalk cross slope
- Constructing a sidewalk through a driveway apron

Many municipalities have developed their own design criteria and policies that may vary somewhat from those indicated in this procedure. Use the municipality's design criteria, when practical and when not in conflict with WisDOT policy. Desirably, design an urban project from the outside toward the center so as first to assure that sidewalks, curbs, driveway grades etc., have the best possible fit to the abutting property.

On urban projects, problems such as steep driveway and sidewalk ramp grades, poor drainage designs and poor blending of roadways and border areas are often due to inadequate design of urban profiles and cross sections. When laying out an urban profile it may be helpful to develop point profiles of critical grades at intersections, sidewalks, adjacent buildings or properties, driveways and other features to visualize key profile elevations and features. Use these key feature profiles and existing curb profiles to develop centerline and traffic lane profiles.

Roadways at some locations are on or along a natural ridge causing elevations to be higher on one side and lower on the other side of the roadway. This also affects and complicates the design of the border area. To better fit site conditions at these locations, cross section designs may need to incorporate elements such as special warping of the parking lanes and possibly travel lanes, steeper slopes and possibly retaining walls within the border area. Make sure that pavement cross-slope transitions are not too abrupt, and that the pavement cross slope rollover does not exceed the maximum allowed (see FDM 11-10-5.3.3 and FDM 11-20-1.1 for urban cross slope requirements). Other design issues at these locations include:

- Adequate drainage to prevent ponding of water and creation of ice patches due to snow melt.
- Designing sidewalks and curb ramps to comply with ADA requirements.
- Driveway grades and break-over angles.

- Preventing water from back draining towards existing houses and or buildings.

5.2.1 Sidewalks

Sidewalks on both sides of urban streets are typical treatments on all federal or state-funded projects (on the state highway system and local road system). It is most practical and cost-effective to incorporate sidewalks when the street is newly constructed or reconstructed.

Generally, sidewalks are placed higher than the curb top and sloped to drain toward the street. Changes in level are vertical elevation differences between adjacent surfaces and are generally not to exceed 0.5 inches (i.e. gutter flow line to top of curb cut for curb ramp installation). Changes in level are important in the sidewalk environment, especially to impaired users.

Minimum sidewalk width is 5 feet if adjacent to a terrace that is equal to or greater than 3-feet wide.

Minimum sidewalk width is 6 feet back of curb if adjacent to a terrace that is less than 3-feet wide. In this case, there will not be enough room within the terrace to place signs, utility poles, light poles, hydrants, or other fixed objects.

Provide wider sidewalk if any of the following conditions apply:

- Higher pedestrian traffic is anticipated such as in a town center area or central business district.
- There are signs, utility poles, light poles, hydrants, or other fixed objects that intrude into the pedestrian zone.
- Angle parking is used, and the vehicle overhang intrudes into the pedestrian zone (note: angle parking is not allowed except in certain limited situations – see FDM 11-20-1.6.1).

The sidewalk slope shall be 5 percent maximum. Where the sidewalk or pedestrian access routes are within a street or highway right-of-way, the running grade is permitted to be equal and shall not exceed the general grade established for the adjacent street or highway (*PROWAG, Chapter R3*).

A sidewalk segment that is not contained within a street or highway right-of-way with a running slope greater than 5 percent and up to a maximum of 8.33 percent shall have 5-foot by 5-foot level landings at each 2.5 feet maximum of vertical change in grade. Do not exceed a 2 percent slope in any direction on the landing. If there is a rise greater than 6 inches, handrails shall be used. (*PROWAG, Chapter R4*)

For the construction of new sidewalk routes, avoid constructing only stairs or steps for primary access, since they are difficult or impossible to negotiate by pedestrians with mobility impairments and are not part of an accessible route. Where stairs currently exist, evaluate designs that remove stairs and provide an accessible route.

The sidewalk cross slope shall be 1.5 percent with a construction tolerance of ±0.5 percent, as stated on SDD 8D5. The maximum sidewalk cross slope according to ADA is 2.0 percent and the minimum cross slope to achieve drainage is 1.0 percent. If this cross slope with this construction tolerance cannot be built, then constructability is “technically infeasible”. Document this condition in the DSR.

There may be locations where a sidewalk may be constructed with less than a 1.0 percent cross slope. If the longitudinal sidewalk slope is greater than 1 percent, it has been determined that there will be no standing water or ponding in these situations.

Transitional sections of sidewalk that connect unaltered sections of existing sidewalk and new curb ramp/sidewalk must comply with ADA technical requirements to the maximum extent feasible. Modifications must not decrease or have the effect of decreasing the accessibility of a facility. Typically, one or two sections of sidewalk (typical length 5 to 10 feet) may be all that is needed for this transition. Document design decisions in the DSR when complying with ADA requirements to the maximum extent feasible.

Curb ramps and detectable warning fields are required in areas with curb and sidewalks. Information on curb ramps is provided in FDM 11-46-10 and SDD 8D5.

See Chapter 5, “Designing Pedestrian Facilities”, of the Wisconsin Guide to Pedestrian Best Practices *(9)* for more detailed information regarding sidewalk design, including guidance on:

- 5.3.1.1. The purpose of sidewalks and general considerations
- 5.3.1.2. Specific design parameters for sidewalk corridors
- 5.3.1.2.1. Corridor widths
- 5.3.1.2.2. Cross slope
- 5.3.1.2.3. Grade/running slope
- 5.3.1.2.4. Surface material

- 5.3.1.2.5. Driveways and sidewalks
- 5.3.1.2.6. Side slopes and vertical drops
- 5.3.1.2.7. Obstructions and other pedestrian obstacles
- 5.3.1.2.8. Street trees and planting strips
- 5.3.1.2.9. Streetscape
- 5.3.1.2.10. Lighting for sidewalks.

Also see the "NACTO Urban Street Design Guide" (23)

5.2.1.1 Walkway/Sidewalks in Areas with a Rural Cross Section

Like sidewalks in urban areas, sidewalks in rural areas must be adequately separated from vehicle travel lanes. Where sidewalks do not exist, pedestrians use shoulders as walkways. Walkways are defined as the continuous portion of the pedestrian access route that is connected to street crossings by curb ramps or blended transitions[15] *(PROWAG, Chapter R1) (26)*. However, Wisconsin State Statute 340.01(54) and 340.01(58) does not define roadway shoulders as legal sidewalks or pedestrian facilities. Even though roadway shoulders are not legal pedestrian facilities and cannot legally be designated as pedestrian access routes, the occasional pedestrian that uses a shoulder as a walkway, benefits from a wide paved shoulder. Evaluate the options described under this subsection below when encountering the following conditions:

- Along places where pedestrians are commonly using the shoulders
- Where footpaths indicate that a separate walking facility is needed
- Along a transitional area where residential and commercial development creates a demand for pedestrian facilities

Sidewalks should be designed and constructed along the outside of the ditch on top of the backslope within the right-of-way. It is important to review the constraints that may prevent providing a sidewalk at this location. If the entire distance of the proposed project cannot accommodate the sidewalk outside the ditch area, then perhaps most of it can be.

The next best alternative to installing a sidewalk outside the ditch is to install a sidewalk at least 5 feet from the edge of where the shoulder would be located even if the existing shoulder does not meet design criterion. This provides room for the shoulder to be updated to the design criteria and shouldn't require moving the walkway in the future. Provide a minimum of five feet of separation between the shoulder and the sidewalk. The minimum 5-foot separation needs to be constructed with different material than the shoulder material. In other words, if the inside portion part of a shoulder, say 3 to 5 feet or so, is paved and the outside portion is aggregate then provide a minimum 5-foot grass separation strip between the outside edge of aggregate shoulder and the inside edge of sidewalk. This is similar to the development of a shared use path with a separation between the shoulder and the path.

When planning for a walkway adjacent to a rural cross-section roadway, always consider final sidewalk location with respect to clear zone or lateral clearance requirements for both existing and ultimate cross section for the roadway's design classification. Additional drainage features may be needed, such as a swale, inlets and storm sewer between shoulder and sidewalk. Consider sloping sidewalk toward the right-of-way and away from roadway if ditching exists. Coordinate with the municipality to address snow removal and minimize freeze/thaw potential on the sidewalk. Document roadside design decisions in the DSR.

5.2.1.2 Sidewalks on Rural Bridges

Consider sidewalks on rural bridges at the following locations:

1. In growth areas around cities, villages, and urban areas where the need for sidewalks may not be readily apparent but will be necessary for future growth as documented in community and regional land use and long-range transportation plans.
2. In town centers where sidewalks are being considered or included on the rest of the roadway because of adjacent land use densities.

Bridges are designed to last up to 75 years. By comparison, reconstructed rural roadways may have useful lives of up to 20 years. While retrofitting sidewalks onto roadways is usually relatively easy, retrofitting sidewalks onto existing bridges is not. Consult with the Bureau of Structures (BOS) if a structure design needs to accommodate future sidewalk.

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[15] WisDOT does not construct blended transition curb ramps.

See FDM 11-35-1.6 and FDM 11-35 Attachment 1.1 for additional guidance.

5.2.2 Terraces

A terrace is the area between the back of the curb and the edge of the sidewalk. The terrace area usually consists of grass, but paved terraces are common in areas with heavy pedestrian usage, such as central business districts.

Terrace width varies but it is generally best to provide 6-feet or more to accommodate snow storage, signing, utilities, plantings and other uses while still maintaining the required lateral clearance from the face of curb (refer to FDM 11-15-1 and FDM 11-20-1 for guidance on lateral clearance). Generally, provide at least a 3-foot clearance from trees to curb, and at least a 3-foot clearance from trees to sidewalk (at least 6-feet total width). Grass terraces have a minimum cross slope of 4% while paved terraces have a minimum cross slope of 2%.

See FDM 11-20 Attachment 1.2, 1.3, and 1.6 for typical urban street cross sections.

See Chapter 5, "Designing Pedestrian Facilities", of the Wisconsin Guide for Pedestrian Best Practices *(9)* for more information on terrace design. Also, see the "NACTO Urban Street Design Guide" *(23)*.

5.3 References

Refer to FDM 11-46-99 for list of references.

LIST OF ATTACHMENTS

Attachment 5.1	Sidewalk Design Considerations

FDM 11-46-10 Curb Ramps

August 15, 2019

10.1 General

The US DOT has adopted the Americans with Disabilities Act (ADA) Accessibility Guidelines (ADAAG) as a standard for complying with ADA and Section 504 of the Rehabilitation Act (49 CFR, Part 27)[16]. Currently, there are design guidance conflicts between Wisconsin Statutes and the ADA requirements. The design guidance in this procedure and associated Standard Detail Drawings (SDD 8D5) have been developed to provide the designer with criteria that is consistent with ADAAG guidance. ADAAG requires detectable warnings fields on curb ramps at all legal crossings, sidewalk and shared-use paths independent of funding source. Detectable warning fields are a distinctive surface pattern of truncated domes detectable by cane or underfoot. They indicate to people with vision impairments a change from the pedestrian way/sidewalk to the vehicular way.

Curb ramps are required by ADA and Section 504 and are separate from Wisconsin law pertaining to complete streets and State Statues 84.01(35).

When a curb ramp is constructed on one side of a street, then companion curb ramp(s) are required on the opposite side if there is either existing sidewalk on the opposite side or sidewalks are being constructed on the opposite side as part of the project. When a project terminates adjacent to or in the middle of an intersection, curb ramps and landings must be constructed, where sidewalk is present, on the street corners beyond the project limits, even though no other construction may be necessary at those corners.

At intersections, including "Tee" intersections, where the side road has sidewalks on one or both sides of the street and the through street has sidewalk on the opposite side of the street from the side road, this condition establishes a legal crosswalk whether the crosswalk is marked or not per State Statues 340.01(10(b).

The typical curb ramp width for a newly constructed curb ramp is 5 feet, or the width of the sidewalk or shared use path area leading to the crossing. This measurement does not include the width of the flared sides. The width of a median cut-through is the same as the crosswalk width, typically 6 feet or wider.

Curb ramps should not be offset more than 10 feet from a sidewalk continuation without the approval of the Regional bike/pedestrian coordinator. The 10-foot offset distance is measured from the back side of the sidewalk to the crosswalk. See Attachment 10.1, Figure 2.

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[16] For more information on ADAAG detectable warnings and accessible design requirements go to www.access-board.gov. Also, each WisDOT regional pedestrian/bicycle coordinator has a copy of (7) Designing Sidewalks and Trails for Access / Part II of II: Best Practices Design Guide. U.S. Access Board; U.S. DOT, 2001. http://www.fhwa.dot.gov/environment/sidewalk2/pdf.htm, which is the primary reference for designing curb ramps and other accessibility considerations.

Curb ramps shall be provided for each sidewalk extended across the through street crosswalks and side road crosswalks as shown in Attachment 10.1, Figure 1, except as noted in FDM 11-46-10.1.2, "Crosswalk Closure". It is generally undesirable to close the crosswalk on one side and direct pedestrians to the other side of the side road before crossing the through street since this requires pedestrians to avoid using what was once a legal crosswalk. Often pedestrians will not detour out of their way when they face an obvious crossing in front of them.

There may be times, especially for safety reasons, where it may be necessary to close a crosswalk. The reason(s) are to be documented for a crosswalk closure. There may also be some locations where curb ramp installation may be desirable, but is not required. For example, if there is a “foot path” that indicates pedestrian traffic within the intersection right-of-way or if there is a future local project that will provide a sidewalk to the intersection in the immediate future. Also, there may be safety reasons to justify a free-standing curb ramp. For example, the distance between crossing locations, adjacent land uses, and destinations may indicate the need, or to provide a space for pedestrians to move temporarily out of the intersection or to access a pedestrian push button. Coordinate with the local community to ensure that any free-standing curb ramps are properly located and maintained.

Provide ADA-compliant curb ramps at intersections (including traffic islands and medians) and mid-block crossings where a sidewalk or other pedestrian walkway crosses the curb at locations where crosswalks (either marked or unmarked) are present on alteration improvement project types. Refer to FDM 3-5 Exhibit 5.1 for list of pavement strategies meeting the ADA “alteration” definition.

Pavement treatments that are considered “maintenance of the road surface” do not require curb ramp installation or curb ramp updating. Curb ramps may be installed/updated on “maintenance of the road surface” project types for other reasons and needs.

For roadway project types that are considered an “alteration” by ADA and there are existing physical or site constraints that make it technically infeasible to make the curb ramp (or other facility fully compliant), refer to FDM 11-46-5.1.1 for further discussion and application of ADA compliance and technical infeasibility.

For more information regarding curb ramp design and ADA compliance, see the “Wisconsin Guide to Pedestrian Best Practices" *(6)*.

10.1.1 Crosswalks

Crosswalks are defined as pedestrian crossings where motorists must legally yield the right-of-way to crossing pedestrians. As stated in State Statute 340.10(10), crosswalks exist at all intersections where sidewalks are present, even if the crosswalks are unmarked. Intersection crosswalks are legally considered prolongations of their contiguous sidewalks. Crosswalks can also exist at mid-block locations. However, unlike crosswalks at intersections, mid-block crosswalks must be marked.

Crosswalk cross slope is important for pedestrian and impaired user navigation.

Side roads that are controlled by a stop sign, yield sign, or signal must provide a 1.5 percent (2% maximum) cross slope on the crosswalk and extend the 1.5 percent side road profile back to a point beyond the stop bar, yield bar or control location, whichever is greater. If any technically infeasible conditions cited under FDM 11-46-5.1 are satisfied, develop side road profile to the maximum extent feasible. Provide documentation in the DSR.

Mainline roads (through traffic movement) that are signal controlled, not controlled at an intersection, or for mid-block crossings the crosswalk may have a cross slope equal to the profile slope of the mainline roadway. An example may be where the mainline roadway has a 5 percent grade then the crosswalk cross slope may also be 5 percent.

10.1.2 Crosswalk Closure

Site conditions, safety concerns, and State Statues 349.185(2) regulate the prohibition of pedestrian crossings and shall be evaluated prior to closing a crosswalk.

When a crosswalk is closed the crossing must be signed as closed and a barrier must be installed to alert blind or low vision pedestrians and other users that a crossing at this location is not permitted.

The standard signs used to close a crossing are shown below in Attachment 10.1, Figure 3. The arrow on the sign may be oriented to the right or to the left, whichever is appropriate for the location. The sign post location must meet lateral clearance requirements as shown in FDM 11-20, Table 1.5 (typically 4 feet from the travel lane, assuming a 2-foot gutter and 2 feet behind the face of curb). A design justification (DJ) is required, per FDM 11-1-2, if lateral clearance requirements are not met.

There are several options for closing a crosswalk where there is a through street terrace width of 3 feet or more.

- One option is a 4-inch to 6-inch curb, with tapered ends, across the end of the side road sidewalk

extended, or a raised planter with perimeter curbing. Install the standard signs on a post behind the Concrete Pedestrian Curb as shown in Attachment 10.1, Figure 4.

- Another option is low growth plantings (18-inch maximum height at maturity) or terrace mound with WisDOT approval. The terrace mound is approximately 6 inches high and across the end of the side road sidewalk extended. The mounding option is acceptable providing the curb, planters, plantings or railing identified above is determined by WisDOT to be unacceptable. Install the standard signs on a post as shown in Attachment 10.1, Figure 5.

Evaluate the conditions and context when selecting a preferred design. Barrier options may include a planter, concrete pedestrian curb, plantings or a terrace berm.

If there is less than a 3-foot terrace, or the sidewalk is adjacent to the back of curb, then close the crosswalk by first moving the sidewalk back and away from the through street back of curb as it approaches the intersection (as shown in Attachment 10.1, Figure 6), and then using one of the options explained above. This option may require purchasing right-of-way, depending on available space. If right-of-way is not available and the sidewalk and furniture area is narrow then it may be acceptable, with WisDOT approval, to install a raised curb along with a “pedestrian crossing closed” sign.

10.2 Curb Ramps and Detectable Warning Fields

On all state or federally funded projects with sidewalk, curb ramps with detectable warning fields shall be installed at all legal crosswalks whether the crossing has pavement marking or not. These include all projects that are defined as an alteration per ADA [17] where curb ramps do not exist, or they are not ADA compliant. This shall be done regardless of whether new or replacement sidewalk is programmed as part of the project.

10.2.1 Curb Ramp Type Selection

Proper curb ramp selection is important for pedestrians who are either walking along a sidewalk, shared use path and attempting to cross the street. It is important to select the best curb ramp type for each crosswalk location. Use perpendicular curb ramps (Type 2) that are in line with the sidewalk because the crossing distance is shorter, and it helps to align people with visual or mobility issues to the opposite side of the street. See Figure 10.1.

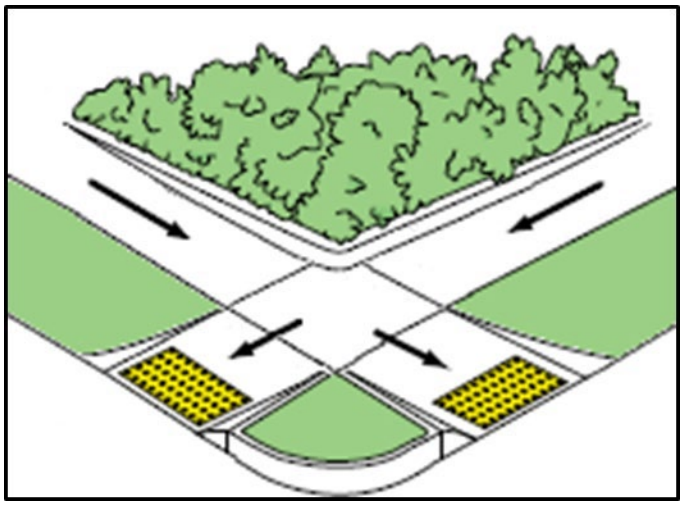


Figure 10.1 Typical Perpendicular Curb Ramp

At times, it may be necessary to offset the perpendicular ramps slightly. Consider Type 3 curb ramps in these situations. Where perpendicular (Type 2) curb ramps are not feasible, parallel ramps are the next preferred ramp type. A parallel ramp consists of two ramps, both parallel, where the running slope is in-line with the direction of travel and the sidewalk is lowered to a level landing space where a turn is made to enter the street crossing, level landings are provided on each side of the of the street-level landing. See Figure 10.2. Parallel ramps are typically installed where the available space between the back of curb and property line is insufficient to permit a typical perpendicular ramp installation. Type 7A or 7B curb ramps are essentially parallel ramps. A curb ramp design may also consist of a combination of a perpendicular and parallel ramps depending on intersection geometry.

[17] See FDM 11-46-1.1.3 and FDM 3-5-1.1.

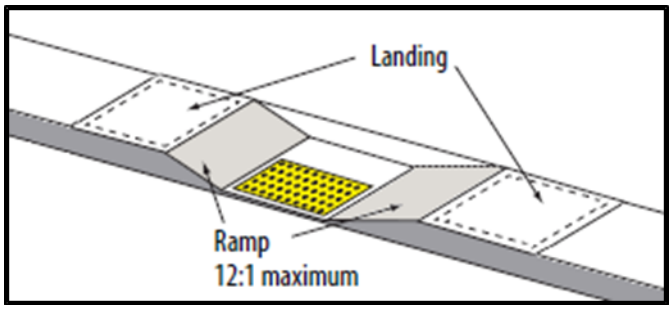


***Figure 10.2** Typical Parallel Curb Ramp*

Lastly, a diagonal ramp (Type 1 or 1A) may be constructed as a single ramp centered on the curb return. Diagonal ramps are the least preferred type of curb ramp because they require wheelchair users to turn at the top and bottom of the ramp, therefore a bottom in-street landing is required in addition to the top landing.

For non-midblock locations that have a single cross walk, use curb ramps Type 4A/A1 or 4B/B1. The ramp type depends on whether a terrace exists.

Other curb ramp types are provided in SDD 8D5 to illustrate the various configurations that require detectable warning fields that may occur on a project (i.e. railroad crossing, median crossing, mid-block crossing and island crossing). Document any technically infeasible design decisions in the DSR relative to curb ramp selection and hierarchy (perpendicular ramp, parallel ramp, diagonal ramp).

Refer to sub-sections 5.3.3.1 (design specifications for curb ramps) and 5.3.3.2 (types of curb ramps) of the "Wisconsin Guide to Pedestrian Best Practices" (6) for further detail guidance. Additional information on the planning and design evaluation on curb ramp solutions and examples may be found in Special Report: Accessible Public Rights of Way Planning and Design for Alterations by the U.S. Access Board *(29).*

10.2.2 Curb Ramp Flares

Curb ramp flares are the sloped transitions from a curb ramp to the surrounding sidewalk. Flares are not considered part of an accessible route and typically have steeper slopes than ramp slopes. Curb ramp flares should also be free of obstacles (fire hydrants, inlets, manholes, etc.). For pedestrians with visual impairments, flares may be one of the cues used to identify a curb ramp and upcoming street edge. If the ramp landing width is less than 5 feet, the slope of the flare may not exceed 8.33 percent. In all cases, the flare slope shall be sloped 10 percent maximum, measured parallel to the curb line.

Flares should only be installed where the curb ramp edge abuts pavement. In locations where the ramp edge abuts a non-walkable surface (grass) or a planting area (other landscaping), and in locations where pedestrians cannot walk across the ramp sides of the curb ramp, a curb return can be installed instead of a flare. See Figure 10.3.

Straight curb returns are a useful orientation cue for pedestrians with visual impairments. Curb ramps may have a combination of a taper and a curb return when applicable. A curb return should not be used where either a planting or a non-walkable surface does not exist in the terrace area. In these situations, a flare would be used instead.

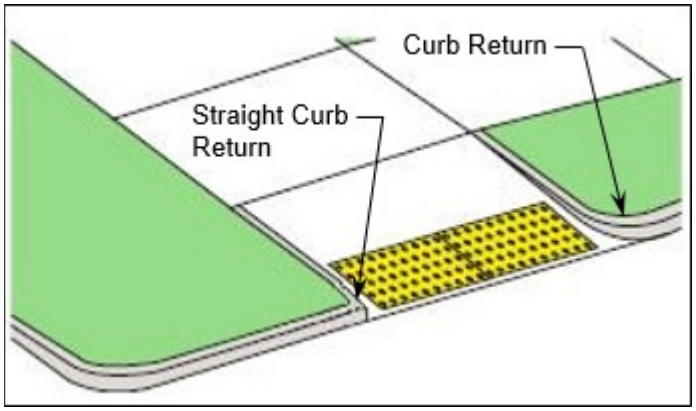


***Figure 10.3** Typical Perpendicular Curb Ramp with Curb Returns*

10.2.3 Curb Ramp Construction Details

The Standard Detail Drawings (SDD 8D5) are developed to address the majority of curb ramp installations. While the SDD's show general layout dimensions for the various types of curb ramps, they are not intended to represent the actual site-specific curb ramp design. The site-specific dimensions, elevations and grades should be shown on separate curb ramp construction details. See Figure 10.4 for the various design elements that are considered essential for a well-constructed curb ramp. When curb ramp construction details are inserted in the final plans, they should include the following items listed below:

Elevation Point Table Columns

- Point ID
- STA
- OFF
- ELEV
- X
- Y

Elevation points locations

- All grade breaks, both sides of sidewalk
- All corners of landings and ramp
- Flange at boundaries of crosswalk
- Flange at all curb profile grade breaks and vertical curvature locations
- Flange at radius points and quarter points
- Flange at gutter slope transition points
- Top of pedestrian curb at grade breaks
- Top of pedestrian curb at horizontal geometry points
- Building steps/landings/doors
- Additional elevation points at designer's discretion

Slope Arrows

- Gutter slope and all gutter slope transition points
- All locations for transverse slope change
- All longitudinal grade locations, both sides of walk
- Special attention to landing and ramp edges
- Slope of gutter in middle of cross walk in direction of pedestrian travel

Miscellaneous

- Curb ramp type
- Detectible warning field
- Proposed inlets and manholes
- Existing Topography Symbols
    - Signal equipment
    - Pole bases
    - Cabinets
    - Lights
    - Signal poles
    - Power Poles
    - Signs
    - Existing inlets and manholes (if not being replaced)
    - Other objects at the designer's discretion

- Horizontal dimensions at designer discretion
- Sidewalk width
- Theoretical joint locations including a general note
    - Sidewalk and Building Locations in some urban environments
    - Existing sidewalk match point
- Non-standard flare dimensions
- Right of Way line work
- Proposed edge-lines
- Sawcuts, removals, and additional miscellaneous callouts as needed
- Roadway reference lines

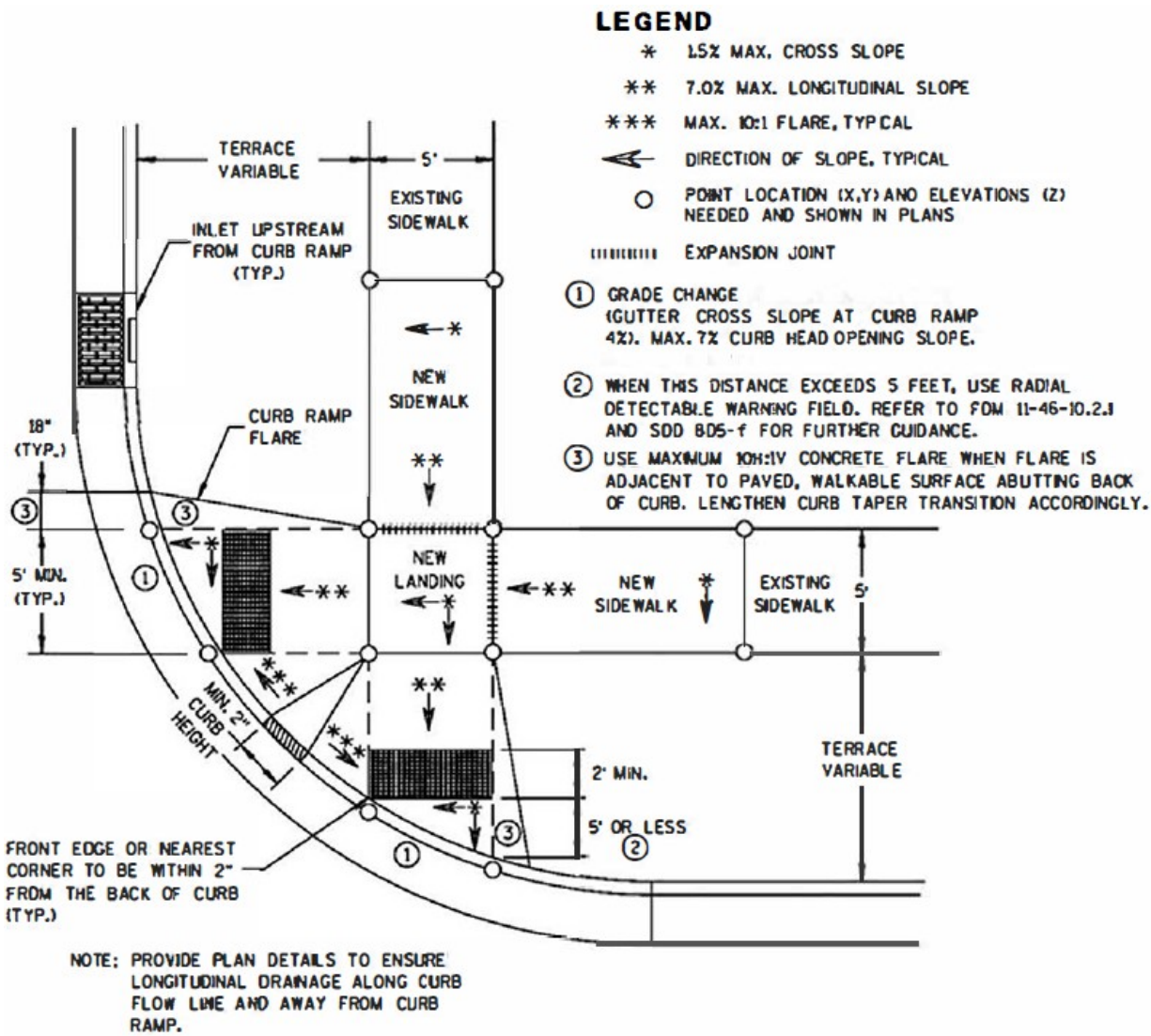


Figure 10.4 Typical Type 2 Curb Ramp Installation with Recommended Plan Details

While the SDD's address the majority of curb ramp installations, there are locations where the SDD's do not work because of site-specific conditions. Develop construction details for these locations showing elevations and curb ramp alignments that meet the site conditions. For example, inclusion of construction details with final plans will be common for replacement of existing curb ramps (retrofit projects) or for curb ramp construction within urban environments.

Construction details must comply with ADA cross slopes, running slopes and other design criteria as defined in FDM 11-46-5 and FDM 11-46-10. Note that WisDOT does not allow blended transitions (long radius curb and gutter applications). Listed below are some scenarios that require construction details for proper curb ramp design:

- Where the terrace is less than 6' wide
- Where the sidewalk is at the back of curb
- Where the terrace is all concrete
- At skewed intersections or wider curb ramp openings
- In pork chop islands or uniquely shaped median refuge areas
- Where there are inlets, manholes, utility boxes, poles and other obstructions close to the proposed curb ramps. Avoid these obstructions or other maintenance obstructions within the curb ramps and gutter in front of curb ramp
- Where concrete pedestrian curb is provided include construction details of the concrete pedestrian curb, such as length, alignment and taper details
- At locations with flat longitudinal gradient along curb flow line

See FDM 11-46-10.3 for further description of curb ramp design considerations for development and inclusion as project construction details.

On Type 2 curb ramps it may be necessary to reduce the curb height between the ramps down to a minimum of 2 inches in the triangular concrete area as shown on the Type 2 ramp, SDD 8D5. Use maximum 10:1 flare slopes within this triangular area since this concrete area is a walkable surface. Use a minimum 1 to 2-foot curb length with the reduced-height curb between the flares. When the terrace is less than 6 feet wide it will most likely be necessary to lower the sidewalk elevation prior to the ramp intersection. The designer may have to show sidewalk grades on a special detail. The offset distance is a maximum of 10 feet measured from the backside of a side road sidewalk extended to the closest side of the crosswalk.

For Type 2 curb ramps with an adjacent concrete sidewalk or paved, walkable surface abutting the back of curb (i.e. no terrace) and for all parallel curb ramps, lengthen the curb taper transitions between flow line and top of curb. Do not use curb return tapers of 1'-6" minimum (2'-0" maximum) for these situations. Use a maximum 10% flare slope (measured parallel to curb line) in this situation at Type 2 curb ramps with the lengthened curb tapers. If Type 2 (perpendicular) and parallel ramps are not feasible and a Type 1 (diagonal) curb ramp is used, provide maximum 10:1 flares slopes since the level portion of the flanking sidewalk apron is considered a walkable surface.

10.2.4 Truncated Domes

Truncated domes are the only curb ramp detectable warning field meeting ADA requirements and the Access Board's draft Public Right of Way Guidelines (PROWAG). These requirements and guidelines apply to all projects involving new or altered pedestrian facilities, not just projects funded by state or federal sources.

Each truncated dome has an acceptable range of values for bottom diameter, top diameter, height and center to center spacing (see SDD 8D5-g for a drawing of the detectable warning field with truncated domes). Domes should be arranged in straight lines and not offset with each other.

The quality of detectable warning field products *(10), (11), (12), (28)* is important to the overall performance of the transportation facility. As shown in Table 10.1, curb ramp detectable warning fields must be on the WisDOT "Approved Products List" (APL) prior to bidding to be eligible for state or federal funding. The WisDOT APL shows the various approved product names, acceptable colors, manufacturer, and distributor information. Click on "curb ramp detectable warning fields" under "roadway appurtenances" on the "Approved Products List" page.

Per FHWA's "Visual Detection of Detectable Warning Materials by Pedestrians with Visual Impairments (Final Report)" (13), the detectable warning field color is a functional part of the product (not aesthetic) for people who are blind or low vision. Based on field reviews with people who are blind or low vision, yellow was the most discernible color. White color also ranked very high in the field review. The natural patina (or rust) of the cast iron product is also acceptable. Therefore, yellow, white, or natural patina are the required colors on WisDOT facilities, including state trunk highways and connecting highways. The designer may choose to coordinate yellow, white, or natural patina with the community on projects where new curb ramps will be installed. The bid item number(s) dictate the color of the detectable warning field to be used and are provided on the backside of SDD 8D5 along with other associated bid items.

Local units of government are encouraged to use yellow, white, or natural patina as the curb ramp detectable warning field color. However, as shown in Table 10.1, local units of government may choose another color that meets national design criteria and ADA requirements. Therefore, local governments must submit desired products that are not already on the WisDOT APL, several months ahead of the scheduled bidding to allow for product review or testing. If time is not available to evaluate or there is current knowledge about the product that it is deemed unacceptable, then it will not be added to the APL.

***Table 10.1* Curb Ramp Detectable Warning Field Policy**

Location	Funding for warning field bid item	Product	Color
STH System (STH or Connecting Highway)	Participating Item	Must be on WisDOT APL prior to bid	Yellow, White, or natural patina
Local System	Participating Item (eligible for state or federal funds)	Must be on WisDOT APL prior to bid	Yellow, white, or natural patina recommended. If color is not yellow, white, or natural patina a letter to WisDOT is required stating that ADA requirements are met.
Local System	Non-participating Item (not eligible for state or federal funds)	APL products are recommended. If product is not on the APL a letter to WisDOT is required stating that ADA requirements are met.	Yellow, white, or natural patina recommended. If color is not yellow, white, or natural patina a letter to WisDOT is required stating that ADA requirements are met.

10.2.5 Detectable Warning Fields

Detectable warnings fields are a distinctive surface pattern of truncated domes detectable by cane or underfoot. They are used to alert people with vision impairments of their approach to streets or hazardous drop-offs. Detectable warning surfaces shall contrast visually with adjacent gutter, street or highway, or pedestrian access route surface, either light-on-dark or dark-on-light.

The cast iron detectable warning panel standard size is 2-foot by 2-foot. Other sizes are also available such as 2’ x 1’, 2’ x 1.5’, 2’ x 2.5’ and 2’ x 3’. Align detectable warning fields at the back of the gutter flow line and the full width of the ramp (as measured perpendicular to the pedestrian direction of travel) and have a minimum length of two feet (as measured parallel to the pedestrian direction of travel). The warning field closest to the back of curb is installed 6 inches to 8 inches from the gutter flow line, or typically about 1 to 2 inches from the back of curb.

Truncated domes will replace the expanded mesh pattern grooves, striations, exposed aggregate or other pre-existing designs at the bottom of a curb ramp. If the existing curb ramp does not have a detectable warning field (i.e. truncated domes) or the current condition does not comply with ADA requirements or the ramp area is severely cracked or has cracks/joints with a change in level that produces a lip greater than 1/4-inch, then replace the curb ramp and install a detectable warning field.

10.2.5.1 Detectable Warning Field Placement

According to PROWAG, detectable warning fields shall extend a minimum of 2 feet in the direction of pedestrian travel and extend the full width of the ramp run. Detectable warning fields shall be placed at the back of curb. Detectable warning fields are to be installed in plastic concrete for proper installation. The concrete border around the detectable warning field perimeter should not exceed 2 inches. Where the back of curb edge is tooled to provide a radius, the border dimension should be measured from the end of the radius. Refer to curb ramp SDDs for more information.

When a sidewalk approaches a curb radius, the placement of detectable warning fields at the back of curb may not be possible while keeping the truncated domes in alignment with the longitudinal path of the wheelchair. Refer to curb ramp SDDs for common applications with detectable warning field placement.

Evaluate each curb ramp for the most effective placement of the detectable warning fields, as conditions may vary. For example, along skewed intersections with narrow terraces, or at perpendicular curb ramps with adjacent sidewalk abutting back of curb, aligning the domes parallel to the direction of pedestrian travel may result in the detectable warning field panels protruding into the adjacent sidewalk. This may result in pedestrians bypassing the warning fields when entering the curb ramp openings. For these situations, ensure the domes are placed as close to back of curb as possible. Dome alignment may not always be parallel to crosswalk alignment in these situations. However, ensure that the curb ramp running slope does not exceed a desirable maximum 1.5 percent (5 percent absolute maximum) for these situations. Orientation of the domes is less critical where detectable warning surfaces are provided on a surface with a slope that is less than 5 percent (PROWAG) (*28*).

For perpendicular and type 4A/A1 or 4B/B1 curb ramps with a larger intersection radius, placing detectable warning fields at full width of the ramp may further increase the grade break distance behind the back of curb

along one edge of the curb ramp. If the grade break distance exceeds 5 feet, then radial detectable warning fields are required. See the next subsection (FDM 11-46-10.2.5) for radial detectable warning field guidance.

Detectable warning fields at parallel curb ramps and diagonal curb ramps shall be placed as close to the back of curb as possible. Refer to SDD 8D5-a and Figure 10.1.

At skewed crossings where the sidewalk intercepts the curb along a tangent and where the grade break distance is greater than 5 feet (see Figure 10.7), the detectable warning fields shall be installed as close as possible to the back of curb. See Figure 10.5.

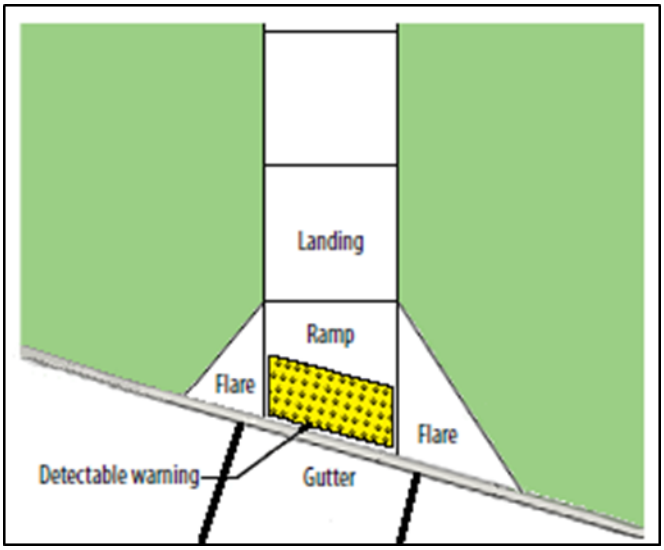


***Figure 10.5* Example of Detectable Warning Field Installation for Skewed Crossing**

At street-level pedestrian refuge islands, place detectable warning fields at the edges of the pedestrian island. Extend the detectable warning fields a minimum length of 2 feet at each edge of the island measured in the direction of pedestrian travel. Separate these fields a minimum 2 feet of surface length without detectable warning fields (PROWAG, U.S. Access Board) (*28*). An 8-foot median width (measured between curb faces) will provide adequate distance to meet these conditions.

Detectable warning fields are not required at street-level pedestrian refuge islands if a minimum 2-foot concrete surface without detectable warning fields, measured in the direction of pedestrian travel, cannot be achieved. For this situation, a traffic signal should be timed for a complete crossing of the street (PROWAG, U.S. Access Board) (*28*).

Install detectable warnings on paved shared-use paths at roadway crossings. Curb ramps with wire mesh imprint warning field, any warning field other than truncated domes, or with missing warning fields are not ADA compliant and need to be replaced. Existing non-cast iron truncated domes, if in good condition, may remain in place if the curb ramp meets ADA accessibility standards.

If a shared-use path crosses a roadway that has curb, then provide a concrete pad adjacent to the back of the curb and install the detectable warning fields into the plastic concrete. If a shared-use path crosses a roadway that has a paved or aggregate shoulder, then provide a concrete pad at the outside edge of the shoulder and install the detectable warning fields into the plastic concrete. See Figure 10.6 for an example detectable warning field installation of a shared-use path crossing a non-curbed roadway. Continue the shared-use path across any unpaved portion of the shoulder.

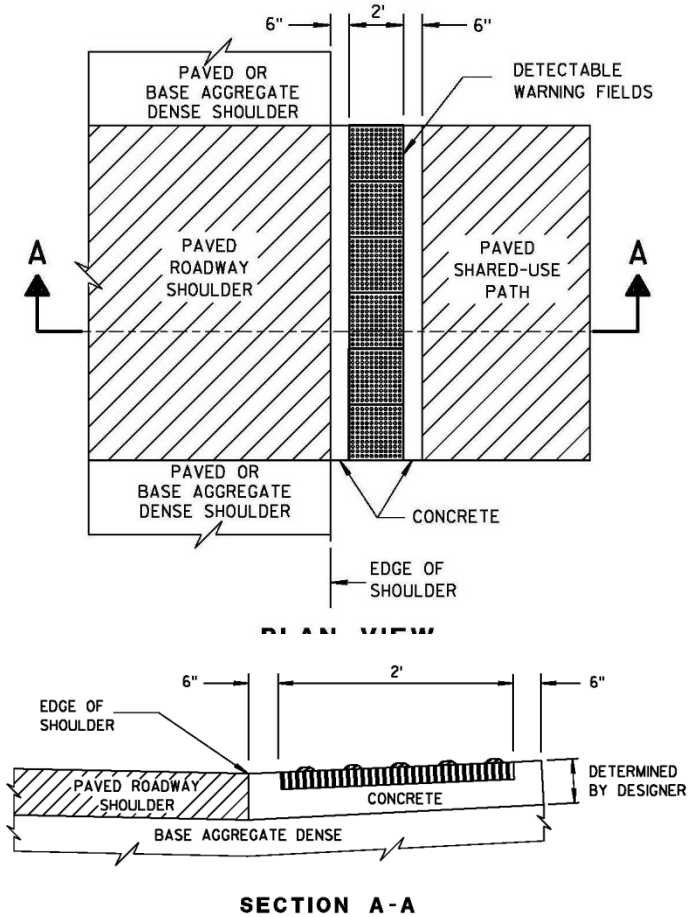


***Figure 10.6** Example of Detectable Warning Field Installation for Shared-Use Path Crossing a Non-Curbed Roadway*

10.2.6 Radial Detectable Warning Fields

Where the grade break distance exceeds 5 feet (see Figure 10.7), radial detectable warning fields (i.e. radial plates) are necessary. Radial plates provide full detectable coverage immediately at back of curb.

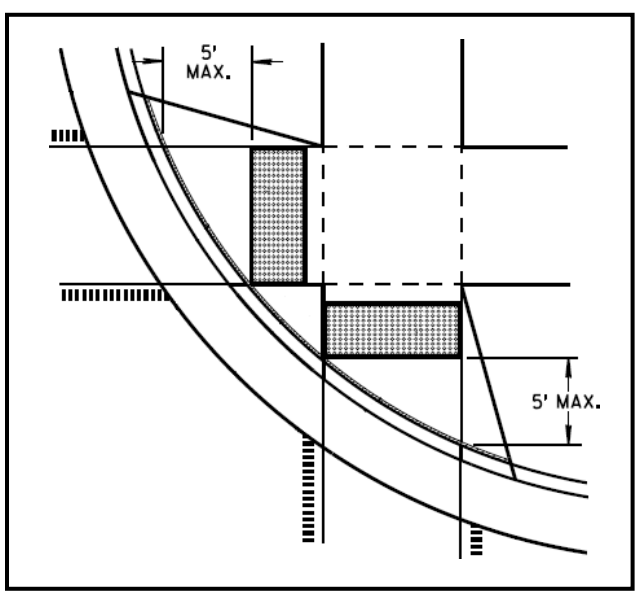


Figure 10.7 Example of Grade Break distance

Radial plates are typically available from the manufacturer's approved list in varying radii. The contractor will select the appropriate radial plate radius that matches the intersection radius design. A slight variance of up to 3 feet between the radii of the detectable warning field and the back of curb will provide a uniform concrete border between back of curb and radial field. A maximum 3-inch concrete border is allowable between the back of curb and radial detectable warning field for constructability purposes, with the concrete border width variable up to 1 inch.

Manufacturers differ with their radial detectable warning field designs. Manufacturers typically do not produce individual plates with all intersection radius sizes. Some manufacturers have developed combinations of sequentially-placed radial and square plates to replicate radius warning field options for larger intersection radii. Some manufacturers supply radial wedge plates, and when placed alongside square plates, the desired detectable warning field radius is developed. Radial plate anchorage into the plastic concrete will also differ between manufacturers. View the various manufacturer's website for radius plate availability and options.

The WisDOT "Approved Products List" (APL) shows the various manufacturers and distributor information. Click on "curb ramp detectable warning fields" under "roadway appurtenances" on the APL page.

When radial detectable warning fields are used, the outermost radial plates will not coincide with the curb ramp edges. The outermost radial plates will need to be field cut to match the curb ramp edges. Develop construction details of each curb ramp, including the layout of individual full-size radial plates as well as flanking cut radial plates. Field-cut plates cannot be shorter than 6 inches along any cut edge. Depict full-size radial plates within the interior of the curb ramp layout, as intermediate joints within the warning field must not be field cut. The radial plate final field placement may vary, as the contractor will determine the final warning field configuration and its individual plate locations.

In addition to the detectable warning field layout, include grade break locations within the detail construction plans. Grade breaks are perpendicular to the direction of pedestrian travel and will coincide with the most-remote radial plate from back of curb. Provide a level landing (i.e. 1.5% longitudinal slope) within the radial detectable warning field limits.

See radial detectable warning field applications and plates under SDD 8D5 (sheets 'f' and 'g') with further details for inclusion in plan construction details. Include coordinates, elevations, slopes, etc. as similarly depicted in Figure 10.4.

Radial detectable warning fields will be paid as Curb Ramp Detectable Warning Field Radial (color) based on final quantity embedded in concrete. Include the following information with the contract plans for bidding purposes:

- Back of curb radius
- Landing length 'XR' (i.e. grade break distance)
- Radial warning field area (square feet)
- Radial long chord dimension (feet) (exclusive of curb ramp flares)

10.3 Curb Ramp Design Considerations

Surface water runoff from the roadway can flood the lower end of a curb ramp. Determine the grades along the flow line and provide catch basins or inlets to prevent flooding of the ramps. Verify that the drainage structure will not be in the path of a wheelchair user or pedestrian.

The grade change between the gutter cross slope and the curb ramp slope is not to exceed 11%. ADA requires curb ramps have a running slope no steeper than 8.33% (12H:1V) and a cross slope of 2% (construct at 1.5% for construction tolerance) unless a greater cross slope is needed to transition into the back of the curb slope. Existing gutters commonly have a common cross slope of 3/4 inch/foot or 6.25%. Adjust the curb ramp running slope and the gutter slope to comply with the 11% grade change requirement. Therefore, use a maximum design curb ramp slope of 7% in combination with a maximum 4% gutter flag slope. Refer to Figure 10.9 for schematic diagram of allowable algebraic differences between gutter cross slope and curb ramp profile.

A rapid change of grade, between the curb ramp slope and the gutter cross slope, may be difficult to negotiate because the wheelchair's footrests or anti-tip wheels cannot clear the ground surface. In general, footrests are positioned low to the ground and extend beyond the front casters. Anti-tip wheels are placed on the back of some wheelchairs, behind the rear axle, to improve stability. Both the footrests and anti-tip wheels limit the clearance height of the wheelchair. Clearance may be a problem at an abrupt change of grade because the footrests or anti-tip wheels extend beyond the wheelbase of the wheelchair and therefore may contact the surface across the transition point from where the wheels are located. See Figure 10.8.

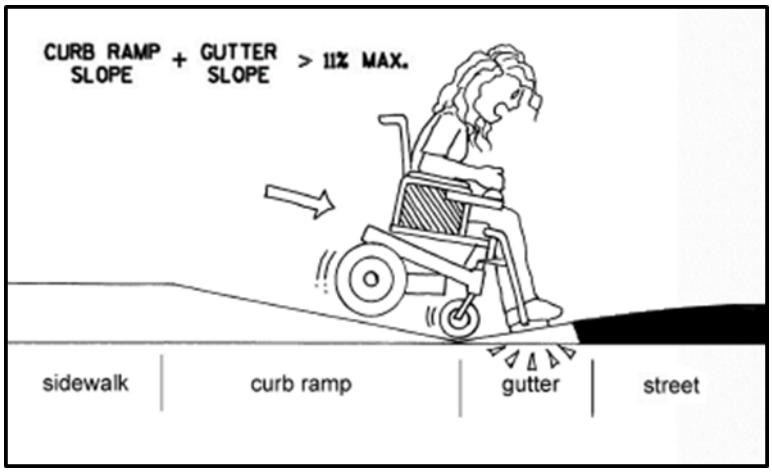


***Figure 10.8** Effect of Greater than 11% Grade Difference Between Gutter and Curb Ramp*

Refer to FDM 11-20-1.2.1.1 for gutter cross slope selection criteria and plan requirements with various improvement projects. A 4% gutter cross slope for rehabilitation and modernization improvement projects will effectively facilitate attaining the 11% algebraic maximum grade change (i.e. rollover) at curb ramps. SDD 8D1 notes the gutter cross slope as 4% unless otherwise noted in the contract plans.

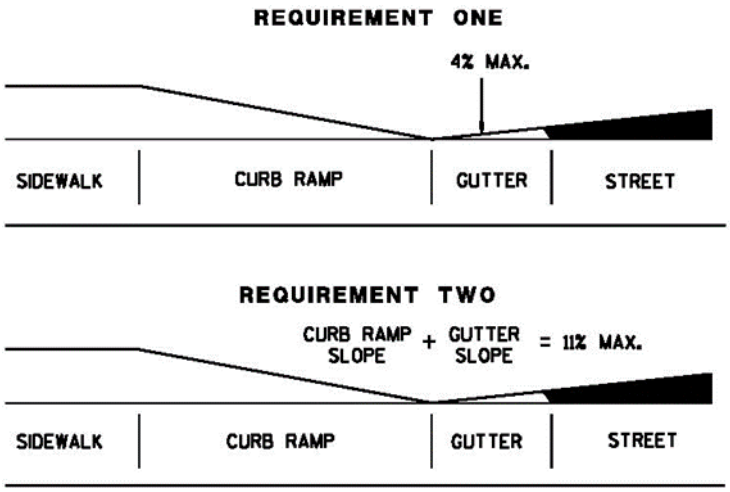


***Figure 10.9** Algebraic Difference in Slope Between the Gutter and the Adjacent Curb Ramp*

Figure 10.8 shows the algebraic difference in slope between the gutter and the adjacent curb ramp may have challenges attaining curb ramp slopes of 7% or less for retrofit projects due to tight site conditions or other constraints. Curb ramps may be designed and constructed at an absolute maximum of 8.33% (12H:1V) in these situations. If the designer elects to design the curb ramp with this absolute maximum of 8.33% slope, then the gutter flag slope must be set to 2.67% or flatter to maintain an 11% maximum grade change. Refer to Figure 10.8. Under these circumstances, it is imperative that the designer gather field survey and provide curb ramp plan details to ensure the ramps are built as planned.

Refer to sub-section 5.3.3.1 (Design specifications for curb ramps) of the "Wisconsin Guide to Pedestrian Best Practices" for retrofit curb ramp conditions when attaining a maximum 8.33% ramp slope is technically infeasible. Justify and document in the DSR if this technically infeasible option needs to be exercised for an improvement project.

Curb ramps at skewed intersections or along wider curb ramp openings may require additional attention during final plan development and subsequently require construction details. For these instances, gutter cross slopes and curb head opening slopes may vary when measured parallel to the direction of pedestrian travel and where measured along the curb ramp (e.g. center of curb ramp vs. edge of curb ramp). Maintain a maximum 7% curb head opening slope at any location along the entire width of a curb ramp opening. Consider flatter (e.g. <7%), consistent curb opening slopes within a project due to the effects of the skew and construction forming practices.

On projects where it may be technically infeasible to properly construct the sloping combination of curb ramps and gutters to current design criteria. The project team must then design the facilities meeting current ADA accessibility standards to the maximum extent feasible (see FDM 11-46-5.1). Document the technical infeasibility design decisions in the DSR. Tables summarizing the technically infeasible designs may be used as a DSR attachment to supplement conclusions. This documentation will serve to demonstrate the situation was evaluated and curb ramps improved to the maximum extent feasible. The documentation will also help address future concerns should they arise.

The change in angle from the gutter slope to the ramp slope (including curb head) shall be flush and without a lip, raised joint, or gap. Lips or gaps between the curb ramp slope, curb head, and the gutter slope can catch caster wheels or crutch tips and cause pedestrian injuries.

A landing is necessary to provide space for a person in a wheelchair to maneuver into position to use the ramp or to bypass it. In new construction, provide a five-foot square landing. A four-foot square landing is the minimum. If the landing is next to a vertical wall, a five-foot wide area is desirable to allow a person in a wheel chair more room to maneuver. In alterations of an existing roadway, where the curb ramps are being modified, the landing must be at least three feet square. Do not exceed 2% slope in any directions within the landing.

Consider the need for tie bars between the concrete pedestrian curb and the sidewalk.

10.4 Other Considerations

Curb ramp installations at intersections may have various options to consider as shown in Attachment 10.2, 10.3 and 10.4:

- Limited right-of-way near a crossing *(14)*
- Accessible Pedestrian signals and push-button locations *(15)*
- On-Street Parking for People with Mobility Impairments *(16)*

10.5 Curb Ramp Adjacent to Historically Significant Resources

Existing curb ramps or sidewalks adjacent to qualified historic facilities need to be evaluated and ADA compliance is required to the maximum extent that does not threaten or diminish the historic significance. The element or facility that is altered must have the historic significance. Location of curb ramps or sidewalk within a historic district does not automatically qualify as a historic facility. The State Historic Preservation Officer or Advisory Council on Historic Preservation determines if compliance would threaten or destroy the historic significance of the element or facility. A qualified historic facility is a facility that is listed in or is eligible for listing in the National Register of Historic Places or is designated as historic under state or local law. Reproductions or replications of historic facilities shall not qualify as historic facilities. If the existing sidewalk/curb ramp remains and does not meet ADA accessibility standards, document the evaluation and decision as technically infeasible in the DSR accordingly.

10.6 References

Refer to FDM 11-46-99 for list of references.

LIST OF ATTACHMENTS

Attachment 10.1	Legal Crosswalk and Crosswalk Closure Figures
Attachment 10.2	Curb Ramp Options with Restricted Right-of-Way
Attachment 10.3	Accessible Pedestrian Signals & Push Button Locations
Attachment 10.4	On-Street Parking for People with Mobility Impairments

FDM 11-46-15 Bicycle Facilities

May 15, 2019

15.1 Introduction to Bicycle Facilities

Department policy, in conformance with Federal law and policy, Section 84.01 (35) Wis. Stats.:

and Connections 2030*(2)(3)*, requires providing due consideration to establishing bikeways and pedestrian ways on all modernization highway projects funded in whole or in part from state or federal funds.

See FDM 11-46-1 for guidance.

Department policy for other project types, such as perpetuation and rehabilitation, may need to complete an evaluation to include bicycle and pedestrian accommodations where possible/practical within the scope of the project. In addition, certain bicycle and pedestrian design practices are required when applicable, e.g., curb

ramps and bicycle-acceptable grates.

The past three surface transportation bills placed increased importance on the use of the bicycles for transportation and calls on each state highway agency to encourage their use. Federal legislation provides the stimulus for planning, designing, and constructing a fully integrated transportation system benefiting the traveling public and the environment. According to federal legislation (23 USC Section 217(g)) transportation officials have to "consider" bicycle and pedestrian accommodations on projects. While this legislation stops short of requiring specific bicycle and pedestrian accommodation on every transportation project, FHWA intends for bicyclists and pedestrians to have safe, convenient access to the transportation system and sees nearly every transportation improvement as an opportunity to enhance the safety and convenience of the two modes. Thus, they developed a policy in 2001 for all projects that use federal funding in urban and suburban areas which requires the inclusion of bicycle and pedestrian facilities unless there are notable exceptions.

15.2 Design Guidelines and Basic Improvements

Certain bicycle-acceptable design practices should be considered regardless of the type of improvement being developed. An important design consideration is to provide adequate width within the roadway for bicycle travel. Information about minimum and typical widths is contained elsewhere in this procedure. Other bicycle-acceptable design factors that require attention are drainage grates, railroad crossings, signing and pavement marking.

Many of the guidelines in this procedure are from the Wisconsin Bicycle Facility Design Handbook *(4)*, which is the most applicable document for the design of bicycle accommodations on state and federally funded projects. The AASHTO "Guide for the Development of Bicycle Facilities *(17)* is the primary basis for the WisDOT Bicycle Facilities Design Handbook.

FHWA's 2013 memos *(19)* encourage agencies to use other guides and resources that build upon the flexibilities provided in the AASHTO guides, as appropriate. These other guides and resources can be useful information in project planning and development when used in context with AASHTO and WisDOT design guidance and expertise. If a project proposes a bicycle facility treatment(s) outside of Wisconsin guidelines approval is required. Contact WisDOT regional bike and pedestrian coordinators to initiate this process. Use the WisDOT regional bike and pedestrian coordinators as a resource for planning and designing bike and pedestrian facilities on state and federally funded projects. Also, see the "references" section for additional documents and resource information.

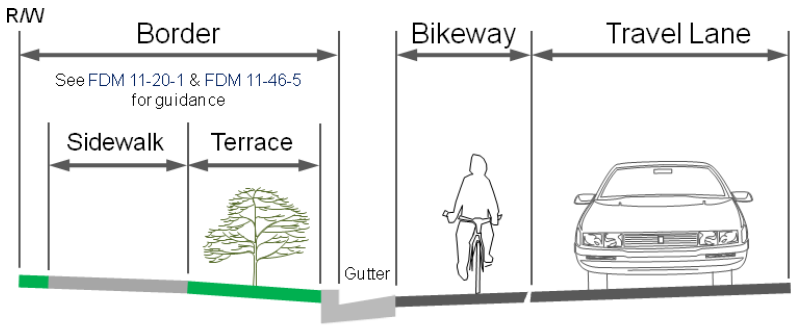
Use the WisDOT Bicycle Facilities Design Handbook if this procedure (or other FDM procedures) does not fully address a design issue. See FDM 11-15-1 and FDM 11-20-1 for additional guidance.

15.3 Urban On-road Bicycle Accommodations

If streets and highways have higher traffic volumes, additional space might be necessary to make it more convenient and safer for motorists to pass bicyclists. An urban on-road bicycle accommodation can be a bike lane, an urban paved shoulder, a wide outside lane or a combined parking/bike lane. A shared travel lane (see FDM 11-46-15.5) is not wide enough for motorist and bicyclists to operate side-by-side and is not a bicycle accommodation.

Requirements for on-road bicycle accommodation depend on whether there is parking or no parking as well as traffic volumes and speeds. Give due consideration to on-road bicycle accommodations on urban and suburban projects that use state or federal funding (see FDM 11-46-1).

Figure 15.1 shows the sequential preference and dimensions needed for bicycle accommodations (bike lanes, urban paved shoulders or wide outside lanes) for urban roadways without parking (also see the Bicycle Facilities Development Handbook). Most cyclists will be most comfortable and feel safest when separation markings are used with wider bicycle accommodations, equating to higher use. Do not use minimum bikeway widths unless cost or land constraints prevent additional widths. Options 11, 12, 13, 14 and 15 may not applicable for concrete pavement with a thickness less than 10-inches due to random longitudinal crack control. See SDD 8D1-a for concrete edge line jointing application adjacent to integral curb and gutter.



1st	2' gutter, 5' bike lane, 11'-12' travel lane
2nd	6' concrete bike lane with integral curb, 11'-12' travel lane
3rd	1' gutter, 5' bike lane, 11'-12' travel lane
4th	2' gutter, 4' bike lane, 11'-12' travel lane
5th	1' gutter, 4' bike lane, 11'-12' travel lane
6th	5' concrete bike lane with integral curb, 11'-12' travel lane
7th	2' gutter, 4' urban paved shoulder, edgeline, 11'-12' travel lane
8th	1' gutter, 4' urban paved shoulder, edgeline, 11'-12' travel lane
9th	2' gutter, 3' urban paved shoulder, edgeline, 11'-12' travel lane
10th	1' gutter, 3' urban paved shoulder, edgeline, 11'-12' travel lane
11th	2' gutter and 15' wide outside lane
12th	1' gutter and 15' wide outside lane
13th	2' gutter and 14' wide outside lane
14th	15' concrete integral curb/gutter (wide outside lane)
15th	1' gutter and 14' wide outside lane

***Figure 15.1* Urban Bicycle Accommodations without Parking (in order of preference)**

Figure 15.2 shows the dimensions needed to accommodate bicyclists side by side with parked autos and adjacent traffic. The bicycle accommodation is always located between the parking lane and the motor vehicle lane. Using the maximum combined width of 28-feet for parking lane, bikeway and travel lane allows the conversion of the parking lane to a travel lane while still providing a bicycle accommodation.

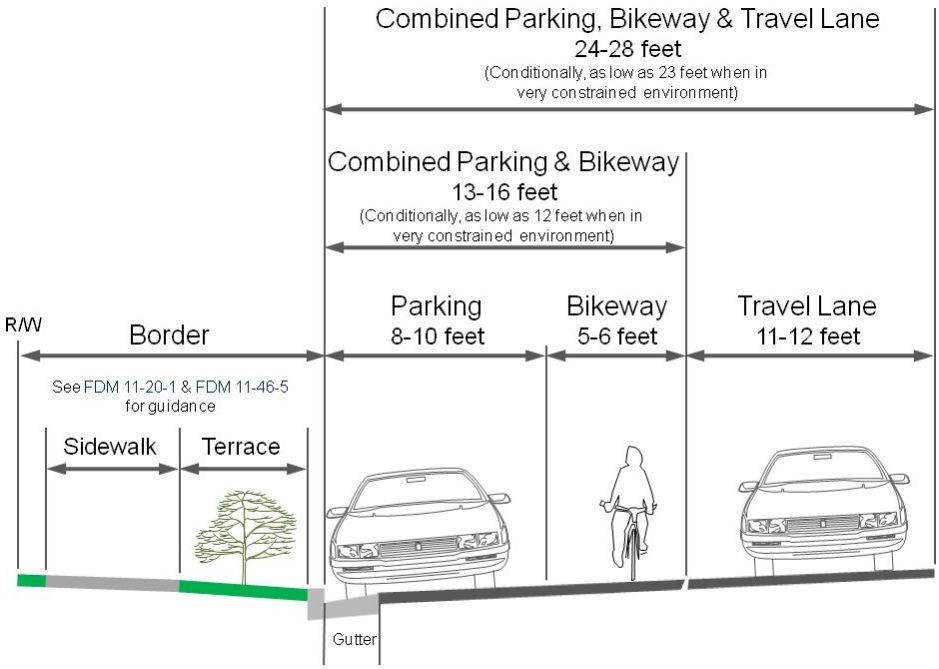


***Figure 15.2* Urban Bicycle Accommodations with Parking**

15.3.1 Bicycle Lanes

Bicycle lanes are usually the preferred form of bicycle accommodation on streets and have been shown to increase the comfort level of bicyclists using them. They are marked and designated as bike lanes, which distinguishes them from other types of bicycle accommodation. Bicycle lanes are always one-way facilities and flow in the same direction as the adjacent motor vehicle traffic. Conventional bicycle lanes may be enhanced with buffer space separating the bicycle lane from the adjacent motor vehicle travel lane or parking lane, this is known as a buffered bike lane. Adequate width must be provided and MUTCD guidelines followed for buffered preferential lanes in (MUTCD section 3D-01). Other design guides (NACTO) (22) may be appropriate to use in planning and design of buffered bike lanes.

A separated bike lane is an exclusive facility for bicyclists located within or directly adjacent to the roadway and is physically separated from motor vehicle traffic with a vertical element. The vertical element is what differentiates separated bike lanes from regular and buffered bike lanes. They are different from shared-use paths by their proximity to the adjacent roadway and that they are bike-only facilities. The planning and designing for this type of facility needs to consider other roadway design elements such as maintenance and drainage issues and roadside design. These facilities may be considered in designs with Bureau of Project Development approval. See FHWA's Separated Bike Lane Planning and Design Guide for more guidance (30).

Separated and marked bike lanes are not allowed within the circulatory roadway of a roundabout.

15.3.1.1 Bike Lane on Curbed Street without Parking

On curbed streets without parking, the bicycle lane is located next to the curb. The minimum width of the bike lane measured from the face of curb is 5 feet when the curb is integral with the pavement (see Figure 15.3). The minimum bike lane width is 4 feet as measured between a gutter/pavement longitudinal joint and an 11-foot minimum motor vehicle traffic lane (see Figure 15.3). The bike lane must be free of longitudinal joint lines.

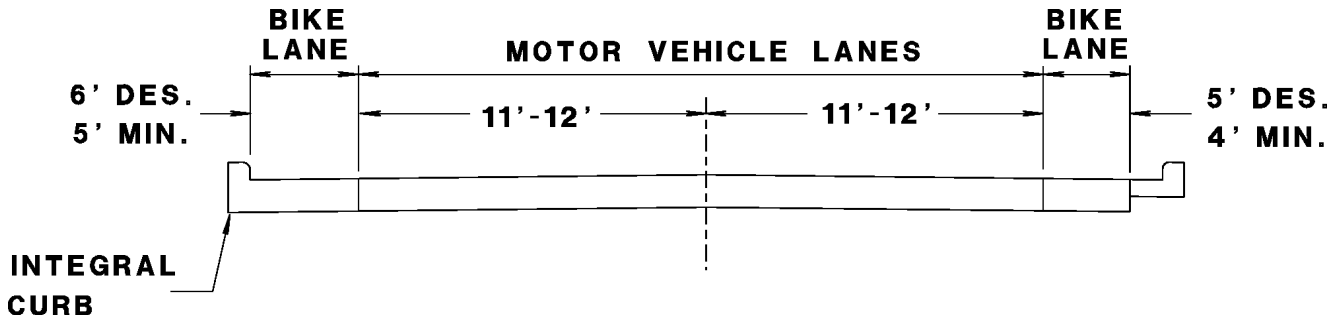


***Figure 15.3* Bike Lane on Curbed Street without Parking**

A concrete bike lane with integral curb that abuts asphalt pavement requires additional design consideration - including concrete thickness, dowel bar installation, straight edging, cross slope(s) and saw cutting - as well as finishing quality.

15.3.1.2 Bike Lane on Curbed Street with Parking

A bicycle lane is always located between the parking lane and the motor vehicle lane. The width of this combined bicycle and parking lane can vary from 13-feet to 16-feet depending on the width required for the parking lane (see Figure 15.4). The width provided for bicycle travel is 5 feet. Use the preferred width of 6-feet to provide safe bicycle operation where there is frequent parking turnover, parked vehicles are mostly commercial vehicles, or posted speed exceeds 40 mph.

See FDM 11-46-15.3.3.1 for possible bike accommodations where site conditions and right of way restrictions preclude providing the minimum width for combined bicycle and parking lane.

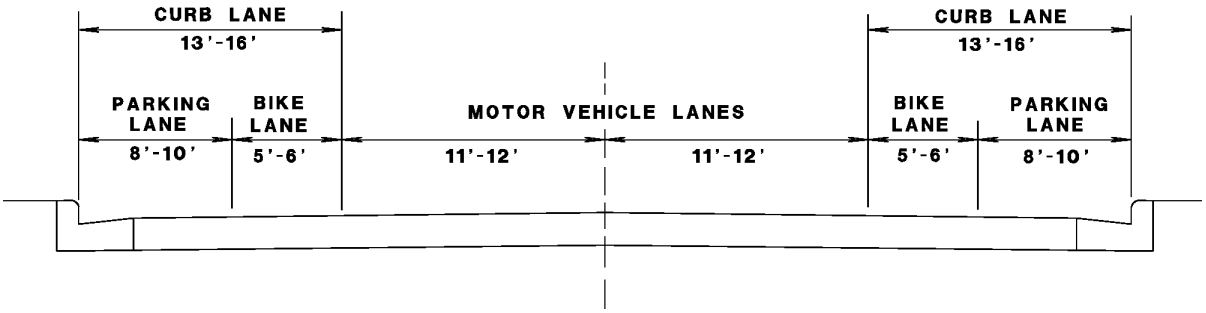


***Figure 15.4* Combined Bike Lane and Parking Lane**

At some locations, even after the above width adjustments are considered, there may not be enough room for accommodating bicycle travel between parked autos and traffic - and there may be no practical means of increasing the width of the roadway without impacting structures, improvements, natural resources, historical sites, or archaeological sites adjacent to the highway. It may be acceptable to consider keeping on-street parking when evaluating a location if *continuation* of on-street parking is warranted and supported by the community. This is particularly relevant in downtowns and neighborhood commercial areas where constraints are prevalent, and parking is at a premium.

However, even in these situations, all options to accommodate bicyclists and pedestrians should be explored and included to the greatest extent practicable. Even if parking is allowed, bicycling conditions can still be improved with methods such as limiting parking to only one side or creating limited parking bays for low parking demand situations (see Figure 15.5). When parking usage is low, these options are more viable.

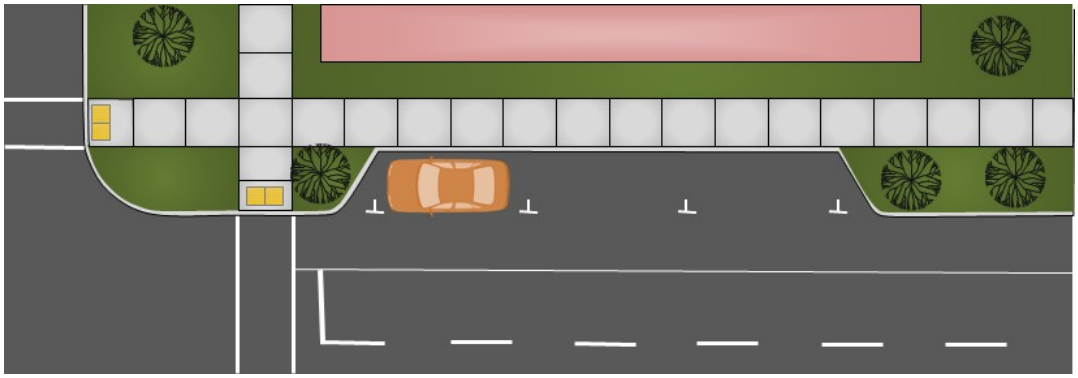


***Figure 15.5* Parking Bay**

The more important the route for bicycling, the more thoroughly options must be considered and documented.

Some municipalities use short-term parking restrictions, i.e., temporarily prohibit parking, on a combined parking lane/bike lane during the peak hour(s) to provide an additional travel lane on some of their urban streets. During this peak-hour time period, bicyclists use the travel lane and do not have their own space on the roadway. The continuation of short-term parking restrictions on a combined parking lane/bike lane in order to provide an additional travel lane during peak hours is acceptable as a bicycle accommodation under the following conditions:

- The parking restrictions are equal to or less than 2 hours per day in any one direction, and
- The WisDOT Regional Project Manager and the WisDOT Regional Bicycle/Pedestrian Coordinator concur with the continuation.

Otherwise, the width of the combined parking lane/bike lane must at least meet the requirement for a wide outside lane on a street with no parking, i.e., 14-feet minimum, not including gutter. This allows the operation of a temporary travel lane while still maintaining a bike accommodation.

15.3.2 Urban Paved Shoulders

An urban paved shoulder is the space between a travel lane and a curb/gutter section delineated with an edge line at the edge of travel lane. The minimum urban paved shoulder width to be a bicycle accommodation is 3-feet adjacent to an 11 or 12-foot travel lanes, and 4-feet adjacent to a 10-foot travel lane, not including gutter. In effect, a minimum width urban paved shoulder bicycle accommodation is a wide outside lane (see FDM 11-46-15.3.3) delineated with an edge line at the edge of travel lane. A minimum width urban paved shoulder bicycle accommodation is preferred over a wide outside lane bicycle accommodation because the edge line better defines the separation between motorists and bicyclists.

An urban paved shoulder that meets the width requirements of a bike lane (see section 15.3.1) will have many of the same benefits as a bike lane, but it is not marked and designated as a bike lane. A bike lane is preferred over an urban paved shoulder bicycle accommodation because it increases motorists' awareness of bicyclists.

15.3.3 Wide Outside Lanes on Urban Streets

A wide outside lane (aka wide curb lanes or wide outside travel lane) is essentially a travel lane plus an urban paved shoulder (see FDM 11-46-15.3.2) without an edge line. A wide outside lane bicycle accommodation is wide enough for bicyclists and motorists to operate side-by-side. In fact, a wide outside lane bicycle accommodation allows most types of vehicles to pass a bicyclist with at least 3 feet of separation without encroaching into the adjacent travel lane. However, motorists and bicyclists might not recognize a wide outside lane as a bicycle accommodation because there is no pavement marking to define their respective space.

A bike lane is preferred over a wide outside lane bicycle accommodation, but wide outside lanes have application where physical constraints such as buildings or environmentally sensitive areas prevent widening a street to provide bike lanes. An urban paved shoulder bicycle accommodation is preferred over a wide outside lane bicycle accommodation because the edge line better defines the separation between motorists and bicyclists.

On urban streets with no parking, the minimum width of a wide outside lane to be a bicycle accommodation is 14 feet not including the gutter. See Figure 15.1 for various widths that constitute a wide outside lane bicycle accommodation on urban streets with no parking.

It is strongly recommended that 2-lane connecting highways and STHs have a minimum curb to curb width of 36 feet when no provision is made for parking (See FDM 11-20-1). This would provide useable lane widths of 16

feet from edge of gutter to the centerline.

On urban roadways with 4 or more lanes, consider widening the outside lane by narrowing the gutter or widening the street's footprint as part of a modernization project. Additionally, narrowing the inside lane to provide a 14-foot outside lane to accommodate bicyclists can work independently or in addition to the techniques above.

15.3.3.1 Wide Outside Lanes on Urban Streets - Wide Parking Lane

On urban streets with parking, (see Figure 15.2), consider a minimum width of 23 feet, including gutter, for the combined travel lane/bicycle accommodation /parking lane where site conditions and right of way restrictions preclude a greater width and the following conditions are met:

- Posted speeds are low (less than or equal to 35 mph),
- There is low parking turnover or little on-street parking, and
- The traffic lane next to the bike accommodation is at least 11 feet wide.
- The combined width of bike accommodation and parking lane is at least 12 feet, including gutter.

Evaluate the location periodically to ensure that the assumed design conditions are still valid and that bicyclists are operating safely on the facility.

15.3.4 Adding Bike Lanes, Urban Paved Shoulders or Wide Outside Lanes to Existing Roadways

Consider one or more of the following methods to retrofit bike lanes, urban paved shoulders or wide outside lanes on existing urban roadways:

1. Physically widen the roadway to add these facilities
2. Mark or remark the pavement to gain space for bicycle accommodations. For example:
    - Reduce the width of traffic lanes.
    - Remove parking.
    - Convert a 4-lane undivided two-way street to a 2-lane street with a center turn lane (TWLTL) (see FDM 11-25-5 for guidance on TWLTLs) and bike lanes on each side (aka a "road diet"). Besides providing bike accommodations, this might also increase safety, decrease delay and improve overall operations.

See FHWA's Incorporating On-Road Bicycle Networks into Resurfacing Projects for guidance and strategies for installing and integrating bicycle facilities onto existing roadways (31).

15.4 Rural On-road Bicycle Accommodations

A paved shoulder is the most common on-road bicycle accommodation on rural highways.

A shared roadway is not a bicycle accommodation but is appropriate on some low-volume rural roads. See FDM 11-46-15.5 for guidance on shared roadways.

A shared-use path is an off-road bicycle accommodation, not an on-road bicycle accommodation. Shared-use paths, which typically parallel a rural divided highway or other high volume rural arterial, are much less common (see FDM 11-46-15.6 for guidance).

A shared roadway is not a bicycle accommodation but is appropriate on some low-volume rural roads. See FDM 11-46-15.5 for guidance on shared roadways. Also see WisDOT Rural Bicycle Planning Guidelines (5) for additional guidance.

***Table 15.1* Conditions Requiring Due Consideration of Bicycle Accommodations**

Condition Number	Condition
1	Identified in the Wisconsin Bicycle Transportation Plan or another WisDOT-endorsed or supported bicycle plan,
2	The two-way bicycle traffic volume is (or is expected to be) 25 per day or more during peak travel days for cycling (average of the 10 most traveled days for bicycling for the year)
3	To complete short gaps in an otherwise continuous bicycle route,
4	To make short connections from communities or urban areas of up to approximately 3 miles to the town or county roadway network (not to a dead-end roadway).
5	If bicycle accommodation projects were proposed and funded as bikeways under the Transportation Enhancement (TE), Congestion Mitigation & Air Quality (CMAQ), or Safe Routes to School (SRTS) programs, a minimum 5' shoulder shall be provided. For projects funded under these programs, 4' paved shoulders may be used only when ADTs are less than 1,500 in the design year or there are extenuating circumstances that will not permit 5' or wider paved shoulders. Appropriate justification and documentation of the extenuating circumstances must be developed and maintained in the project file.

15.4.1 Rural Paved Shoulders

Paved shoulders are a common feature on rural state highways and consist of at least a 3-foot paved area to the right of the edge line which provides on-road bicycle accommodations. See FDM 11-15-1.7 and FDM 11-15-1.8 for more information on paved shoulder width and rumble strip installation on modernization projects. Also, see FDM 11-15, Attachment 1.5 and FDM 11-15-5.3.2.

For paved shoulder and rumble strip information on rehabilitation projects, see FDM 11-40-1.5.1 and FDM 11-40-1.7.1.

Table 15.2 shows minimum rural paved shoulder widths for on-road bicycle accommodations. If a wider paved shoulder is called for in FDM 11-15-1 or FDM 11-15-5, then use that width. Paved shoulders with shoulder rumble strips may require additional width.

Typically, paved shoulders result in just a small marginal project cost, especially on modernization and rehabilitation projects. In some cases, it may be necessary to rebuild or widen the shoulder to provide wider paved shoulders, which could result in adding substantial costs for the project. In these cases, it may be appropriate to widen the paved shoulders as much as possible even if falling short of the required width. However, local conditions and expected bicycle use must be thoroughly evaluated. Additionally, on some lower volume state and county highways, a 3-foot paved shoulder may be acceptable where the overall shoulder widths are currently not wide enough to support a wider paved shoulder and are not being widened as part of a project. See the "WisDOT Rural Bicycle Planning Guidelines".

Use these guidelines as an aid to determine the suitability of roadways when 3-foot paved shoulders are the only feasible option. If these guidelines indicate a rating of "moderate conditions for bicycling" for the design year ADT, 3' paved shoulders are permitted under this procedure.

Table 15.2 Minimum Paved Shoulder Width for On-Road Bike Accommodation on Rural Roads

Design Year AADT	Conditions from Table 15.1	Adjacent Travel Lane Width (feet)	Paved Shoulder Width (feet)	
			without shoulder rumble strip*	with shoulder rumble strip
< 750	Meets 0 or more of conditions 1, 2, 3, or 4 AND DOES NOT meet condition 5 none of the conditions are met	10	4	5
		11 or 12	3	5
	Meets 0 or more of conditions 1, 2, 3, or 4 AND Meets condition 5	10, 11 or 12	4	5
>= 750	DOES NOT meet ANY of conditions 1, 2, 3, 4, or 5	10	4	5
		11 or 12	3	5
750-1,499	Meets 1 or more of conditions 1, 2, 3, 4, or 5	10 or 11	4	5
	Meets 1 or more of conditions 1, 2, 3, or 4 AND DOES NOT meet condition 5	12	3	5
	Meets 0 or more of conditions 1, 2, 3, or 4 AND Meets condition 5	12	4	5
1,500-1,999	Meets 1 or more of conditions 1, 2, 3, 4, or 5	11	5	5
	Meets 1 or more of conditions 1, 2, 3, or 4 AND DOES NOT meet condition 5	12	4	5
	Meets 0 or more of conditions 1, 2, 3, or 4 AND Meets condition 5	12	5	5
>= 2,000	Meets 1 or more of conditions 1, 2, 3, 4, or 5	11 or 12	5**	5**

* Width is OK if Rumble Strips (see SDD 13A10-b, "Type 2 Milled Rumble Strip") used instead of shoulder Rumble Strips

** When AADT exceeds 4,500, a 6ft paved shoulder is advisable[18]

15.5 Shared Roadways

On a shared roadway, there is inadequate pavement width or paved shoulder width for motorists and bicyclists to operate side-by-side, i.e., bicyclists share the same travel lane with motorists.

Shared roadways do not comply with criteria for a bikeway and are not a bike accommodation. However, shared roadways are appropriate under certain conditions.

[18] *Table 2.1 page 2-19 of reference (4) Wisconsin Bicycle Facility Design Handbook*. Wisconsin DOT, 2004. http://www.dot.wisconsin.gov/projects/state/docs/bike-facility.pdf, Table 2.1 on p.2-19

15.5.1 Shared Roadways on Urban Streets

Residential streets in communities that are not functionally classified almost always have low enough speeds and traffic volumes (design year <1,500 ADT) that bicyclists can use most of or the entire travel lane for bicycling. No special bicycle accommodations are necessary on these roadways. The low volume of traffic provides ample passing opportunities for motorists and increases the comfort level for bicyclists. Use the "Pavement Marking for Shared Lanes" shown in SDD 15c29-f to help increase motorists' awareness of bicyclists.

Another application of a shared roadway on an urban street is providing a shared parking/bicycle lane of less than 12 feet. This is not a bicycle accommodation but can be justified for short segments in highly constrained environments (e.g., through a two-block downtown segment or commercial zone where buildings are directly adjacent to the sidewalk).

Consider a shared parking / bicycle lane of less than 12 feet (next to 11-foot or wider travel lanes) if parking usage is 20% or less, even during peak parking periods, and the following thresholds are met for residential areas (these are based on the FHWA Bicycle Compatibility Index):

1. For street widths of 44 feet from curb face to curb face and posted speeds of 25 mph, design year AADTs of 5,000 or less
2. For street widths of 44 feet from curb face to curb face and posted speeds of 30 mph, design year AADTs of 4,000 or less
3. For street widths of 42 feet from curb face to curb face and posted speeds of 25 mph, design year AADTs of 4,000 or less
4. For street widths of 42 feet from curb face to curb face and posted speeds of 30 mph, design year AADTs of 2,500 or less

Use the following thresholds for commercial and industrial areas with 20 percent parking use or less:

1. For street widths of 44 feet from curb face to curb face and posted speeds of 25 mph, design year AADTs of 3,000 or less
2. For street widths of 44 feet from curb face to curb face and posted speeds of 30 mph, design year AADTs of 1500 or less

15.5.2 Shared Roadway on Rural Highways

A Rural highway is a shared roadway if it has no paved shoulder or it has a paved shoulder whose width is less than the minimum required width for a bicycle accommodation shown in Table 15.2. A shared roadway on a rural highway is not a bike accommodation and does not comply with criteria for a bikeway. A shared roadway is not appropriate other than on very low volume roads - less than 750 ADT - and sometimes not on those. However, with very low volumes, motorists will generally have ample passing opportunities and additional features are usually not necessary for compatibility with bicycling.

15.6 Shared-use Paths

See chapter 4 of the Wisconsin Bicycle Facility Design Handbook *(4)* for guidance on shared-use path design.

According to FHWA website "Shared Use Paths Along or Near Freeways and Bicycles on Freeways" *(18)*, "the term "shared-use path" means a multi-use trail or other path, physically separated from motorized vehicular traffic by an open space or barrier, either within a highway right-of-way or within an independent right-of-way, and usable for transportation purposes. Shared use paths may be used by pedestrians, bicyclists, skaters, equestrians[19], and other non-motorized[20] users."

Bicyclists are legal users of roadways, and the first responsibility is to provide on-road accommodations for bicycles where appropriate. Shared-use paths shall only replace on-road bicycle accommodations in exceptional situations (e.g. bicyclists and pedestrians prohibited). In certain situations, shared-use paths can supplement on-road bicycle accommodations, or be used in place of a sidewalk (on a given side of the road) as a pedestrian facility.

The decision to use shared-use paths along roadways must meet the guidelines found in this procedure and in

[19] Equestrian use is not typical on shared-use paths.

[20] Although shared-use paths are usually non-motorized facilities, there are some state trails in Wisconsin that permit snowmobile use.

the “Wisconsin Bicycle Facility Design Handbook” (4).

Because it is a facility intended for pedestrian use, American with Disabilities Act (ADA) regulations and guidance shall also be followed in the design of these projects. The width of a shared-use path is 10 feet (see Figure 15.6). Use the width unless there is justification for using a different width. See section 4.4 of the Wisconsin Bicycle Facility Design Handbook for guidance when considering a non-standard width.

A minimum 5-foot separation of a shared-use path from the roadway shoulder or curb is required and the separation should be as wide as practical (and preferably outside the clear zone) to prevent operational and safety problems that may occur when two-way bike traffic operates adjacent to motor vehicle traffic.

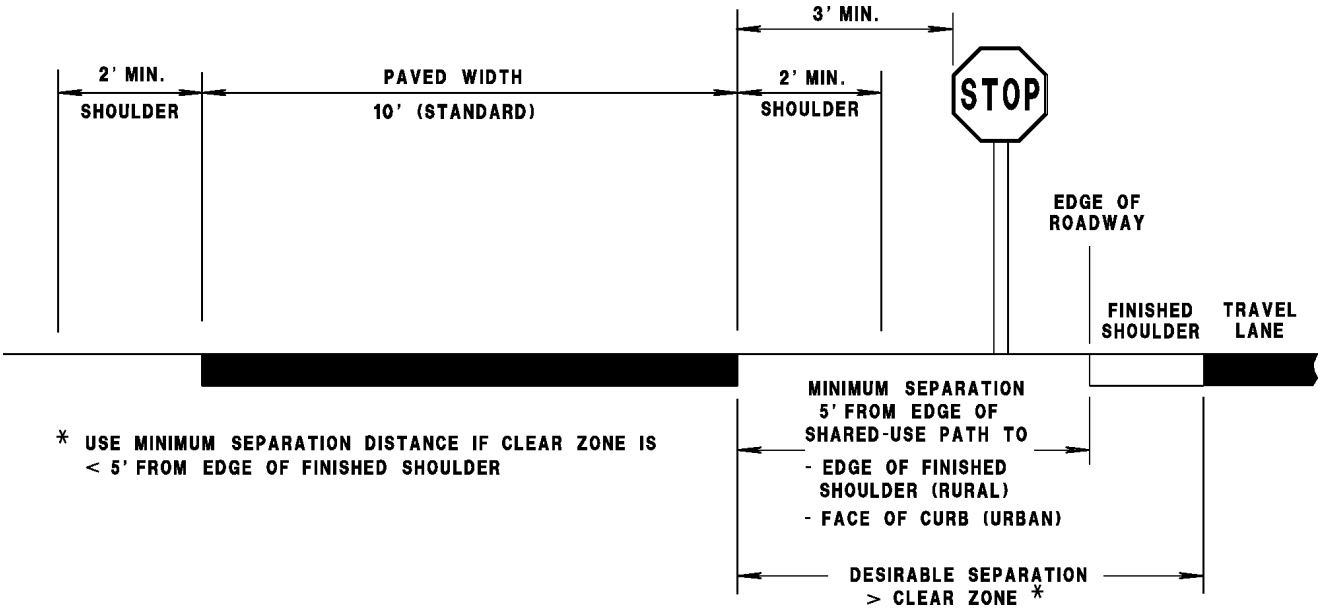


***Figure 15.6* Shared-use Path Design**

A shared-use path is generally more expensive to construct and maintain than bike lanes or paved shoulders. In addition, a shared-use path may be a less direct route for a bicyclist and safety is often a concern at street intersections or driveways when a shared-use path is located adjacent to a roadway. Nevertheless, under some circumstances, a shared-use path may be the best option but does not substitute or preclude the need to provide on-street bicycle accommodations.

In a rural setting, there are fewer intersection and driveway crossings than in urban/suburban areas. This reduces potential hazards for bicyclists and helps make a shared-use path for bicyclists a viable option, particularly when 2-lane roadways are re-designed as expressways or freeways, typically with posted speed limits over 55 mph. The greatest opportunity to include a shared-use path presents itself when real estate is being purchased for the expansion of a roadway.

Consider a shared-use path on a rural highway if either of the following guidelines apply and right-of-way is either available or can be readily acquired through the real estate acquisition process.

1. Safety and Access: When rural highways undergo changes that will cause restrictions for bicyclists and pedestrians, and posted speeds increase to over 55 mph, a shared-use path is often a viable solution to provide a bike accommodation. This is especially relevant when there are no frontage roads or nearby parallel roadways (within one-half mile). When a new 4-lane roadway is built on the alignment of an existing 2-lane roadway, bicyclists and pedestrians still need to access the corridor. In other cases, bicyclists and pedestrians may be permitted, but high speeds (over 55 mph) on 4-lane highways make on-road bicycling difficult and undesirable. Though shared-use paths are generally more expensive to construct and maintain than paved shoulders, in certain situations they are the best way to provide connectivity for short to moderately long distances in this type of setting.

2. Usage: Usage is expected to be at least moderate (25 users per day). Good indicators of sufficient future path usage include connections between specific destinations (e.g., schools, major subdivisions, parks), or connections between two communities separated by 5 miles or less, or regional connections that may extend more than 5 miles. In urban or suburban areas, shared-use paths next to roadways can pose operational problems and often increase the hazards to bicyclists,

particularly at intersections and driveways. For this reason, on-street bicycle accommodations are almost always the best choice.

Use the following guidelines to evaluate whether a shared-path is an appropriate choice in urban and suburban areas. Most of the conditions shall be met.

1. Considerable numbers of bicyclists and pedestrians are expected to use the facility daily.
2. The shared-use path is sited in a sound location for travel by bicyclists and pedestrians. This usually occurs where there are both high traffic volumes and vehicle speeds on the adjacent roadway and the shared-use path would not have to cross many roadways or driveways (especially commercial driveways). Only in rare cases would the path substitute for on-street bicycle accommodations.
3. There are no reasonable alternatives for bicycle accommodations on nearby parallel roadway routes.
4. The shared-use path connects to an existing or planned bicycle facility (shared-use path or another bikeway) or street/road where bicycle travel is accommodated. For instance, the shared-use path would be part of a larger bicycle transportation network that provides continuity for bicycle travel. As an alternative, a shorter shared-use path could provide direct access to a park, school, business district, etc. Where the shared-use path will be part of a planned bicycle facility that does not yet exist, the local government should provide a written commitment to complete the facility within a reasonable time frame.
5. The shared-use path is consistent with local, regional and state adopted land use/smart growth plans and current transportation plans for the area by an MPO, local or state government.
6. There is ample room for the shared-use path itself and for its separation from the roadway.
7. There is a reasonable expectation that the safety and service benefits derived from the shared-use path would be worth the total cost of the facility, including right of way, construction, marking and signing, and maintenance.

15.6.1 Roundabout Sidepaths

A roundabout sidepath is a variant of a shared-use path. “A “roundabout sidepath” is a sidepath around the perimeter of an isolated roundabout or a sidepath between two closely spaced roundabouts and around their perimeters. Bicyclists on the roadway enter and exit roundabout sidepaths via ramps upstream and downstream from the roundabout circular roadway. Bicycle traffic on roundabout sidepaths is assumed unidirectional. Roundabout sidepaths connect to sidewalks where there are sidewalks and are standalone facilities where there are no sidewalks. Roundabout sidepaths do not connect to community/region shared-use paths. See FDM 11-26-30.5.13 for additional information.

15.7 Bicycle Accommodations on Highway Structures

See FDM 11-35-1.6, “Structures/ Sidewalks, Bicycle Accommodations, Shared Use Paths and Roundabout Sidepaths”, and FDM 11-35 Attachments for width requirements for sidewalks, shared-use paths and roundabout sidepaths, as well as criteria and height requirements for parapets and fences adjacent to bikeways, sidewalks, shared-use paths or roundabout sidepaths.

Also, See section 2.9, “Structures”, and section 4.16.4 “Separation on Combined Structures” of the Wisconsin Bicycle Facility Design Handbook *(4)* for guidance.

Generally, continue the bicycle accommodations provided (or planned) on the approaches to a structure across the structure. New highway structures need to be wide enough to accommodate required bikeways and sidewalks, shared-use paths or roundabout sidepaths. Width requirements vary depending on whether the bikeway is a wide outside lane, a continuation of a paved shoulder, a bike lane, a shared-use path, or roundabout sidepath; and whether there is a sidewalk.

In urban and suburban areas, the preferred design is a 6-foot striped area (unmarked or marked as bike lanes). The 6-foot shoulder on the structure is typically comprised of the width needed off the structure to accommodate a 2-foot gutter and a 4-foot bike lane. The next preferred design is a 4 or 5-foot striped area (not marked as a bike lane). If the bike accommodation on the approach roadway is a wide outside lane, the minimum accommodations is at least 14-foot lane, not including curb and gutter, or if next to a parapet or concrete barrier, provide a 4-foot shy distance.

Current design criteria for clear roadway width of structures for most – but not all - rural highway design classes provide adequate width for bicycle accommodations (see FDM 11-15 Attachments 1.1 thru 1.4 and FDM 11-15 Attachment 1.16 thru 1.18). Also, see FDM 11-35-1 and FDM 11-26-30-5.13 for additional information on structure widths.

At some locations, it may be appropriate to provide a shielded shared-use path in addition to bike lanes, wide outside lanes or shoulders across the structure. This situation arises when a structure (or the roadway under a structure) provides continuity for a shared-use path serving a different corridor than the highway.

For example, a shared-use path could follow a river corridor and use the bridge to cross to the other side of the river where it will continue to follow the same river corridor. At the same time, the bridge and the highway leading to and from the bridge could serve an entirely different corridor. Having only a shared-use path facility would be especially problematic for cyclists who are traveling on the opposite side of the bridge who would have to cross several lanes of traffic to get to and from the shared-use path. These cyclists are not likely to have an origin or destination served by the shared-use path.

15.7.1 Shared-use Path Grade Separations

Safety concerns may require providing a grade separation structure for a shared-use path rather than an at-grade crossing on rural highways (see FDM 11-46-20, “Permanent Public Trails Crossing Rural Public Roads”).

Guidance is limited on design treatments for intersections involving shared-use paths and roadways in urbanized areas. Constrained environments are often an additional impediment to providing grade-separated facilities in urbanized areas. Use engineering judgment to decide when such safety measures are necessary and cost effective by considering traffic volumes, motor vehicle speeds, site conditions and the age and experience of typical bicyclists. One possibility is to consider bicyclist and pedestrian actuated traffic signals where shared-use paths intersect high speed/high volume highways or streets.

15.8 Inlet, Manhole and Utility Covers

Inlet, manhole and utility covers can be hazardous to bicyclists. The front wheel of a bicycle may drop into the openings of the parallel bar drainage grates causing the bicyclist to crash. Likewise, grates and utility covers that are not flush with the pavement surface and located in bicyclists' expected path can cause the bicyclists to crash.

The grates for the following inlet cover Types A, H, B, B-A, F, HM, HM-GJ, S, and Z are considered bicycle acceptable. The inlet covers which are narrow and therefore encroach the least into a bicycle curb lane and that use the vane style grate are Types A, H, and HM. These inlet cover types should be used for modernization projects and also as replacement covers for Perpetuation and Rehabilitation improvements providing they have the necessary hydraulic capacity.

Pavement overlays should be designed and constructed to taper into grates and covers to prevent an abrupt drop at the frame edge. As an alternative, the inlet grate or utility cover can be adjusted to be flush with the new surface. Do this regardless of work type, whenever grates are installed where there might be bicycle traffic.

15.9 At-Grade Railroad Crossings

Where possible, a bikeway should cross railroad tracks at or near a right angle to minimize the potential for trapping a bicyclist's front wheel in the flangeway and causing a loss of steering control.

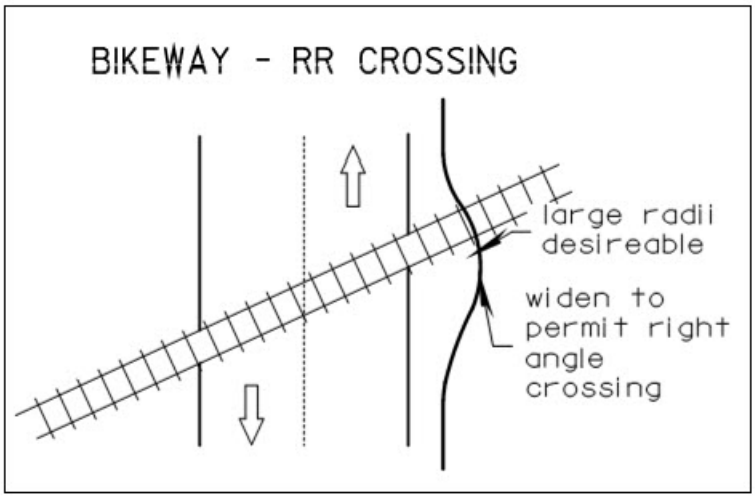


***Figure 15.7* Bikeway – Railroad Crossing Detail**

If the crossing angle is less than approximately 60 degrees, consider widening the outside lane, shoulder or bicycle lane to improve the angle of approach (see Figure 15.7). The typical crossing angle is 60 ° to 90° (AASHTO) (17).

It is also important that the roadway surface be at the same elevation as the rails. The type of crossing surface is negotiated between WisDOT and the railroad company on state highway projects.

15.10 Signing and Marking

Marking and signing of bicycle accommodations and bikeways shall be in accordance with the Wisconsin Manual on Uniform Traffic Control Devices (MUTCD) and applicable local ordinances. Additionally, use the WisDOT Traffic Engineering Operations and Safety Manual (TEOpS) for state highway projects.

The Region Traffic Engineer determines marking and signing requirements for the state highway system. It is permissible and encouraged to provide a marked shoulder segment not only on rural cross-section highways, but also on urban cross-section streets.

Pavement marking and signing are especially important at the approaches to intersections and at the ends of a bike lane. At intersections, bicyclists proceeding straight through and motorists turning right must cross paths. Motorists/bicyclists should be encouraged to make these crossings in advance of the intersection if possible. When a marked bike lane exists at an intersection with an exclusive right-turn only lane, the bike lane must be located between the exclusive right-turn lane and the through travel lane. Two channelizing lines without bike symbols (although bike lanes symbols are recommended) or a wider through lane are typical in order provide adequate bike accommodations to the left of an exclusive right-turn lane and to the right of a through travel lane (see SDD 15c29).

Appropriate marking and signing is essential where bike lanes end. These locations require bicyclists to merge with motor vehicle traffic.

15.11 References

Refer to FDM 11-46-99 for list of references.

FDM 11-46-20 Permanent Public Trail Crossing Rural Public Roads

November 30, 2018

20.1 Introduction

A trail (path) is a travel way, physically separated from motor vehicle traffic by an open space or barrier. It can be either within a highway right-of-way or within an independent corridor, such as a former railroad right-of-way. On-road bikeways such as bike lanes, paved shoulders or signed bike routes are not considered trails.

The “Engineering Warrants for Trail-Highway Crossings”, along with the guidelines presented in this procedure, apply only to permanent public trails crossing rural public roads with posted speeds from 40 to 55 mph. They are meant to be a starting point in determining whether a crossing is to be grade separated or at-grade. Final determination of the appropriate crossing type requires the application of engineering judgment.

Safety is the primary factor determining whether a grade separation structure or an at-grade treatment will be needed for a crossing. Other important considerations include cost, cost sharing with the trail owner, maintenance, and maintenance responsibilities. A project agreement is needed in order to define the public trail owner’s cost sharing and maintenance responsibilities.

Crossings not covered in this procedure include:

- Permanent public trails crossing urban roadways. Trails in urban areas may require moreflexibility.
- Temporary trails. Temporary trails, where land easements are established year-to-year, are to be handled through WisDOT right-of-way access permit process.
- Nonpublic trails. Private trails are often temporary in nature. To be eligible for cost sharing, a privately-owned trail must be put into the hands of a public sponsor, who will ensure its long-term use

20.2 Engineering Warrants For Trail-Highway Crossings

Warrants for trail-highway crossings must consider the potential users of the crossing. Trail users can be categorized into two types, motorized and non-motorized. Motorized users include snowmobilers and all-terrain vehicles (ATV) users. Non-motorized users include bicyclists and pedestrians but can include equestrians as well.

The engineering warrants for trail-highway crossings shown in Attachment 20.1 are based on gap analysis, similar to the method found in the Manual of Uniform Traffic Control Devices (MUTCD) for determining warrants for traffic signals. Gap analysis helps to identify whether there are sufficient gaps in traffic for users to safely and comfortably cross a roadway with little delay. Justification for using these warrants for trail-highway crossings is based on:

- Snowmobiles and ATV’s are motorized vehicles, and traffic signal warrants were developed for motorized vehicle crossings.

- Grade separations and traffic signals have similar purposes, i.e. reducing potential conflicts between opposing streams of traffic.

The MUTCD warrants most applicable to trail-highway crossings are those that address hourly, as opposed to daily, trail and highway volumes, namely the Fourth Highest Hourly Exposure Factor and the Highest or Peak Hourly Exposure Factor.

In addition, these warrants include special reduction factors for pedestrians and bicyclists. Because non-motorized trail users include pedestrians, the reduction factors recommended in the MUTCD for pedestrians are applied to all non-motorized users when applying the engineering warrants for trail-highway crossings.

20.2.1 Steps to Follow When Using the Engineering Guidelines

1. Determine the proposed posted speed of the roadway to be evaluated for a grade separation under this procedure. The road must have a posted speed limit between 40 and 55 mph, because urban conditions typically exist when the speed limit is less than 40 mph.

2. Obtain site information for crossing location, including existing crossing type, available sight distance, structure dimensions and condition, trail owner, etc.

3. Obtain current and design year traffic volumes for both highway and trail (both motorized and non-motorized) users.

4. Evaluate traffic counts. Use current traffic counts for perpetuation or rehabilitation roadway projects with trail crossings within the project limits, as they have a shorter user life. Use design year traffic counts (typically 20 years), for modernization roadway projects with trail crossings within the project limits. When determining design year trail counts, a 1-2% per year trail growth is recommended.

   To be considered for a grade separation, the minimum highway Average Daily Traffic (ADT) is recommended to be 3500 or greater. (This threshold is a starting point and does not preclude looking at highways with ADT's < 3500). Determine if trail users are predominantly motorized or non-motorized (Use Attachment 20.2 worksheet).

5. Calculate Exposure Factors. Once the traffic counts for the trail and highway have been obtained, exposure factors need to be calculated for the entire counting period. An "Exposure Factor" is the product of the highway volume times the trail volume during the same hour that the count was taken. The result is then divided by 1000 to obtain an exposure factor that can be compared with those listed in Attachment 20.1.

   The "Fourth Highest Exposure Factor" represents the fourth highest product over the traffic counting period, and the "Highest Exposure Factor" is the highest product over the same traffic counting period.

   Attachment 20.3 shows examples of calculating exposure factors.

6. Using the Engineering Warrant Table. The engineering warrant table in Attachment 20.1 has three columns to be used as a starting point for helping decide whether to build a grade separation or not. The numbers in each column are the exposure factors in thousands. They differ depending on whether the trail users are predominantly motorized or non-motorized. Find the cells that match the computed "Fourth Highest Exposure Factor" and the "Highest Exposure Factor". The value in the right-most column controls.

   6.1 The first column "Does Not Meet Warrants" indicates that a grade separation is not warranted for traffic volumes. However, a grade separation might still be provided if site conditions would make an at-grade crossing unsafe.

   6.2 The second column "May be Justified" indicates that a grade separation may be justified for traffic volumes. However, evaluate other alternatives because grade separations can present their own safety problems. Sight lines, available gaps in traffic and future trail plans are some of the factors to be considered. Alternatives to a grade separation may include:

   - Improving the sight distance for the trail and highway user.
   - Evaluating traffic signal alternatives in fringe/suburban areas to provide more gaps in traffic.
   - Relocating the trail to a safer crossing area.
   - Relocating the trail crossing to an existing grade separation.
   - Enhanced signing and marking.

   6.3 If the other alternatives for the site are found to be either inadequate or not appropriate, then a grade separation is justified. The third column "Meets WisDOT Warrants" indicates that a

grade separation is warranted for traffic volumes, unless circumstances such as poor site conditions require that other alternatives be considered.

7. Present alternative(s) to the trail owner, including cost estimates and cost sharing information. Accommodate trail owner's request - even for a grade separation at a location where it is not warranted or justified - if it is possible to do so without compromising the safety of either motorists or trail users, and if the trail owner agrees to the required cost share and maintenance responsibilities.

20.3 Freeways and Expressways

20.3.1 Freeways

Freeways are multi-lane divided highways on which access is provided only at interchanges. Do not allow at-grade trail crossings on freeways.

20.3.2 Expressways

Expressways are non-freeway multi-lane divided highways where access is provided at interchanges and at at-grade intersections. Do not allow new at-grade trail crossings on expressways with posted speeds greater than 55 mph. Consider grade-separating existing at-grade crossings when they are within the limits of highway improvement projects on these routes. Work with the trail owner when making this determination. Look at such things as trail use and volume, crash history and the type of impending improvement project (modernization projects will offer a greater opportunity to incorporate a grade separation than a perpetuation project would).

Trail crossings on expressways with posted speeds of 55 mph, or less, can be evaluated with the procedures in this section. Warrant thresholds are adjusted per Note 1 of Attachment 20.1.

20.4 At-Grade Treatments

- Design trails to cross roadways at right angles, and at relatively flat grades.
- Provide sufficient intersection and approach sight distances at crossings for both motorists and trail users (see Attachment 20.4). Improve sight distance by removing trees or brush, lowering highway profile or relocating a trail to a more visible area. Evaluate traffic signal options in suburban area to see if it is possible to provide more available gaps in traffic.
- Provide median refuge for trail users at wider crossings and at other crossings, if appropriate.
- Provide appropriate traffic control devices and markings for both roadway and trail. This includes advance warning, including, if necessary, flashing signals. Use signs that are large enough to meet the size requirements for trail speed on trails that allow motorized vehicles. Also, traffic signals may be appropriate at some suburban locations. Review signing and marking options with the region traffic engineer.

20.5 Grade Separation Structure Guidance

In addition to structural requirements, a grade separation structure for a trail-highway crossing must meet the following minimum requirements:

- Provide for the safety of both trail and highway users. Although a grade separation reduces potential conflicts between trail users and motorists, the structure itself can pose a hazard. In addition to being a fixed obstruction, structures can be more prone to icing.
- Build structures large enough to accommodate maintenance equipment, including snow-grooming equipment on trails where snowmobiles are allowed.
- Box culvert-type structures must have sufficient height and width to accommodate trail users.

Structures for trail crossings include box culverts, as well as bridge overpasses or underpasses. Also, as an alternative to building a new structure, consider relocating the trail crossing to a suitable nearby existing grade separation.

Consult with the Regional Bike and Pedestrian Coordinator as well as the Bureau of Structures if a grade separation for a permanent public trail is warranted.

20.5.1 Structures on a "Rails-to-Trails" Trail

"Rails-to-Trails" trails are railroad corridors that have been deeded to a public agency (usually the DNR) and converted to interim trail use. The corridors must be preserved for possible re-conversion to railroad use. If re-conversion is necessary, then the corridor is sold to the railroad company involved.

Existing structures on these corridors may be in use as grade separations at trail-highway crossings. If a "Rails to Trails" structure is included within the limits of a highway project, evaluate the crossing based on the guidelines presented in this procedure. The possibility of re-conversion to railroad use presents additional

factors to consider when making the final determination of crossing treatment, including:

- Whether to perpetuate a grade separation, even if it is not warranted
- Whether to design a structure to accommodate railroad use, or to accommodate trail use only

Contact the Bureau of Railroads and Harbors for additional information on "Rails-to-Trails" corridors.

20.6 Financial and Cost Share Responsibilities

Cost share percentages for trail-highway crossings are in the WisDOT's Program Management Manual (PMM) Chapter 02-05-25. Apply these percentages to the Net Structure Cost:

NET STRUCTURE COST = STRUCTURE COST - COST FOR AN AT-GRADE CROSSING

These cost share percentages apply only when:

1. The trail crossing is included as part of a WisDOT highway improvement project: Projects will be given consideration based on safety needs and engineering warrant criteria. In cases where there is not a highway improvement project, communities may be able to find funding help from one of the programs listed in "Programs for Local Governments" website.
2. The trail is publicly owned.
3. A privately-owned trail has been put into the hands of a public sponsor, who ensures its long-term use.
4. The trail crosses existing highway alignment. In cases of new alignment where WisDOT's highway impacts an existing trail, WisDOT would work with the trail owner to provide the appropriate crossing type and to negotiate a cost share.
5. The has no pre-existing agreements. (including those with the former railroad). Existing agreements may take precedence. Contact the Bureau of Railroads and Harbors when a WisDOT project impacts a "Rails-to-Trails" crossing, because pre-existing agreements with the former railroad owner may take precedence.
6. The trail is a permanent facility. Temporary trails will be handled through WisDOT's access permit approach process.

Contact WisDOT's Region Planning Office or WisDOT's Division of Transportation Investment Management (DTIM) for more information.

20.6.1 Maintenance Agreements

Maintenance Policy for trail-highway crossings are also in WisDOT's Program Management Manual (PMM) Chapter 02-05-25. Include the following provisions in a signed maintenance agreement, unless over-ridden by a pre-existing agreement:

1. For at-grade crossings, trail owners would be responsible for the maintenance of trails on WisDOT right-of -way.
2. For grade separations, trail owners would be responsible for funding the maintenance cost of the structure. WisDOT would be responsible for structure inspection.

LIST OF ATTACHMENTS

Attachment 20.1	Grade Separation Warrants
Attachment 20.2	Grade Separation Warrant Worksheet
Attachment 20.3	Sample Grade Separation Warrant Determination
Attachment 20.4	Sight Distance for Trail Crossing

FDM 11-46-99 References *July 23, 2015*

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May 21, 2010

In Reply Refer To:
HDA-WI

Secretary Frank Busalacchi
Wisconsin Department of Transportation
4802 Sheboygan Avenue, Room 120B
Madison, WI 53707

Dear Secretary Busalacchi:

We are writing in response to your request for guidance concerning the apparent conflict between State law and Federal policy regarding the recently enacted State Statute 84.01(35), addressing State Policy on Bicycle and Pedestrian ways, which we have enclosed for your reference. Our Headquarters office has reviewed your new statute and has provided us guidance.

Federal emphasis to incorporate pedestrian and bicycle accommodations on improvement projects has recently been elevated in a new US DOT policy as the Federal Government continues to promote livable communities and complete streets. We are pleased with the overall intent of the new law which will increase this national emphasis.

FHWA policy for pedestrian and bicycle accommodations are as follows:

Bicycle and pedestrian ways shall be established in new construction and reconstruction projects in all urbanized areas unless one or more of three conditions are met:

- Bicyclists and pedestrians are prohibited by law from using the roadway. In this instance, a greater effort may be necessary to accommodate bicyclists and pedestrians elsewhere within the right of way or within the same transportation corridor.
- The cost of establishing bikeways or walkways would be excessively disproportionate to the need or probable use. Excessively disproportionate is defined as exceeding twenty percent of the cost of the larger transportation project.
- Where sparsity of population or other factors indicate an absence of need. For example, the Portland Pedestrian Guide requires "all construction of new public streets" to include sidewalk improvements on both sides, unless the street is a cul-de-sac with four or fewer dwellings or the street has severe topographic or natural resource constraints.

State Law 84.01(35) appears less restrictive than federal policy for certain projects. We note three of the state exceptions are fully consistent with our three Federal exceptions. However, there are two additional state exceptions in the Statute that allow an agency not to include adding sidewalks in a case where State exception #3 *"Establishing bikeways or pedestrian ways would*

have excessive negative impacts in a constrained environment" or State exception #5 "*The community where pedestrian ways are to be located refuses to accept an agreement to maintain them."* The last exception raises considerable concern and is unacceptable for use on National Highway System (NHS) projects. The NHS projects require FHWA approval of design standards, and lacking proper project design standards jeopardizes federal-aid funds on the entire project per the requirements in 23 CFR 625.2 & 3.

Therefore, if a NHS project proposes not to include sidewalks based on State exception #5, that will cause us not to authorize the project. The prohibition on the use of this State exception on NHS projects should be brought to the attention of local agencies during the planning process in order to preclude the requirement of a possible payback situation for federal-aid funded design work.

In addition, we strongly encourage the WisDOT to minimize the use of the State exception #5 on non-NHS projects. Regarding State policy exemption #3, *"Establishing bikeways or pedestrian ways would have excessive negative impacts in a constrained environment,"* we believe this exception may be addressed in the environmental process and may have applicability to one or more of the three federal exemptions. However, this can be addressed on a project by project basis.

In addition, we want to know if a local government decides to exercise state exception #5, to determine federal eligibility, and we encourage our early involvement in these decisions.

If you have any questions or concerns regarding these terms and conditions please contact John Berg at (608) 829-7515.

Sincerely,

George R. Poirier, P.E.
Division Administrator

Enclosure

ecc: Rubin Anthony (WisDOT)
~~Chris Cline~~ (WisDOT) Christopher Klein
Thomas Huber (WisDOT Statewide Planning Unit)
Kevin Chesnik (WisDOT DTSD)
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John Berg
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Bill Bremer

Wisconsin State Law

84.01(35) (a) In this subsection:

1. "Bikeway" has the meaning given in s. 84.60 (1) (a).
2. "Pedestrian way" has the meaning given in s. 346.02 (8) (a).

(b) Except as provided in par. (c), and notwithstanding any other provision of this chapter or ch. 82, 83, or 85, the department shall ensure that bikeways and pedestrian ways are established in all new highway construction and reconstruction projects funded in whole or in part from state funds or federal funds appropriated under s. 20.395 or 20.866.

(c) The department shall promulgate rules identifying exceptions to the requirement under par. (b), but these rules may provide for an exception only if any of the following apply:

1. Bicyclists or pedestrians are prohibited by law from using the highway that is the subject of the project.

2. The cost of establishing bikeways or pedestrian ways would be excessively disproportionate to the need or probable use of the bikeways or pedestrian ways. For purposes of this subdivision, cost is excessively disproportionate if it exceeds 20 percent of the total project cost. The rules may not allow an exception under this subdivision to be applied unless the secretary of transportation, or a designee of the secretary who has knowledge of the purpose and value of bicycle and pedestrian accommodations, reviews the applicability of the exception under this subdivision to the particular project at issue.

3. Establishing bikeways or pedestrian ways would have excessive negative impacts in a constrained environment.

4. There is an absence of need for the bikeways or pedestrian ways, as indicated by sparsity of population, traffic volume, or other factors.

5. The community where pedestrian ways are to be located refuses to accept an agreement to maintain them.

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NOTE: Document can be found at: https://www.fhwa.dot.gov/civilrights/programs/doj_fhwa_ta.cfm

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Civil Rights

U.S. Department of Justice
Civil Rights Division
Disability Rights Section

U.S. Department of Transportation
Federal Highway Administration

Department of Justice/Department of Transportation Joint Technical Assistance[1] on the Title II of the Americans with Disabilities Act Requirements to Provide Curb Ramps when Streets, Roads, or Highways are Altered through Resurfacing

Title II of the Americans with Disabilities Act (ADA) requires that state and local governments ensure that persons with disabilities have access to the pedestrian routes in the public right of way. An important part of this requirement is the obligation whenever streets, roadways, or highways are *altered* to provide curb ramps where street level pedestrian walkways cross curbs.[2] This requirement is intended to ensure the accessibility and usability of the pedestrian walkway for persons with disabilities.

An alteration is a change that affects or could affect the usability of all or part of a building or facility.[3] Alterations of streets, roads, or highways include activities such as reconstruction, rehabilitation, *resurfacing*, widening, and projects of similar scale and effect.[4] Maintenance activities on streets, roads, or highways, such as filling potholes, are not alterations.

Without curb ramps, sidewalk travel in urban areas can be dangerous, difficult, or even impossible for people who use wheelchairs, scooters, and other mobility devices. Curb ramps allow people with mobility disabilities to gain access to the sidewalks and to pass through center islands in streets. Otherwise, these individuals are forced to travel in streets and roadways and are put in danger or are prevented from reaching their destination; some people with disabilities may simply choose not to take this risk and will not venture out of their homes or communities.

Because resurfacing of streets constitutes an alteration under the ADA, it triggers the obligation to provide curb ramps where pedestrian walkways intersect the resurfaced streets. See *Kinney v. Yerusalim*, 9 F 3d 1067 (3rd Cir. 1993). This obligation has been discussed in a variety of technical assistance materials published by the Department of Justice beginning in 1994.[5] Over the past few years, state and local governments have sought further guidance on the scope of the alterations requirement with respect to the provision of curb ramps when streets, roads or highways are being resurfaced. These questions have arisen largely due to the development of a variety of road surface treatments other than traditional road resurfacing, which generally involved the addition of a new layer of asphalt. Public entities have asked the Department of Transportation and the Department of Justice to clarify whether particular road surface treatments fall within the ADA definition of alterations, or whether they should be considered maintenance that would not trigger the obligation to provide curb ramps. This Joint Technical Assistance addresses some of those questions.

Where must curb ramps be provided?

Generally, curb ramps are needed wherever a sidewalk or other pedestrian walkway crosses a curb. Curb ramps must be located to ensure a person with a mobility disability can travel from a sidewalk on one side of the street, over or through any curbs or traffic islands, to the sidewalk on the other side of the street.

However, the ADA does not require installation of ramps or curb ramps in the absence of a pedestrian walkway with a prepared surface for pedestrian use. Nor are curb ramps required in the absence of a curb, elevation, or other barrier between the street and the walkway.

When is resurfacing considered to be an alteration?

Resurfacing is an alteration that triggers the requirement to add curb ramps if it involves work on a street or roadway spanning from one intersection to another and includes overlays of additional material to the road surface, with or without milling. Examples include, but are not limited to, the following treatments or their equivalents: addition of a new layer of asphalt, reconstruction, concrete pavement rehabilitation and reconstruction, open-graded surface course, micro-surfacing and thin lift overlays, cape seals, and in- place asphalt recycling.

What kinds of treatments constitute maintenance rather than an alteration?

Treatments that serve solely to seal and protect the road surface, improve friction, and control splash and spray are considered to be maintenance because they do not significantly affect the public's access to or usability of the road. Some examples of the types of treatments that would normally be considered maintenance are: painting or striping lanes, crack filling and sealing, surface sealing, chip seals, slurry seals, fog seals, scrub sealing, joint crack seals, joint repairs, dowel bar retrofit, spot high-friction treatments, diamond grinding, and pavement patching. In some cases, the combination of several maintenance treatments occurring at or near the same time may qualify as an alteration and would trigger the obligation to provide curb ramps.

What if a locality is not resurfacing an entire block, but is resurfacing a crosswalk by itself?

Crosswalks constitute distinct elements of the right-of-way intended to facilitate pedestrian traffic. Regardless of whether there is curb-to-curb resurfacing of the street or roadway in general, resurfacing of a crosswalk also requires the provision of curb ramps at that crosswalk.

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1. The Department of Justice is the federal agency with responsibility for issuing regulations implementing the requirements of title II of the ADA and for coordinating federal agency compliance activities with respect to those requirements. Title II applies to the programs and activities of state and local governmental entities. The Department of Justice and the Department of Transportation share responsibility for enforcing the requirements of title II of the ADA with respect to the public right of way, including streets, roads, and highways.
2. See 28 CFR 35.151(i)(1) (Newly constructed or altered streets, roads, and highways must contain curb ramps or other sloped areas at any intersection having curbs or other barriers to entry from a street level pedestrian walkway) and 35.151(i)(2) (Newly constructed or altered street level pedestrian walkways must contain curb ramps or other sloped areas at intersections to streets, roads, or highways).
3. 28 CFR 35.151(b)(1).
4. 2010 ADA Accessibility Standards, section 106.5.
5. See 1994 Title II Technical Assistance Manual Supplement, Title II TA Guidance: The ADA and City Governments: Common Problems; and ADA Best Practices Tool Kit for State and Local Governments: Chapter 6, Curb Ramps and Pedestrian Crossings under Title II of the ADA, available at ada.gov.

Page last modified on June 28, 2013.

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NOTE: Document can be found at: https://www.fhwa.dot.gov/civilrights/programs/doj_fhwa_ta_glossary.cfm

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Civil Rights

U.S. Department of Justice
Civil Rights Division
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U.S. Department of Transportation
Federal Highway Administration

Glossary of Terms for DOJ/FHWA Joint Technical Assistance on the ADA Title II Requirements to Provide Curb Ramps When Streets Roads or Highways are Altered Through Resurfacing

This glossary is intended to help readers understand certain road treatments referenced on page 2 of the DOJ/FHWA Joint Technical Assistance on the ADA Title II Requirements to Provide Curb Ramps when Streets Roads or Highways are Altered Through Resurfacing. The definitions explain the meaning of these terms from an engineering perspective and are provided in the order in which they appear in the Technical Assistance document.

Treatments that are considered alterations of the road surface

Reconstruction – Reconstruction refers to removing all or a significant portion of the pavement material and replacing it with new or recycled materials. This may include full-depth reclamation, where the pavement surface is demolished in place and new pavement surface is applied. In addition, reconstruction may also include grinding up a portion of the pavement surface, recycling it and placing it back, and then adding a wearing surface, such as in cold in-place asphalt recycling. Reconstruction often includes widening or geometrical changes to the roadway profile.

Rehabilitation – Rehabilitation refers to significant repairs made to a road or highway surface, including activities such as full slab replacement, filling voids under slabs (slabjacking), widening, and adding additional structural capacity.

Open-graded surface course – Open-graded surface course, also known as “open-graded friction course,” involves a pavement surface course that consists of a high-void, asphalt concrete mix that permits rapid drainage of rainwater through the course and off the shoulder of the road. The mixture consists of either Polymer-modified or rubber-modified asphalt binder, a large percentage of one-sized coarse aggregate, and a small amount of fibers. This treatment prevents tires from hydroplaning and provides a skid-resistant pavement surface with significant noise reduction.

Microsurfacing – Microsurfacing involves spreading a properly proportioned mixture of polymer modified asphalt emulsion, mineral aggregate, mineral filler, water, and other additives, on a paved surface.

Microsurfacing differs from slurry seal in that it can be used on high volume roadways to correct wheel path rutting and provide a skid resistant pavement surface.

Thin lift overlays – Thin lift overlays are thin applications of mixtures of hot mix asphalt. Thin lift overlays may also require some milling along curbs, manholes, existing curb cuts, or other road structures to assure proper drainage and cross slopes.

Cape seal – A cape seal is a thin surface treatment constructed by applying a slurry seal or microsurfacing to a newly constructed chip seal. It is designed to be an integrated system where the primary purpose of the slurry is to fill voids in the chip seal.

In-place asphalt recycling – In-place asphalt recycling is a process of heating and removing around 1-2 inches of existing asphalt and remixing the asphalt with the addition of a binder additive and possible aggregate to restore the wearing surface for placement and compaction. All of this is performed in a train of equipment.

Treatments that are considered maintenance of the road surface

Crack filling and sealing – Crack filling and sealing involves placing elastomeric material directly into cracks in pavement.

Surface sealing – Surface sealing involves applying liquid sealant to pavement surface in order to stop water penetration or reduce oxidation of asphalt products. Sand is sometimes spread over liquid to absorb excess material.

Chip seals – Chip Seals involve placing graded stone (chips) on liquid emulsified asphalt sprayed on pavement surface. The surface is rolled to enable seating of chips.

Slurry seal – Slurry seals involve spraying a mixture of slow setting emulsified asphalt, well graded fine aggregate, mineral filler, and water on the pavement surface. It is used to fill cracks and seal areas of old pavements, to restore a uniform surface texture, to seal the surface to prevent moisture and air intrusion into the pavement, and to improve skid resistance.

Fog seals – Fog seals are a type of surface sealing.

Scrub sealing – Scrub sealing is type of surface sealing

Joint crack seals – Joint crack seals are usually associated with concrete pavement. This work consists of routing and cleaning existing cracks and joints and resealing to prevent water and non-compressibles from entering into the pavement joints and subgrade materials.

Joint repairs – Joint repairs are usually associated with concrete pavement. This work consists of selectively repairing portions of the pavement where the slabs are generally in good condition, but corners or joints are broken. The depth of the patch could be full depth or partial depth.

Dowel retrofit – Dowel retrofits are usually associated with concrete pavement. This work involves the installation of dowel bars connecting slabs in existing pavements. Pavement with dowel bar retrofits can have life extensions of as much as 20 years. Its application is almost exclusively on high-speed Interstate highways.

Spot high-friction treatments – Spot high-friction treatments involve using epoxy based resin liquids as a binder for an aggregate with high-friction properties. These are used in locations where drivers are frequently braking and the pavement surface has less resistance to slipping.

Diamond grinding – Diamond grinding involves using a gang saw to cut grooves in the pavement surface to restore smoothness and eliminate any joint faulting.

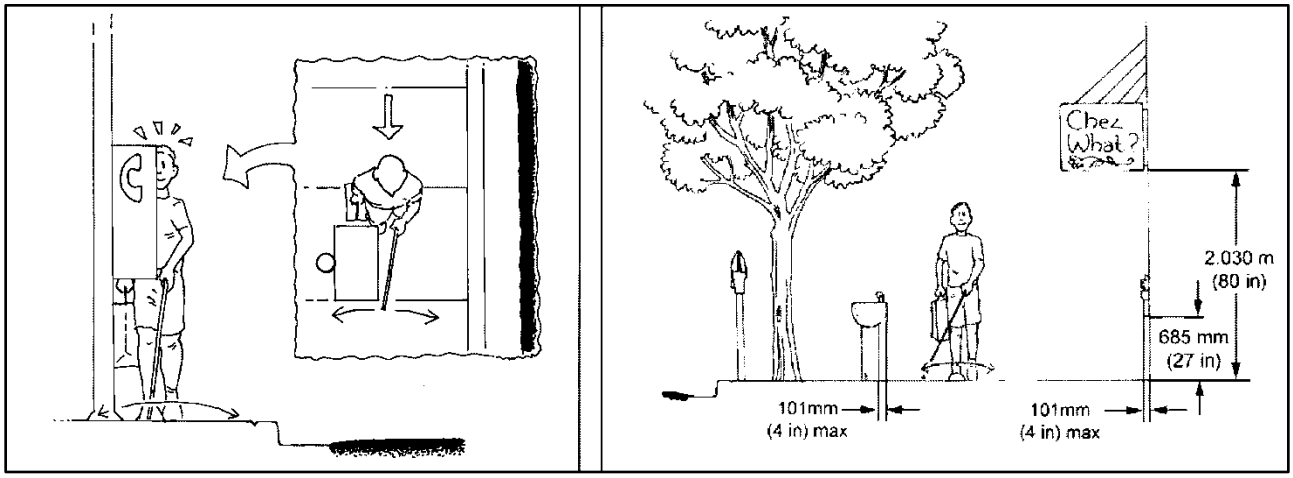
Pavement patching – Pavement patching involves selectively repairing portions of the pavement where the slabs are generally in good condition, but corners or joints are broken. The depth of the patch could be full depth or partial depth.

Page last modified on May 15, 2019.

Sidewalk Design Concepts

From “Designing Sidewalks and Trails for Access / Part II of II: Best Practices Design Guide”, September 2001, (http://www.fhwa.dot.gov/environment/sidewalk2/pdf.htm)

Protruding Objects and Vertical Clearance

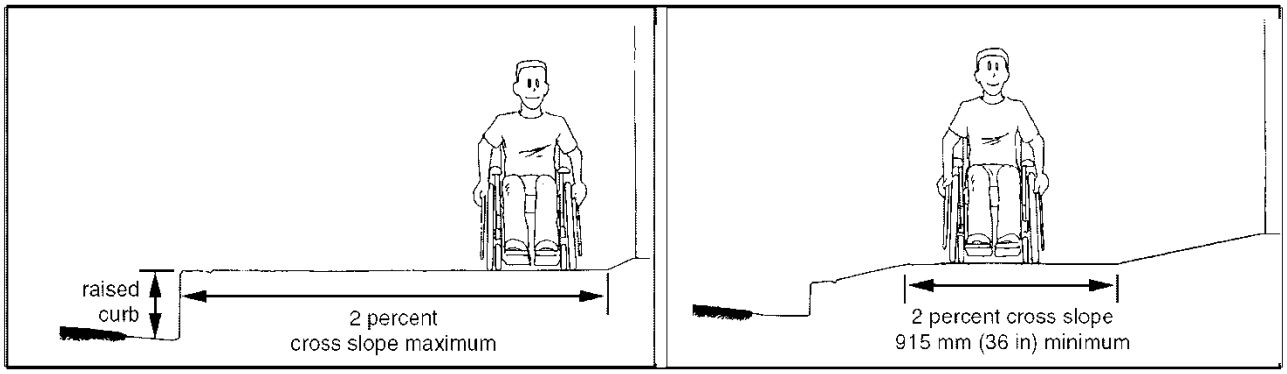


The two most important issues for people with vision impairments along the pedestrian corridor are protruding objects and vertical clearance. Objects that protrude into the sidewalk corridor but are higher than 6.7 ft are not a problem for people with vision impairments because most people require less than 6.7 ft of headroom. In addition, people who use long white canes to navigate will usually detect and avoid objects on the sidewalk that extend below 2.3 ft. Guide dogs take their owners around obstacles.

- Objects mounted on a post should protrude only 4 in.
- Wall mounted objects should protrude only 4 in.
- Signs mounted between two posts with a clear distance greater than 12 in. should be connected with a bar 15 in above the walking surface.

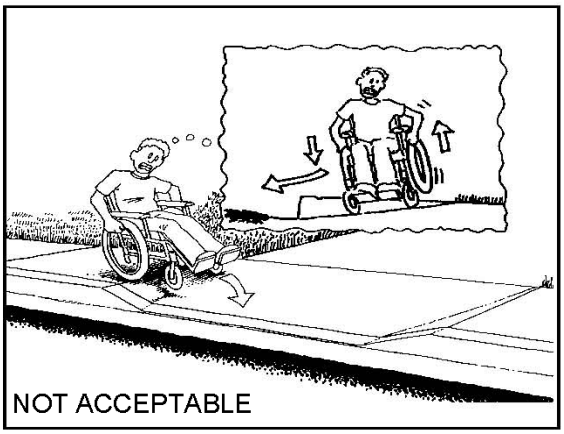
In all scenarios, the least amount of protrusion should be used. Furthermore, because people with vision impairments cannot detect the abstract division of the zones, protruding objects should be eliminated from the entire paved portion of the corridor.

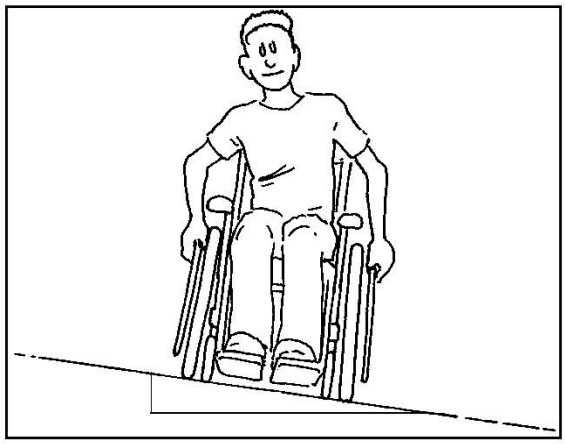
Elevation Difference between Street and Building



Raise the curb or provide a fillet no more than a foot wide at the edge of the building or the combination of both to make up the elevation difference. Less desirable is to create a level area at least 36 in. wide (5 feet or wider where possible) in the center of the sidewalk and slope the edges.

Cross Slope

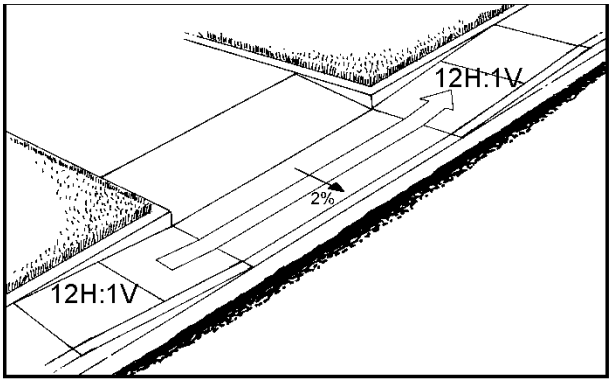


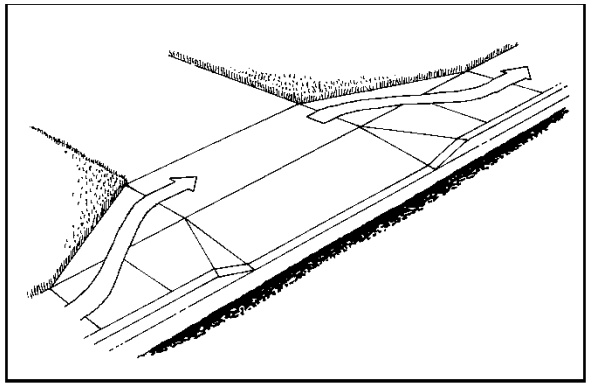


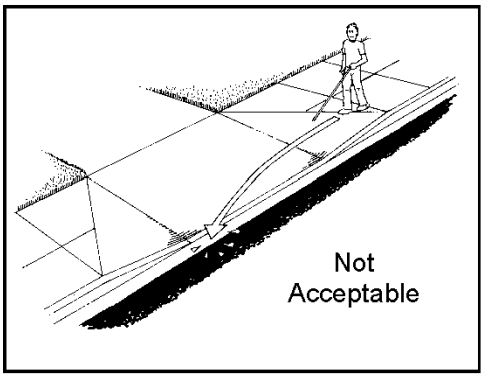
Unlike grade, cross slope is not determined by the contours of the roadway. In all scenarios, the cross slope of the pedestrian corridor is 2%.

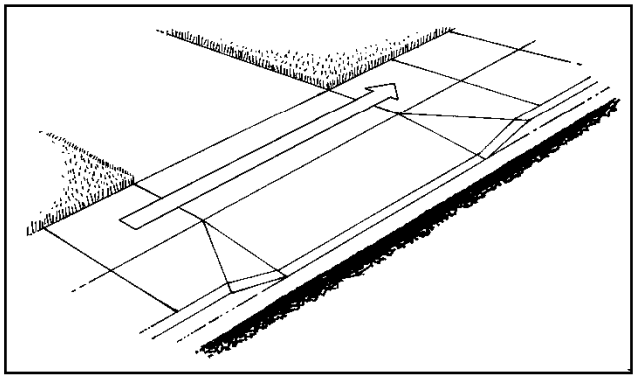
It is critical that the masons and carpenters are trained to understand how the 2% maximum benefits people with mobility impairments. Unfortunately, in many instances, the cross slope is designed for 2%, but then increased during construction either through unintentional error or as a way to improve drainage.

Sidewalks Crossing Driveways





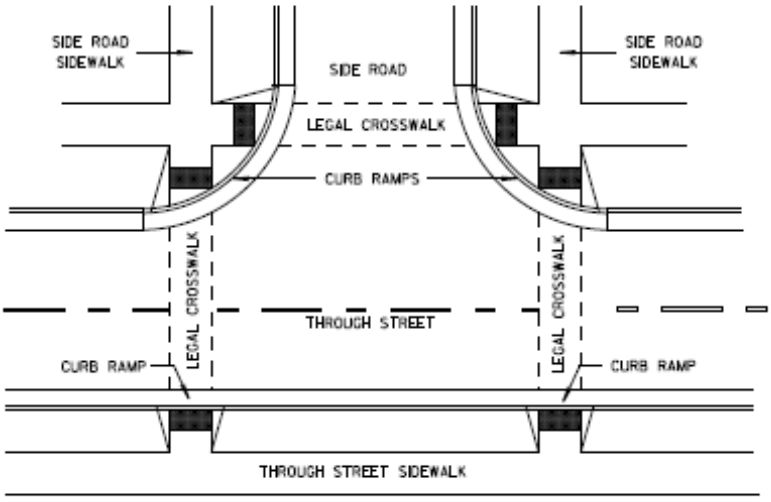




On a narrow sidewalk, where space is at a premium, a sidewalk landing can be maintained by adding additional right-of-way just at the driveway. This can be done by purchasing the additional land or obtaining an easement from the adjacent property owner.

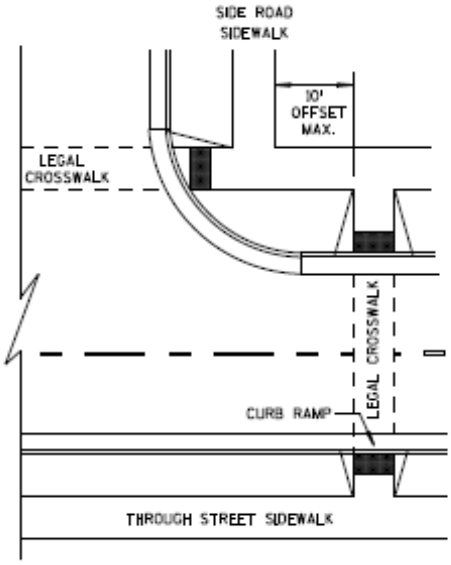
Gradually sloped driveway crossings are beneficial to people with mobility impairments, they can be problematic for people with vision impairments unless there is a detectable difference in slope at the edge of the street. If a person with a vision impairment veers towards the street and is not able to recognize where the driveway ends and the street begins, they may enter the street without realizing it.

Having the steeper driveway apron with a 2% cross slope 36-inches wide at the top serves as an effective way to slow motorists and accommodate pedestrians. Check the apron slope so the vehicle doesn’t bottom-out at the front or rear.



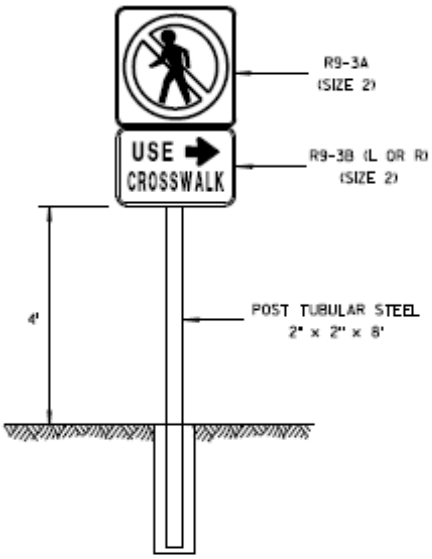
LEGAL CROSSWALK LAYOUT

FIGURE 1



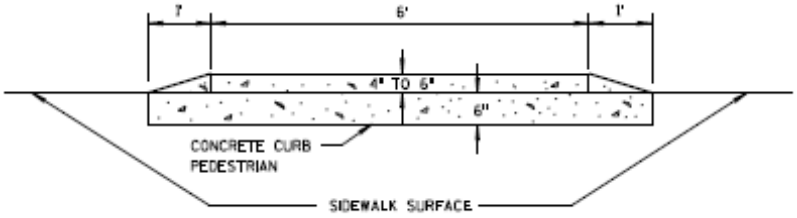
SIDEWALK TO CROSSWALK OFFSET

FIGURE 2

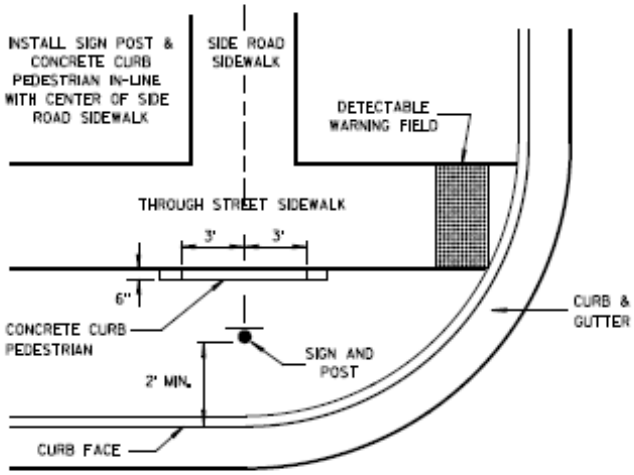


CROSSWALK CLOSURE SIGN

FIGURE 3

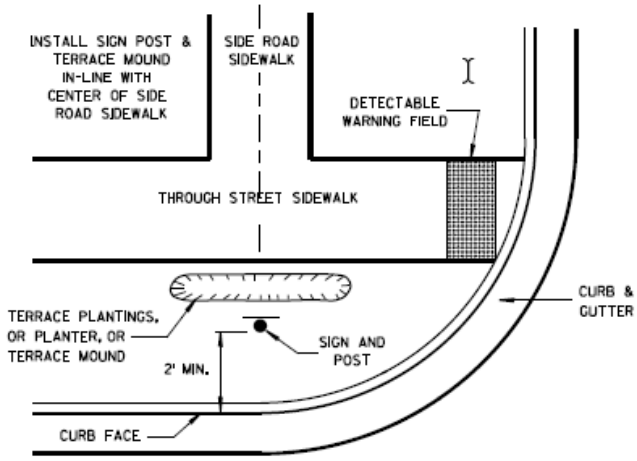


CONCRETE CURB PEDESTRIAN DETAIL
CURB ELEVATION VIEW

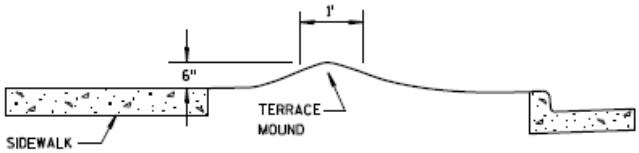


CURB AND SIGN LOCATION DETAIL

FIGURE 4

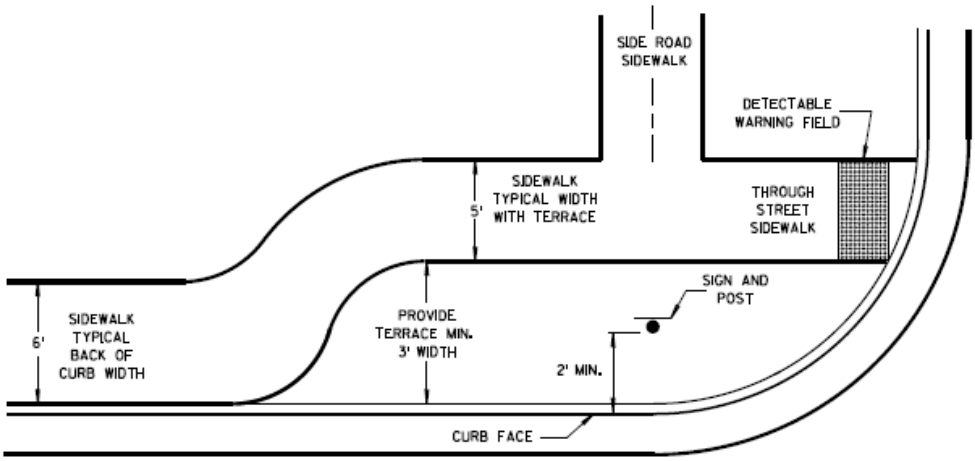


MOUND AND SIGN LOCATION DETAIL



TERRACE MOUND DETAIL

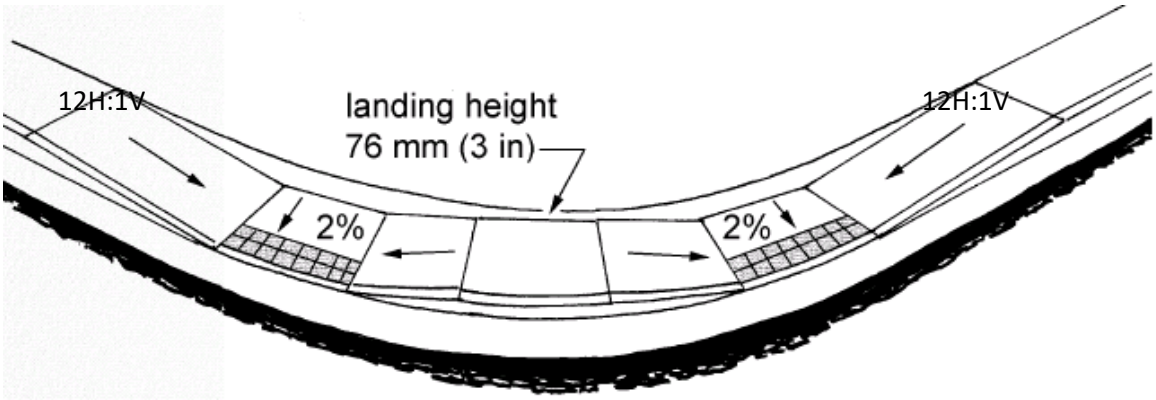
FIGURE 5

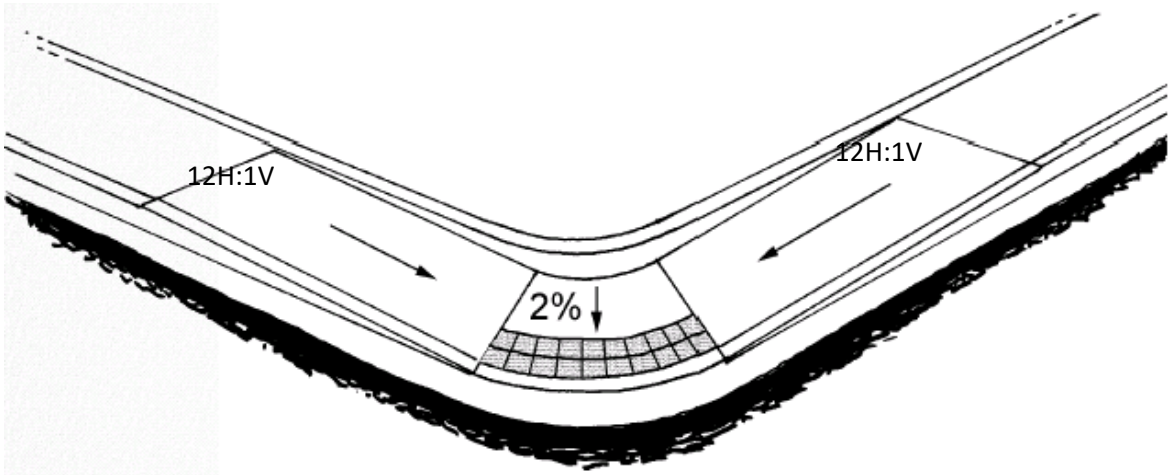


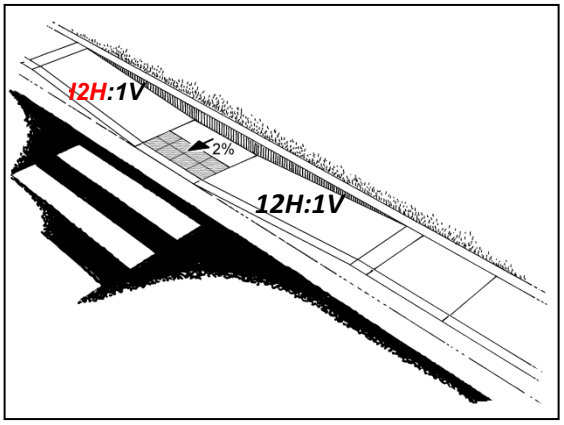
SIDEWALK REALIGNMENT

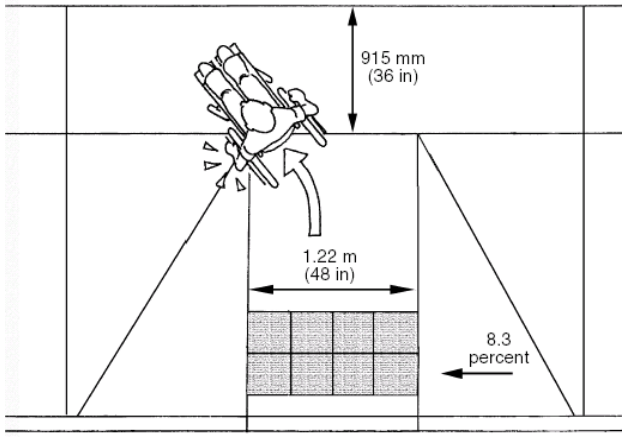
FIGURE 6

Curb Ramp Options With Restricted Right-of-Way and Mid-block Crossing

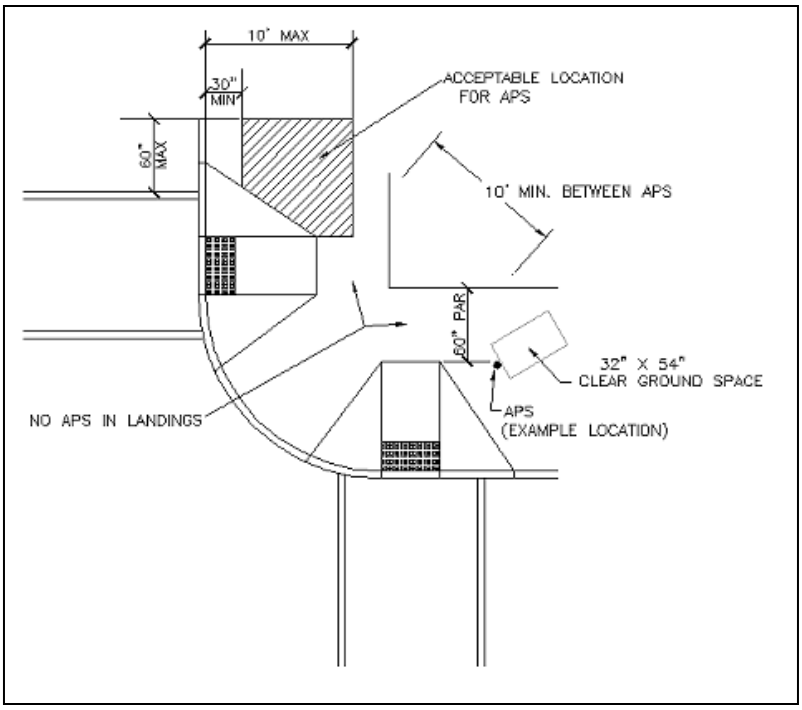








A parallel curb ramp has two ramps leading down, 12H:1V or flatter, towards a center level landing at the bottom between both ramps. The center landing slopes 2 percent toward the back of curb. The side flares slope, 12H:1V (8.3%) or flatter, toward the center landing as well.



Accessible Pedestrian Signals

Push Button Location

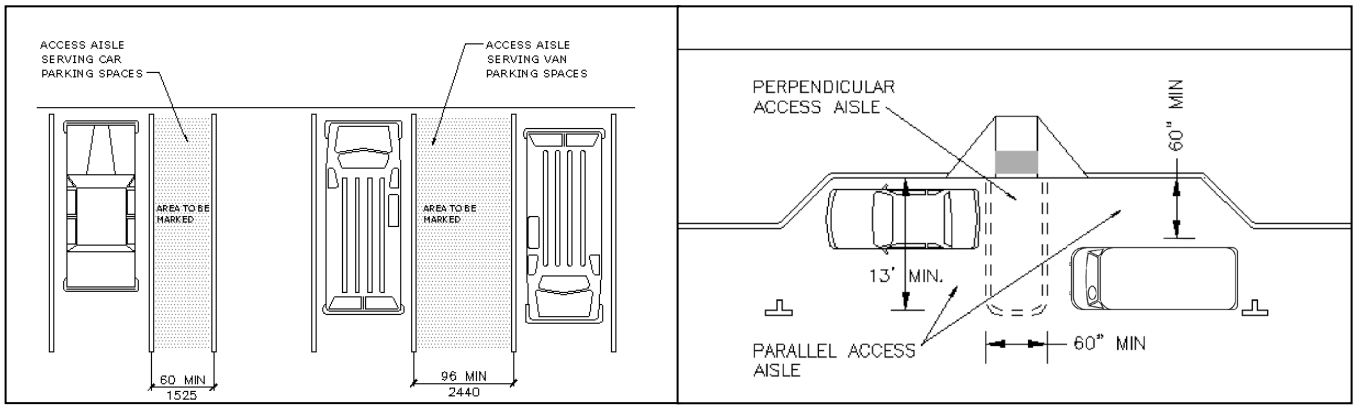
The push button location can have a significant impact on usability for wheelchair users and other people with disabilities. At signalized intersections consider a 2-stage crossing. For this reason, the PROWAAC[1] report established the following requirements for locating push buttons *(U.S. ATBCB[2], 2001: http://www.access-board.gov/)*

- Adjacent to landing - locate the push button adjacent to a level landing (maximum slope = 2% in all directions) at least 2.5 ft x 4.5 ft.
- Direction of control face - mount the control face parallel to the direction of the corresponding crosswalk and no closer than 2.5 ft to the curb.
- Mounting height - mount push button 3.5 ft above the sidewalk.
- Close to crosswalk - mount no further than 5 ft from the extension of the crosswalk lines and within 10 ft of the curb line, unless the curb ramp is longer than 10 ft. On median islands mount within 2 ft of the crosswalk and accessible from a wheel chair.
- Proximity to curb ramp - place the push button within 2 ft horizontally of the top corner of the ramp. At a parallel ramp, the push button should be adjacent to the lower landing.
- Separation - where there are two accessible pedestrian signals at the same corner, mount the push buttons on poles separated by at least 10 ft.

[1] Public Rights-of-Way Access Advisory Committee

[2] U.S. Architectural and Transportation Barriers Compliance Board (the Access Board)

On-Street Parking for People with Mobility Impairments



Perpendicular or angle parking **Parallel parking**

To address the needs of people with mobility impairments, the PROWAAC committee provided guidance on how to address on-street parking. According to their report, if on-street parallel parking is provided in commercial areas, it should include accessible spaces for pedestrians with mobility impairments. The design guidance for the accessible parking spaces can be found in their report *(U.S. ATBCB, 2001: http://www.access-board.gov/)*.

For perpendicular and diagonal parking, the committee further specified that one of every eight spots of mobility-impaired parking be van accessible. If fewer than eight spots of mobility-impaired parking will be provided, one of them shall be van accessible. Van spaces have larger design guidance than other accessible parking spaces *(U.S. ATBCB, 2001)*.

In addition to providing accessible parking spaces, designers should also provide an accessible curb ramp that connects the access aisle to the pedestrian zone.

Trail-Highway Crossing Guidance for Rural 2-Lane Highway Facilities [1,2]

Grade Separation Alternatives [3,4]

Hourly Exposure Factor (In Thousands)	Trail Use	Does Not Meet WisDOT Warrants6	May be Justified 6	Meets WisDOT Warrants 6
4th Highest Exposure Factor 5	Non-Motorized	<25	25-35	>35
	Motorized	<35	35-50	>50
Highest Exposure Factor 5	Non-Motorized	<40	40-60	>60
	Motorized	<55	55-80	>80

Notes:

1. For non-freeway, non-expressway divided highways with medians; each direction of traffic shall be considered separately. Exposure factors for divided highways to be 120% of the requirements listed above.
2. This table is applicable to rural highways with posed speed limits ranging from 40 to 55 mph.
3. Use existing box culvert, waterway structure, or roadway grade separation for trail, whenever practical.
4. Structure warrants: Minimum ADT on highway should be 3500 or greater.
5. Exposure factor is the product in thousands of the highway volume times the trail volume for the same hourly time period.
   - 4th Highest Exposure factor is the 4th Highest such product for a given counting period.
   - Highest Exposure Factor is the highest such product for a given counting period.
6. Trail Counts:
   - For Perpetuation and Resurfacing, or Spot Improvements to Include New or Existing Trail Crossings: Use existing highway and trail counts. For new trails, estimate trail counts based on similar trails in the local area.
   - For Modernization: Use projected highway and trail counts for the design year. Estimate a 1 – 2% per year-projected growth for the trail over the design year period.

Use link for a working copy of this worksheet: FDM 11-46 A20.2 File 1

GRADE SEPARATION WARRANT WORKSHEET

Project ID		Road Description *		Date of count	
Road Name		Lane width (ft)		Day of week	
County		Shoulder width (ft)		Begin time	
Project type		Median width (ft)		End time	
Trail Name		Posted speed (mph)		weather cond.	
Trail Owner		road ADT (current)	(year)		
Crossing Location		road ADT (design year)	(year)		
Rails-to-Trails? (Y or N)		road ADT (count year)	(year)	interpolated	
		Trail description			
		Trail width (ft)			

USE Proposed Design values for roadway

Traffic counts to use for determining grade separation warrants	
ACTUAL UNADJUSTED (**enter Y or N**)	
DESIGN YEAR - ADJUST counts to reflect estimated traffic growth (**enter Y or N**)	
Estimated yearly rate of growth for trail traffic (%)	

** e.g. 2-lane roadway ; or 4-lane divided roadway ; or 4-lane undivided roadway*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Hour No.	From time	to time	UNADJ. Exposure factor (col. 7 x col. 18 / 1000)	ADJ. Exposure factor (col. 8 x col. 19 / 1000)	RANK of ADJ. Exposure factors	Road User Counts - cars, trucks, motorcycles		(3) Trail User Counts (ACTUAL)									(4) Hourly total - all trail users (UNADJ.) (sum col.'s 9 - 17)	(5) Hourly total - all trail users (ADJ.)	(6) Overall Trail Use (based on UNADJ. Counts)		
								Low Speed (non-motorized)			Medium Speed (non-motorized)			High Speed (motorized)					non-motorized		motorized
						(1) ACTUAL COUNTS (UNADJ)	(2) ADJUSTED	Disabled / Ped	Equestrian	Jogger/ Runner	X Country Skiing	Roller Blader	Bicycle	ATV	other motorized vehicles	Snowmobile			Low Speed (sum col.'s 9-11)	Medium Speed (sum col.'s 12-14)	High Speed (sum col.'s 15-17)
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					
11																					
12																					
13																					
14																					
					TOTALS																
																					Percent of overall trail use

SUMMARY

Trail speed:			
Trail Use:			
Highest exposure factor:		4th Highest exposure factor:	
Hour No.		Hour No.	
Grade separation Warrant		Grade separation Warrant	
Controlling:		Controlling:	

HIGHEST EXPOSURE		4TH HIGHEST EXPOSURE		
NM	**M**	**NM**	**M**	**GRADE SEPARATION WARRANT**
0	0	0	0	DOES NOT MEET WISDOT WARRANTS
40	55	25	35	MAY BE JUSTIFIED
61	81	36	51	MEETS WISDOT WARRANTS

Notes:

1. Enter road user hourly counts in this column. See traffic count guidance below.
2. Adjust Road User hourly counts so that they are the same percentage of design year ADT as they are of count year ADT.
3. Enter trail user hourly counts in these columns. See traffic count guidance below.
4. Seasonal representative average daily count. This should be representative of normal usage on a typical day. Do not use counts for special events.
5. Adjust trail user hourly counts by applying the estimated yearly rate of growth for trail traffic.
6. The overall trail use is calculated by adding all trail uses within each trail use category (low, medium and high speed). The following thresholds determine the trail class for the at-grade grossing sight distance tables:

If more than 85% of the trail use is high speed, the trail is classified as HIGH SPEED, and trail use is MOTORIZED.

If more than 15% of the trail use is low speed, the trail is classified as LOW SPEED, and trail use is NON-MOTORIZED.

If neither of the above thresholds are met, the trail is classified as MEDIUM SPEED, and trail use is NON-MOTORIZED.

Traffic Counts

Define the appropriate (average) time period to take the counts.

A. Summer-Use Trails: Take an average weekend day count between Memorial Day and Labor Day (no holiday times or special events). Take a minimum of one 14-hour period count between 6am to 8pm under appropriate weather conditions (i.e., not raining). Consult with the DNR, municipalities, region traffic section, and others as appropriate to determine when to take the count. The count should be taken as if done for a traffic signal.

B. Winter-Use Trails: Take an average weekend day count between December 1st and April 1 st (no holiday times or special events). Take a minimum of one 14-hour count between 10am and 2 am when there is enough snow to allow winter-use trails to be open. Determine how long the trail was in use or officially open for snowmobiles during the last 5-year period. Consult with the DNR, municipalities, region traffic section, and others as appropriate to determine when to take the count. The count should be taken as if done for a traffic signal.

If a trail is used during both summer and winter, take counts during both seasons.

EXAMPLE - Grade separation warrant determination for a resurfacing project using UNADJUSTED counts

Project ID	1000-00-00	Road Description *	2-lane asphalt			Date of count	May 4, 2002
Road Name	USH 00	Lane width (ft)	12	**USE Proposed Design values for roadway**		Day of week	Saturday
County	Dane	Shoulder width (ft)	6			Begin time	8:00 AM
Project type	re-surface	Median width (ft)	NA			End time	10:00 PM
Trail Name	Greenway	Posted speed (mph)	55			weather cond.	70-degrees, sunny, no-wind all-day
Trail Owner	DNR	road ADT (current)	2000	(year)	2000		
Crossing Location	2 mi. west of CTH OO	road ADT (design year)	2500	(year)	2020		
Rails-to-Trails? (Y or N)	N	road ADT (count year)	2050	(year)	2002	interpolated	
		Trail description	asphalt bike / ped trail				
		Trail width (ft)	10				

Traffic counts to use for determining grade separation warrants	
ACTUAL UNADJUSTED (**enter Y or N**)	**Y**
DESIGN YEAR - ADJUST counts to reflect estimated traffic growth (**enter Y or N**)	
Estimated yearly rate of growth for trail traffic (%)	

** e.g. 2-lane roadway ; or 4-lane divided roadway ; or 4-lane undivided roadway*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Hour No.	From time	to time	UNADJ. Exposure factor (col. 7 x col. 18 / 1000)	ADJ. Exposure factor (col. 8 x col. 19 / 1000)	RANK of ADJ. Exposure factors	Road User Counts - cars, trucks, motorcycles		(3) Trail User Counts (ACTUAL)									(4) Hourly total - all trail users (UNADJ.) (sum col.'s 9 - 17)	(5) Hourly total - all trail users (ADJ.)	(6) Overall Trail Use (based on UNADJ. Counts)		
								Low Speed (non-motorized)			Medium Speed (non-motorized)			High Speed (motorized)					non-motorized		motorized
						(1) ACTUAL COUNTS (UNADJ)	(2) ADJUSTED	Disabled / Ped	Equestrian	Jogger/ Runner	X Country Skiing	Roller Blader	Bicycle	ATV	other motorized vehicles	Snowmobile			Low Speed (sum col.'s 9-11)	Medium Speed (sum col.'s 12-14)	High Speed (sum col.'s 15-17)
1	8:00 AM	9:00 AM	3	3	3	100	100			10		2	10				22	22	10	12	
2	9:00 AM	10:00 AM	1	1	9	25	25			5			10				15	15	5	10	
3	10:00 AM	11:00 AM	1	1	9	32	32			1			15				16	16	1	15	
4	11:00 AM	12:00 PM	1	1	9	25	25			1			25				26	26	1	25	
5	12:00 PM	1:00 PM	5	5	2	100	100			10		10	25				45	45	10	35	
6	1:00 PM	2:00 PM	2	2	7	50	50						30				30	30		30	
7	2:00 PM	3:00 PM	2	2	7	50	50						35				35	35		35	
8	3:00 PM	4:00 PM	3	3	3	100	100						25				25	25		25	
9	4:00 PM	5:00 PM	6	6	1	200	200			5			25				30	30	5	25	
10	5:00 PM	6:00 PM	3	3	3	100	100			10		10	5				25	25	10	15	
11	6:00 PM	7:00 PM	3	3	3	75	75			15		10	5				30	30	15	15	
12	7:00 PM	8:00 PM	1	1	9	75	75					5	5				10	10		10	
13	8:00 PM	9:00 PM	1	1	9	75	75						5				5	5		5	
14	9:00 PM	10:00 PM	1	1	9	50	50						5				5	5		5	
					TOTALS	1057	1057			57		37	225				319	319	57	262	
																			17.87%	**82.13%**	
																			Percent of overall trail use		

SUMMARY

Trail speed:	Low Speed		
Trail Use:	Non-Motorized Use		
Highest exposure factor:	6	4th Highest exposure factor:	3
Hour No.	9	Hour No.	1
Grade separation Warrant	DOES NOT MEET WISDOT WARRANTS	Grade separation Warrant	DOES NOT MEET WISDOT WARRANTS
Controlling:		Controlling:	

HIGHEST EXPOSURE		4TH HIGHEST EXPOSURE		
NM	**M**	**NM**	**M**	**GRADE SEPARATION WARRANT**
0	0	0	0	DOES NOT MEET WISDOT WARRANTS
40	55	25	35	MAY BE JUSTIFIED
61	81	36	51	MEETS WISDOT WARRANTS

EXAMPLE - Grade separation warrant determination for a reconstruction project using counts which have been adjusted for projected future traffic

Project ID	1000-00-00	Road Description *	2-lane asphalt			Date of count	January 5, 2002
Road Name	STH 00	Lane width (ft)	12	USE Proposed Design values for roadway		Day of week	Saturday
County	Washburn	Shoulder width (ft)	10			Begin time	10:00 AM
Project type	reconstruct	Median width (ft)	NA			End time	12:00 AM
Trail Name	arrow way	Posted speed (mph)	55			weather cond.	15 degrees, cloudy, no wind
Trail Owner	Washburn County	road ADT (current)	3000	(year)	2000		
Crossing Location	150 ft west of Red River	road ADT (design year)	4500	(year)	2020		
Rails-to-Trails? (Y or N)	Y	road ADT (count year)	3150	(year)	2002	interpolated	
		Trail description	Snow mobile				
		Trail width (ft)	12				

Traffic counts to use for determining grade separation warrants	
ACTUAL UNADJUSTED (**enter Y or N**)	N
DESIGN YEAR - ADJUST counts to reflect estimated traffic growth (**enter Y or N**)	Y
Estimated yearly rate of growth for trail traffic (%)	1.0%

** e.g. 2-lane roadway ; or 4-lane divided roadway ; or 4-lane undivided roadway*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Hour No.	From time	to time	UNADJ. Exposure factor (col. 7 x col. 18 / 1000)	ADJ. Exposure factor (col. 8 x col. 19 / 1000)	RANK of ADJ. Exposure factors	Road User Counts - cars, trucks, motorcycles		(3) Trail User Counts (ACTUAL)									(4) Hourly total - all trail users (UNADJ.) (sum col.'s 9 - 17)	(5) Hourly total - all trail users (ADJ.)	(6) Overall Trail Use (based on UNADJ. Counts)		
								Low Speed (non-motorized)			Medium Speed (non-motorized)			High Speed (motorized)					non-motorized		motorized
						(1) ACTUAL COUNTS (UNADJ)	(2) ADJUSTED	Disabled / Ped	Equestrian	Jogger/ Runner	X Country Skiing	Roller Blader	Bicycle	ATV	other motorized vehicles	Snowmobile			Low Speed (sum col.'s 9-11)	Medium Speed (sum col.'s 12-14)	High Speed (sum col.'s 15-17)
1	10:00 AM	11:00 AM	8	13	12	100	143									75	75	90			75
2	11:00 AM	12:00 PM	15	26	10	150	214									100	100	120			100
3	12:00 PM	1:00 PM	40	69	4	200	286									200	200	239			200
4	1:00 PM	2:00 PM	45	77	2	200	286									225	225	269			225
5	2:00 PM	3:00 PM	45	76	3	222	317									200	200	239			200
6	3:00 PM	4:00 PM	69	118	1	345	493									200	200	239			200
7	4:00 PM	5:00 PM	25	43	5	250	357									100	100	120			100
8	5:00 PM	6:00 PM	25	43	5	250	357									100	100	120			100
9	6:00 PM	7:00 PM	21	36	7	125	179									166	166	199			166
10	7:00 PM	8:00 PM	20	35	8	100	143									200	200	239			200
11	8:00 PM	9:00 PM	20	35	8	100	143									200	200	239			200
12	9:00 PM	10:00 PM	15	26	10	100	143									150	150	179			150
13	10:00 PM	11:00 PM	2	3	13	100	143									15	15	18			15
14	11:00 PM	12:00 AM	1	1	14	100	143									5	5	6			5
					TOTALS	2342	3347									1936	1936	2316			1936
																					100.00%
																			Percent of overall trail use		

SUMMARY

Trail speed:	High Speed		
Trail Use:	Motorized Use		
Highest exposure factor:	118	4th Highest exposure factor:	69
Hour No.	6	Hour No.	3
Grade separation Warrant	MEETS WISDOT WARRANTS	Grade separation Warrant	MEETS WISDOT WARRANTS
Controlling:		Controlling:	

HIGHEST EXPOSURE		4TH HIGHEST EXPOSURE		
NM	M	NM	M	GRADE SEPARATION WARRANT
0	0	0	0	DOES NOT MEET WISDOT WARRANTS
40	55	25	35	MAY BE JUSTIFIED
61	81	36	51	MEETS WISDOT WARRANTS

Sight Distance for Trail Crossing (feet)

Highway Design Speed (mph)		(1) High Speed Trail Use			(2) Medium Speed Trail Use			(3) Low Speed Trail Use (85th percentile users)			(4) Low Speed Trail Use (elderly or other slower pedestrians)		
	No. of Lanes Crossed	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
	Crossing time t (sec.)	**7.0**	**7.0**	**7.5**	**7.8**	**9.0**	**10.2**	**7.6**	**11.0**	**14.4**	**8.3**	**12.3**	**16.3**
30		310	310	330	350	400	450	340	490	640	370	550	720
35		360	360	390	410	470	530	400	570	740	430	640	840
40		420	420	440	460	530	600	450	650	850	490	730	960
45		470	470	500	520	600	680	510	730	960	550	820	1080
50		520	520	550	580	660	750	560	810	1060	610	910	1200
55		570	570	610	630	730	830	620	890	1170	670	1000	1320
60		620	620	660	690	800	900	670	970	1270	740	1090	1440
NOTE: Vision triangle distance on trail shall be 20 feet back from the traveled edge of pavement on highway.													

Based on Intersection Control Case B3 as shown on Page 668 of 2001 AASHTO GDHS, as modified to reflect the values used in the 1995 WisDNR Design Standards Handbook (time rounded up to 7.0 sec for 2-lane crossing).

Based on formula $$t = \frac{S}{V} + \frac{V}{2a} + PRT$$

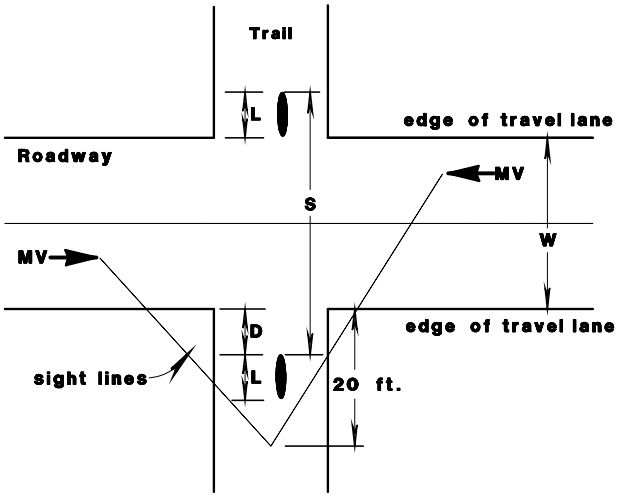
t =total crossing time (sec)
v = velocity (use 9.84 fps)
a = acceleration (use 2.43 ft/s^2)
PRT = perception reaction time (use 3.5 sec)
S = crossing width = D+W+L where:
D = distance from near edge of traveled way to the front of the bicycle (use 4.0 ft assumed)
W = traveled way width along path of crossing bicycle (ft) = no. of lanes x assumed 12 ft lane width
L = overall length of bicycle (use 5.9 ft)

Based on formula $$t = \frac{S}{V} + \frac{V}{2a} + PRT$$

t =total crossing time (sec)
v = velocity (use 3.5 fps)
a = acceleration (use 300000 ft/s^2 basically instantaneous
PRT = perception reaction time (use 3 sec)
S = crossing width = D+W+L where:
D = distance from near edge of traveled way to the front of the bicycle (use 4.0 ft assumed)
W = traveled way width along path of crossing bicycle (ft) = no. of lanes x assumed 12 ft lane width
L = overall length of pedestrian (use 0.0 ft)

Based on formula $$t = \frac{S}{V} + \frac{V}{2a} + PRT$$

t =total crossing time (sec)
v = velocity (use 3 fps)
a = acceleration (use 300000 ft/s^2 basically instantaneous
PRT = perception reaction time (use 3 sec)
S = crossing width = D+W+L where:
D = distance from near edge of traveled way to the front of the bicycle (use 4.0 ft assumed)
W = traveled way width along path of crossing bicycle (ft) = no. of lanes x assumed 12 ft lane width
L = overall length of pedestrian (use 0.0 ft)



FDM 11-50-1 Work Zone Policy Statement

May 15, 2019

See the Traffic Engineering, Operations and Safety (TEOpS) Manual Chapter 6 Section 1 for the Work Zone Policy Statement.

FDM 11-50-5 Transportation Management Plan Process

February 18, 2020

5.1 Introduction

The Federal Highway Administration (FHWA) published a final rule on Work Zone Safety and Mobility in the Federal Register on September 9, 2004. The rule took effect on October 12, 2007 and affects all states and local governments that receive Federal-Aid Highway funding. The purpose of the update is to address changing times of more traffic, more congestion, greater safety issues and more work zones on our highways. These challenges require a systematic and structured approach to ensure traffic management consistency statewide. The work zone policy statement in the TEOpS 6-1, addresses the Department's goals and objectives as well as discussing where responsibilities lie when implementing the work zone rule.

5.1.1 Key Features of the Work Zone Rule

- The rule takes a policy-based approach to institutionalize work zone processes and procedures.
- Emphasizes safety and mobility impacts of work zones.

5.1.2 How the Work Zone Rule Works

- It advocates for work zone considerations to be initiated as early as possible in the project delivery process.
- It underscores the adoption of policy and procedures that support systematic consideration and management (consistency) of work zone impacts.
- It encourages states and local governments to develop and implement strategies to manage impacts.
- It requires monitoring and assessing work zone performance.
- It encourages the use of work zone safety and mobility data to improve policy, processes and procedures.

5.2 What is a TMP?

A transportation management plan (TMP) is a set of coordinated transportation management strategies and describes how they will be used to manage work zone impacts of a road project. Transportation management strategies for a work zone include temporary traffic control measures and devices, public information and outreach, and operational strategies such as transportation operations and incident management strategies. The scope, content, and level of detail of a TMP may vary based on anticipated work zone impacts of the project. A transportation management plan is required on all projects.

5.2.1 Purpose

The Wisconsin Department of Transportation (WisDOT) is committed to promoting safety for the traveling public and workers, minimizing congestion and adverse traffic impacts, and providing for improved public satisfaction during construction, maintenance, utility and all other activities performed on or near the WisDOT highway network. Compliance with this policy will reduce work zone crashes, travel time and provide benefits to all stakeholders. All regional offices and statewide bureaus are responsible for implementing the portions of this policy that affect their operations. For further details on the WisDOT policy, refer to TEOpS 6-1.

Maintaining safe flow of traffic through a work zone during construction should be planned and executed. Providing detours is often a better alternative, but, due to many reasons, it is frequently impractical, and flow of traffic is maintained through the work zone. Sometimes traffic lanes are closed, shifted, or encroached upon to undertake construction. A transportation management plan must be developed to minimize the effect on traffic operations by providing adequate layout of traffic control devices and minimizing the frequency or duration of interference with normal traffic flow.

This document establishes guidelines for developing TMPs for all highway construction, maintenance, utility, and construction activities performed by WisDOT, municipalities and other agencies.

Managing traffic is a continuous process that requires monitoring and updating the TMP as traffic flow or construction scheduling changes. Review the TMP at project completion to determine its effectiveness and incorporate lessons learned in future projects.

An effective TMP generally addresses project and site-specific issues with traffic impact analyses performed in accordance with WisDOT's Facilities Development Manual (FDM), Traffic Engineering Operations and Safety Manual (TEOpS), Wisconsin Manual on Uniform Traffic Control Devices (WisMUTCD) and other supplemental policies or directives.

Notify stakeholders about potential impacts early in the project initiation process to seek input and buy-in for the project. Larger projects may require the formation of a TMP Team to facilitate coordination and smooth project delivery. If a TMP Team is required, as determined by the regional project scoping team, it's advisable to have multi-faceted and multi-disciplinary members who share a common understanding of the project goals and objectives. Occasionally, a multi-jurisdictional team may be needed for projects whose scope extends to other regions or state(s).

5.2.2 Scope of these Guidelines

The intent of this guideline is to assist regional planners, traffic engineers and designers in developing TMPs for work zones. Many of the strategies developed and discussed facilitate planning, managing, operating, and evaluating work zone safety and mobility. The guideline defines a coherent framework for integrating TMPs and traffic operation policies into the project development process and encourages consideration of TMPs at an early stage in project development. Incorporating a TMP early into the project delivery process has three advantages:

- Some TMP elements require lead times and should be identified early so funds can be allocated and work planned for each element,
- Identifying TMP components early in project delivery facilitates overall project budgeting and approval processes,
- It ensures that impacts to highway users, businesses, workers and communities are minimized.

This guideline will help WisDOT develop and implement TMPs effectively and consistently statewide to enhance safety and mobility while minimizing delays caused by construction work zones.

5.3 Project Development Process

It is important to identify traffic management issues earlier in project development. Traffic management is not a snap shot of the project at a particular point in time during project development, but rather a continuous activity that is revisited, refined and updated to reflect changes in project scope. FDM 3-1 Attachment 1.1 illustrates the current Facilities Development Process. Traffic management must be considered until construction is complete.

Complete the following steps for each project:

1. Work Zone Impact Assessment before Life Cycle 11
2. 60% TMP during Life Cycle 12
3. 90% TMP before Life Cycle 20

5.4 Work Zone Impact Assessment

The Work Zone Impact Assessment is conducted during the project scoping and is completed before Life Cycle 11. The objective of the Work Zone Impact Assessment is to define the TMP type, recommend mitigation strategies based on estimated delay through a cost-benefit analysis, and determine potential alternative contracting strategies. These items should all be done to properly scope and determine the estimated cost for the projects temporary traffic control.

The degree of work zone impact assessment depends on project complexity. Each project is different and will have different impacts. It is advisable to perform an impact assessment because the level of traffic safety and mobility is directly affected by the appropriateness of the TMP.

Work zone impacts are not limited to the actual project limits. Impacts can be far reaching and have adverse effects on businesses, communities, schools, other roadways, highway corridors, other highway projects, and even on other regions if the project is located at critical segments on the network.

5.4.1 Work Zone Impact Assessment Team

Regional scoping teams are responsible for developing the Work Zone Impact Assessment in conjunction with regional traffic operations and project development. The design and construction project development staff must be included to provide the appropriate knowledge of how a project could be constructed. For larger projects, it

will become necessary to bring in additional resources who have experience and expertise to ensure successful TMP development and project success. The team may include representatives from:

- Real Estate
- Technical Services
- Regional Communications
- Bureau of Traffic Operations
- Division of State Patrol
- Bureau of Project Development
- Bureau of Technical Services
- Bureau of Structures
- Office of Public Affairs
- Local Government (county or city)
- FHWA
- Others deemed necessary.

5.4.2 Work Zone Impact Assessment Contents

The Work Zone Impact Assessment should contain the following:

- Project Description
- Description of Work Zone Traffic Control Alternatives
- Work Zone Safety Considerations
- Work Zone Operational Considerations
- Other Considerations
- Work Zone Cost Considerations
- Feasibility of Work Zone Alternatives
- Recommendations

The following will describe the details for each section listed above. Some of the information developed for the Work Zone Impact Assessment will be used in the TMP.

5.4.2.1 Project Description

Provide a brief description of the project background and a summary of the existing conditions of the project area. Include the existing capacity of the impacted roadway.

5.4.2.2 Description of Work Zone Traffic Control Alternatives

List all alternatives taken into consideration (no matter how briefly) and provide a brief description of each of the analyzed alternatives.

5.4.2.3 Work Zone Safety Considerations

In most cases, crashes increase on a corridor that has a work zone present and the purpose of this section is to determine the potential safety impacts resulting from the work zone. The safety impacts can be to the road users as well as the workers. This section could include a diagram of all the crashes within the project limits as well as any areas that may be impacted by the project, from queuing, detours, or alternate routes. For each alternative, document the safety impacts, if any, the work zone may cause.

5.4.2.4 Work Zone Operations Considerations

At a minimum, this section should provide a qualitative discussion on the work zone operational and capacity concerns. Field surveys or photographs taken during the peak periods are some ways to demonstrate capacity concerns if the data needed for detailed operational analysis is not available. Average annual daily traffic volumes (AADT), which are available through the coverage count program (https://wisconsindot.gov/Pages/projects/data-plan/traf-counts/default.aspx), can also provide insight into potential capacity concerns. Consideration should be given to all modes of transportation (passenger vehicles, bicycles, pedestrians, freight, etc.) when assessing the operational and capacity concerns.

Ideally, the Work Zone Impact Assessment should provide a summary of the quantitative capacity analysis conducted using the methodologies from the most recent version of the Highway Capacity Manual (HCM).

For mega and major projects, the region shall conduct a peer review of the traffic analyses for Work Zone Impact Assessment in accordance with the procedures outlined in TEOpS 16-25. In most cases, the peer review will consist of a region-level review of the analysis.

Always include the worst-case alternative, with travel delays exceeding the 15-minute delay threshold. Include all traffic staging alternative analyzed and document the travel delays for each alternative (i.e. full closure, lane closures, off peak lane closures, etc.) The travel delay will be used for justification of the chosen alternative.

5.4.2.5 Other Considerations

Determine if alternative contracting methods will have an impact on the work zone. This would include cost-plus-time bidding, design/build contracting, or incentives/disincentives. For more information on Alternative Contracting methods see FDM 11-2-1. These items could have an impact on the project schedule and cost. When considering alternative contracting methods, road user costs may need to be determined.

5.4.2.6 Work Zone Cost Considerations

Determine the estimated cost of each major alternative. Costs should be included for the following: temporary widening, improvement to detour/alternate routes, temporary structures, temporary concrete barrier, crossover construction, temporary traffic signals and any smart work zone device deployment.

5.4.2.7 Feasibility of Work Zone Alternatives

Highlight the advantages and disadvantages of each alternative. Advantages and disadvantages could include but are not limited to the following: constructability, project duration, availability/distance of detour routes. Clearly identify and justify whether each alternative is feasible or not.

If the region requires assistance in determining if a traffic control alternative requires further evaluation in the Work Zone Impact Assessment, consult with BTO.

5.4.2.8 Recommendations

Summarize the findings of the analysis, document the process followed to evaluate the alternatives, provide and recommend the viable alternative to carry forward to the 60% TMP. Determine the type of TMP and justification of the chosen type.

5.4.3 TMP Type Description

All highway construction, roadway maintenance, utility and construction activities performed by WisDOT, municipalities and local governments have been grouped into three categories characterized by the degree of traffic impacts on mobility, safety, and cost. The categories are based on the severity of impacts. At the lower end are type 1 projects that have little or no traffic impacts. At the high-impact end are project types requiring detailed stand-alone TMP documentation. Below are the descriptions that identify the three TMP project types and differentiates the impacts the projects may have on road users, local communities and businesses. Also included are the required TMP components (see FDM 11-50-5.5.2 for details on TMP components) and elements for each project type.

Type 1

Projects requiring this TMP type have little or no impacts to the traveling public. The duration of work may be short to moderate and occur during off-peak hours. Work zones may involve mobile operations or short duration lane closures for less than one hour. Hazards do not require shielding or positive protection. Pedestrian facilities are not impacted.

Required TMP components:

- WisTMP form
- Traffic Control Plan (TCP), as appropriate
- Public Information & Outreach, as appropriate

Type 2

Most projects will be Type 2. Type 2 projects may have high public interest locally and potentially regionally because they affect more road users for a longer period during construction. Detours may be lengthy or require improvements to surface, geometry, or traffic controls. In urban areas, reconstruction may potentially disrupt business access and pedestrian/bicycle movement. Examples of projects that require this type of TMP include: resurfacing, reconstruction, pavement replacement or reconditioning, urban or intersection reconstruction

projects with unusual access needs or high traffic delays, bridge replacement, or rehabilitation, etc.

Required TMP components:

- WisTMP form
- Traffic Control Plan (TCP)
- Public Information & Outreach
- Incident Management Plan (IMP) for projects on freeways/expressways

Type 3

Type 3 projects are long-duration, extensive (mega) projects with traffic and mobility impacts that may extend beyond metropolitan, regional, and state lines. Public interest is very high in these projects because traffic impacts affect many road users, communities, interest groups, and businesses within the corridor and the transportation network. These are long lasting projects that require detailed staging. They typically involve multiple contracts and have significant impacts on regional and inter-regional traffic flow. Examples of projects requiring this type of TMP include: Zoo Interchange, IH 41 corridor, IH 94 N/S corridor and IH 39 Wausau corridor.

Required TMP components:

- WisTMP form
- Traffic Control Plan (TCP)
- Public Information & Outreach Plan (PIOP)
- Incident Management Plan (IMP)

The FDM provides guidance and tools to help project managers and traffic engineers through the process of evaluating the extent of traffic impacts of a given project.

5.5 TMP Development

Once the project moves into the Life Cycle 11 and project teams are created by regional project development, work shall begin on the TMP based on the results of the Work Zone Impact Assessment. For TMP development, WisDOT has partnered with the UW TOPS lab to create a system for developing, routing, approving, and storing TMPs. The WisTMP system was built with features that have automated many parts of the approval process. The Project Manager is ultimately responsible for the TMP. The WisTMP system (https://transportal.cee.wisc.edu/tmp/) allows any user to view a TMP that has been created. All projects must use the WisTMP system for TMP development. When entering information into the WisTMP system, the form will adjust if additional information is needed.

5.5.1 TMP Approval

All TMP approval is performed in the WisTMP system and controlled by the Project Manager. TMPs are reviewed and approved at two stages: 60% and 90%. Most TMPs stay within the region for approval at both levels. TMPs that have Federal Oversight checked will be routed to FHWA and to the Bureau of Traffic Operations (BTO). BTO will also review and approve all Type 3 projects and any project that includes:

- Innovative contracting (lane rental, enhanced liquidated damages, etc.).
- Temporary speed declarations on all Interstates and facilities with a normal posted speed of 65 mph or greater.
- Nonstandard mitigation strategies (i.e. ruggedized ambulance, fire station, drones)
- Law enforcement mitigation.

Once the TMP attains approvals, it is automatically routed to the Region Project Development Chief. Once signed, the TMP is Approved.

5.5.2 TMP Components

Each TMP has ten sections as follows:

- Section 1 Project Information
- Section 2 Project Description
- Section 3 Existing Conditions
- Section 4 Work Zone Strategies
- Section 5 Work Zone Impacts

- Section 6 Traffic Analysis
- Section 7 Public Information Strategies
- Section 8 Incident Management Strategies
- Section 9 Staging Plans
- Section 10 Additional Information.

Complete each section in order and as sections are filled out, additional information may be required.

Section 1 Project Information

This is basic information about the project. The location information is also included in this section and must be completed.

Section 2 Project Description

The Project Description should only be a brief overview of what the project is going to accomplish. Attach the Work Zone Impact Assessment to this section of the TMP.

Section 3 Existing Conditions

The Existing Conditions section asks project teams about the project area. The first set of questions are simple yes/no questions to determine the users impacted by the project. The answers to these questions will determine what needs to be filled out later in the form. The second part asks for existing traffic conditions such as: posted speed limit, normal travel time, current capacity, truck percentage and the presence of queuing. The Traffic Forecast Report, any Automated Traffic Recorder (ATR) station data or traffic volume data should be attached to the TMP in this section.

Section 4 Work Zone Strategies

The Work Zone Strategies section allows preparers to list of all strategies that will be used on the project. The planning estimate cost of those strategies should be added as they are being chosen. The strategies are listed in FDM 11-50 Attachment 5.2. When some of these strategies are selected, additional information in the TMP will need to be filled out. An example is when Lane Closures are selected, Section 6 of the TMP will inquire about the closure schedule and how it was developed.

Section 5 Work Zone Impacts

The Work Zone Impact section will have varying amounts of information to fill out based on what has been answered earlier in the TMP. Impacts to other routes, regions, or states will always need to be answered. Determine the holidays and major special events that are anticipated to occur during construction and identify the ways these events will be handled. Attach any correspondence from the impacted groups that discuss how the issues will be mitigated.

Section 6 Traffic Analysis

The Traffic Analysis section is the only location that traffic analysis will be shown in the TMP. Work Zone capacity, delay, queuing, lane closure hours, and road user costs may all be entered in this section.

Each project will be required to fill in a table about the anticipated traffic conditions. The table will include what the anticipated delay and queuing will be for the project based on strategies selected for the preferred alternative. The table is based off the locations entered in Section 1c. The work zone capacity, delay, queue, and the cause of the delay will be input into the table. Preparers are also asked how the work zone capacity was calculated, including an explanation of the method used. Attach any calculations in the section.

Preparers will be asked if the lane and ramp closures will have time restrictions. If yes, a table will be enabled for input. It is anticipated that projects will have some delay, up to 15 minutes or greater if there is an exception. If the project is reporting zero delay, preparers must explain the delay incurred if the lane closure hours identified are not followed.

If a detour is selected in Section 4, a table will be enabled for entering detour route information. The normal travel time, detour travel time, and detour distance for all routes are to be input. The detour plan sheets can then be attached in this section.

If changes are being made to an intersection or temporary signals are being used, preparers will be asked to describe what those changes will be.

For projects that select any of the innovative contracting strategies, preparers will be asked to show how the road user costs were determined for the project. Upload the worksheets used to develop the road user costs in this section of the TMP.

Section 7 Public Information Strategies

The Public Information Strategies section allows preparers to select strategies that will be used immediately before and during construction to address traffic concerns with the public. When the strategy is selected, preparers will fill out information on the intended audience and any additional comments. At a minimum, all projects should attach the Public Information and Outreach Plan.

Section 8 Incident Management Strategies

The Incident Management Strategies section allows prepares to list strategies applicable to the project. Details on the strategies may be found in FDM 11-50 Attachment 5.4. Document the costs associated with a strategy. Attach an Agency Emergency Contact Table (FDM 11-50-10 Table 10.2) to the TMP that is as complete as possible. For larger projects, the following may also be added in the attachments section:

-Emergency Alternate Route Maps/Operations Guide
-Communications Flow Chart
-Available Barricade/Ramp Gate Locations for Ramp Closures
-Emergency Access, Pullout and Traveler Information Equipment Locations Map

Section 9 Staging Plans

The Staging Plan section is where the preparer should upload the staging plans. Include a brief overview of the staging and highlight any unique reasons for project staging. If pedestrian presence has been selected on the project, then Section 9 will request plans for accommodating pedestrians during construction. For more information on developing plans for pedestrians, see FDM 11-50-31.

When developing the TMP, consider the impact to OSOW vehicles and their ability to travel through the project. Determine what the minimum height and width restriction will be in the project based on the chosen mitigation strategies. Document the measures taken to mitigate impacts to freight in the TMP. The Vehicle Size Restriction table is included in the TMP to document the minimum width and shy distances for each location in the project. For more information on freight in work zones, see FDM 11-50-21.7.

Section 10 Additional Information

The Additional Information section only needs to be filled out when a nonstandard mitigation strategy is used. If a nonstandard mitigation strategy is selected, Section 10 will request that FDM 11-50 Attachment 5.5 be completed and attached to the TMP.

5.5.3 60% TMP

The 60% TMP must be approved before the Design Study Report is completed. When developing the 60% TMP, much of the information developed for the Work Zone Impact Assessment can be used. Thoroughly complete Sections: 1, 2, 3, 4, 5, 6, and potentially 10 before submitting the TMP for 60% approval. If the use of law enforcement mitigation is recognized before 60%, include its selection in Section 8. Sections 7 and 9 may still be conceptual at the 60% point, but include discussion points for the design moving forward.

5.5.4 90% TMP

The 90% TMP must be approved before the PS&E is completed. The 90% TMP will pick up where the 60% TMP left off. Any information that was left incomplete or conceptual at 60% will be fully developed at 90%. Any new requests for nonstandard traffic mitigation must also be added to the TMP. The 90% TMP Approval will document BTO's approval for all contents including Temporary Speed Declarations, and mitigation strategies included except for Law Enforcement Mitigation which requires additional approval, see FDM 11-50-5.7.1.

5.6 TMP Strategies Matrix

5.6.1 TMP Strategies Matrix Overview

In Sections 4, 7, and 8 of the TMP, preparers will be asked to select different strategies. Work zone impact management strategies are used to:

1. Minimize traffic delays
2. Improve mobility
3. Improve safety for both motorist and worker
4. Reduce work duration
5. Maintain access to businesses, residents and other stakeholders

These strategies are not all inclusive and may not always be appropriate for all projects. An extensive list of TMP strategies is found in the TMP Management Plan Strategy Matrices found in Attachments 5.2 to 5.4. The strategies are broken down into the following types of strategies:

- Work Zone Mitigation Strategies (Constructability, Contracting, Innovative, Temporary Traffic Control, Detours, Restrictions, Coordination)
- Public Information and Motorist Mitigation Strategies
- Incident Management Mitigation Strategies

Strategies not identified in Attachments 5.2 to 5.4 are considered nonstandard strategies. To use a non-standard mitigation strategy, complete the "Request for nonstandard mitigation strategies approval" form found in Attachment 5.5 and submit to the BTO Work Zone Operations Engineer for approval through WisTMP.

The following are examples of services that are *not* eligible for funding:

1. Procurement of equipment such as speed display boards, total stations, uniforms, traffic control devices. (Consider exception if equipment can be reimbursed at a daily/weekly/monthly rate, or if equipment is consumable, i.e., typically has no useful life remaining after the project.)
2. County or local agency staff time involving project planning, providing data, meetings, or training, unless related directly to project incident management such as for dry run exercises. (Consider exception if a mitigation contract has been executed with the agency based on complexity of project, i.e. if there are multiple ramp/road closures involving frequent modifications to emergency access.)

5.6.2 Project Exception

The criteria used to determine the impact of a proposed work zone will be the 15 minutes of delay on freeways and expressways (FDM 11-50-30). When the delay exceeds 15 minutes above normal recurring traffic delays, request a project exception. The degree of detail in the exception request will vary with project complexity and expected impacts. The exception request should include a short discussion on the alternative mitigation strategies that were considered and those that are recommended to minimize delay while enhancing safety and mobility. For non-freeway projects, exemptions are not required.

5.7 Mitigation Contracts

5.7.1 Law Enforcement Mitigation Contracts

Use law enforcement mitigation contracts for freeway and expressway construction projects with significant safety and mobility impacts to the motorists. Identify the need for the Law Enforcement Mitigation Contracts in Section 8 of the TMP.

Non-freeway projects requesting law enforcement assistance will be on a project-by-project basis based on the specific work zone characteristics and roadway volume.

The following are factors to consider when determining the need for law enforcement assistance on freeways and expressways:

- Roadway Annual Average Daily Traffic (AADT) greater than 20,000
- Crash history in the project area
- Expected queuing
- Expected delay
- Experience on previous projects in the area
- Poor Site Distance/Roadway Geometry

- Work zone characteristics:
  - bi-directional traffic
  - crossovers
  - rolling closures
  - full freeway or system ramp closures

Law enforcement assistance for speed enforcement should be considered on a project specific basis. Consider speed enforcement if shoulders are greater than 10 feet wide and there are locations within the work zone for law enforcement to park without impacting motorists.

To request law enforcement mitigation services for a project, work with your Regional Work Zone Engineer.

Law enforcement mitigation contracts are completed annually, starting each year in Fall with final authorization completed by February the next year. Refer to Attachment 5.6 for the law enforcement mitigation contract process map.

Division of State Patrol

The Division of State Patrol (DSP) is the primary law enforcement provider for work zone traffic mitigation. DSP has the first right of refusal. If DSP they cannot commit to providing services deemed necessary in the proposed contract a local agency contract may be considered only after internal discussions with BTO, DSP and the Regional Work Zone Engineer are completed. Regions shall not reach out to any local agency without previous discussion of mitigation needs with BTO and DSP.

Local Agency

If DSP cannot commit to providing services deemed necessary in the proposed contract and internal discussions have been held between DSP, BTO and the Regional Work Zone Engineer and agreed upon, the local agency may be contacted to develop a contract. Local agency contracts require approval by BTO as well as signatures from the local agency, DTSD Bureau of Project Development and the Governor. The process of getting signatures may be lengthy so consider additional time for contract approval.

Local agency cost estimates shall use the same spreadsheet required for DSP and shall be attached to the contract. Similar to DSP, only meals, mileage and time will be paid for by the department, which are included on the cost estimate spreadsheet. Meals and mileage are based on the total number of law enforcement hours requested.

Local agencies should submit monthly invoices with a daily breakdown identifying each officer's hours worked during the month of enforcement.

5.7.2 Emergency Law Enforcement Mitigation

Emergency law enforcement mitigation is to be used for unexpected/unplanned work zone mitigation. Any planned work zone mitigation should have a signed contract in place, regardless of the contract cost.

Requests for the use of emergency law enforcement mitigation requires approval by the Bureau of Traffic Operations, State Traffic Engineer. Typically, approvals are completed in less than a day. Work with your regional mitigation contact to request emergency law enforcement mitigation. The following information should be written up and submitted to the statewide work zone engineer via email:

- Mitigation Need
- DSP Cost Estimate Spreadsheet

5.7.3 Freeway Service Team Mitigation Contracts

The Freeway Service Team (FST) provides expedited relocation of disabled and crashed vehicles made possible by the presence of FST vehicles continuously patrolling designated segments of interstate and state highways during designated hours and work zones. The continuous patrol will facilitate a quick response time to non-recurring traffic incidents such as breakdowns and traffic crashes, thus reducing the total time needed to clear the incident from the highway and restore normal traffic flow.

FST are frequently used as part of a project's work zone mitigation strategy and identified in the work zone TMP. Refer to TEOpS 6-3-6 Freeway Service Team Policy and Procedure" for further information.

5.7.4 Traffic Control or Capacity Improvement Mitigation Contracts

Major or mega projects may consider the need for traffic control or capacity improvements to minimize work

zone delay. Once the need for traffic control or capacity improvements are identified, work with your regional work zone engineer to determine the scope of the improvements necessary. If the strategy is a nonstandard mitigation strategy, then the "Request for nonstandard mitigation strategies approval" form shall be completed. See Attachment 5.5.

As stated on the approval form, the following information should be provided at the time of the request:

- Type of strategy
- Cost of strategy
- Justification of strategy

A follow-up analysis will also need to be completed 30 days after the strategy was implemented during construction to determine if it is effective. If it is not effective, the strategy should be removed from the project.

5.7.5 Multi-Modal Improvement Mitigation Contracts

Major or mega projects may consider the need for multi-modal improvements to minimize work zone delay. Once the need for multi-modal improvements are identified, work with your regional work zone engineer to determine the scope of the improvements necessary. If the strategy is a nonstandard mitigation strategy, then the "Request for nonstandard mitigation strategies approval" form shall be completed. See Attachment 5.5.

As stated on the approval form, the following information should be provided at the time of the request:

- Type of strategy
- Cost of strategy
- Justification of strategy

A follow-up analysis will also need to be completed 30 days after the strategy was implemented during construction to determine if it is effective. If it is not effective, the strategy should be removed from the project.

5.8 Implement TMP

The TMP is implemented in the plans and specifications. If the Project Manager changes between design and construction, the new Project Manager must become familiar with the TMP. Before the project begins, it is advisable to identify key personnel and their responsibilities and provide contact information. The project manager/engineer and the contractor may discuss and agree (preferably at the project preconstruction meeting) on how emergency operations will be carried out. Further guidance is provided in FDM 11-50-10.4. This information should be added to the TMP. If the project stipulates that a daily log of traffic control operation be kept, document this requirement in the implementation plan and share information with parties before beginning construction activities.

Identify line of authority for project manager and contractor personnel responsible for traffic control. Also identify personnel assigned the TMP monitoring responsibility.

5.9 Monitor TMP

Project teams should monitor the traffic on the project and make changes if necessary. TMP changes that should be documented are described further in FDM 11-50-5.10. Some elements of TMP strategies such as media releases, notifications to target groups, brochures, flyers, newsletters, etc., may need early distribution. Additionally, motorist notification, installation of fixed message signs, signing of detour routes, placing changeable message signs and work zone ITS require lead time.

During construction, the region should assign an individual(s) to collect data on the TMP. The data collected may be used to prepare a report on the successes and failures of the TMP. The data collected may include:

1. Verification of work zone setup
2. Changes that were made during construction
3. Changes that were made to the original TMP (include successes or failures)
4. Public/motorist reaction
5. Identification of peak hours
6. Average daily delays and queues experienced
7. Frequency of complaints and the nature of the complaints
8. Crash occurrence (type and frequency)
9. Surveys/feedback

10. A track of implementation cost
11. Person(s) responsible for the implementation of TMP.

For Type 3 TMPs, a monthly report summarizing the above information should be developed.

5.10 Documentation of Changes to TMP

TMP documentation has an added advantage of enhancing communication among stakeholders by enabling sharing of information from project scoping through construction. It is therefore essential that TMP revisions be documented if there is significant change to the impacts on the traveling public or if the TMP revisions cause a contract change order.

Examples that may require revisions to the TMP documentation include:

- Extended duration of temporary full roadway closures into weekday or weekend peak traffic hours (example - taking an unanticipated weekend full freeway closure to erect bridge girders or to trench a culvert across the freeway).
- Additional road closure, or additional ramp closure that adds more than 15 minutes of delay above typical travel time.
- Additional closures that affect OSOW freight movement.
- Changes in scope or intent of work, including work limits, work hours and time of year.
- Construction stage changes that affect roadway geometry, lateral clearance, design speed, vertical clearance, lane width and roadway closures.
- Extra Law enforcement contracts that were not originally anticipated.
- Both positive and negative lessons learned that impact safety, traffic flow and project delivery time.
- Revised detour routes that are an increase in distance and travel time for motorists compared to the original approved detour.

Project engineers are encouraged to engage and confirm with the region traffic engineer and BTO to determine whether the above listed traffic impact changes warrant an official documented change to the TMP.

Examples of changes that may not need revised TMP documentation may include:

- Planned long-term closures that are extended for short durations compared to their original planned closure schedule.
- Lane closure time period that does not cause additional travel delay.

Document the addendum to the TMP and complete the following:

1. Amend the TMP in the WisTMP System and revise the necessary sections. Attach any correspondence related to the change to the TMP.
2. E-mail to Regional PDS and Traffic (who signed the original TMP) and Statewide Bureaus (BPD/BTO), and FHWA if Federal Oversight project, describing the changes.

5.11 Post Construction Project Evaluation

Following good planning principles, the strategies should be linked to measures of performance to determine how effective the applied strategy was in promoting safety and mobility of a work zone. Use the data collected while monitoring the TMP during construction to assess the quality, performance, and effectiveness of the TMP in achieving project objectives.

Performance measures are typically applied to fulfill four functions:

- To continuously improve services (i.e., to understand how the strategy is performing and whether modification of its application is necessary to improve performance).
- To strengthen accountability of either the Department's or the Contractor's personnel to ensure the strategy is achieving the desired effect.
- To communicate the results of strategies to the public, stakeholders, and upper management.
- To provide better information for effective decision-making, and resource allocation in the future.

Performance measures for work zones differ from one project to the next. For example, car-pooling usage would be used to measure the effectiveness of a TMP mitigation strategy such as ride share incentives. Additionally, a work zone may include new strategies, such as new technology (ITS) or innovative contracting strategies. In these instances, a unique performance measure may be developed to evaluate the effectiveness of the new strategy.

The post construction report should provide brief discussion on the following areas:

- Overall statement reflecting the usefulness of the TMP
- Changes that were made to correct oversights in the TMP
- Changes that were made to the original TMP and how successful those changes were
- Public reaction to the TMP (using surveys)
- Average delay time, queue, etc., during construction
- How frequent complaints were made about the project, the nature of the complaints and how they were resolved
- Type of crashes/incidents that occurred during construction, and how they were resolved
- Recommendations or suggestions for future projects
- Highlight the areas of the TMP that were successfully implemented

Once the project is complete, the Project Manager shall mark the project as complete in the WisTMP system and attach the post construction report.

5.99 References

1. WisDOT Work Zone Policy Statement, TEOpS 6-1
2. Transportation Management Plan Guidelines, State of California, Department of Transportation
3. Traffic Management in Work Zones Interstate and Other Freeways, State of Ohio, Department of Transportation
4. Traffic Management Guideline for Work on Roadways, Ministry of Transport, British Columbia
5. Traffic Control Plan/Design, State of Indiana, Department of Transportation
6. Traffic Management Plan, Forest Road, New Mexico Tech.
7. I-5 Interstate Bridge Trunnion Repair Project, Traffic Management Plan, Report
8. Traffic Management Plan, Effectiveness Study, California Department of Transportation, Traffic Operations Division, Wilbur Smith Associates
9. Mosman Municipal Council, Guide for construction Traffic Management plan
10. Implementing the Rule on Work Zone Safety and Mobility, FHWA
11. Work Zone Public Information and Outreach Strategies, FHWA
12. Developing and Implementing Transportation Management Plans in Work Zones, FHWA
13. Meeting the Customer's Needs for Mobility and Safety during construction and Maintenance Operation
14. Work Zone Impacts Assessment – An Approach to Assess and Manage Work Zone Safety and Mobility Impacts of Road Projects, FHWA. Final Report, August 2006, U.S. Department of Transportation, Federal Highway Administration, Office of Operations, FHWA-HOP-05-068. Website: http://www.ops.fhwa.dot.gov/wz/resources/final_rule/wzi_guide/index.htm
15. Federal Highway Administration. September 2005. Work Zone Safety and Mobility Final Rule Implementation Guide. Prepared by Cambridge Systematics, Inc., Washington, D.C. https://ops.fhwa.dot.gov/wz/rule_guide/rule_guide.pdf
16. Federal Highway Administration. 2004. Final Rule on Work Zone Safety and Mobility on September 9, 2004. Federal Register (69 FR 54562). Washington, D.C. www.ops.fhwa.dot.gov/wz/resources/final_rule.htm
17. California Department of Transportation, Office of System Management Operations, Traffic Operations Program. 2004. Transportation Management Plan and Major Lane Closure Guidelines. Sacramento
18. Department of Civil Engineering, McMaster University, Hamilton, Ontario, Canada, Effect of Darkness on the Capacity of Long-Term Freeway Reconstruction Zones, Ahmed F. AL-Kaisy & Fred L. Hall
19. Virginia Transportation Research Council, sponsored by Virginia Department of Transportation, Guidelines for Developing Transportation Management Plan in Virginia, Richmond, June 2005
20. Midwest Work Zone Roundtable Discussions, May 2006 & May 2007
21. Facilities Development Manual, Wisconsin Department of Transportation

22. Traffic Engineering Operations and Safety Manual (TEOpS), Wisconsin Department of Transportation

24. Federal Highway Administration. 23 CFR Part 630, November 29, 2007. Subpart K –Temporary Traffic Control Devices. Available at http://ops.fhwa.dot.gov/wz/resources/policy.htm

25. Federal Highway Administration, Accommodating Pedestrians in Work Zones. Available at http://safety.fhwa.dot.gov/wz/planning/fhwasa03011/fhwasa03011.pdf

LIST OF ATTACHMENTS

Attachment 5.1 Transportation Management Plan Development Process

Attachment 5.2 Standard Work Zone Strategy Matrix

Attachment 5.3 Standard Public Information and Motorist Mitigation Strategy Matrix

Attachment 5.4 Standard Incident Management Strategy Matrix

Attachment 5.5 Non-Standard Mitigation Approval Form

Attachment 5.6 Law Enforcement Process Map

FDM 11-50-10 Transportation Management Plan Attachments

August 15, 2019

10.1 Transportation Management Plan Attachments

A Transportation Management Plan (TMP) includes public and motorist information, demand management/transportation operation, incident management, alternative routes, construction strategies and other innovative/alternative contracting strategies. Type 1 projects may have not have any TMP Attachments, while a Type 3 project will require all components to be discussed and included in the TMP.

Refer to FDM 11-50-15 for further discussion on work zone traffic control plan process.

10.2 Public Information & Outreach Plan (PIOP)

WisDOT has a major role in ensuring the public is informed about traffic impacts related to construction activities. Accurate and timely reporting of project information to the public is a valuable element of the overall TMP strategy. A public information and outreach plan (PIOP) lays out clear and concise strategies and procedures to reach out to the traveling public and other stakeholders with information about existing traffic operations and planned changes due to proposed project activities. The PIOP must be updated throughout the project life cycle to address issues as they arise.

Regional offices perform public information and outreach activities and implement the overall PIOP in coordination with the Office of Public Affairs (OPA). PIOP is used to ensure that:

- Stakeholders are informed about the project and its impacts.
- OPA is aware of all PIOP issues.
- Communities, businesses, and schools directly impacted by the project are informed about the project's impacts through participation.
- Road users are informed in a timely manner of possible negative impacts and where possible information on alternate routes are given.
- Emergency response agencies (e.g., law enforcement, ambulance service providers, hospitals, city and county officials) are informed of changes that might affect their operations.

10.2.1 PIOP Requirements

Each project presents varying degrees of challenges. Freeways/expressways, high-volume urban locations with commercial access requirements, and pedestrian/bicycle traffic present the most challenges and require the most extensive PIOP. Minor rural projects on low volume roads will not require as much detail. A PIOP may consist of any of the following basic items: (see Attachment 10.1)

- Media news release
- Public meetings or speaker forums
- Stakeholder and emergency response agencies meetings
- Notices to the traveling public (radio, TV, print media, social media, etc.)
- Brochures and mailers, videos, slides, presentations, etc.
- Paid advertising

- Special notification to targeted groups
- Telephone hotline
- Public information center
- Traveler information
- Portable changeable message signs (PCMS)
- Dynamic message signs (DMS)
- Ground mounted signs
- Portable work zone traveler information systems (ITS)
- Other affected group information
- Other methods including the Internet and social media

10.3 Work Zone Incident Management Plan (IMP)

A Work Zone Incident Management Plan (IMP) is a set of strategies used to help the contractor and the Department respond appropriately to incidents during construction within a reasonable timeframe in order to maintain safe traffic flow through the work zone. These strategies include monitoring traffic conditions within the work zone and adjusting traffic operations based on changing conditions. IMPs address unplanned events or incidents for TMP Type 2 project on freeways/expressways and are included in all TMP Type 3 projects to ensure effective management of responses within the work zone. Formal IMP documents are not required for TMP Type 2 projects on conventional highways, but if the project has detours or other temporary access restrictions on priority routes, coordinate with emergency service providers regarding incident and access planning. Modify and update the IMP to address field issues as they occur. The IMP is part of the TMP and is submitted or uploaded to the online WisTMP system. The IMP should be discussed early on during the TMP development. Identify the potential stakeholders/responders at the time of the 60% TMP Approval and Design Study Report (DSR) submittal to Bureau of Project Development (BPD). Upload a draft IMP to the WisTMP system for the 90% TMP Approval. Once the contractors have been identified finalize the IMP and upload it to the WisTMP system.

Key points to remember when using the IMP:

- IMPs serve as a plan and not a procedure.
- IMPs are applicable to any traffic incident or backup that occurs on any highway.
- IMPs are flexible and can be adapted based on the type of incident since no two projects are the same, apply experience and judgment in each situation.

IMP reference resources:

- Wisconsin Emergency Traffic Control and Scene Management Guidelines
- Emergency Traffic Control and Scene Management Field Operations Guidelines
- Regional Incident Management Coordinator Field Operations Guidelines
- Crisis Communication Management Plan
- Emergency Traffic Operations Plan
- Incident Command Flowchart

It is the intent of WisDOT to minimize impacts and delays to motorists and to promote safety in work zones. Planning for traffic incidents that occur within work zones is a critical component of reducing delay and increasing the safety, mobility, and reliability of the highway system. The level of complexity of the IMP depends upon the duration, complexity, and impacts of the project in the corridor/network. Long-term, complex reconstruction projects necessitate a comprehensive effort with procedures and processes to support the project. Short-term projects on lower-volume roads may simply require a meeting, ongoing coordination with the appropriate local or regional emergency response agencies.

Below are questions listed to help identify the appropriate elements within the IMP:

- How will this project impact emergency response in this corridor?
- Are there access issues for responding to incidents within the work zone?
- If an incident closes the highway in one or both directions, how will traffic be rerouted?
- Are there strategies to minimize project impacts on response agencies?
- Are there strategies to minimize incident impacts on the public?
- Are there procedures that would enhance incident clearance and safety?
- How will project personnel coordinate and assist emergency responders?

If additional strategies are needed to ensure stakeholders' needs are met during construction, the strategies should be identified, documented, and implemented. They may include:

- Contact list for construction and utility personnel (Emergency Contact Sheet)
- Procedures for communicating during an incident (Communication Flow Chart)
- Procedures for updating response agencies on traffic control changes
- Emergency access requirements
- Variable message signs or other traveler information strategies
- Emergency routes to be used in the event of a long-term incident

On projects with multiple stages, develop a plan for each stage of the project. Document and distribute the procedures and recommended strategies to all response agencies and construction personnel. Plan and budget strategies that require implementation (e.g., signing, ITS devices, and Freeway Service Team) as part of the project and are implemented at the start of the project. Training and follow-up sessions will be necessary to ensure that all agencies and construction personnel are familiar with the procedures in the plan. Review, revise, and update the procedures as necessary throughout the life of the project.

Identify on any project the minimum requirement, whether a traffic migration strategy already exists, and determine the role of the contractor in the implementation. Project staff or the contractor should also contact appropriate response agencies in the corridor to discuss their concerns with the proposed work zone and agree to procedures and strategies that will support the IMP. This communication and coordination is essential for any work zone. On more complex projects, coordination will become more formalized and require the involvement of more stakeholders. It will necessitate a greater commitment of time and resources on the part of the contractor.

10.3.1 Developing an Incident Management Plan (IMP)

Develop the IMP once the TMP type is determined. The level of IMP required is based on TMP type depending on if the project is on a freeway/expressway and the duration or the project (i.e., not needed for maintenance-type work).

The following process illustrates the common steps in developing an IMP:

1. Determine if there is a work zone incident management plan in place for the corridor
2. Identify response agencies
3. Meet with agencies to identify: existing protocols, concerns/issues, goals and objectives
4. Determine appropriate level of detail including availability of access points
5. Evaluate strategies
6. Recommend actions
7. Provide documentation to all response agencies via the IMP

If the construction project has multiple stages, the IMP should account for changes in project limits, ITS device locations, and contact information. Each construction project presents unique problems for emergency responders and the management of incidents that occur in the work zone.

10.3.1.1 Identify Stakeholders

To ensure work zones are safe and minimize the impact and delay to the traveling public, the plan should be developed in a collaborative effort with the emergency response and the public safety community and incorporated in the IMP. Planning for incidents that occur within work zones is a critical component for reducing delay and increasing the safety and reliability of the transportation system. Identify special events that may occur during construction and could affect work times. Acquire special event coordinator contact information.

10.3.1.2 Components

Each IMP provides a quick, in-the-field reference for response personnel. A standard format IMP ensures fast, effective, and consistent responses to incidents. Use the format listed below as the standard table of contents when developing each IMP for each TMP Type, note that the lists are not necessarily comprehensive. The recommendations of each section are described more in depth below.

TMP Type 2 Projects

- Project Summary
- Project Location Map
- Emergency Contact Information with TMC number

- Communication Flow Chart
- Inserts from the Emergency Alternate Routes Operations Guide (if available) or other Alternate Route Maps
- Available Barricade/Ramp Gate Locations for Ramp Closures if not already identified

TMP Type 3 Projects

- Project Summary
- Project Location Map
- Roles and Responsibilities
- Emergency Contact Information
- Support Services for Work Zone Mitigation (if available)
- Communication Flow Chart
- Inserts from the Emergency Alternate Routes Operations Guide (if available) or other Alternate Route Maps
- Available Barricade/Ramp Gate Locations for Ramp Closures if not already identified
- Activation of Traveler Information Systems
- Emergency Access, Pullout and Traveler Information Equipment Locations Map
- Appendices
    a. Emergency Alternate Route Maps (develop or insert if already available)
    b. Emergency Access, Pullout and Traveler Information Equipment Location Map
    c. Project Location Map

10.3.1.2.1 Project Summary

Provide a project description in the IMP. It may simply be the description used in the TMP document. Describe the location and type of project, the number of construction stages including closure locations and anticipated dates and special events that may affect the work zone. Also include a brief description of traffic volumes and any extraordinary circumstances that need to be accounted for.

10.3.1.2.2 Roles and Responsibilities

This section of the plan outlines the potential role of those agencies that could be involved in the response to an incident on the freeway/expressway. In addition, the day-to-day operational or project-related roles of each agency are summarized. An

example incident agency role **and** responsibility table is included as Table 10.1.

Table 10.1 Example Incident Agency Role and Responsibility

Agency	Day-to-Day Operational or Project-Related Roles	Potential Role in Freeway Incident
WisDOT – Traffic Management Center (TMC)	Coordinate and communicate lane and ramp closures for maintenance and construction projects Monitor traffic camera information Operate state-maintained PCMS	Manage Incidents from TMC - Watch for traffic problem areas on the freeway - Locate/verify incidents - Provide traveler information - Provide information to IH-41 Team Communication Officer
County Sheriff's Department	Responsible for patrolling the freeway Primary agency for traffic enforcement and incident response	Generally, first responder on scene Establish incident command at incident scenes Contact additional responders as necessary Provide traffic control Investigate crash scene
Wisconsin State Patrol	Responsible for patrolling the freeway Primary agency for traffic enforcement and incident response Monitor traffic camera information	Generally, first responder on scene Contact additional responders as necessary Provide traffic control Investigate crash scene Provide Recon Team and CMV Specialists (MCSAP) Fond du Lac Post Communication Center - Watch for traffic problem areas on the freeway - Locate/verify incidents - Provide traveler information - Provide information to IH-41 Team
County Highway Department	Primary agency responsible for freeway maintenance	Provide traffic control assistance during incidents Assist with incident clean-up
County Department of Emergency Management	No day-to-day operational responsibilities for the freeway system	Help coordinate large scale incidents (e.g., HAZMAT) Provide incident responders with additional resources if needed
Local Transit	Operate local bus routes on city streets	Reroute buses around incident or congestion as necessary

10.3.1.2.3 Emergency Contact Information

The following list identifies contact information for emergency response agencies that will be responsible for responding to or designating response for incidents involving their agency. Complete the contact information sheet at the preconstruction meeting by the project team. Table 10.2 is an example agency emergency contract table. The contact list is organized as follows:

- Project Team & State Government

- Project Contracts
- Other Agencies
- County Agencies
- City or Village Agencies

***Table 10.2** Example Agency Emergency Contact Table*

AGENCY	CONTACT	OFFICE	CELL/OTHER
TRAFFIC MANAGEMENT CENTER (TMC)			
TMC	Main Number	800-375-7302*	414-227-2166 (Office)
Responders			
Wis. State Patrol Emergency			
State Patrol Dispatch			
State Patrol Officers			
_____ County Sheriff			
_____ County Sheriff			
_____ Police Dept.			
_____ Police Dept.			
_____ Fire Dept.			
_____ EMS			
DOT REGION MANAGEMENT			
Regional Duty Officer			
RIMC			
DOT Supervisor – PDS			
DOT Manager – PDS			
Regional Director			
Maintenance Supervisor			
Traffic Supervisor			
COUNTY PERSONNEL			
On call Maintenance			
_____ County Commissioner			
PROJECT STAFF			
Project Field Office			
Project Engineer			
Project Manager			
Region Communication Manager			
PRIME CONTRACTOR			
Specialized Equipment Contractor			
TRAFFIC CONTROL – GENERAL			
General _____			
Message Boards _____			
OTHER TRAFFIC/EMERGENCY CONTACTS			
DOT Public Information Officer			
Freeway Service Team			
Special Events Coordinators			
Additional Resources			
Specialized Equipment available			
TIM Trailer at _____ location			
Jersey Barrier at _____ location			

10.3.1.2.4 Support Services for Work Zone Mitigation

TMP Types 2 or 3 often employ mitigation contracts for services such as law enforcement, freeway service teams, emergency response services, traffic control or capacity improvements on alternate routes, and multi-modal improvements. Reference the FDM 11-50-5.7 for more details on the process to follow in determining need and scope for mitigation contracts.

10.3.1.2.5 Communications Flow Diagrams

Interagency communication flows ensure that information is shared in a consistent and accurate manner when an incident occurs. It is imperative that all responding agencies have a clear understanding of this document. The following communication flow diagrams were created to illustrate the communication flows that exist between agencies during the reconstruction project. All communication flows are assumed to be two-way.

The communication flow diagrams do not represent a hierarchy for responding agencies. Rather, the communication flow diagrams are meant to illustrate the initial flow of communication between agencies. An example communications flow diagram is provided as Attachment 10.3.

10.3.1.2.6 Emergency Alternative Routes

If the corridor does not already have emergency alternate routes established, identify project-specific alternate routes with each work zone on the highway system. Consistency in selecting alternate routes is an important aspect of the program. Use the following criteria help to evaluate potential alternate routes:

- Use state highways whenever possible
- Consider long truck routes when available
- Avoid alternate routes with weight restrictions
- Avoid height restrictions imposed by bridge clearances, power lines, etc.
- Avoid routes that require traffic to make 90-degree turns
- Avoid at-grade railroad crossings, especially those with a high number of trains
- Avoid four-way stops
- Select routes that carry traffic in the same general direction as the interstate
- Minimize length of alternate routes
- Consider routes with coordinated signal timing plans or avoid routes with multiple uncoordinated signals
- Avoid traversing residential areas and school zones
- Consider all route options and closure requirements at interchanges, especially system interchanges

Based on these criteria, identify a preliminary list of emergency alternate routes for freeway segments within a given study area. Evaluate potential routes to ensure that the roadway can handle freeway-type traffic volumes. Conduct a field review of potential emergency alternate routes to confirm route selection. For further guidance in determining appropriate alternate routes, contact the TMC.

Provide brief explanation of emergency alternate routes.

> *Example: The preferred alternate routes for I-94 are the existing frontage roads. These provide quick access by traffic and limit the amount of adverse travel. If traffic back-ups extend beyond the listed access points, longer alternate routes can be implemented.*

Explain alternate routes in detail below and provide alternate route maps (as shown in Attachment 10.4).

> *Example: For SB: Traffic can be diverted west on WIS-100 (Ryan Rd) to WIS-36, southwest on WIS-36 to US-45, south on US-45 to WIS-20 and then east on WIS-20 back to I-94. For NB: Traffic can be diverted west on WIS-20 to US-45, north on US-45 to WIS-36 to WIS-100 (Ryan Rd) and then east on WIS-100 back to I-94.*

If traffic backups extend beyond the access points of the barricade locations listed, longer alternate routes can be implemented. Provide information on who needs to be contacted for each alternate route option.

> *Example: Contact TMC, State Patrol, Racine County, Village of Caledonia when alternate routes are implemented. See Contact list.*

See Attachment 10.4 for Emergency Alternate Route Map for an example.

10.3.1.2.7 Available Barricade/Ramp Gate Locations for Ramp Closures

If not already identified in the Regional Emergency Alternate Routes Operations Guides, a list of the available locations of barricades/ramp gates shall be included on the Emergency Access, Pullout and Traveler Information Equipment Location Map as shown in Attachment 10.5. During an incident, the Incident Commander organizes the ramp closures.

***Table 10.3* Available Barricade Location Example Table**

Highway Ramp & Direction	Number of Barricades	Distance from Work Zone
Ex. Hwy KR to I-94 East (SB) ramp	*1 ramp gate*	*1 mile*

10.3.1.2.8 Activation of Traveler Information Systems

Contact TMC at 800-375-7302 for activation of traveler information systems such as 511 updates, Dynamic Messaging Signs (DMS), Portable Changeable Messaging Signs (PCMS) and Traffic Incident Alerts (TIAs). Also, for DMS special signage and considerations, contact the Control Room Engineer.

Regularly review and revise the IMP to monitor current practices, identify, and resolve issues to minimize frequency of incidents and severity. Assign an individual(s) on complex projects with the responsibilities of ensuring the IMP is up to date.

LIST OF ATTACHMENTS

Attachment 10.1	Public Information and Outreach Plan Checklist
Attachment 10.2	Transportation Operations Plan Checklist
Attachment 10.3	Example Communications Flow Diagram
Attachment 10.4	Example Emergency Alternative Route Maps
Attachment 10.5	Example Emergency Access, Pullout, and Traveler Information Equipment Location Map

FDM 11-50-15 Work Zone Traffic Control Plan Process

December 18, 2015

This procedure explains the process used to develop a work zone traffic control (WZTC) plan. The overall process is shown in Attachment 15.1. The text below explains some of the more significant actions in this process.

15.1 Project Scope

This refers to the Project Scoping Process described in FDM 3-1-10. Traffic engineers from the region Planning & Operations Section need to be included in this initial scoping process.

15.2 Traffic Control Scope

The Project Manager will collect all input received during scoping and begin developing the traffic control scope. Refer to the Design Plan Review Checklist for Work Zone Traffic Control in FDM 11-50 Attachment 20.2.

15.3 Construction Under Traffic

Early in the process the feasibility of constructing the project under traffic must be addressed. The designer must consider issues such as length of construction with a detour and without, and the preferences of local officials and the public.

15.4 Detour Determination

The region Project Development Section and the region Planning and Operations Section traffic staff will determine if the project will have a detour and where it will be. This will be done with input from local officials and other Department staff as appropriate. Designers must also determine who will sign the detour (a contractor or state forces) and what improvements, if any, the detour route needs to accommodate the increased traffic.

15.5 Develop Staging Plan

Based on scoping decisions, designers develop a staging plan on how traffic will be handled throughout the life of the project. The staging of the construction work and the traffic handling are often dependent on each other. Therefore, planning for construction operations and planning for traffic handling need to be considered together.

15.6 Standard Detail Drawings

If the traffic control can be handled entirely by Standard Detail Drawings (SDDs), then designers will submit a

list of those drawings to the region traffic engineer for review and concurrence. This list shall then be considered to be the final traffic control plan. For many projects, a useful addition to the plan is a project overview sheet with a line drawing showing locations to use details of the SDD's. Such a drawing is useful to illustrate how the SDD's relate to each other and to ensure that no necessary traffic control details are overlooked. It also helps the contractor and project manager to determine exactly what will be needed on the project. If the SDD's do not adequately deal with the traffic control requirements, then a preliminary traffic control plan & details will be prepared.

15.7 Prepare Preliminary Traffic Control Plan & Details

The preliminary plan should detail the exact traffic patterns, types of devices to be used, taper lengths, spacing, etc. However, since these are preliminary sheets, it is not necessary to show each individual traffic control device. Designers must also identify which SDDs will be needed in the plan. Special provisions are usually not necessary at this point.

15.8 Preliminary Plan & Details Review

The designer meets with region personnel (and central office staff and others if necessary) to review the preliminary drawings before proceeding on the final Traffic Control Plan. This review will aid the traffic control plan designer.

15.9 Finished Traffic Control Plan & Review Meeting

It is recommended that this step become a new milestone in the project development process. The meeting can be an actual face to face meeting, a teleconference, or some combination. The designer's Work Zone Traffic Control(WZTC) checklist (see FDM 11-50-20) should be completed by this time and brought to the plan review meeting. The plan and special provisions at this stage shall be complete with all the detail and information necessary for PS&E except that quantities are not necessary at this time. Designers should document the results of this meeting, including meeting participants, and place a copy in the region files. The date of this meeting shall also be documented in the PS&E plan letter.

15.10 Contractor Involvement

In rare instances, the Wisconsin Transportation Builders Association (WTBA) may be used as a resource on traffic control issues. Contractor involvement in the WZTC process shall be limited to such topics as, general constructability, production rates, and timing constraints. Contractor involvement should be coordinated with the WTBA.

15.11 Bureau of Traffic Operations (BTO) Involvement

The decision to involve BTO on a project shall be determined by the region Planning & Operations Section. The region Planning & Operations Section will act as the liaison.

Projects that may require BTO input into a traffic control plan include, but are not limited to, plans that contain traffic control staging, complex urban or rural projects, projects that involve at-grade railroad crossings, politically sensitive projects, and highly unique situations that require a statewide perspective. BTO shall be involved in the review and approval of temporary speed zone declarations when reducing the speed limit from 65 and 70 mph.

FDM 11-50-20 Design of Work Zones

August 15, 2019

20.1 General Requirements

This procedure is intended to assure the maximum safety of motorists, pedestrians, and construction workers on all WisDOT construction projects.

The guidance for the design of work zone traffic control is found in WisMUTCD Part 6. Part 6 contains national requirements for all roads, with the consideration that a state trunk highway has characteristics and traffic volumes greater than the minimum type of roadway which Part 6 addresses. For this reason, statewide policy has been developed concerning long term work zone traffic control on the state trunk highway system. When WisDOT administers projects on the local system, the devices used must meet WisDOT specifications and the minimum requirements of Part 6; however, the layout for the work zone traffic control itself should meet the maintaining authority's policy which may differ from WisDOT policy.

21.1 Signing

On STH projects, all warning signs which represent a changed condition are to be orange and black except the No Passing Zone Pennant (W14-3), Object Marker (W5-52) and RR X-ing Ahead (W10-1). This is generally noted by changing the code to WO instead of W and including the general note "WO signs are the same as W signs except the background is orange". If there are existing yellow and black warning signs in place, they do not need to be changed to orange as long as the condition being warned of still exists. Any signs which are no longer applicable due to the traffic control should be covered or removed. All diamond shaped signs are 48" x 48" unless space constraints such as a narrow median or terrace do not allow this size sign to be used.

21.1.1 Modification of Type I and Type II Signs

At times, an existing message on a freeway guide signs or other permanent signs need to be altered or the sign covered if it is no longer appropriate. Indicate conflicting permanent signs to be covered on the traffic control sheets, and clearly show the sign or the part of the sign to be covered. List signs required to be covered in the quantities with the appropriate sign covering details. Under some circumstances, there may be multiple cycles of covering and uncovering throughout the course of construction staging. The sign covering will be measured separately for each cover/uncover cycle. In addition, list the number of cycles in the quantities and, if necessary, indicate the stage the sign will be covered and uncovered. For route assemblies, measure one sign covering per location.

Do not write special provisions that make covering type II signs incidental. Table 21.1 is an example table format that can be used for covering signs for traffic control in the miscellaneous quantities sheets.

Table 21.1 Covering Signs for Traffic Control Example Table

Stage	643.0910 Traffic Control Covering Signs Type I			643.0920 Traffic Control Covering Signs Type II		
	Each	Number of Cycles	Number of Signs	Each	Number of Cycles	Number of Signs
Stage 1	*a * b*	*a*	*b*	*x * y*	*x*	*y*
Stage 2	*a * b*	*a*	*b*	*x * y*	*x*	*y*
Stage 3	*a * b*	*a*	*b*	*x * y*	*x*	*y*
Stage 4	*a * b*	*a*	*b*	*x * y*	*x*	*y*
TOTAL						

21.1.2 Custom Sign Details

When a new sign with a special message is needed, a detail for that sign needs to be developed and included in the plan. Examples of these types of messages include:

- USE ALTERNATE ROUTE
- 40 TON WEIGHT LIMIT
- HWY XX BRIDGE
- UNDER CONSTRUCTION
- BEGINNING "DATE"
- USE ALTERNATE ROUTES
- 10 FEET MAX WIDTH
- 6 MILES AHEAD
- HWY XX CONSTRUCTION

On some projects, it may be advisable to sign an alternate route or construction bypass. For questions send an email to DOTBTOSignDetails@dot.wi.gov.

21.1.3 PCMS and DMS

PCMS and DMS may also be used to help supplement the standard signing found on the SDDs. Determine if there are any DMS boards upstream of the project, if so they may be incorporated into the temporary traffic control signing plan. Work with the TMC staff to incorporate the DMS into the plan. TEOpS 6-2-55 states how to use PCMS on projects. For DMS, TEOpS 17-1-1 states when DMS may be used.

21.1.4 No Hand-Held Phones in Work Zone

A no hand-held phone in work zone sign may be used in the advanced warning area of the work zone as well as on-ramps within the work zone for projects on freeways and expressways that have a law enforcement mitigation contract. The G Series construction information sign, G20-68, may be used and can be found at the following link:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/signplate/gseries.aspx

Work with your regional work zone engineer to determine if the project has an associated mitigation contract before adding the G20-68 sign to the traffic control plan.

21.2 Pavement Marking

The use of temporary raised markers type I to supplement the temporary line is very helpful, especially in areas where the alignment is changed from the existing condition and crosses different colors of pavements. Temporary raised markers provide unique wet night reflectivity throughout the project life; however, they are not resistant to snowplows, so the season of the project must be carefully considered to be sure the markers will stay in place. The feasibility of using temporary raised markers depends on the need for additional guidance based on the geometric difficulty of navigating the work zone during different stages.

Paint or epoxy's greatest use is on binder or lower courses, other surfaces which will be covered or removed, or when the temporary marking location coincides with the location of the future permanent marking. On relatively new asphaltic surfaces, removable black mask-out tape may be used to cover the existing markings.

Removable tape has the capability of adhering to the pavement throughout the construction season and can be easily removed intact or in large pieces, without grinding, blasting, or solvents. Its greatest use is on surface courses where revisions in traffic flow are necessary and where removal must be easily and quickly accomplished.

21.3 Channelizing Devices

Channelizing devices are used to guide drivers through work zones and prevent them from entering restricted areas. Channelizing devices include:

- drums
- tubular markers
- barricades
- cones, and
- other devices.

For information on channelizing devices for pedestrians see FDM 11-50-31. Each device has a target value which is how formidable it appears to drivers. The higher the target value the more likely the driver will respect the device. Drums are the Department's preferred channelizing device in work zones.

21.3.1 Drums

Drums have a high target value and provide a consistent dimension regardless of orientation to traffic. Use drums as the primary channelizing device for lane closures, lane shifts, shoulder closures, and ramp closures. For placement of lights on drums see FDM 11-50-20.6.

21.3.2 Flexible Tubular Markers

Use flexible tubular markers to divide opposing traffic lanes. For spacing information see SDD 15d6. Tubular markers may also be used where space restrictions do not allow for the use of other more visible devices or where specific conditions such as high wind may require a device that can be secured in place.

21.3.3 Barricades

Use Type III barricades to prevent drivers from entering restricted areas by placing them in the closed traffic lane, closed shoulders, across closed roadways, or at closed ramps. In areas where the roadway is closed to through traffic, barricades are staggered to allow access to businesses and residents. Type II barricades are useful in low speed situations and for pedestrian guidance. Type II and III barricades may also have signs placed on them.

21.3.4 Traffic Control Cones

42-inch traffic control cones may be used to delineate and channelize traffic through the tangent section or activity area of lane closures and to mark specific hazards. Also, the 42-inch traffic cones may be used during flagging operations on two-lane two-way roadways.

42-inch Traffic Control Cones are allowed as channelizing devices and may be used in the following situations:

- On an urban project where there is space or sight restrictions.
- Any duration of work where the use of a plastic drum would restrict proposed lane widths to less than 11 feet including shy distance.

42-inch traffic control cones are not allowed in the following situations:

- Lane tapers
- Shoulder closures
- To delineate temporary traffic signal trailers, message boards or arrow boards
- To delineate roadside materials or equipment.

Contractor requests to replace plastic drums with 42-inch channelizing devices should not be allowed unless changes in proposed construction will restrict the lane widths as described above.

21.3.5 Vertical Panels

Consider using vertical panels when a project stage will remain in place for multiple years or where mounting other traffic control devices is impractical. In both cases, contact the Regional Work Zone Engineer for further guidance.

21.3.6 Lights on Devices

Four types of lights exist that may be used in a work zone. They are classified A-D and more detailed information may be found in WisMUTCD Part 6. The most common types of lights used in Wisconsin are Type “A”, which are typically used on barricades and Type “C”, which are used on drums.

It is the policy of the Department of Transportation that Type "C" steady-burn lights should be used as a supplement to traffic control drums only where drums are used as channelization devices and the condition of the usage requires that motorists must deviate from their expected travel path when approaching or within a work zone:

1. In transition tapers at lane-drops, lights should be used on each drum from the beginning to the end of the lane-drop taper. In the case of lane-drops where the traffic will subsequently cross through a median crossover into a two-lane two-way traffic condition, lights should be placed on each drum in the initial transition, the tangent buffer area and the drums used to direct traffic from the single lane into the crossover. Where the length of the tangent buffer area exceeds three times the taper length, lights should not be used in the tangent buffer area.

2. At temporary exit ramps, lights should be placed on each drum in the gore area of the temporary exit ramp as follows: If drums are used adjacent to the mainline, on the first 5 drums, and when drums are used along the left side of the temporary ramp, to the point where traffic rejoins the permanent ramp. A minimum of 5 drums to a maximum of 10 drums will normally be used for the latter condition.

3. Short areas of control within a work zone such as a shift of traffic onto part or all of the shoulder around bridge work or other isolated work areas. Lights should be placed on the drums used to taper or transition the traffic into the temporary path.

4. Other areas which the designer or field engineer feels necessitate the use of lights on drums to provide a higher degree of control to attain an appropriate condition for motorist safety. Urban or suburban areas where adjacent development creates a high level of ambient lighting which may reduce the effectiveness of drums with sheeting only is an example.

5. Lights should not be used on drums that are used for delineation of a lane and are placed parallel to the lane, except as provided in preceding paragraphs.

6. Steady burn lights, where used, shall be one-way (unidirectional) with the light source showing only toward adjacent approaching traffic, unless there is a clear application in which two-way lights would logically benefit traffic control and safety.

21.3.7 Concrete Barrier Temporary Precast (CBTP)

Temporary concrete barrier may act as a channelizing device, see the requirements in FDM 11-50-35 for use.

21.3.8 Temporary Lane Separators

Consider using temporary lane separators when a location needs greater attention, such as a gore. Flexible tubular markers or vertical panels may be used in conjunction with temporary lane separators. Contact the Regional Work Zone Engineer for further guidance when considering this device.

21.4 Temporary Portable Rumble Strips (TPRS)

Temporary Portable Rumble Strips (TPRS) are traffic control devices used to alert motorists of changing roadway conditions. TPRS consist of textured rubber strips placed perpendicular to the direction of travel and weigh approximately 110 pounds. TPRS are not fastened or adhered to the pavement and are able to be placed with two workers. A 2016 speed study performed on a rural two-lane flagging operation during off-peak hours using TPRS in Wisconsin resulted in a daily average 85th percentile speed reduction of 5 MPH, a daily average reduction of speed violators by 45%, and a daily average of motorists braking of 33%.

Advantages of TPRS:

- Increase driver awareness through audible and vibratory alert of upcoming conditions
- Increase compliance to standard traffic control devices
- Increase braking and reduced speeds
- Ease of installation and removal
- Reusable

Disadvantages of TPRS:

- May cause erratic or avoidance maneuvers by drivers
- May cause rough ride or hazard for motorcycles
- May move due to inadequate installation
- Nearby residents may complain due to noise

Refer to SDD 15c12 for layout details.

21.5 Work Area Ingress and Egress

Ingress to and egress from work areas presents significant challenges. Hazards are compounded when the roadway carries high traffic volumes, high heavy vehicle percentage or operates at high traffic speeds. Safety challenges include:

- Motorists following construction vehicles into the work area;
- Deceleration of construction vehicles as they enter the work area and acceleration as they exit and enter open traffic lanes; and
- Proximity of workers on foot to ingress and egress locations.

In order for roadway construction projects to maintain safe operations, there must be procedures to allow for safe and efficient passage of work vehicles into and out of the work area and for motorists to travel through the work zone. Effectively addressing safe ingress and egress at the project level requires planning during the project development phase and implementing traffic control plans throughout the entire project. Therefore, designing work area ingress and egress is a critical aspect of the design process and should be considered when developing the TMP during planning and design phase of project development.

Consideration must be given to addressing how the contractor will safely move personnel, materials, and equipment into and out of the work area with minimum disruption. Proper work area ingress and egress improves safety for both the workers inside the work area and the traffic which may be traveling adjacent to the work area. Proper work area ingress and egress plans will:

- Allow for completion of intended work in the stage
- Minimize the impacts of slow construction vehicles on through traffic
- Reduce the number of vehicles following construction vehicles into the work zone
- Provide access control for driveways, intersections, and interchanges
- Improve communication with emergency responders; and
- Separate workers on foot from construction vehicles accessing the work zone.

Providing safe work area ingress and egress is mandated by the FHWA's Final Rule on Temporary Traffic Control Devices (23 CFR 630 Subpart K § 630.1108 e). Proper work area ingress and egress is unique to every project and each project will have different requirements.

The design of ingress and egress points on a project with positive protection such temporary concrete barrier

has safety and operational impacts to the work zone. Openings in this type of construction may potentially expose blunt ends to traffic.

21.5.1 Work Area Ingress and Egress Maps

The location of the work area ingress and egress points should be considered early in project development when developing the staging plan. Consider the following characteristics when identifying work area ingress and egress locations:

- Traffic characteristics (volume, speed, lane distribution, etc.)
- Lane and shoulder width
- Presence of concrete barrier, guardrail, crash cushions
- Pavement condition (joints), location of storm sewer structures (inlets, manholes)
- Adequate space for signs (type I, type II, fixed message)
- Stopping sight distances
- Location of horizontal or vertical curves
- Lighting
- Roadway geometry between travel lane and work zone
- Type of work to be performed in the area (for example, excavation for storm sewer or above- grade obstructions such as piling or bases for bridges, signs or lights)
- Weaving patterns between access points, intersections or interchanges (for example, access locations cannot be placed within 1,500 feet of interchanges)
- Emergency responders accessing the work zone
- Number of ingress/egress points to improve communication with emergency responders and delivery personnel
- Size, frequency and timeframe of deliveries
- Road restrictions for truck sizes
    - OSOW restrictions on Interstates or State Highways
    - County or City restrictions on local roads

21.5.2 Traffic Control Construction Details for Work Area Ingress and Egress

Provide a traffic control construction detail for work area ingress and egress on high profile public interest, especially on high speed, high volume projects. These construction details should be unique to each project but consider the following characteristics as well:

- Advanced warning signing and spacing
    - Fixed message and traffic control signs for trucks entering or exiting
    - Ingress and egress identification signing for emergency responders
- Channelizing device layout and spacing
- Temporary pavement marking layout
    - Identify locations for temporary raised pavement markers (RPMs)
- Concrete barrier layout
    - Exposed ends must be protected with approved end treatments
    - Identify locations for glare screens
- Acceleration and deceleration lane length and width
- The grade for the acceleration and deceleration lanes
- Taper rates or lengths
- Nighttime operations may require additional lighting
- Provide a procedure for when the ingress or egress is not in use:
    - Barricades with “Lane Closed/Road Closed/Bridge Out” signs
    - Channelizing devices
    - Covering inappropriate signs or installing fixed message signs over existing signs
- If necessary, develop a procedure for flagging or stopping traffic to allow ingress and egress.
- Tracking pads
- Parking/stopping locations or loading/unloading areas.

Consider the adequacy of tapers to allow construction vehicles to slow down before entering the work area, or conversely to merge at an appropriate speed upon exiting the work area. Improper design of work area ingress and egress points can cause traffic speeds to drop as merging construction vehicles impact the flow of through traffic. The slower speed may lead to rear end or run off the road crashes in the queue that form well away from the ingress and egress points.

21.5.3 Other Design Considerations - Work Area Ingress and Egress

In addition to the development of work area ingress and egress maps and construction details, there are many other work area ingress and egress elements which must be considered during the design phase. The elements to be considered can be categorized as design tasks, traffic control enhancements, traffic operations impacts, and construction operations effects. The elements listed below vary from project to project and are not all inclusive of potential construction ingress or egress operations.

Design Tasks:

- Development of work area ingress and egress plan for each individual construction stage
- Design of temporary haul roads
- Temporary fence or gates required during active and inactive operations
- Display the work zone clear zone requirements on the construction staging typical sections

Traffic Control:

- Proper guide sign placement for entrance and exit ramps
- Use of traffic control drums, type III barricades, flexible tubular markers, temporary raised pavement markers (RPMs),
- Use of temporary precast concrete barrier, end treatments or guardrail
- Utilization of PCMS or DMS during active access operations
- Locating speed limit reduction signs and speed trailers in advance of ingress locations

Traffic Operations:

- Signalization needs including temporary signals, vehicle detection, or signal phasing
- Ramp meter operation for ingress and egress near entrance ramps
- Physical turn restrictions for trucks at intersections or other ingress and egress locations
- Staged overhead clearances with utility wires, signal arms, sign bridges and bridges
- Pavement marking modifications
- Construction traffic speed differential with the posted speed upon re-entering travel lane
- CCTV camera utilization
- Work area ingress and egress restrictions during adverse road conditions

Construction Operations:

- Safe contractor parking locations outside clear zone, acceleration or deceleration lanes, and local roads
- Deceleration and acceleration lane shall be clear of debris and dirt that can be tracked onto the roadway through roadway sweeping and tracking pad installation
- Deceleration and acceleration lanes should be properly delineated from live traffic lanes and should be accessible at all times when in use
- Consider specialized construction operations such as bridge demolition, deck pours, crane mobilizations, beam setting, lighting, etc.
- Provide maps for truck drivers for clear work area ingress and egress, and establish good communication with truck drivers
- Staging of heavy equipment inside the work area
- Anchoring temporary concrete barrier if needed to protect a hazard or work area

21.6 Pavement Drop-off Protection

A drop-off is considered a change in elevation parallel to an adjacent travel lane 2 inches and greater with a slope steeper than 3H:1V. Drop-offs need to be properly protected to ensure vehicles and pedestrians can safely traverse the work zone. Common locations of drop-offs are between adjacent lanes of traffic, at pavement edges, on bridge decks, or between a work area and the sidewalk. Adjacent lane drop-offs are particularly dangerous for motorcycles. Prior to reopening travel lanes ensure an uneven lane condition does not exist, if it

does add appropriate signing to the plans. In order to fulfill this goal, certain traffic control devices can be utilized. Use SDD 15d39 when drop-offs are anticipated.

If drop-offs greater than 4 inches are anticipated to exist for more than 48 hours and is within 8 feet of the edge of the traveled way, use temporary barrier or eliminate the drop-off using a 3H:1V slope of compacted aggregate material. See FDM 11-50-35 for more information on temporary concrete barrier.

For activities such as base patching, consider developing special provisions that limit the work area for a contractor.

If the project team determines that more clear zone is necessary, use special provisions to change the standard specifications.

Use special provisions to limit the depth of drop-offs. Contact your Regional Work Zone Engineer when developing limits for drop-offs.

21.7 Freight Consideration

Construction staging can adversely affect larger vehicles ability to maneuver into and within the project limits.

For projects located on the OSOW Truck Route, verify that all OSOW-MT and OSOW-ST vehicles which can safely navigate in the preconstruction condition, can navigate safely during all stages of construction (see FDM 11-25-2.1.1 and FDM 11-25 Table 2.2). If unable to accommodate all required vehicles throughout construction, document these vehicles and propose mitigation techniques.

21.7.1 Multi-Trip Vehicle Dimension Consideration

Multiple-trip permit OSOW vehicles (OSOW-MT) exceed the legal semi-truck criteria to use the highway system. The permits are not load specific or route specific and are not required to check 511 prior to commencing a trip. Multiple Trip permits authorized by Wisconsin state statutes 348.27(2) and (7) may travel on any road or over any bridge (including culverts), unless the roadway or structure has been restricted in a manner consistent with various laws authorizing local or State personnel to restrict, e.g., weight posting. The envelope for these multiple trip permits are: 16 ft high; 15 ft wide; 150 ft long and 170k gross vehicle weight (gvw).

Lane and height restrictions that would restrict the movement of these OSOW-MT vehicles shall be identified and signed using appropriate signage. Special consideration shall be given to tight radius loop and interchange ramps to accommodate the longer vehicles.

21.7.2 Wind Tower Corridor Considerations

Wind towers sections are currently built and shipped out of Manitowoc, Wisconsin. The typical maximum load dimensions for these loads are 15 ft-8 in High, 205 ft Long, and 15 ft-1 in Wide. The dimensions of these loads have required extensive coordination and research to identify and maintain available corridors. See the OSOW maps for routes designated as Wind Tower corridors.

On projects located on these corridors, a minimum 16 ft travel lane shall be maintained in each direction. Due to the length of these vehicles, route the “Wind Tower Base” vehicle through the work zone using Autoturn to confirm off tracking will not impact the work zone.

If unable to maintain a 16 ft clear width, coordinate with adjacent regions and the BHM Freight Section to ensure viable routes exist.

21.7.3 High Clearance Routes

The Department has adopted statewide high clearance routes to maintain clearance for oversize loads up to 20 ft in height. On these routes, all temporary signals, signage etc. should be positioned to not impede loads up to 20 ft in height.

21.8 Traffic Control Quantities

When developing the traffic control quantities, include Traffic Control 643.5000. This item covers the installation, repositioning, and removal of the traffic control devices. However, Traffic Control 643.5000, does not include providing the devices and each project will need to include the individual bid items for each device that are used on the project. For sign covering see FDM 11-50-20.7.2.

21.9 Design of Traffic Control Plans

A checklist for use in the design of traffic control plans is included in Attachment 20.2.

21.10 Speed Limits During Construction

Some motorists respond to a reduced speed, while others do not see a need to slow down. This may cause a

differential in speed among drivers which is at times more dangerous than consistent higher speeds. Studies have indicated motorists will drive the speed they feel comfortable driving. Unless there appears to be a physical limitation to their speed they will typically not reduce their speed unless there is an enforcement presence. Part of the difficulty in enforcing lower speeds is the difficulty of stopping a vehicle in the work zone. This means enforcement must be stationed on either end of the work zone to ticket vehicles.

In 1994, Wisconsin legislature passed a law doubling the fines in work zones for certain moving violations. Speeding in a work zone is one of the violations for which the fine is doubled. For this law to be effective, reduced speed limits must be warranted, consistently set, and clearly posted in the work zone. On projects which have tourist traffic, congested conditions, major traffic volumes or other factors which make speed or other moving violations a major concern, the sign "Fines Double in Work Zones" (W21-61 or W21-62) may be placed on either end of the project.

Accepted practice has been to reduce the speed limit on some roads while the road is under construction, especially at times of work activity. The speed reduction is typically limited to 10 mph below the regular posted speed limit on the rural 70 or 65 mph freeways and expressways. It is normally not recommended to reduce the speed on a rural freeway which is normally posted at 55 mph. On some freeways in urban areas a reduction from 55 mph to 45 mph may be warranted if geometrics during construction are modified from the preconstruction situation. Cases where the speed is usually reduced include where traffic is shifted over to run two-way on a two-lane roadway. The rural speed limit (typically 70 or 65 mph) should be reduced because of the crossover geometrics and, at times, narrowed lanes and shoulders. The length of the reduced speed zone should be as short as feasible.

Factors to consider when exploring a reduced regulatory speed include proximity of the work to the traffic lanes, separation method of vehicles from the work area, and type of work being performed.

Where only one lane is closed, and workers are not present, conformance to a reduced speed is poor.

A reduction in regulatory speed limit on a rural 2 lane highway normally posted at 55 mph is not needed in most cases. If the method of construction and staging of traffic requires a reduced speed, it should most frequently be handled by posting an advisory speed at the geometric problems.

If a decision is made to reduce the regulatory speed, a maximum speed reduction of 10 mph is allowed, but a 15 mph speed reduction may be warranted. Refer to the temporary traffic control zones speed reduction policy in TEOpS 13-5-6 for further details.

Safety of motorists through a work zone can be handled by a combination of advisory speeds and the actual speed limits. Workers need to be protected but staging to remove traffic from areas near the workers or providing positive separation such as barrier is a better way to enhance worker safety than is a reduced speed zone.

The reduction in speed should be considered on a case by case basis, must have region traffic approval and a declaration prepared to make the speed enforceable. When reducing the speed on interstates and facilities with a normal posted speed of 65 mph or greater, a temporary speed zone declaration shall be completed and approved by the BTO.

In some cases, some of the design elements of the temporary traffic control are designed at less than the posted speed. In these cases, if the feature is isolated or at a spot location, this can be handled by posting an advisory warning sign with a subsign with the appropriate speed.

21.11 Detours

The Department will normally provide detours for traffic routing when the contract closes a state trunk highway to through traffic during construction. These are usually intended for use for short duration. See FDM 4-15-1 for a discussion of detour use.

When the detour causes abnormal inconvenience to the public which results in excessively high vehicle operating costs, the addition to the contract of interim liquidated damages should be considered.

These interim liquidated damages are separate from, and are assessed in addition to, the liquidated damages as contained in the Standard Specifications. The intent of their use is to motivate the contractor to complete a portion of the construction timely, as stated in the contract, to allow discontinuation of the detour and to reopen the specified section of highway to through traffic.

Interim liquidated damages are considered fixed and agreed damages due the state from the contractor for the inconvenience caused to the public by the continued closure of the section of highway beyond that time specified in the contract.

The use of interim liquidated damages may be appropriate on all projects where there is a need, regardless of

the source of funding. Justification for such use shall be included in the Design Study Report.

The method for calculating the amount of interim liquidated damages to be applied to a project is contained in FDM 11-2-1.7 and additional information is contained in FDM 11-50-32.

21.11.1 Detours - Construction Under Traffic

The method of constructing a project, including handling the traffic (whether it be local, through, or emergency traffic), needs to be resolved early in the project development process. If the job is to be built under traffic, traffic safety and construction methods must be considered in specific detail in the planning, design, and construction of the project. If a detour is planned, some degree of construction on the detour route may be necessary in order to accommodate the detoured traffic, and this construction must be completed before traffic is detoured.

Road user costs should be considered when determining the merits of a detour. Incentive/disincentive contract provisions should be considered when road user costs for a detour are very high. The shortest detour that will provide adequate service at a reasonable cost should be selected. Selection of a long detour route over state trunk highways which may encourage heavy use and damage to local roads, should be avoided. The state can maintain only the marked detour route.

Early coordination with affected people and local units of government is necessary. Consideration must be given to not only thru traffic but also to farming operations, businesses, tourists, school transportation, civic events, police, fire and ambulance service. Detours should be discussed at public information meetings.

Even though the state has the right to detour a state trunk highway over any public road, agreement with local officials should be attained.

If a detour may encourage use of local roads which are not the marked detour, local officials should be notified of this possibility and informed that the state cannot repair damage to local roads that are not the marked detour.

Evaluation of the detours (as well as potential haul roads) by the region staff and local officials is required before traffic is detoured. Special consideration must be given to roadway geometrics, pavement condition, bridge ratings, and all safety items. Agreement should be reached on what repairs are needed before the road can be used for the detour. A video tape of the route serves as a very good log of pre-detour conditions.

Detours that may affect another region should be coordinated with that region office.

Selection of detours for connecting highway construction should be closely coordinated with local officials since they are responsible for maintenance of detours over their local streets.

For projects on local roads, the signing of detours is normally performed by the responsible local authority; however, it may be assigned to a contract. If the work is to be assigned to a contractor, then this fact should be stated in the special provisions and a signing plan shall be a part of the PS&E.

21.99 References

1. Wisconsin Manual on Uniform Traffic Control Devices (WisMUTCD)
2. FHWA's "Guidelines on Work Zone Access and Egress" AASHTO Roadside Design Guide
3. ATSSA Guidance for Use of Temporary Rumble Strips in Work Zones, 2013

FDM 11-50-22 Traffic Control Plans for Divided Highways

August 17, 2020

22.1 Traffic on Divided Roadways

When planning construction projects on divided highways, all feasible alternatives that would maintain one-way operation on each roadway should be considered. These include the following options:

- Construction under traffic
- Placing traffic on existing or renovated shoulders
- Constructing temporary bypasses
- Detouring traffic to other routes

If one of these alternatives is determined to be feasible, the cost should be compared to the alternative of providing a means of separating two-way traffic on one roadway of the divided roadway. Maintaining one-way traffic on each roadway is the preferred method of control unless the construction operations do not allow it.

Two-lane, two-way operation (TLTWO), otherwise known as bi-directional traffic, on one roadway of a normally divided highway shall be used only after careful consideration of other available methods of traffic control.

Where the TLTWO is used, the traffic control plan shall include provisions for the separation of opposing traffic.

When the TLTWO is used on one roadway of a normally divided highway, it is not sufficient to separate traffic with only centerline striping, raised pavement markers and complimentary signing. Typically, the separation of opposing traffic in this situation includes the use of either tubular markers, drums or concrete barriers in addition to other items mentioned above.

In the transitions at the ends of the TLTWO, the typical traffic control plan will include a variety of the commonly available types of traffic control devices depending on the situation. Concrete barriers should be considered for use in high speed and relatively high traffic volume situations.

22.2 Lane Shifts

Lane shifts are a good way of maintaining lanes of traffic. In some locations lane shifts can be deployed with only removing and replacing the pavement markings. In other locations, temporary widening or replacing the shoulders may be necessary to accommodate a lane shift. Document the cost of the temporary surface in the TMP. SDD 15d41 provides details for lane shifts on divided highways.

22.3 Lane Closures

Lane closures are frequently used to complete work on the roadway. When considering lane closures, traffic analysis must be completed. For more information on the traffic analysis see FDM 11-50-30. The traffic analysis will determine when and for how long lane closures are acceptable.

When lane closures will be used on a project, use the standard detail drawings. SDD 15d12-a is for a single lane closure with a speed reduction. For more information on the process of speed reductions, see FDM 11-50-21.10. When a speed reduction is used, the traffic control should follow SDD 15d12-b. For projects that expect delay and will be deploying a dynamic late merge system, SDD 15d12-c should be used.

Look to make sure the lane closure SDDs will be sufficient. Do not locate lane closure tapers on horizontal and vertical curves.

Lane closures that use the dynamic late merge system or have potential issues with speed, a lane shift may be added. In the case of the dynamic late merge system, the lane shift would be used to keep the DLMS one side of the roadway for the duration of the project. For speed, the lane shift after the lane closure will help slow drivers down.

In cases when more than one lane will be closed use SDD 15d14. This would only be used for closures less than 24 hours as most roadways would have too much volume for the remaining single lane to handle.

22.4 Lane Width

When space constraints become an issue, lane widths may be narrowed. Lanes widths may be reduced to 11 feet. Make sure to consider freight movements within the narrow lanes. When this is considered, also look at the shy distance from roadside hazards.

22.5 Entrance and Exit Ramps within Lane Closures

The entrance and exit ramp design guidance in this section pertains to locations that are affected by lane closures as shown in SDD 15d15. Interchanges affect how the work zone operates especially when volumes are higher on the mainline or the ramp. Limitations do exist on the standard detail drawings and each location must be examined to determine the best option, which may require the development of specific details for each project. Work with your regional traffic section when determining the best treatment for a specific interchange.

22.5.1 Design Elements

Evaluate the following design elements when lane closures will impact interchanges:

1. Determine where the interchanges are located.
2. For each location determine:
    a. Location of work
    b. Closed lane
    c. Volumes
    d. Truck percentage
    e. Existing geometry
3. When work occurs within a right lane closure provide a parallel ramp entrance and exit ramp as shown

in SDD 15d15-a and SDD 15d15-e.

4. If the work is near the end of the ramp, determine if the ramp can be closed.
    a. Consider if the location is used regularly for emergency vehicles as an access point to the mainline or for hospitals in the area.
    b. Determine a detour for traffic that has lost access to and from the mainline facility.
    c. If the ramp must remain open and a physical barrier is present that prevents the creation of a parallel entrance ramp, provide enough acceleration length as possible. SDD 15d15-c may be used in this case.
5. When work occurs within a left lane closure examine the existing geometry to determine if additional traffic control is needed.
    a. If the location has a parallel entrance ramp design or an auxiliary lane is present and will remain in operation, the existing traffic control may be adequate.
    b. For locations that do not have a parallel entrance ramp or auxiliary lane, determine if the combined volume of the mainline and ramp is approaching the capacity of the single open lane. If the closure will be in place long term and is cost effective use SDD 15d15-b to create a parallel entrance ramp with temporary pavement.
    c. Interchanges that include loops and ascending ramps may create issues for merging traffic to find gaps. Consider using a lower capacity threshold for the mainline traffic that allows gaps for the merging traffic. Work with your regional traffic section to determine the lower threshold. If that capacity is exceeded than the use of SDD 15d15-b would be warranted.
    d. If the closure is in place intermediate duration or less use SDD 15d15-d.
    e. For exit ramps, the existing geometry and traffic control may be adequate.
6. When a left lane closure occurs on a facility that has three lanes or more, additional traffic control will not be needed, unless more than one lane is closed. If mainline traffic is reduced to a single lane then see #4 of this section.
7. When mainline traffic has been shifted to either the median or outside shoulder, the ramp alignment will potentially need to be shifted to maintain proper merging geometrics. This may require temporary grading and asphalt paving.

Locations that have high truck volumes, consider extending the temporary parallel entrance ramps for a longer acceleration lane.

For exit ramps, consider the potential of traffic backing onto the mainline during construction.

22.6 Crossover Design (Construction)

The crossover design guidance in this section pertains to a construction crossover as shown in Figure 20.1, Figure 20.2, Figure 20.3 and SDD 15d11 (not a maintenance crossover), which is shown in SDD 11a11. There are two types of construction crossovers shown in SDD 15d11 - temporary crossovers and crossovers to remain in place.

The typical temporary crossover roadway has a 4:1 side slope. This type of crossover is intended for use in a construction season or contract. Occasionally, there is more than one contract that will require the use of a crossover constructed in a previous contract. However, at the end of the contract(s) using the crossover, the crossover is removed and the median restored.

The typical crossover roadway to remain in place has a 10:1 or flatter side slope for high-speed facilities. This type of crossover is intended to remain in place after the construction contract(s) is completed. Occasionally, there is more than one contract that will require the use of a crossover constructed in a previous contract(s). However, at the end of the contract(s) the crossover will remain in place for future use. During rare situations where a permanent crossover is used on a lower speed facility, follow the slope guidance in FDM 11-45-30.

Construction traffic control is the same for temporary crossovers and crossovers to remain in place. Crossovers that remain in place require traffic control after construction that makes clear to drivers that the crossover is not open and that using the crossover is not allowed.

Identify the station location and construction crossover type for each installation in the plan.

22.6.1 Location of Crossover

When locating the crossover, be sure the superelevation can fit in with the existing pavement. Locate it far enough away from intersections and interchanges to allow traffic to normalize prior to potential conflicting traffic from an intersection or ramp. Typically, a lane closure is prior to a crossover so enough space must be provided to allow the lane closure to occur outside the interchange or intersection area. Physical constraints such as bridges, marshy median areas, bridge piers, etc., also influence the locations of the crossover. The location of the crossover should be such that the height of both roadways is approximately the same. Terrain must be suitable for a crossover: adequate decision sight distance, median width, and minimal difference in elevation of the opposing lanes, preferably in a tangent section of the roadway.

22.6.2 Crossovers to Remain in Place

Cost savings may be realized if some crossovers on freeway projects are left in place after the project is completed. Because these crossovers are designed to carry Interstate traffic, they are constructed with a high-type pavement that adds to the cost. If crossovers are left in place, this cost may be partially recovered as a cost savings to future construction. Crossovers also leave options open for emergency construction and remain available for future transportation operations plans, including incident management.

Crossovers left in place must be closed with positive separation when not in use, unless the opening is designed to be left open and an exception is obtained from FHWA. The following are some examples where it may be advisable to leave temporary crossovers in place:

- Major River Crossings. At these locations, there is usually one preferred location where a crossover can be placed, and any future work would require the rebuilding of the same configuration.
- Locations with Physical Constraints. In some instances, certain factors (e.g., sight distance problems, closely spaced structures, nearby interchanges, elevation differences between lanes) limit where a crossover can be built. Even though projects may be at different locations, the location of a crossover may be set by these limitations.
- Future Projects in Same Area. If structure work is scheduled for one year and roadway work anticipated in the next five years, the same crossover may be used for both projects. Another example would be a series of structures that are rehabilitated over several years.
- In the area of a long bridge, if the long bridge is damaged, the crossover could be used for emergency rerouting of traffic.
- Use for future work if a project is programmed in the near future (2-4 years) and the crossover is in an appropriate location.

When encountering situations as outlined above, the designer should:

- give consideration to leaving the temporary crossovers in place after the project is completed, include provisions in the contract to close the crossover during the time it is not in use
- discuss these provisions at the regular coordination meeting
- obtain FHWA and BTO/BPD concurrence

22.6.2.1 Criteria for Crossovers to Remain in Place

There are times when it is useful to leave a temporary median crossover in place after the construction is complete. Although it is not WisDOT policy to leave all median crossovers in place, there is merit in looking at crossovers on a case by case basis to determine if removal is appropriate. Concerns about leaving a crossover in place include:

- Drainage such as culvert sizing, culvert apron endwall (10:1 slope or flatter) according to FDM 11-45-30, and consideration of vane drains
- Snow melt running onto the travel lanes
- Illegal U-turn usage
- Future maintenance, including the periodic field review of the flexible tubular marker condition
- Life of the surface without traffic on it
- Appropriate location for future use. It may not be appropriate to install a permanent crossover where flood maps indicate a potential flood area
- Side slopes/end slopes shall be 10:1 or flatter when a crossover is left in-place after construction

Typically, there are issues using temporary barrier in permanent crossovers (adequate length of need, adequate length of barrier system for properly function, end treatments, etc.). It is not recommended that temporary barrier be used in permanent crossovers without discussion with BPD.

When leaving a crossover in place the following design parameters must be considered:

- Safety
- Alignment, desirable degree of curve, width
- Cross slope for drainage to median
- Median drainage, pipe size, design frequency
- Pavement thickness and type to support traffic and resist weathering during non-use
- Delineation when not in use (See SDD 15d11 - Traffic Control, Single Lane Crossover for an example) and provide appropriate signing to disallow U-turns

22.6.3 Design Elements

Evaluate these design elements for the installation of a construction crossover. Many of the items listed below are shown on Figure 20.1, Figure 20.2 and Figure 20.3. Traffic control for a single lane crossover is on SDD 15d11.

1. Determine appropriate location(s) for the crossover early in the design process to allow subsurface investigation to take place at the same time as the roadway subsurface investigation.
    a. Conduct subsurface exploration/investigation in the crossover area, which may include power or hand borings.
        i. Many times, the median becomes a location where waste material or other debris may be deposited. There is no way of knowing the depth and extent of possible poor soils without an investigation.
2. Provide a construction drawing in the plan showing the various design elements.
3. Fore slope design.
    a. Temporary crossover - provide a 4H:1V fore slope or flatter.
    b. Crossover that remain in place - provide a 10H:1V fore slope or flatter.
4. Show the curve radii at each end of each crossover roadway. If the pre-construction posted speed is 65 or 70 mph on the roadway, design the radius of curve based on the posted speed, but it should not be less than 4000 feet.
5. Provide a sag curve in the crossover between the mainline roadways. This may become more challenging when the mainline roadways are at different elevations and the median width is narrow. Drainage must flow away from each mainline roadway to prevent water/ice from forming on the mainline.
6. Show profile elevations in each direction and on each side of the proposed roadway, typically where the pavement marking edge line would be installed. Provide an elevation at least every 50 feet along curved sections, and every 100 feet along tangent sections.
7. When the profiles indicate that water ponding may occur it is recommended to consider a slotted drain installation. Contact BPD Design Standards and Oversight Section, Drainage Unit for assistance in the design and installation of slotted drains. The crossover is a rather large impermeable area and is generally difficult to get the surface water removed from the pavement quickly and surface drains must be considered.

    Pay attention to drainage in areas of cross slope rotation. One-lane crossovers typically have reverse curve alignments where the cross slope rotates from 2-percent left to 2-percent right. With a 2-percent cross slope, it is not necessary for this transition to be in the curve. It may be in the tangent at a location that is more favorable for drainage.
8. Pavement Structure. A pavement design is not required for crossovers, but the pavement structure should provide a practical, maintenance-free pavement for its intended surface life considering the soil conditions and estimated ESALs. A pavement crossover configuration is typically in the form of an X for a median width of 50 feet or wider (see Figure 20.1). A pavement crossover configuration may be in the form of a rectangle (large block) when the median width is less than 50 feet (see Figure 20.3).

    Experience has shown that a five-inch or six-inch thick HMA pavement over 12 inches of base aggregate dense has performed well on interstates and other high-volume roadways throughout the state. Four or five inches of HMA over 10 or 12 inches of base aggregate dense is typically used for all other roads.
    a. Temporary crossover - HMA pavement is recommended and will accommodate efficient removal. Use Asphaltic Surface Temporary bid item. Experience has shown that an HMA mix

with 19 mm, 25 mm, or 37.5 mm aggregate is preferable since it can be placed in a single layer up to six inches thick (see Standard Spec 460.3.2).

b. Crossovers to remain in place - may be HMA or concrete pavement.

i. If using HMA for crossovers to remain in place, use the HMA Pavement bid items. The pavement can be placed in one or multiple layers.

ii. If using jointed plain concrete pavement, then local aggregates may be used in the concrete mix even if the adjacent pavement will be constructed with high performance concrete.

9. Traffic control for on-ramps and off-ramps. Refer to SDD 15d7 for exit ramp traffic control where the exit crosses the median. Refer to SDD 15d8 for entrance ramp traffic control where the entrance crosses the median.

WisMUTCD Part 6 states "the basic safety principles governing the design of permanent roadway and roadsides should also govern the design of temporary traffic control zones." The goal should be to route traffic through such areas using geometrics and traffic control devices comparable to those for normal highway situations.

***Figure 22.1* Eastbound Crossover**

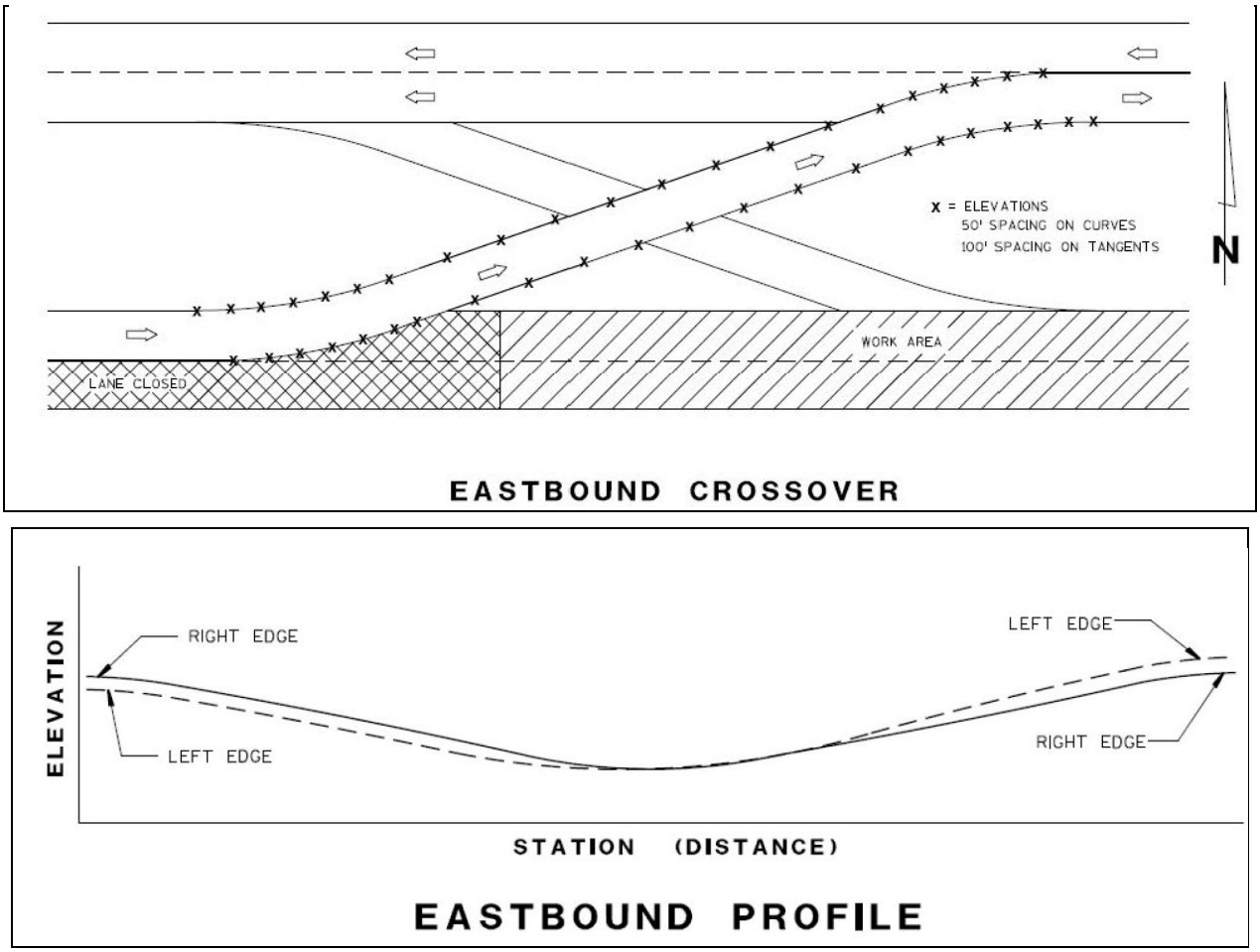
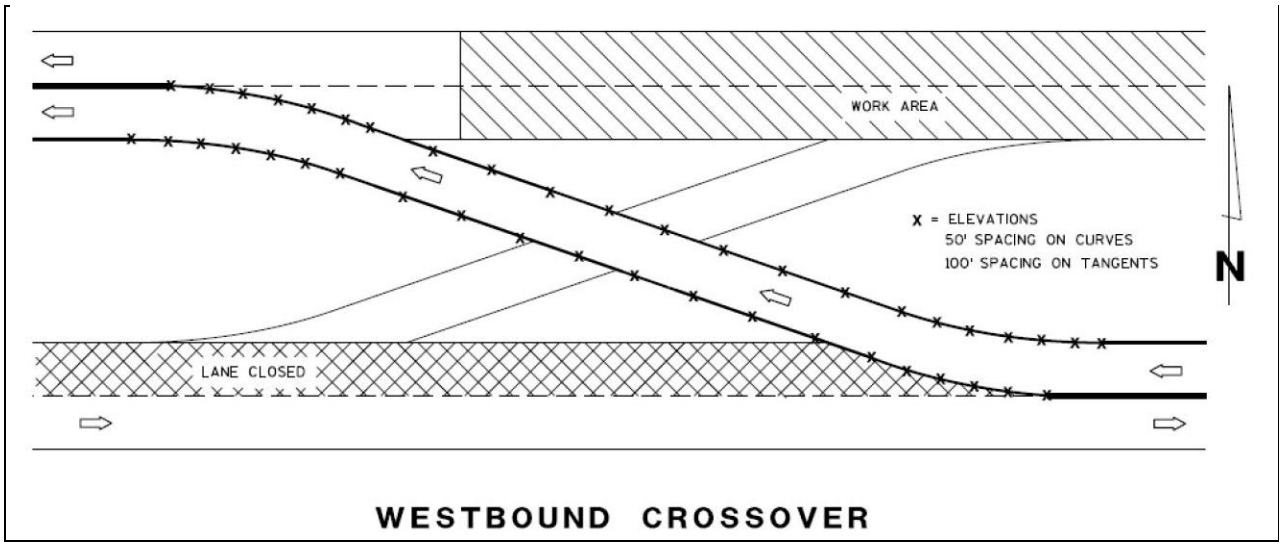


***Figure 22.2* Westbound Crossover**



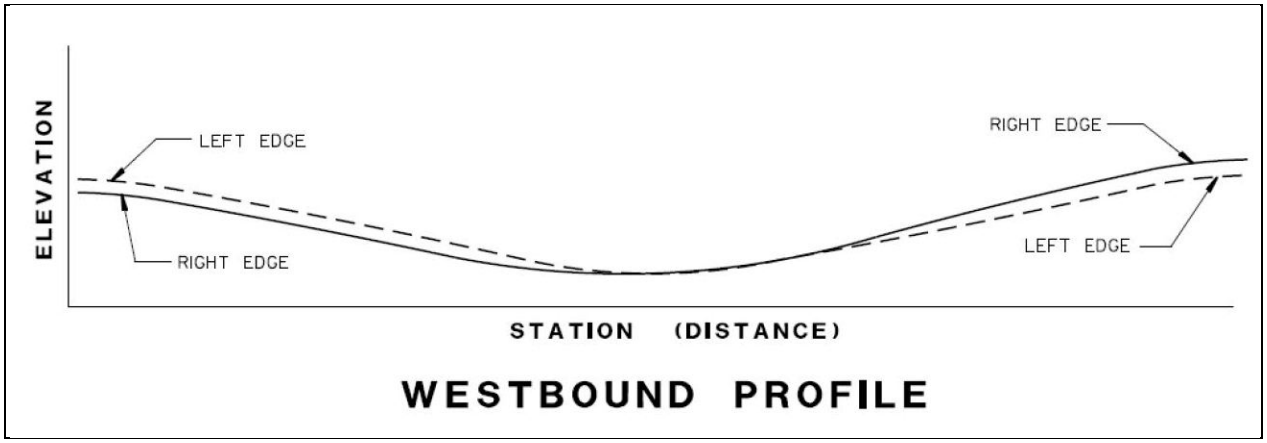
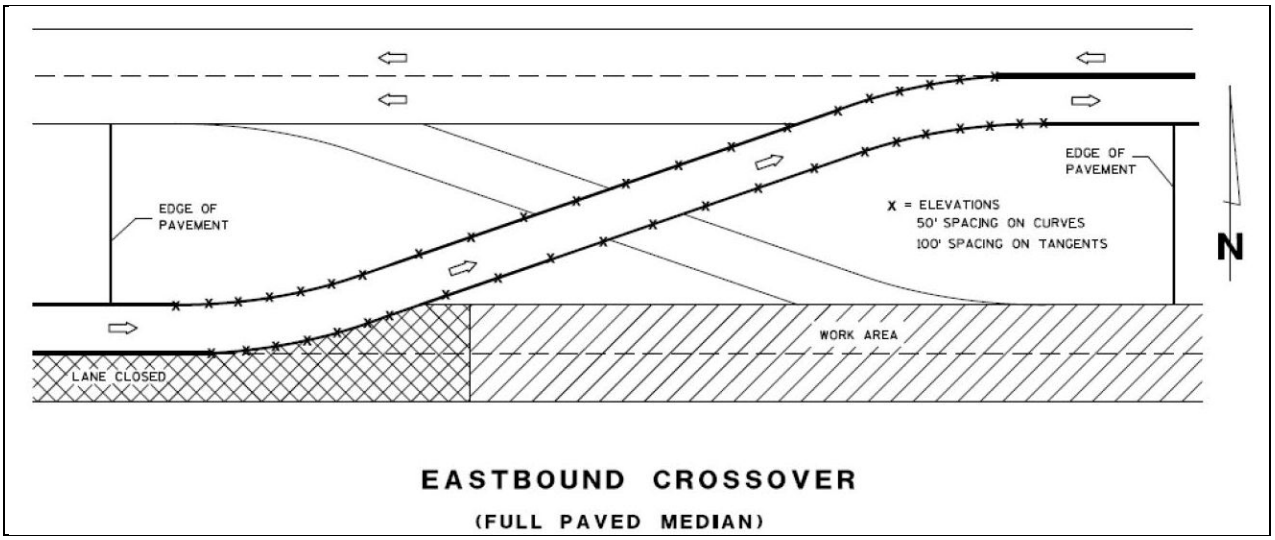


***Figure 22.3* Eastbound Crossover (Block Paving Style)**



22.99 References

References:

1. Wisconsin Manual on Uniform Traffic Control Devices (WisMUTCD)
2. Southwest Improvement Guide 7-25-50

FDM 11-50-23 Traffic Control Plans for Undivided Highways *August 15, 2019*

23.1 Traffic on Undivided Highways

When planning constriction projects on undivided highways, all feasible alternatives that would maintain traffic operations should be considered. Evaluate the following design elements to determine which strategy will be the most feasible:

1. Determine the traffic volumes
2. Determine the construction activities that will be taking place
3. Determine the roadway geometry

23.2 Lane Shifts

When the roadway geometry allows, traffic may be maintained by utilizing a lane shift. This will typically occur in locations that have parking lanes that may be used. Traffic may also be shifted onto a shoulder that is paved. Traffic shifts may require construction staging to complete the work.

23.3 Lane Closures

Lane closures may be utilized on roadways that have multiple lanes in each direction. In an area with signals, the signal timing must be considered when closing a lane. Lane closures may also be used in conjunction with lane shifts and would function like a crossover on a divided highway by putting all traffic to a single side of the

roadway. Construction staging is typically used when closing lanes.

23.4 Flagging

When considering different strategies, flagging may be considered on many roadways. Flagging is typically performed when work on the roadway can be completed within a day and an appropriate driving surface is available when the work is complete. Flagging is also used when an alternative route is impractical. Most roadways that have the best ability to accommodate flagging typically have an AADT of 5,000 vehicles per day (vpd) or less. Hourly volumes should then be checked to determine if they are below 600 vehicles per hour (vph). If volumes exceed 600 vph, add hourly restrictions to when flagging may occur. Check the area where the project occurs to determine if there are any traffic generators such as schools or factories that will cause significant queuing during a flagging operation. If the roadway is hilly, check to make sure truck percentages are low, as large trucks will have a difficult time accelerating up hills and this could have an impact on clearing the queue traffic.

Depending on the type of work flagging operations will move over the course of a day.

Temporary Portable Rumble Strips are typically used on flagging operations. See FDM 11-50-21.4 and SDD 15c12 for more information on using TPRS.

Pilot cars may be used on any flagging operation. Pilot cars are used to lead traffic from one end of the project to the other end and are the best method of controlling the speed that is traveled through the work zone. Pilot cars are typically used on projects that will have long distances between flaggers.

The distance of a flagging operation is determined by the work activity occurring. During pavement surface work flagging operations may extend a few miles. Culvert or landscape work the flagging operation may only be a few hundred feet. As the distance between flaggers increases the more likely additional flaggers will be needed at intersections within the work zone.

Nighttime flagging may be used when an alternative route does not exist and nighttime volumes are low. This allows some flagging operations on routes that are significantly higher than 5,000 AADT. Nighttime flagging is typically done only when necessary. Flaggers need to be illuminated so they can be seen by drivers. PCMS (portable changeable message sign) may also be added for additional advanced warning. Consult your Regional Work Zone Engineer when considering nighttime flagging.

All costs for the flagging are incidental to the contract as per Standard Spec 104.6. Additional bid items are not required if flagging is the only traffic control strategy used.

23.5 Temporary Signals

Temporary signals can be used to replace permanent signals during construction. Their use should be considered with the guidance of the Regional Signal Engineers. Temporary signals are another option in maintaining traffic in an area with a two-way one-lane configuration, such as during bridge or culvert work. See TEOpS 6-6-20 for more information.

23.6 Full Closures and Detours

When construction activities prevent traffic from using the route, a detour is typically set up. These types of activities are typically sewer, utility, or bridge work that will cause the road to be impassable. See FDM 11-50-21.11 for more information.

FDM 11-50-25 Smart Work Zones

February 18, 2020

25.1 Smart Work Zones

Use the smart work zone guidance to identify possible strategies that minimize work zone delay and improve work zone safety. Smart work zones consist of a variety of different devices and technologies that provide motorists with reliable real-time information about upcoming traffic conditions in the work zone.

Work with your Regional Work Zone Engineer or BTO Work Zone Engineer in determining the appropriate applications of smart work zone strategies.

25.2 Dynamic Late Merge System (DLMS)

A dynamic late merge system (Zipper Merge) may be used when there is heavy congestion and traffic is either slow or stopped due to a single lane closure as part of the work zone. When there is congestion, motorists use all lanes of traffic until reaching the defined merge area and then alternate merging into the open lane. When traffic is free flow or has light congestion, motorists move out of the closed lane as early as possible, which is often referred to as an early merge.

The DLMS is used to improve the flow of traffic on congested freeways to help reduce queue lengths and encourages drivers to stay in the closed lane until the merge point or taper through portable changeable message signs (PCMS). Deploying a DLMS can reduce the overall queue length by as much as 40% (from Minnesota Department of Transportation). Additional benefits of the system include:

- Increase in overall throughput
- Uniformly distributed speeds per lane
- Lane utilization
- Reduction in the maximum queue length
- Reduction of aggressive driving
- Reduction of crashes
- Alerts drivers of upcoming traffic conditions

A DLMS is typically made up of a series of PCMS used to display messages to motorists upstream of the work zone, portable traffic sensors to detect real-time traffic speeds, arrow boards. Flashing beacon signs (FBS), and an automated traffic system which stores the data and turns the system on and off based on a set of algorithms.

The system is real-time and only activates when there is congestion and speeds drop below 40 mph. When speeds drop below 40 mph, the system activates a series of PCMS with messaging encouraging the motorists to stay in their lane, take turns and merge at a designated area/location, thus achieving improved traffic flow and reduced queue. Once the congestion dissipates and speeds are back to free flow which is generally above 50 mph, the PCMS are deactivated and motorists follow the early merge process.

Consider a DLMS if the project has a single lane closure on a freeway, expressway or multi-lane commuter route with the potential to experience moderate to heavy congestion.

In order for a DLMS to be successful, extensive public outreach is required to ensure the motorists know how to drive through the system. Several public outreach documents have been developed and may be used. Work with the Regional Communications Manager (RCM) and the BTO to determine the most effective public outreach.

Table 25.1 can be used as a reference for miscellaneous quantities in the plan in conjunction with Standard Special Provision 643-040, Dynamic Late Merge System and SDD 15D12-c, Dynamic Late Merge System (SDD 15D12-c). The example in the table below displays each location the system will be used, specific stages, and distance or number of flashing beacon signs (FBS) required as well as the total days for each location. For example, Location IH 94 EB is anticipating a queue of 6 miles, which would require a total of 6 FBS and Location IH 94 WB is anticipating a queue of 4 miles, which would require a total of 4 FBS. The FBS are typically spaced every mile, starting 500 feet upstream from the W20-1F Road Work Ahead Sign until 1 mile downstream of PCMS #1.

Table 25.1 DLMS Miscellaneous Quantities Reference

DYNAMIC LATE MERGE SYSTEM (DLMS)			
LOCATION	STAGE	DISTANCE (MILES)	DYNAMIC LATE MERGE SYSTEM (DAY)
IH 94 EB	1,2	6	125
IH 94 WB	2,3,4	4	180

25.3 Portable Automated Real-Time Traffic Queue Warning System (QWS)

A Queue Warning System (QWS) is used when extensive queueing is expected upstream of a work zone. The QWS alerts motorists of upcoming traffic conditions (e.g., slowing traffic, stopped traffic) by displaying warning messages on PCMS.

A QWS has the potential to reduce end of queue crashes by up to 45% (from Texas Department of Transportation). Other benefits include:

- Alerting motorists of upcoming slow or stopped traffic conditions
- Diversion onto alternate routes

A QWS is typically made up of a series of PCMS used to display messages to motorists upstream of the work zone beyond the maximum queue, traffic sensors to detect real-time traffic speeds and an automated traffic

system which stores the data and turns the system on and off based on a set of algorithms. The PCMS are typically spaced every one mile upstream of the work zone to one mile beyond the maximum queue.

The system is real-time and only activates when traffic speeds drop below 40 mph, at all other times the system is inactive. When a portable traffic sensor detects speeds below 40 mph, the system activates the next upstream PCMS and displays a message to alert motorists of stopped or slow traffic ahead and to be prepared to stop. Once the queue dissipates and speeds are back to free flow (above 50 mph), the PCMS are deactivated. If the project has no adjacent projects within 15 miles, consider a QWS if at least one of more of the following criteria are met:

- Queuing
- Queue lengths expected to vary day to day and hour by hour
- Queues located near horizontal or vertical curves
- History of crashes in the project and queue area

In urban areas with primary commuter traffic and predictable queues, static signs with individual flashers may be used in place of PCMS. The static signs would say “Be Prepared to Stop When Flashing’.

A decision support system (DSS), which is incorporated into the WisTMP system, provides engineers with guidance as to when a QWS should be considered on a project. The DSS will consider the queue length, roadway geometry and crash history one mile upstream of the maximum queue.

Table 25.2 can be used as a reference for miscellaneous quantities in the plan in conjunction with Standard Special Provision 643-045, Portable Automated Real-Time Traffic Queue Warning System. The example in the table below displays each location the system will be used, specific stages, and distance or number of devices required as well as the total days for each location. For example, Location IH 94 EB is anticipating a queue of five miles, which would require a total of five PCMS and Location IH 94 WB is anticipating a queue of four miles, which would require a total of four PCMS. The PCMS are typically spaced every one mile, starting one mile upstream from the taper until one mile upstream of the end of anticipated queue.

Table 25.2 QWS Miscellaneous Quantities Reference

PORTABLE AUTOMATED REAL-TIME TRAFFIC QUEUE WARNING SYSTEM (QWS)

LOCATION	STAGE	DISTANCE (MILES)	QUEUE WARNING SYSTEM (DAY)
IH 94 EB	2,3	5	100
IH 94 WB	2,3,4	4	150

25.3.1 Basic Traffic Queue Warning System (BQWS)

A basic queue warning system operates the same as a QWS but consists of static traffic signs with flashing beacon signs (FBS) alerting motorists of stopped or slow traffic ahead, instead of PCMS.

If the Average Annual Daily Traffic (AADT) is between 20,000 and 25,000, projects should consider installing a BQWS on interstate/expressway lane closure projects that are expected to last longer than 4 weeks and do not anticipate regular queuing.

If the AADT is greater than 25,000, projects shall install a BQWS on interstate/expressway lane closure projects that are expected to last longer than 4 weeks and do not anticipate regular queuing.

See FDM 11-50-25.2 and FDM 11-50-25.3 for interstate/expressway projects expecting regular queueing for installation of a DLMS or QWS.

The BQWS will consist of three or six FBS for a two-lane configuration depending on truck percentages and six FBS for three lanes or greater configuration (both sides of the roadway). If truck percentages are greater than 20%, consider installing FBS on both sides of the roadway. Each FBS should be spaced approximately one mile from each other, as field conditions allow.

Table 25.3 can be used as a reference for miscellaneous quantities in the plan in conjunction with Standard Special Provision 643-046, Basic Traffic Queue Warning System and SDD 15D12-d, Traffic Control, Lane Closure, Basic Traffic Queue Warning System (SDD 15D12-d). The example in the table below displays the stage and direction the BQWS will be used as well as the number of FBS required for the set up based on number of lanes and truck percentages (i.e. two-lane highway with greater than 20% trucks or a three lane

roadway) and number of days the system will be used.

Table 25.3 BQWS Miscellaneous Quantities Reference

BASIC TRAFFIC QUEUE WARNING SYSTEM (QWS)			
LOCATION	STAGE	Flashing Beacon Signs (FBS)	BASIC TRAFFIC QUEUE WARNING SYSTEM (DAY)
IH 90/94 EB	2,3	6	100

25.4 Digital Speed Limit (DSL) Sign Assembly

A digital speed limit sign assembly may be used in place of a standard post mounted speed limit sign in work zones. The DSL sign assembly has the flexibility to display different speed limits based on specific times when the temporary speed declaration warrants the speed limit to be changed. An example would be a project with lane closures only at night, and no work occurring during the day and the temporary speed declaration is written to reduce the speed only at night when there is a lane closure. At all other times, the permanent speed limit should be posted.

The DSL sign assembly has the potential to reduce the number of times workers are exposed to live traffic covering and uncovering the temporary posted speed limit.

Consider the following criteria when determining if a DSL sign assembly is warranted for a project:

- Nighttime or daytime lane closures requiring a temporary speed reduction; no lane closures during the other time periods
- Temporary speed reduction warranted only when “workers are present” in the work zone

25.5 Construction Truck Entering and Exiting System

A construction truck entering and existing system is used to automatically detect when construction vehicles are planning to enter or exit the work zone and provide advanced notification to motorists. The purpose of this system is to alert motorists there may be construction vehicles slowing down to enter the work zone or merging at slower speeds when exiting the work zone.

The truck entering/exiting system has the following possible benefits to improve mobility and safety:

- Alerting motorists of slow construction vehicles entering/exiting the work zone
- Reducing frequency of motorists following construction vehicles into the work zone
- Reducing rear-end crashes caused by abrupt slow downs

The system is real-time and only activates when a construction vehicle is entering or exiting a work zone. When a traffic sensor detects a construction vehicle, either entering or exiting, a PCMS message is displayed upstream to alert motorists of a truck slowing down or entering the flow of traffic.

The following criteria should be considered when determining if a truck entering/exiting system should be installed:

- A construction vehicle uses a live traffic lane to either decelerate or accelerate because a deceleration or acceleration lane can’t be provided
- Construction stage will be in place for an extended period
- Construction stage changes are minimal and infrequent

A truck entering/exiting system typically includes traffic sensors or video detection, PCMS and an automated traffic system to activate the messaging. A static sign option may be used as well for trucks entering traffic which would include static signs with individual beacons that would flash when a truck was entering or exiting.

25.99 References

1. Wisconsin Manual on Uniform Traffic Control Devices (WisMUTCD)
2. FHWA’s "Guidelines on Work Zone Access and Egress" AASHTO Roadside Design Guide
3. Minnesota Intelligent Work Zone System Selection Toolbox, “Minnesota IWZ Toolbox”
4. Texas Department of Transportation, “Innovative End-of-Queue Warning System Reduces Crashes Up to 45%”

LIST OF ATTACHMENTS

Attachment 20.1 Work Zone Traffic Control Plan Review Checklist

FDM 11-50-30 Statewide Freeway and Expressway Lane Closure and Delay Guidelines

February 18, 2020

30.1 Introduction

Maintaining safe flow of traffic through a work zone during construction should be carefully planned and executed to improve work zone safety and minimize inconvenience and protect motoring public. Providing detours is sometimes a preferred alternative, but, for many reasons it is frequently impractical for freeway and expressway traffic, and traffic flow is maintained through the work zone. Traffic lanes may be closed, shifted, or encroached upon to provide room for construction or maintenance activities. When this happens, the remaining lanes available should be evaluated for expected work zone capacity and how they will perform under the demand volume on the roadway during the closure. See FDM 11-50-5 and FDM 11-50-10 for further details.

This section includes guidelines for planning typical lane closures and methodologies for considering regularly occurring high volume periods with special considerations for holidays and planned special events. These guidelines also include suggested procedures and methodologies to estimate the capacity of a roadway segment, determine traffic demand, and estimate queues and delays using traffic volume data. Once these factors are determined, necessary mitigation strategies can be developed to alleviate or eliminate user delay during a lane closure. Guidelines for emergency maintenance and construction operations and night freeway work operations are discussed and strategies are referenced for further investigation. The following process will be described in detail throughout the document.

1. Determine route-specific maximum delay guideline and recommended lane closure times
2. Estimate capacity under proposed lane closure (using Table 30.2 and other factors)
3. Estimate hourly demand profile (traffic volumes)
4. Estimate queues and delays using appropriate tools
5. Identify appropriate mitigation strategies
6. Plan and prepare for special conditions

30.2 Lane Closure System (LCS)

The Lane Closure System (LCS) is a web-based system for the request and approval of lane closures on all state trunk networks (STN). The LCS was developed for streamlining and enhancing the ability to track lane and shoulder closures on the STN. The system enhances communication between the Department and freight operators by providing advance notification on roadways with width restrictions to facilitate route planning. The benefits of LCS include:

- Enhanced coordination of activities to reduce back-ups and potential conflicts (i.e., multiple activities can utilize the same closure; avoid lane closures during a special event; avoid right lane closure near a left lane closure on the same roadway)
- Eliminating duplications and inefficiencies by streamlining information into one system
- Providing historical data that can be used to make informed decisions

All lane and shoulder closures and restrictions require approval by the Regional Traffic Engineer or Regional Traffic Supervisor. Include the LCS Standardized Special Provisions (STSP) in the specials. Lane closure entry and training are located on the internet at the Wisconsin Traffic Operations and Safety Laboratory (UW-TOPS Lab) WisTransPortal System.

30.3 Special Events and Holiday Work Restrictions

Special events that generate traffic in addition to normal traffic volumes should be considered in developing the transportation management and lane closure plans. A special event is defined as an event that generates a certain minimum attendance threshold according to the location of the event. Refer to TEOpS 17-2 for more information.

The contractor shall not close a lane(s) in the direction on approaches to the event unless the lane closure is part of an acceptable long-term traffic control staging for the project. Work with your Regional Traffic Engineer to identify the hours before and after an event. An illustrative list of specific events that may apply is provided for the Regions in Table 30.1.

Table 30.1 Statewide Special Events that May Prohibit Lane Closures

All Regions	Region Specific
Major holidays	Local Festivals
Major recreational destinations	Summer Fest
Major shopping malls	State Fair
Farm progress days	Brewer games
Major auctions	EAA fly-in
Concerts	Packer football home games
Tournaments	Badger football home games
Opening fishing	
Deer hunting season	
County fairs	

- Freeway and expressway lane closures are not allowed on the following holidays, other than accepted long-term traffic control staged projects:
  - Easter
  - Memorial Day
  - Independence Day
  - Labor Day
  - Thanksgiving
  - Christmas
  - New Year's Day
- Freeway and expressway lane closures are not permitted after noon on the day preceding a holiday. For holiday weekends, freeway lane closures are not permitted after noon on the day preceding the holiday weekend until 6:00 AM (or after the peak hour traffic volumes occur) the day after the holiday weekend. See FDM 19-15-40.1 for more details.
- Permitted freeway and expressway lane closure times may vary when high attendance is expected for special events. The actual permitted periods of lane closures at locations influenced by increased traffic due to special events will depend on the assessment of roadway capacity available compared to expected demand volumes including additional traffic generated by the special event.
- Freeway and expressway shoulder closures shall follow the same restriction times as lane closures during special events.

30.4 Peak Hour Restrictions

Peak hours are defined as the hours of the day that observe the largest utilization of capacity, which may cause user delay. Peak hour times vary depending on the location of the roadway and the types of users traveling on the roadway. In developed, urbanized locations, there is typically a morning and evening peak period during the weekdays. Consult the Regional Traffic Engineer for potential peak hour restrictions for the particular roadway segment being analyzed. No lane closures shall be permitted for short-term or short duration maintenance, utility, or surveying during normal peak periods unless peak hour volumes are below 1,600 passenger cars per hour per lane (pcphpl) and accepted by the Regional Traffic Engineer.

30.5 Freeway Work Zone Capacity

Accurately estimating freeway work zone queuing, delay, and road user costs is an important step in safely and efficiently planning lane closures for freeway work zones. To standardize how freeway work zone capacity analysis is performed, a work zone traffic analysis tool was developed for calculating work zone capacity and estimating queue, delay, and road user costs.

The maximum number of vehicles that can travel on a freeway at a given time is considered its capacity. In Chapter 10 of the HCM 6th Edition, base capacities of freeway facilities are provided. For a freeway with a free-flow speed of 70 mph, the base capacity is 2,400 passenger cars per hour per lane. In work zones, the capacity

of freeway lanes can be greatly reduced due to the characteristics of the work zone site.

Delay is the amount of travel delay incurred by vehicles traversing a work zone. Estimating the potential delay resulting from a freeway work zone closure helps identify the impact to the road users and adjacent roadway networks. Motorists who do not find the delay acceptable may divert from their original route and travel on adjacent roadways.

Queues occur when traffic is stopped or slowed. In freeway work zones, queues are typically the result of either an incident or the volume of a freeway exceeding its capacity. In planning work zone closures, it is important to accurately estimate the length of queue from a potential work zone closure in which the freeway volumes are expected to exceed the capacity of the work zone.

Time spent traveling in a vehicle is a resource with economic value[1]. Therefore, when road users incur travel delay, there is an economic cost associated with delaying the road users. In freeway work zones, when the volume of a roadway exceeds the capacity, a queue of vehicles will form thereby delaying motorists.

30.5.1 Freeway Work Zone Traffic Analysis

The equation below should be used to determine freeway work zone capacity:

$$Average\ QDR_{PCE} = 1{,}866 - 40f_{LCSI} - 132f_{barrier} - 101f_{TOD} - 205f_{area} - 207f_{CI} - 47f_{regional}$$

where,

Average QDR_{PCE} = average queue discharge flow rate (pcphpl),

f_{LCSI} = lane closure severity index; $\frac{1}{\#\ of\ open\ lanes * open\ ratio}$, where open ratio is the ratio of open lanes during construction to the total number of lanes,

$f_{barrier}$ = barrier type; concrete = 0, cone/barricade/drum = 1,

f_{TOD} = time of day; day = 0, night = 1, and

f_{area} = area type; urban =0, rural = 1

f_{CI} = construction intensity; low = 0, high = 1, and

$f_{regional}$ = regional area; south = 0, north = 1.

The work zone traffic analysis tool should be used for all freeway construction projects to determine queueing, delay and road user costs based on the work zone capacity and should be documented in the TMP.

Contact your Regional Traffic Engineer or the BTO Work Zone Engineers for additional information with the tool or calculating work zone capacity.

FDM 11-50-31 Temporary Pedestrian Accommodations *August 17, 2020*

31.1 Introduction

The Wisconsin Manual on Uniform Traffic Control Devices (WisMUTCD), Section 6A.01 states -"*The needs and control of all road users (motorists, bicyclists, and pedestrians within the highway, or on private roads open to public travel, including persons with disabilities in accordance with the Americans with Disabilities Act of 1990 (ADA), Title II, Paragraph 35.130) through a TTC (Temporary Traffic Control) zone shall be an essential part of highway construction, utility work, maintenance operations, and the management of traffic incidents.*"

Per WisMUTCD Section 6D.01, if the TTC zone affects the movement of pedestrians, adequate pedestrian access and walkways shall be provided. If the TTC zone affects an accessible and detectable pedestrian facility, the accessibility and detectability shall be maintained along the alternate pedestrian route.

In addition, per WisMUTCD Section 6D.02, when existing pedestrian facilities are disrupted, closed, or relocated in a TTC zone, the temporary facilities shall be detectable and include accessibility features consistent with the features present in the existing facility.

Pedestrian and bicycle facilities are critical transportation routes for communities. They allow people to travel

[1] US Federal Highway Administration. (2011) Work Zone Road User Costs: Concepts and Applications. Final Report. FHWA-HOP-12-005. Washington, DC.

from one place to another, stimulate business districts by encouraging shopping, keep communities safe by providing more activity on the street, and enhance community health and well-being.

The range of pedestrians in a work zone can vary widely and includes the young, the elderly, and people with disabilities such as audio, visual, or mobility impairments. All pedestrians need protection from potential injury and must be provided a smooth, firm, stable, slip-resistant, and continuous hard surface with a clearly delineated travel path (without abrupt changes in grade or terrain). Pedestrian facilities parallel or crossing the work zone must provide these characteristics.

This guideline supplements FDM 11-46-1 "Bicycle and Pedestrian Elements Affecting Complete Streets" and is intended to minimize conflict between competing construction activities that produce unsafe or inconvenient conditions for pedestrians and bicyclists in work zones.

31.2 Project Scoping/Planning

Collect general information on the project, especially pedestrian and bicycle volumes if possible. The surrounding land uses will also be an indicator for pedestrian and bicycle travel. Identify stakeholders (e.g. walking, jogging, and cycling groups, etc.), who may be affected and need to be notified about the status of the project. Include other groups such as water and utility companies that may have a project scheduled concurrently to discuss how advance utility work may impact pedestrian travel. Provide pedestrian accommodations during utility relocations and begin discussions during the permitting process.

31.3 Transportation Management Plan/PS&E

Include a detailed pedestrian description in the TMP; refer to FDM 11-50-5. Also include a pedestrian traffic control plan clearly showing pedestrian diversions and necessary traffic control devices with locations of barricades, signage, and channelizing devices. If a detour is provided, include signage for the detour and attach an approved detour plan, when necessary. Also, attach necessary construction details for nonstandard items such as temporary curb ramps, temporary surfaces with detectable edging, channelizing devices, etc. If using nonstandard items in the design, include special provisions in the contract documents.

31.4 Design Considerations

Identify existing pedestrian volumes, ages, and pedestrian generators, including shopping centers, schools, playgrounds, parks, housing, hospitals, churches, and concurrent work beyond the project limits that may influence the staging of construction. It is preferred to separate pedestrian movement from both work zone activity and adjacent traffic. Additional field data may be required to provide adequate design information to build an ADA compliant temporary facility.

As the TMP is developed, consider the available non-motorized data to develop a comprehensive pedestrian mitigation strategy. There are three primary considerations in planning for pedestrian safety in work zones on highways and streets:

1. Provide a safe, convenient travel path for pedestrians that replicates as nearly as possible the characteristics of the existing sidewalks. If necessary provide an alternate accessible pedestrian route.
2. Avoid creating pedestrian paths that lead pedestrians into direct conflict with work vehicles, equipment or construction operations.
3. Avoid creating pedestrian paths that lead pedestrians into direct conflict with mainline traffic moving through or around the work zone.

The TMP process needs to evaluate traffic patterns: vehicles, pedestrians, and bicyclists travelling parallel to the work zone and crossing the work zone. Operating speed is another consideration in selecting the most effective treatment (e.g., using positive protection devices to separate the work zone from pedestrians, or using a wider buffer space or fence, between vehicular traffic, workers, and pedestrians). Consider temporary concrete barrier for pedestrians diverted into a portion of the street used concurrently by moving vehicular traffic. See FDM 11-50-31.4.4.1 for more information.

These devices are used to minimize vehicle intrusion into workspace or pedestrian walkways.

It may be necessary to provide curb ramps (see FDM 11-46-10 and SDD 15d30) to maintain accessibility.

When determining pedestrian needs in the proposed work zone, consider information obtained during the public input process and through field visits to understand travel patterns and access to facilities in the work zone.

In work zones:

- Provide walkways that are clearly marked and if temporary pedestrian barriers are required they should be continuous, rigid, and detectable to blind or low vision persons to navigate. See FDM 11-45-30 and FDM 11-50-35.

- If sidewalk is available on both sides of the road, stage sidewalk replacement/closure so one side of the sidewalk is accessible at any given time. Utilize temporary pedestrian surface and curb ramps when required to maintain pedestrian access.

Also, keep:

- Clear pedestrian headspace, minimum 7 ft.
- Walkways free from pedestrian hazards such as holes, debris, abrupt changes in grade or terrain and clear of equipment.
- Sidewalks clear of obstructions such as construction traffic control signs and other construction materials. Features should not intrude into the usable width of the sidewalk or temporary pedestrian facility.
- Access to bus stops if possible; otherwise consider relocation of bus stops.

Design temporary pedestrian facilities to meet accessibility criteria to the maximum extent feasible. Where pedestrian's routes are closed, pedestrian route detours are to be provided; however, detours are a last resort. See FDM 11-46-5 for pedestrian circulation path and pedestrian access route accessibility criteria.

Communicate blocked routes, alternate crossings, signs, and signal information to pedestrians with visual disabilities by using devices such as audible information devices, accessible pedestrian signals, barriers, and channelizing devices that have a detectable edge. When using channelization to delineate the pedestrian walkway through the work zone, use a continuous detectable edge. With respect to the channelizing devices, the bottom surface shall be no higher than 2 inches above the ground, and the top surface shall be no lower than 32 inches above the ground. Where multiple channelizing devices are aligned to form a continuous guidance pedestrian channelizer, the connection points should be smooth to optimize long-cane and hand trailing. See Chapter 5 "Designing Pedestrian Facilities" of the Wisconsin Guide for Pedestrian Best Practices.

The use of flaggers on the arterials to assist at crossings may be beneficial during certain construction stages as a spotter to help pedestrians at non-signalized intersections. Use flaggers for short or intermittent situations in addition to other work zone control devices. If necessary, include these types of services as well as advance public notification of sidewalk closures in the contract special provisions and plans.

At locations where adjacent alternate temporary walkways cannot be provided, post appropriate signs at the limits of construction and in advance of the closure at the nearest crosswalk or intersection to divert pedestrians across the street. Advance signing encourages crossings at intersections and not at midblock. If the placement is too far in advance, the signs will be ignored and pedestrians will likely travel into the work zone. When determining crossing placement, observe adjacent land uses, travel patterns, and origins and destinations for proper location of temporary crossings.

31.4.1 Temporary Pedestrian Accommodation

Incorporate a detail showing where temporary pedestrian accommodation will be located. Use signing to direct pedestrians to safe and accessible street crossings in advance of a temporary traffic control zone.

Place signs at intersections so that pedestrians, particularly in high-traffic-volume urban and suburban areas, are not confronted with mid-block work sites that will force them to skirt the temporary traffic control zone or make a mid-block crossing. Whenever mid-block crossing is necessary, provide a clearly marked pedestrian crosswalk with temporary pavement marking and signs that do not interfere or conflict with work zone traffic control signs.

Pedestrians will generally not retrace their steps to make a safe crossing, so providing temporary curb ramps and advanced warning of sidewalk closures at intersections for safe pedestrian crossings is necessary. For typical layout for pedestrian accommodation refer to FDM 11-45-20.4.1 and SDD 15d30.

Provide a smooth, firm, stable, slip-resistant and continuous hard surface throughout the entire length of the temporary pedestrian facility. Minimize abrupt changes in grade or terrain that could cause tripping or be a barrier to wheelchair use. Verify that accessible crossings are maintained throughout the work zone.

31.4.2 Sidewalk Diversion, Detours and Closures

If pedestrians must be diverted or detoured from their normal path, select an alternate route that may be on a temporarily closed parking lane next to the work zone, sidewalk on the opposite side of the roadway, or a path around the block. Generally, a route on the same side is best.

There are cases where a temporary barrier between traffic and the pedestrian detour route must be spelled out in the TMP and be included in the specials.

Closing pedestrian sidewalk or pathways is undesirable. However, if the sidewalk must be closed; locate the

alternative pedestrian access route in the same alignment or corridor to provide pedestrian travel continuity or access to buildings along the route. For instance, if a parking lane is available or a traffic lane can be temporarily closed, a sidewalk diversion could be used instead of closing the sidewalk and placing a detour. When a detour is required, provide pedestrian crossings preferably at intersections, not at midblock locations. A staging plan is critical for this alternative because accommodation can be challenging if the crosswalks are to be disturbed. When selecting the alternate route, provide a temporary traffic barrier if adjacent to traffic or construction equipment.

Use detectable channelizing devices to delineate the route and use positive protection to separate pedestrians from vehicular traffic. Protect pedestrians from hazards such as holes, cracks, debris, light pole bases, terrace furniture, street fixtures, overhead fixtures, etc. Maintain a 5 ft wide path, 4 ft minimum, for wheelchair access and provide temporary curb ramps where necessary. When it is not possible to maintain a width of 5 ft throughout the entire length of the pedestrian route, provide a 5 ft × 5 ft passing space at least every 200 ft, to allow individuals in wheelchairs to pass. However, a 4 ft minimum clear width needs to be maintained. See SDD 15d30 for details.

A crosswalk closure may be necessary at times, see SDD 15d30 for recommendations on how to provide accommodations at the crossing. Any temporary pedestrian crosswalk provided shall be accessible as stated in WisMUTCD 6F.13.

31.4.3 Pedestrian Separation in the Work Zone

When pedestrians are required to navigate the work zone, consideration needs to be given to potential hazards. Excavations, drop-offs, manholes, etc., that exist near the pedestrian pathway require delineation, covering or shielding. Consider pedestrian barricades or other protective barriers to prevent pedestrian access into a work zone (tape, rope, barrels or plastic chain are not adequate). Temporary work on sidewalks (e.g., utility openings, vaults, and sidewalk reconstruction) also needs to be barricaded. Verify that adequate sight lines are provided between pedestrian and drivers at intersections, midblock crosswalks and other potential conflict points. Potential pedestrian vehicle sight obstructions include safety fences, boundary fences, bridge abutments, buildings, street furniture, queued vehicles, work vehicles, work equipment, and other local features. Refer to FDM 11-10-5.1 for additional sight distance information.

31.4.3.1 Temporary Concrete Barrier

In locations where pedestrians may be vulnerable to impact by errant vehicles, separate foot traffic from vehicular traffic with positive protection. Temporary concrete barrier may be needed due to increased risk for vehicle intrusion into temporary pedestrian pathway on high-speed roadways. Install a temporary concrete barrier (SDD 14b7) channelizing device, if the location meets the guidelines in FDM 11-45. Barrier deflection details and warrants are explained in detail in FDM 11-45-30. If temporary concrete barrier is used to protect pedestrians, ensure that it is firmly anchored and interlocked. Interlocking the barrier allows the device to perform as tested and prevents pedestrians from straying from the channelized path.

Research and experience have shown that vertical curbs cannot prevent vehicle intrusions onto sidewalk. As a result, a normal vertical curb is not a satisfactory substitute for temporary concrete barrier protection where needed. There are instances when temporary barriers may be necessary to prevent pedestrians from unauthorized movements into the active work area and to prevent conflicts with traffic by eliminating the possibility of mid-block crossings.

31.4.3.2 Pedestrian Barricades

Use pedestrian barricades to separate pedestrians from the work area, drop-offs, or low speed traffic. When pedestrian barricades are needed to identify the path of pedestrian travel around or through the work zone, use retroreflective material for improved night time visibility on the top and bottom. See WisMUTCD 6F.63 for additional guidance.

The MUTCD prohibits the use of tape, rope, barrels, or plastic chain strung between devices because they are not detectable. Close joints between channelizing devices to prevent canes or small wheels from being trapped, to reduce the risk of tripping, and to facilitate safe hand trailing. Furthermore, when used as a sidewalk closure mechanism, channelizing devices must run the *entire width* of the sidewalk without gaps.

31.4.4 Signage

Provide signage to alert pedestrians of sidewalk closures, diversions, or detours at an accessible controlled crossing point in advance of construction impacts. Ensure the sign does not block access to ramps or push buttons. Additional signs downstream may be needed to reinforce the message. Install a type III barricade across the full width of the sidewalk with a sidewalk closed sign; if the sidewalk is detoured, include a detour sign. Mount traffic control signs and other control devices at least 7 ft above the finished surface of the

temporary pedestrian route. In addition, ballast for the signs and devices should not extend into the pedestrian walkway narrowing the path to less than 4 ft.

31.4.5 Temporary Surfaces

Provide a smooth, firm, stable, slip-resistant and continuous hard surface throughout the entire length of the temporary walkway. Compacted soils, aggregate, and sand are not to be used as a surface course for temporary sidewalks (Figure 31.1). These materials present challenges to pedestrians especially those with disabilities. Examples of smooth, continuous hard surfaces include asphalt, slip resistant metal plates and 3/4-inch plywood.

Construct temporary sidewalks across unimproved streets and drives designed in accordance with Chapter 5 “Designing Pedestrian Facilities”, of the Wisconsin Guide for Pedestrian Best Practices.

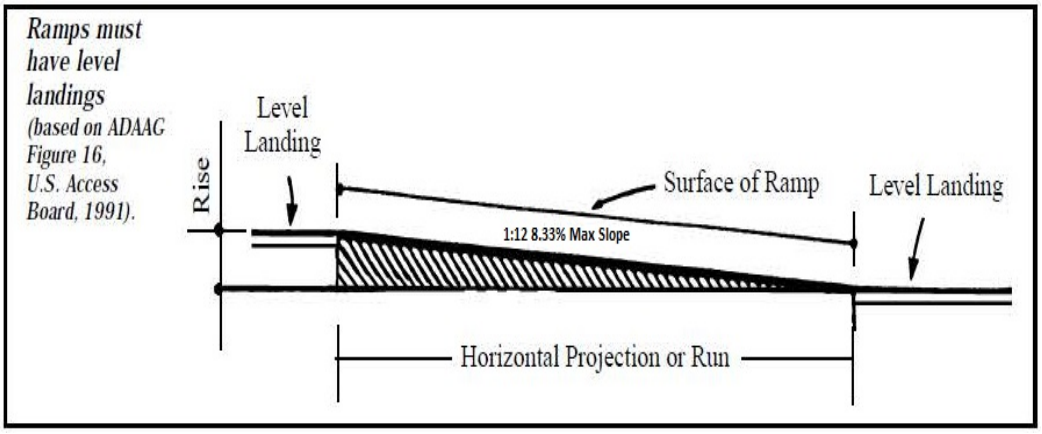
Construct and maintain temporary sidewalks so there are no abrupt changes in grade or terrain that could cause a tripping hazard or could be a barrier for wheelchair use. Maintain temporary sidewalks to ensure that joints in the sidewalk have a vertical difference in elevation of no more than 1/4 inch and that the horizontal joints have gaps no greater than 1/2 inch. The grade of the temporary sidewalk should parallel the grade of the existing sidewalk or roadway and the cross slope be no greater than 2 percent. Any change of level, which exceeds 1/4-inch height, must be beveled at 45 degrees. For closed trenches, temporary paving surfaces, walking surfaces, steel plates, etc., provide a smooth finished, firm, slip-resistant walking surface made even with surrounding sidewalks.

Pavement joints in the sidewalk are to be closed and flush to prevent tripping and to reduce the possibility of canes or small wheels getting trapped in gaps or spaces. If drainage openings are located within the pedestrian route, the grating should run perpendicular to the sidewalk and must be narrow enough that a sphere greater than 1/2 inch in diameter will not pass through it.

31.4.6 Temporary Curb Ramps

Provide temporary curb ramps to enable pedestrians to negotiate curbs safely when they are diverted to temporary routes in the roadway (Figure 31.2). Temporary curb ramps are to be the full width of the temporary route, with a 5 ft recommended width and a minimum width of 4 ft.

Figure 31.2 Temporary Pedestrian Surface



All curb ramps are to be firm, stable, and have a non-slip surface. Design curb ramps to have free draining surfaces with a maximum cross slope of 2 percent. The cross slope for midblock crosswalks can match the longitudinal slope of the roadway up to a maximum of 5 percent.

When a curb ramp is installed parallel to the curb, provide a minimum 4 ft by 4 ft platform at curb level to allow pedestrians to turn 90 degrees before descending the ramp. Indicate the type of curb ramp that is to be installed on the pedestrian accommodation plan.

Temporary curb ramps are to be concrete, asphalt, or commercially available prefabricated ramps and provide a safe path of travel for mobility-impaired pedestrians at all locations where ramps have been temporarily removed or required to route pedestrians. For projects with winter layover, construct curb ramps out of concrete with cast iron detectable warning fields. Design temporary curb ramps to:

- Be constructed such that installation and removal will not damage existing pavement, curb or curb and gutter
- Have a slope less than or equal to 8.33 percent
- Meet existing surfaces without gaps, while accounting for drainage of the roadway

- Have a transition between ramps and the street surface that is smooth such that no lip exists at the base of the ramp
- Include edge protection where there is a drop-off greater than 3 inches

Example calculation

Given:

Max Slope (S) = 8.33%

Max Cross slope ("C") = 2%

Curb height (H) = 6"

Then,

Run (R) = H/(S- C)"

R= 6"/(8.33% - 2%) = 7ft 11 in

(dimension S, C, and H are project specific)

31.4.7 Overhead and Protrusion Protection

If construction is planned to occur above pedestrian walkways, protect pedestrians from falling debris (Figure 31.3). If a canopied walkway is required, cover the entire width of the walkway and where necessary, light the travel path and ramps for night use. If necessary, extend the length of the canopy to meet field conditions.

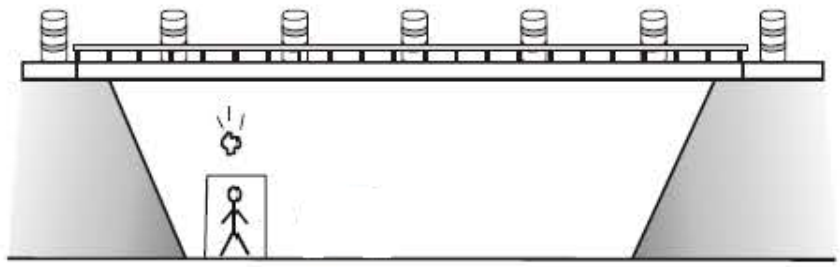


Figure 31.3 Temporary Pedestrian Walkway

Provide a minimum of 7 ft of headroom for canopied walkways. Objects with leading edges of more than 27 inches and not more than 80 inches above the walk (such as signs) are not to protrude more than 4 inches into the pedestrian pathway. Maintain proper sight distances at intersections and crosswalks.

31.4.8 Access to Bus Stops, Businesses, Residence, etc.

Maintain accessibility to all pedestrian traffic generators in the vicinity of the work area. If the pedestrian facility currently has a bus stop that will be impacted by the work zone, consult the appropriate bus operator to develop strategies to mitigate disruptions during all stages of construction. When necessary, provide a drawing of this plan, and if the plan layout deviates from the layout of the Temporary Bus Stop Pad shown in SDD 15d30 sheet "b", provide the details necessary to properly construct it. If the construction zone is extensive and will impact multiple stops, it may be necessary to arrange for a shuttle or establish a temporary route that transports pedestrians safely around the work area. When feasible, same side stop relocation is preferred for temporary bus stops.

31.4.9 Temporary Pedestrian Signal Accommodations

When temporary signals are installed as part of a construction project, consider providing pedestrian heads and call buttons for pedestrians. If an alternative pedestrian pathway is provided and requires pedestrians to cross multi-lane intersections, pedestrian walk phase may need timing adjustment.

31.4.10 Lighting Temporary Pedestrian Accommodations

Consider the lighting that will be present during each stage of construction. Stage the project so that lighting will be maintained as long as possible to avoid the need for temporary lighting. If the permanent lighting is removed during construction, work with the local agencies in determining the need for temporary lighting. Some examples that may warrant temporary lighting include:

- Business districts

- Midblock crossings
- Intersections

Use lights with similar properties to the devices removed for temporary application. Consider using hanging lights at intersections and midblock crossings. Type C steady burn lights attached to the temporary pedestrian channelizing devices may provide enough lighting for a tangent section. Work on a cost sharing plan with the local agencies for the temporary lighting.

31.99 References

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12. Americans with Disabilities Act (ADA), http://www.ada.gov/
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15. Update of the AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities, Prepared for: The National Cooperative Highway Research Program Transportation Research Board of the National Academies, October 11, 2010
16. Washington State Department of Transportation, Field Guide for Accessible Public Right-of-Way, 2012 Edition; http://www.wsdot.wa.gov/publications/fulltext/roadside/ada_field_guide.pdf
17. Guideline on the use of Positive Protection in Temporary Traffic Control Zones, American Traffic Safety Services Association (ATSSA)

FDM 11-50-32 Road User Costs

August 15, 2019

32.1 Introduction

Road User Costs in the work zone are added vehicle operating costs and delay costs to highway users resulting from construction, maintenance, or rehabilitation activity. They are a function of the timing, duration, frequency, scope, and characteristics of the work zone; the volume and operating characteristics of the traffic affected; and the dollar cost rates assigned to vehicle operations and delays.

Designers should consider road user costs when determining the most appropriate construction staging and final design. This should be done early in the design process while there is still flexibility in the design. The

optimal design will mitigate or avoid disruptions before they can be created. In addition to considering road user costs for the present construction needs, the analysis procedure provides the tools to determine future road user costs based on future construction needs. By understanding the major factors influencing road user costs, the analyst can take steps to minimize the effect of planned future rehabilitation activities on highway users.

Road User Costs play an important role in computing:

- "Enhanced" Liquidated Damages (FDM 11-2-1.6)
- Interim Liquidated Damages (FDM 11-2-1.7)
- Incentives/Disincentives (FDM 11-2-1.8)
- Cost per unit of time specified in Cost-Plus-Time bidding (FDM 11-2-1.9)
- Lane rental fee assessments for the failure to open a lane (or shoulder) in Lane Rental specifications (FDM 11-2-1.5)

The contractor's failure to complete a contract or reopen a lane of traffic on time results in damages in terms of delay and cost to the motoring public and the Department. Typically, these damages will never be imposed because it is preferable to avoid high road user costs by adhering to the completion dates and allowable work hours provided in the contract.

Road user costs that are more than the amounts shown as Liquidated Damages in Standard Spec 108.11 shall be approved by the Supervisor of the Traffic Design Unit in BTO and, if the project is on the National Highway System or subject to FHWA review, by the FHWA.

Road user costs can be used in Benefit/Cost ratios, Life Cycle Cost Analyses, and selecting the most appropriate project delivery method (i.e., Incentive/Disincentive, Interim Liquidated Damages, A+B Bidding, Lane Rental, detour selection, etc.).

32.2 Road User Cost Computation

Road user costs can be estimated using a number of different techniques. These techniques are classified either as simulation models or by manual technique, (such as tables, graphs, or hand calculations). Various models and techniques are used by other state DOTs.

Contact your Region Traffic Engineer or BTO for the current information on computing road user costs.

FDM 11-50-35 Concrete Barrier Temporary Precast in Work Zone *August 17, 2020*

35.1 Introduction

The following procedure establishes design guidelines for the use of Concrete Barrier Temporary Precast (CBTP). CBTP is effective in providing positive separation between traffic and the work area. When used appropriately, CBTP has the potential to reduce the severity of crashes. However, the CBTP itself and the proximity of the end of the CBTP can also be a hazard to traffic. Whenever feasible, it is preferable to remove the hazard and avoid the need for CBTP. Typical reasons for use of CBTP are:

- To separate high-speed vehicular traffic from the work area, especially at locations that place workers at increased risk from motorized traffic
- To shield a hazard
- To protect vehicles from embankments or drop-offs
- To separate opposing directions of traffic

35.2 Factors to Consider

In this procedure, situations are listed that would typically justify CBTP. However, each project has a unique set of factors that should be considered. These factors include:

1. Speed and volume of traffic
2. Vertical and horizontal alignment of the roadway
3. Severity of the hazard, obstacle, or drop-off/slope adjacent to the roadway
4. Lateral clearance to the hazard, obstacle, or drop-off/slope
5. Duration of exposure to the hazard
6. Nature of the work zone (e.g., whether it is a stationary work zone, at a spot location, or a moving work zone)

7. Hazard that would be presented by the barrier itself and by the barrier installation and removal activity

For example, greater lateral clearance to a hazard results in a lesser need to shield the hazard with CBTP. Where a range of distances for the lateral clearance is listed in this procedure, consider factors such as traffic speed/volume and duration of exposure to determine appropriate lateral clearance for a project, and whether CBTP should be used.

35.3 Guidelines for CBTP Use

If the work area closure is anticipated to last more than 48 hours without a change to the traffic control layout or staging, CBTP is recommended for the following situations:

1. A bridge deck or culvert replacement/rehabilitation where any of the following conditions is anticipated to exist for more than 48 hours:
   - Full-depth holes in the deck
   - Railing removed
   - Confined/restricted work area
2. Dropping/removing a bridge deck over roadway if the work activity is more than 48 hours
3. A bridge painting project over the roadway
4. To separate counter directional traffic where two or more lanes in each direction are provided during the work and posted speed limit >= 45 mph
5. At freeway/expressway crossover entrances to prevent vehicles from entering opposing traffic lanes (as shown on SDD 15d5). CBTP should also be considered at crossover exits that will be in place for more than one week, as shown on SDD 15d10 where AADT is >=20,000.

Depending on the significance of the factors listed at the beginning of this procedure, other common situations which may justify CBTP, include:

1. Spot (or isolated) locations where the work area closure will last for more than 48 hours without a change to the traffic control layout or staging, and either of the following conditions is anticipated:
   - Exposed hazard that is at the same spot for more than three consecutive days and nights and is closer to an open traffic lane than:
     a. Posted speed limits above 55 mph: 15 ft lower minimum, 20 ft typical
     b. Posted speed limits from 45 mph to 55 mph inclusive: 10 ft lower minimum, 15 ft typical
     c. Posted speed limits of 45 mph or less: 8 ft lower minimum, 10 ft typical

   -Examples include footings, abutments, and construction activities such as false work.

   The distance between the edge of the open traffic lane and the work is less than 6 feet (4 feet if non-freeway/expressway) and the work is anticipated to continue for more than 48 hours at the same spot location.

   If the work area closure and hazard will last for extended length of time (e.g., more than 2 months), lateral clearance should be greater than noted above, or CBTP should be considered.

   Whenever feasible, it is preferable to remove the hazard and avoid the need for CBTP. Where the hazard cannot be removed, an option in lieu of CBTP to shield some hazards is to use attenuators, or crash cushions as described in FDM 11-45.
2. Where a drop-off exists as defined in FDM 11-50-21.6.
3. Other situations where a combination of severity of hazard, high traffic volume, geometric concerns, or more than 48 hours of exposure exist.

35.4 CBTP Deflection Distance/Anchoring Requirement

Although CBTP is designed to prevent an errant vehicle from entering a construction work zone, research tests have shown lateral deflection of the barrier after a vehicular hit.

35.4.1 CBTP Deflection Distance

The values shown below are recommended buffer space behind a freestanding concrete barrier installation.

Refer to SDD 14b7 for additional guidance.

When shielding hazards above ground:

Posted Speed	Deflection Distance
40 mph or less	2 ft
45 mph or greater	4 ft

When shielding drop-offs:

Posted Speed	Deflection Distance
40 mph or less	2 ft
45 mph or greater - Vertical Drop-off 6” or less and no traffic below - Vertical drop-offs greater than 6”	 2 ft 4 ft

When used as a temporary median barrier separating opposing traffic lanes:

Posted Speed	Deflection/Shy Distance
40 mph or less	0 ft minimum but 2 ft preferred
45 mph or greater	1 ft minimum but 2 ft preferred

35.4.2 CBTP Anchoring Requirement

The barrier shall be anchored if the distance to a 2-foot or greater drop-off is steeper than 3H:1V, and:

1. The posted speed is 45 mph or greater and the drop-off is less than 4 feet from the side of the barrier closest to the drop-off
2. The posted speed is 40 mph or less and the drop-off is less than 2 feet from the side of the barrier closest to the drop-off

For example, the edge of a bridge deck or a drop-off at the edge of pavement.

Where lateral displacement of the barrier cannot be tolerated, anchor the barrier to the underlying pavement surface according to the details in SDD 14b7.

35.5 Intersection Sight Distance

When specifying the need for CBTP, it is recommended that the designer check all side road approaches to ensure the CBTP does not restrict intersection sight distance. This is especially critical when the roadway segment has horizontal and vertical curves that may further affect sight distance. Provide appropriate turning radii in urban areas to accommodate school buses and other large vehicles. Install portable crash cushions so the end of the cushion is located at least 50 ft from the intersecting side road. The intersection may need grading to minimize drop-offs.

35.6 CBTP End Treatments

35.6.1 Clear Zone

For determining the need for end treatment for temporary precast concrete barrier in work zones, the following clear zones are appropriate. Where a range of values for clear zone is noted, consider traffic volume, speed, and duration of exposure to determine appropriate clear zone for the project. For stage switches and short-term work operations of no more than 24 hours duration, lesser clear zone than the minimum noted may be allowed. For end treatment barrier installations in place for extended length of time (e.g., more than 2 months), a greater clear zone should be considered.

- Posted speed limits above 55 mph: 15 ft lower minimum, 20 ft typical
- Posted speed limits from 45 mph to 55 mph inclusive: 10 ft lower minimum, 15 ft typical
- Posted speed limits of 45 mph or less: 8 ft lower minimum, 10 ft typical
- Bridge projects with temporary traffic signals, one open lane shared by both directions: 12 ft from the open traffic lane

35.6.2 Barrier Flare

The typical treatment for the exposed end of CBTP is to flare the barrier away from open traffic lanes to the edge of the clear zone as defined above. Cost effective flare rates range from 4:1 (low speed roadways) to 8:1 (high speed roadways). Longer flare rates increase the number of impacts while shorter flare rates increase the severity of crashes. For additional guidance, refer to the Roadside Design Guide. The recommended flare rates are shown below.

- 8:1 for operating speed of 45 mph or more
- 6:1 for operating speed of 40 mph or less

Often it is not possible to flare the barrier to the edge of clear zone due to space limitations or need for construction vehicles and equipment to access the work area. If the barrier is not flared to the edge of clear zone and speeds are 35 mph or greater, temporary grading may be required for uneven ditch sections or barrier end treatment from the Wisconsin Approved Products List(APL). The Roadside Design Guide contains recommended barrier end placement examples in non-level shoulders and medians.

35.6.3 Construction Work Operations and Traffic Stage Switches Near Flared Barrier

Even if the barrier is flared away from traffic, the barrier may have to be straightened and the barrier end moved closer to traffic to complete some work operations and traffic stage switches. If the barrier end would be located within the clear zone for longer than 24 hours and speeds are 35 mph or greater, one of the following treatments should be done:

1. Provide a portable crash cushion
2. Taper traffic to the shoulder or adjacent lane to provide more lateral clearance to the barrier end
3. Remove the barrier and stockpile it off the work site

35.6.4 Crash Cushion or Sand Barrels.

As indicated earlier in this procedure, if it is not possible to flare the barrier to the edge of the clear zone and speeds are 35 mph or greater, then an approved portable crash cushion or sand barrels should be provided as the barrier end treatment. Install a crash cushion or sand barrels from the Wisconsin APL on the exposed end of the barrier if within the clear zone. These end treatments are designed to absorb energy of an impacting vehicle by reducing the impact force to acceptable levels. A crash cushion or sand barrels are required on the upstream end for divided or one-way facilities, and on both ends for all two-way facilities, including temporary two-way facilities, such as in freeway counter-directional operations. The types of crash cushions currently used are listed in the WisDOT Approved Products List.

Sand Barrels consist of a group of free-standing barrels and are discussed in FDM 11-45. When selecting the crash cushion or sand barrels, consider the frequency of nuisance hits.

FDM 11-50-45 Pavement Marking

February 18, 2020

45.1 General

Guidance on pavement marking selection for various pavement types TEOpS Chapter 3.

45.2 Pavement Marking Selection

The selection of material is based on the expected life of the pavement, type of roadway, and type of line. The initial cost for durable markings is relatively expensive, but their use on new pavements is justified because of their durability and the likelihood that the pavement surface will not require short-term maintenance. This reduces the exposure of a marking crew to traffic and minimizes disruptions to the traveling public.

Use TEOpS 3-10-1 for selection of pavement marking. Additional information to take into consideration:

- Allow an additional 5 days or more if grooved into asphalt
- Allow the groove to dry before placing the marking
- If temporary markings are placed on the final surface removable tape may be used. If any other temporary marking is on the permanent surface it shall be removed with the Removing Pavement Markings Waterblasting bid items to reduce scarring.

Same day pavement markings are only for centerlines, on the upper surface layer placed on conventional two-lane highways that are open to traffic and that have surfaces capable of retaining markings. These markings are placed the same day the existing markings are no longer functional or when the upper surface layer is placed. If markings are installed before the centerline rumble strips use temporary pavement markings. Once rumble strips are installed, use permanent pavement marking. Use temporary pavement markings for intermediate lifts.

Marking durability is jeopardized by cold pavement temperatures below 50 degrees Fahrenheit for tape and waterborne and 35 degrees Fahrenheit for epoxy. For this reason, permanent markings **shall not** be placed outside manufactures specifications and the Cold Weather Marking bid item should be used if projects are expected to be completed after October (refer to Standard Spec 646.3.1.4).

50.1 General

Control devices in this category include traffic and pedestrian control signals, beacons, lane use control signals, lift bridge and swing bridge signals and gates, emergency traffic control signals, and railroad crossing signals and gates, all of which are either pre-timed or traffic actuated.

50.2 Traffic Signal Investigation

As part of the scoping process for a highway improvement project, the designer must consider whether traffic signals are anticipated within the project design life. If signals are currently located within the project area, it is very likely that signal operations/controls will require modification and updating.

Table 50.1 and Table 50.2 are NOT signal warrants but are a guide for determining if special intersection treatments or signals may be needed within the design life of the project. If the current or projected volumes come close to or exceed the suggested minimum threshold AADT volumes on both the major and the minor street listed in Table 50.1 or Table 50.2, notify the region traffic personnel that special intersection treatment or safety improvements may be needed. Case 1 is related to the volume of intersecting traffic through-put of an intersection. Case 2 is related to the lack of gaps, or continuous traffic, on the major street that may cause excessive delay on the minor street.

Table 50.1 should be used when the 85th percentile or posted speed exceeds 40 mph, or when the intersection lies in an area having a population of less than 10,000. Table 50.2 should be used in conjunction with facilities not covered by Table 50.1. When the traffic volumes are approached or exceeded in the following tables, the traffic section will evaluate possible solutions such as: the need for a four-way stop, improved signing, geometric changes, traffic signals, roundabouts or other improvements.

Table 50.1 Minimum Threshold Traffic Volumes for Case 1 & 2 (typically rural) 1

Lanes per Approach		Case 1		Case 2	
Major St.	Minor St.	Major St. (2-way ADT)	Minor St. (2-way ADT)	Major St. (2-way ADT)	Minor St. (2-way ADT)
1	1	5,600	3,400	8,400	1,700
2	1	6,700	3,400	10,100	1,700

[1] ITE, Manual of Traffic Signal Design, 1982, p18

Table 50.2 Minimum Threshold Traffic Volumes for Case 1 & 2 (typically urban) 1

Lanes per Approach		Case 1		Case 2	
Major St.	Minor St.	Major St. (2-way ADT)	Minor St. (2-way ADT)	Major St. (2-way ADT)	Minor St. (2-way ADT)
1	1	8,000	4,800	12,000	2,400
2	1	9,600	4,800	14,400	2,400

[1] ITE, Manual of Traffic Signal Design, 1982, p18

Region traffic personnel will evaluate the intersection for meeting various traffic signal warrants. The designer may have to provide information to the traffic personnel on the proposed design such as: adjacent parking, bus pullout bays, approach grades, lane widths, number of lanes, speed, percent trucks, design hour volumes, turning movement volumes and intersection layout showing access and sight distance. Part IV, Section C of the Manual on Uniform Traffic Control Devices (MUTCD) shows a complete list of the traffic signal warrants.

Traffic control signals should not be installed unless one or more of the traffic signal warrants are met. The satisfaction of a warrant or warrants is not in itself justification for a signal. If signals are to be installed on portions of the State Trunk System or on connecting highways, a region traffic engineer must submit a recommendation on the matter (form DT1199) and Signal Investigation Report for approval by the State Traffic Engineer before the signals may be incorporated into the project.

50.3 Design Criteria

The design of traffic signal systems shall conform to the WisDOT's Traffic Signal Design Manual (TSDM).

FDM 11-50-55 Signing

August 17, 2020

55.1 General

Signs are essential when special regulations apply at specific places or at specific times only, or when hazards are not self-evident. They also provide information concerning highway routes, directions, destinations, and points of interest. Signs are classified in accordance with their basic function as either regulatory, warning, or guide signs. For a detailed description of the various types, refer to the WisMUTCD.

When permanent signing is included under a contract with other construction operations such as grading, base, paving, etc., the permanent signing shall be shown on signing plan detail sheets separate from the plan and profile sheets.

If permanent signing is LET as a separate contract, the permanent signing layout detail sheets will become the plan sheets.

Permanent signing layout details shall show the location of sign bridges, sign bridge numbers, new signs, moving signs, removal of existing signs, revision of existing signs, signs being furnished or moved by others, delineators and other pertinent signing information.

Designers should contact the region signing staff on Type II signpost preferences. Do not use 4” x 4” wood posts on new permanent sign installations.

If the project contains specific information signs (SIS - the blue informational signs for gas/food/lodging, etc.) that will be affected by the project, then the designer shall include special provision 638-010 (Blue Specific Service Signs).

Any tourist oriented directional signs (TODS) or white arrow boards present within the project limits can be removed and reinstalled by the contractor. The contractor is responsible for any damage to the signs during this time.

In general, all new Type I signs have Type SH (super high intensity prismatic) sheeting, except yellow Type I signs and plaques, which are Type F (fluorescent high intensity prismatic) sheeting. For all new Type II and Type F sheeting shall be used for all orange work zone signs, all yellow W series signs, and all fluorescent yellow-green S series signs. Type H (prismatic high intensity) sheeting shall be used for all other Type II.

Careful attention needs to be given to signs at intersections on OSOW vehicle routes. Periodically signs and posts may have to be temporarily removed to accommodate vehicles passing through the intersection and turns properly. The designer should refer the OSOW freight network maps in FDM 11-25-1.4 and contact the Region freight coordinator to confirm if the project is located on an OSOW vehicle route. Confirm the proposed post type on these routes with Region Traffic Operations.

If conflicts may occur with signs at intersections on OSOW route, tubular steel signposts assemblies should be considered for signs that could be impacted by an OSOW vehicle. If removable signs are needed, install tubular steel sign post assemblies in accordance with Standard Spec 634.3.2 and standard sign plate A4-9. Place notes on the permanent signing plan to notify contractors of the required height of the top of the anchor system.

Each standard sign should be displayed only for the specific purposes as prescribed in the WMTCD. Before any new or reconstructed highway, temporary route or detour is opened to traffic all necessary signing should be in place. Signs required by road conditions or restrictions should be removed when those conditions are no longer present, or the restrictions are removed. Uniformity of application is as important as standardization with respect to design and placement. Identical conditions should always be marked with the same type of sign irrespective of where those particular conditions occur.

55.2 Reflective Sheeting and Replacement Guidelines for Highway Signs

In general, all new Type I signs have Type SH (super high intensity prismatic) sheeting, except yellow Type I signs and plaques, which are Type F (fluorescent high intensity prismatic) sheeting. For all new Type II and Type F sheeting shall be used for all orange work zone signs, all yellow W series signs, and all fluorescent yellow-green S series signs. Type H (prismatic high intensity) sheeting shall be used for all other Type II.

Type I signs

1. Per Department policy, type I guide signs should be replaced in qualifying improvement projects. Exceptions to this policy include:
    - It is not required to replace Type 1 signs on non-pavement-preservation preventive maintenance projects (see FDM 3-5-5), and
    - It is not required to replace Type 1 signs on Group 3 pavement-preservation preventative

maintenance projects (see FDM 3-5-5 – work consists of milling, rut filling, seal coating, micro-surfacing and crack filling projects) because:

- When Group 3 pavement strategies are applied early in the pavement life cycle, most signing should still be in good condition.
- The work can easily exceed 10% of the project, i.e., it would not meet the requirements for incidental construction.

- Exceptions to replacement of overhead mounted Type 1 guide signs can also be made if there is another improvement project programmed or scheduled on the same roadway segment within the next five years. Any signs not conforming to WisDOT and MUTCD policies shall be replaced in the improvement project. *Any exceptions to replacement of Type I signs shall be coordinated with the Region Traffic Engineering Supervisor.*

2. Galvanized steel I-beams should only be replaced if Type I signs are not at the proper offset (30-foot typical / 17.5-foot lower minimum offset from edge line to edge of sign) or if the new Type I sign is larger. All corten steel I-beams and bases shall be replaced.
3. Steel I-beams and bases that are re-used should have the base bolts replaced by utilizing bid item 635.0300 (Sign Supports Replacing Base Connection Bolts).
4. Below are the guidelines for calculating miscellaneous quantities for steel I-Beams, concrete masonry and reinforcing steel for Type I sign supports.

   Quantities for Sign Supports Structural Steel HS (Bid Item 635.0200):

   Determine Length of I-beams For Ground Mounted Signs.

   1. Determine Type of I-beams (Type A, B, C, D or E). Utilize A3-2 and A3-3 sign plates to determine I-beam type which is based on horizontal and vertical dimensions of Type I sign.
   2. Determine weight of I-beams from A3-1 plate.
      a. W6x15 is 15.0 lbs per foot.
      b. W8x18 is 18.0 lbs per foot.
      c. W8x21 is 21.0 lbs per foot.
      d. W10x22 is 22.0 lbs per foot.
      e. W12x26 is 26.0 lbs per foot.
   3. Add “V” value to each I beam weight calculated in step 3. The V value is the weight for the stub, base plates, stiffeners, bolts and washers.
      a. W6x15 post V value is 73.0 lbs.
      b. W8x18 post V value is 83.0 lbs.
      c. W8x21 post V value is 124.0 lbs.
      d. W10x22 post V value is 134.0 lbs.
      e. W12x26 post V value is 152.0 lbs.

   Quantities for Concrete Masonry Ancillary Structure Type NS (Bid Item 531.1000)

   1. W6x15 base is 0.8 CY for each base.
   2. W8x18 base is 0.9 CY for each base.
   3. W8x21 base is 1.0 CY for each base.
   4. W10x22 base is 1.0 CY for each base.
   5. W12x26 base is 1.2 CY for each base.

   Quantities for Steel Reinforcement HS Ancillary Structures Type NS (Bid Item 531.1140)

   1. W6x15 base is 71 lbs for each base.
   2. W8x18 base is 102 lbs for each base.
   3. W8x21 base is 110 lbs for each base.

4. W10x22 base is 151 lbs for each base.
5. W12x26 base is 180 lbs for each base.

Type II signs

1. In general, per Department policy, the replacement of Type II signs will be handled through maintenance as part of a 12-year corridor replacement schedule. However, there are situations that will require Type II signs to be placed in improvement projects that include:
   - Project is on a new alignment.
   - Projects that are installing new signs, signs that are not currently at the needed locations, e.g. changing intersection control or adding chevrons.
   - Updating or adding signs that were not there before, e.g. population, street name signs, overhead signs.
   - Placing no passing zone signs after the roadway has been re-spotted.
2. Projects that require removal, stockpiling and re-installation of Type II signs and posts will use the bid items of Moving Signs Type II and Moving Small Sign Supports.
3. Designers should include an undistributed quantity of posts (10% of existing) to account for the replacement of any posts that are rotted, warped, too short or get damaged during the removal/re-installation.
4. The designer should consult with the Region Signing Engineer or Region Sign Program Supervisor to confirm the use of improvement projects for the installation of Type II signs.

Pictorial drawings of signs and sign fabrication details are available from the BTO Traffic Design Unit at: DOTBTOSignDetails@dot.wi.gov, and will be prepared upon request. A minimum of three weeks lead-time is required by central office for the preparation of sign details. The TEOpS gives guidance for optimum sizes of signs for roadways and sizes of stop signs that should be used at roadway intersections.

FDM 11-50-60 Lighting

September 19, 2013

60.1 General

WisDOT takes a conservative approach to the use of lighting, primarily because of the high cost of installation, coupled with the long-term maintenance and energy expenditures involved. There are several cases where safety concerns have been evaluated and lighting is always installed. These are:

- at signalized intersections
- at roundabouts
- the Milwaukee area freeways

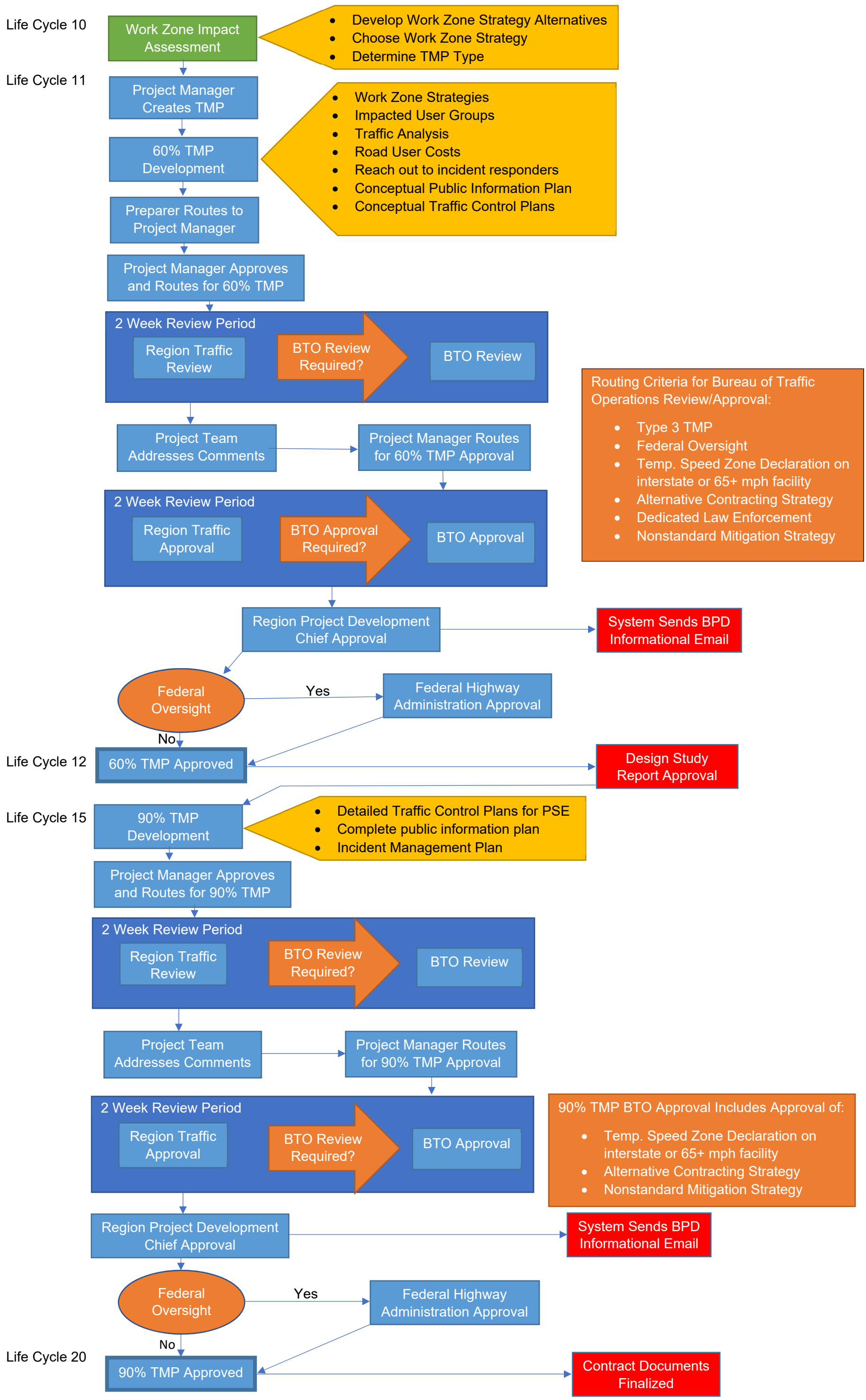
Other than these, lighting is typically not installed unless it can be proven that the lack of illumination is the cause of the accidents/confusion at the site and the installation of lighting is the only remedy. TEOpS 11-3-1 describes the policy and the approval process for lighting on State Highways.

Local units that are insistent upon WisDOT providing the lighting for various locations on the State Highway systems can be accommodated and the lighting included as part of the construction contract if the local unit will pay for the installation and all future maintenance and energy costs involved. This is accomplished with a permit. The permit policy and process are described the TEOpS Chapter 11.

WisDOT also makes provisions for the lighting of major bridges in communities by installing necessary conduit, etc., during construction of the bridge. However, lighting of such bridges is the responsibility of the community, and all costs relating to installation, maintenance, and operation must be assumed by them.

A related topic concerns the use of breakaway supports for lighting installations as well as for signs and traffic signals. WisDOT has adopted the 1985 AASHTO Standard Specifications on the subject, which delineate requirements for the usage and design of such devices. The primary criterion of breakaway supports is that they allow the luminaire, sign, or signal to be safely displaced by a vehicle impact (from any possible direction or by any portion of the vehicle) without hazardous intrusion into the passenger compartment or causing a more serious accident (such as overturning the vehicle or directing it back into traffic, etc.).

Various release mechanisms have been developed, utilizing slip planes, plastic hinges, fracture elements, and combinations thereof. Since product costs vary considerably, contact BTO for more information. For installations within the clear zone (as well as for those beyond the clear zone, where the need exists), the designer should


Life Cycle 10
Work Zone Impact Assessment
Develop Work Zone Strategy Alternatives
Choose Work Zone Strategy
Determine TMP Type
Life Cycle 11
Project Manager Creates TMP
60% TMP Development
Work Zone Strategies
Impacted User Groups
Traffic Analysis
Road User Costs
Reach out to incident responders
Conceptual Public Information Plan
Conceptual Traffic Control Plans
Preparer Routes to Project Manager
Project Manager Approves and Routes for 60% TMP
2 Week Review Period
Region Traffic Review
BTO Review Required?
BTO Review
Project Team Addresses Comments
Project Manager Routes for 60% TMP Approval
2 Week Review Period
Region Traffic Approval
BTO Approval Required?
BTO Approval
Routing Criteria for Bureau of Traffic Operations Review/Approval:
Type 3 TMP
Federal Oversight
Temp. Speed Zone Declaration on interstate or 65+ mph facility
Alternative Contracting Strategy
Dedicated Law Enforcement
Nonstandard Mitigation Strategy
Region Project Development Chief Approval
System Sends BPD Informational Email
Federal Oversight
Yes
Federal Highway Administration Approval
No
Life Cycle 12
60% TMP Approved
Design Study Report Approval
Life Cycle 15
90% TMP Development
Detailed Traffic Control Plans for PSE
Complete public information plan
Incident Management Plan
Project Manager Approves and Routes for 90% TMP
2 Week Review Period
Region Traffic Review
BTO Review Required?
BTO Review
Project Team Addresses Comments
Project Manager Routes for 90% TMP Approval
2 Week Review Period
Region Traffic Approval
BTO Review Required?
BTO Approval
90% TMP BTO Approval Includes Approval of:
Temp. Speed Zone Declaration on interstate or 65+ mph facility
Alternative Contracting Strategy
Nonstandard Mitigation Strategy
Region Project Development Chief Approval
System Sends BPD Informational Email
Federal Oversight
Yes
Federal Highway Administration Approval
No
Life Cycle 20
90% TMP Approved
Contract Documents Finalized

Transportation Management Plan (TMP) Strategy Matrix

		Work Zone Mitigation Stratgies	When to Consider	Potential Benefits	Potential Challenges
Constructability Strategies	1	Construction phasing/staging	• Applicable to any work zone	• Less traffic impacts during each construction phase	
	2	Continuous Full Closure (for a project phase/stage or the entire project/'blitz')	• Detour routes available • Project needs to be completed in a compressed timeframe • Traffic volume through the project can be accommodated on detour route(s) • Highway facilities • Short project length	• Faster construction • Easier, more efficient construction – larger workspace with more flexibility • Safer for workers • Better construction (e.g., smoother ride) • Public feedback often positive • Reduces need to set up and take down traffic control	• May increase cost to motorists (time and fuel) • Accessibility to businesses and residences • May significantly impact local roadways used for detours
	3	Off-Peak/Night/Weekend Full Closure	• Detour routes available • High traffic volumes • Low traffic volumes during work time period	• Faster construction • Less traffic impacts • Safer for workers	• May impact local roadways
	4	Reduced Lane Widths	• Applicable to any work zone	• Can maintain existing number of lanes • Easier design • Ramps can remain open	• Can reduce traffic capacity • May interfere with contractor access • Barrier could still be required for some drop-offs
	5	Lane closures	• When the remaining lanes provide adequate capacity to handle the traffic demand	• Safer for workers • Can provide more worker space	• May sacrifice project quality • May cause delays
	6	Reduced Shoulder Width	• When more work area is needed	• Traffic remains on routes	• May compromise safety • No room for breakdowns
	7	Shoulder Closure			
	8	Lane Shift to Shoulder/Median	• Enough space available • Where bridges can accommodate use • Shoulder has structural capacity	• Traffic remains on routes • Low cost • Allows wider work area or maintains capacity	• May compromise safety • No room for breakdowns • May damage the shoulder/median
	9	Shoulder Widening	• Need to maintain number of lanes	• Number of lanes are maintained	• Structural capacity to handle traffic • Cost
	10	Enhancements to Shoulders to Accommodate Traffic	• Need to maintain number of lanes	• Need to maintain number of lanes	• Cost
	11	Flagging Operation/One-lane, Two-Way Operation	• 2 lane highways • Rural areas • Project covering a short distance • Low traffic volume through the project	• Easy to set-up	• May result in long delays
	12	Temporary Signal/One-lane, Two-Way Operation			
	13	Temporary Stop Sign/One-lane, Two-Way Operation			
	14	Two-way traffic on one side of divided facility/Bi-Directional Traffic (Crossover)	• Long project duration • Projects with multiple construction stages/phasing • Concerns for worker safety • When detour routes and/or median or shoulder is not available	• Provides a more efficient work space • Can reduce construction period • Safer for workers	• Additional cost to construct crossovers and separations between opposing traffic • Difficulty handling ramps
	15	Rolling Closure/Slowdown/Roadblock	• Setting bridge beams • Placing overhead sign structures • Pulling power lines across the roadway • Blasting Operations • Installing cantilever trusses • Pavement repair • Moving Equipment Across the Roadway	• Short duration work • Worker safety	• Slow traffic • Requires coordinated communication effort • Law enforcement
	16	Split-lane Merge	• High traffic volume • Limited availability of detours • Where incidents can create significant delays	• Maintains safe and smooth freeway operations	• Driver confusion • Requires more traffic control devices • Requires longer temporary concrete barrier (TCB)
	17	Reversible Lanes	•Where there are capacity limitations and no alternate routes •Significant directional peaking of traffic	• Accommodates peak traffic flow	• May be labor intensive • Cost
	18	Ramp Closures	• Alternative ramps/routes available • Shorter construction period required • High traffic volumes	• Faster construction • Reduces mainline and cross road traffic congestion • May simplify the work zone	• Diverts congestion elsewhere • Increases cost to motorists (time and fuel)
	19	Temporary Ramp	• Need to maintain access to ramp (large business/hospital generator)	• Accommodates traffic	• Cost
	20	Freeway-to-Freeway Interchange Closures	• Alternative routes available	• Construction duration can be reduced • May simplify the work zone	• May significantly affect facility capacity • Additional signage to route motorists
	21	Night work	• High traffic volume during the day	• Maintains normal capacity during the day • Fewer delays	• May be less safe due to lighting distractions, higher speeds, and increased driver impairment
	22	Weekend Work	• High traffic volume • Commuter traffic is significant	• Maintains normal capacity during weekdays • Fewer delays	• May extend project duration
	23	Separate Truck Lanes	• Long-duration projects with high truck volume • High expectation for delay • When significant reduction in capacity anticipated • When capacity/safety concerns exist for truck movements through work zone • Passenger cars are expected to be significantly delayed due to the trucks (e.g., areas with major inclines)	• Can increase capacity of the roadway	• Requires additional signage/personnel to enforce separate truck lane
	24	Bus Turnouts	• High occurrence of bus traffic and stops	• Improves traffic flow and safety by minimizing traffic conflicts	• Cost
	25	Roadway/Intersection Improvements	• Long project duration • High expectation for delay • When work zone results in major congestion that can be alleviated by street/intersection improvements • Detoured traffic	• Provides increased capacity • Improves motorist safety	• Cost
	26	Pedestrian/Bicycle Access Improvements	• Significant pedestrian/bicyclist activities • Existing sidewalks traverse the work zone • A school route traverses the work zone	• Safer for pedestrians and bicyclists	• Cost
	27	Business Access Improvements	• Where access to businesses may be reduced • Anticipated impacts to businesses	• Accessibility to businesses, • Positive community relations	• Cost

Transportation Management Plan (TMP) Strategy Matrix					
		Work Zone Mitigation Stratgies	**When to Consider**	**Potential Benefits**	**Potential Challenges**
Contracting Strategies	28	"Low bid" design-build	REFER TO FDM 11-2 (http://wisconsindot.gov/rdwy/fdm/fd-11-02.pdf#fd11-2)		
	29	"Enhanced" Liquidated Damages			
	30	Interim Liquidated Damages			
	31	Cost Plus Time Bidding			
	32	Incentive/Disincentive Clauses			
	33	Lane Rental			
Innovative Construction Strategies	34	Precast Members	• Where traffic restrictions need to be minimized • When work activities need to be completed during night or weekend periods	• Reduces construction time • Fewer traffic impacts	• Cost
	35	Rapid Cure Materials			
	36	Accelerate Bridge Construction (ABC)	• Emergency Bridge Replacement • Evacuation route or over railroad or navigable channel • Costly temporary structure • Remote site locations • Limited construction periods	• Reduced on-site construction time • Minimized traffic impacts of bridge construction projects • Increased construction work zone safety • Less disruption to the environment • Increased constructability • Increased quality and lowers life cycle costs • Flexibility in design	• Traffic detour issues • Technical issues related to seismic design, structure durability and reliability • Poor communication and coordination between stakeholders • Lack of technology for rapid bridge construction and replacement technologies for extreme events • Development needed in design methodologies, contracting approaches, material supply chain management • Cost of self-propelled modular transporter (SPMT)
	37	Prefabricated Elements & Systems (PBES)			
	38	Geosynthetic Reinforced Soil (GRS)			
	39	Precast Pavement Repair	• High public exposure • High user delay • Limited availability of detours	• Expedite project opening to traffic • Minimize user delay • Reduced lane closures • Less traffic disruption • Improved safety in work zone • Low maintenance service life	• Higher cost of fabricating pavement slabs • Higher initial learning curve • May need justification
Temporary Traffic Control Strategies	40	Temporary Pavement Markings (does not include chevrons or orange pavement markings)	• When additional markings are necessary to guide road users through the work zone •Applicable to any work zone	• Provides guidance and information for road users through the work zone	• Visibility and durability of the markings may be limited by weather conditions and debris
	41	Steel Median Barrier Gate	• When traffic needs to be rerouted for emergency access • When access is needed for construction vehicles or emergency vehicles	• Can be deployed on gradients up to 8% • Robust transition design • Easily installed on bridge decks and viaducts •Available as a 26', 39' or 52' system • Performance tested to open and close in under 2 minutes	
	42	Movable Steel Barrier	• Short term work zones and bridge repair projects where barrier deployments and lane closures are frequent	• Quick and easy deployment • Can be moved laterally or longitudinally to optimize traffic flow and work zone space • High mobility provides flexibility • Low deflection premium mobile steel barrier	
	43	Temporary Concrete Barrier	• When long-term work zone activity is next to the travel lanes • When high-speed opposing travel lanes are present • Drop-Offs	• Enhances safety to workers by the physical separation of the motorists from work zone • Enhances motorist safety by physically separating traffic traveling in opposite directions	• Potential for a reduction in capacity
	44	Movable Traffic Barrier Systems	• Long project duration • Projects with multiple construction stages/phasing • High traffic volume • When roadway capacity can be gained • Roadways with capacity limitations in the direction of travel and no alternate routes • When repeated barrier shifts are needed • When frequent lane closures are anticipated • When reversible lanes are used	• Rapid and safe reconfiguration of the traffic barrier system • Can provide additional space for the contractor to work • Enhances motorist safety by clearly delineating direction of travel	• Cost • Labor for movement of barrier
	45	Crash Cushions	• High crash rate • When temporary hazards (e.g., work zone vehicles and other work zone-related barriers) are in proximity to motorists	• Protects a temporary hazard • Prevents vehicle intrusion into the work space • Significantly enhances safety of both motorist and worker	• Cost • Space and labor for placement
	46	Automated Flagger Assistance Devices (AFAD)	• Where flaggers are needed • Short-term lane closures	• Improves worker safety by removing worker from the roadway	• Cost
	47	Temporary Portable Rumble Strips (TPRS)	• Static Flagging Operations	• Alerts motorists about the presence of work zone • Alerts motorists to change in traffic pattern	
	48	Channelizing Devices	• Applicable to any work zone	• Helps to direct road users through the work zone • Easy to set-up • Delineates potential work zone hazards	• Errant vehicles are not prevented for intruding beyond these devices
	49	Signal Timing/Coordination Improvements and Upgrades	• When additional capacity is needed through the intersection in the work zone or on nearby roadways during construction	• Increases throughput of the roadway • Improves traffic flow • Optimizes intersection capacity • Reduces frequent stops	
	50	Ramp Metering/Temporary Suspension of Ramp Metering	• Project is on a freeway • There are a number of entrance ramps near the work zone	• Maintains safe and smooth freeway operations • Controls entrance of vehicles to the roadway	• May result in ramp queues on local streets • Cost
	51	Temporary Traffic Signals	• High expectation for delay • When safety needs to be improved for new (temporary) turning movements through the work zone • When additional capacity is needed	• Improves traffic flow through and near the work zone • Helps achieve re-routing of traffic from project location • Improves driver safety by separating conflicting movements	• Cost
	52	Temporary Speed Limit Reduction/Temporary Speed Zone Declaration	• Where significant reduction in capacity is anticipated • When there are lane or shoulder closures, traffic shifts, or other changes in geometry • When work is adjacent to the traffic lane	• Enhances motorist and worker safety	• Traffic mobility • Compliance with speed limit reductions is often poor

Transportation Management Plan (TMP) Strategy Matrix

		Work Zone Mitigation Stratgies	When to Consider	Potential Benefits	Potential Challenges
TTC Cont'd	53	Temporary Lighting Devices	• When night work is being conducted • Lighting currently exists	• Enhances visibility of devices and delineations in the work zone • Improves worker safety • Guides road users through the work zone particularly during night and under adverse conditions	• Cost
Detour	54	Detour Route	• Where significant reduction in capacity is anticipated on the mainline • When a full road closure is used	• More efficient utilization of existing transportation facilities • May reduce motorist delays	• May require additional cost • May significantly impact roadways used for detours
	55	Use of Alternate Route			
	56	Local Detour Route	• Only for local agencies		• Local detours signed by WisDOT make WisDOT responsible for any damages
Roadway Restriction Strategies	57	Work hour restrictions for peak travel	• Significant peaking of traffic	• Maintains normal capacity during traffic peak times • Fewer delays	• May extend project duration
	58	Turn Restrictions	• When turning vehicles are causing unreasonable delays or crash potential in the work zone • When the geometric design or the available sight distance at the intersection does not adequately provide for a safe turning movement	• Simple, cost-effective • Increases roadway capacity • Reduces potential congestion and delays • Improves safety	• Additional delays for turning vehicles • Turning vehicles need to re-route
	59	Parking Restrictions	• When significant reduction in capacity anticipated • When traffic demand at the location can be reduced by parking restrictions • When parking spots can be converted to an additional travel lane • When restricting parking spots can improve work zone access and quicken work zone activity	• Simple, cost-effective solution • Increases roadway capacity	• Affects local parking
	60	Truck/Heavy Vehicle Restrictions	• Projects with high truck volume • When significant reduction in capacity anticipated • When capacity/safety concerns exist for truck movements through work zone	• Improves passenger car flow through the work zone by removing trucks from the traffic stream	• Provision of an alternate truck route may adversely affect other traffic or roads • Requires additional signage/personnel to enforce truck restrictions
Traffic Control Signing Strategies	61	Dynamic Lane Closure System (DLMS)/Zipper Merge	• Moderate traffic volume and congestion • When needed capacity can be gained • When frequent lane closures are anticipated	• Enhances mobility and safety • Controls vehicle merging at the approach • Reduces vehicle conflicts	• Cost
	62	Queue Warning System (QWS)	• Moderate traffic volume and congestion • Queueing Expected • History of Crashes • Lane Closure • Roadway Geometry	• Enhances mobility and safety • Alerts drivers of upcoming traffic conditions (slow/stopped traffic) • Reduces vehicle conflicts	• Cost
	63	Temporary Traffic Control Signs	• In a situation that may not be readily apparent (e.g., speed reductions, road or lane narrows, etc.) • When necessary to inform road users of traffic laws or regulations	• Reduces potential for incidents • Encourages reduced speeds • Reduces incident potential	• May be ignored or missed by motorists when a lot of signage is present
	64	Fixed Message Signs	• When detours are being used • When advanced notice is necessary for road users to choose an alternate route	• Provides alternate route and work zone information to road users	• May be ignored or missed by motorists when a lot of signage is present
	65	Portable Changeable Message Signs (PCMS)	• When work zone information is subject to frequent changes	• Effective way to communicate real-time information to road users • Allows road users to adjust travel plans based on information • Draws special attention to key information • Can be used for incident management	• May be ignored or missed by motorists when a lot of signage is present • Additional cost
	66	Arrow Panels/Board	• Lane closures, particularly on high-speed roadways	• Assists motorists in navigating and merging through and around the work zone • Effective method to alert motorists of lane closures • Highly visible	• Additional cost
	67	Dynamic Message Signs (DMS)	• When work zone information is subject to frequent changes	• Effective way to communicate real-time information to road users • Allows road users to adjust travel plans based on information • Draws special attention to key information • Can be used for incident management	• May be ignored or missed by motorists when a lot of signage is present
Coordination	68	Coordination with Other Projects	• May be beneficial to any project	• Reduces motorist delay • Minimizes impacts to potentially affected businesses and communities • Reduces exposure time to road work • May increase efficiencies	
	69	Right-of-Way Coordination	• May be beneficial to any project	• Reduces construction duration and delay	
	70	Utlity Coordination	• May be beneficial for any project	• Significant cost saving • Reduce and manage traffic disruptions from road work • Reduce project delays	• Utility relocation may be required resulting in more expensive R/W • Utility construction activities may affect project phasing • Utility construction may may occur during project construction • Utility work may not be completed prior to start of construction
	71	Coordination with Other Transportation Infrastructure (Rail, Harbors, Transit, Aeronautics)	• May be beneficial to any project	• Minimizes potential impacts on other transportation facilities	• May be difficult to identify coordination opportunities
	72	Project On-Site Safety Training	• Long project duration • In locations where worker and motorist safety are of particular concern	• Improves worker safety due to the clear understanding on safety procedures and specific risks associated with the project by all workers	• Cost of safety training for all personnel

Transportation Management Plan (TMP) Strategy Matrix

	Public Information and Motorist Mitigation Strategies	When to Consider	Potential Benefits	Potential Challenges
1	Brochures and Mailers	• Urban area • Long project duration • Alternate travel modes available • High public exposure • Significant business and residential impacts	• Condensed format of brochures lends itself to brief, high-impact messages • Brochures have a relatively long shelf life, which is useful for projects of long duration • Low cost • Easy to distribute	• Information (e.g., dates of road closures) may change and not be reflected in the printed materials • Often targets local motorists only
2	Press Releases/Media Alerts	• Large projects - Mega/Major projects • Projects with multiple phases/construction stages • High public exposure • Significant business and residential impacts	• Cost effective if it uses free publicity to inform	• Often targets local motorists only
3	Paid Advertisements	• Large projects - Mega/Major projects • Alternate routes available • High public exposure • Significant business and residential impacts	• Gives travelers advanced warning to plan for delays or alternate routes • Covers a large or multi-jurisdictional area • Reinforces public awareness of the project • Can reach many people at one time	• Requires advanced planning • Cost • Newspaper readers may skip over ads
4	Community Task Forces	• Long project duration • High public exposure • Significant business and residential impacts	• Gets buy-in from different stakeholders	• Requires coordination beforehand • May not be cost effective
5	Coordination with Media/Schools/ Businesses/Emergency Services	• Long project duration • High crash rate • High public exposure • Significant business and residential impacts	• Travelers at major activity centers can plan in advance to take alternate routes	
6	Special Event Coordination	• Long project duration • High crash rate • High public exposure • Significant business and residential impacts	• Notifies travelers of closures • Observe operational and safety issues on local roads	• Requires advanced planning • Cost • May only target local motorists
7	Traffic Radio	• Long project duration • Projects with multiple phases/construction stages • Detour routes available • Alternate travel modes available • High public exposure	• Can reach many commuters over a wide area • Little to no cost • Targets people who are likely to use the information	• Accurate information
8	Highway Advisory Radio (HAR)	• When longer, more detailed messages than can be provided using signage are necessary • Alternate routes available • Long project duration • Projects with multiple phases/construction stages • Frequent lane and/or ramp closures expected	• Provides current information directly to motorists • Allows for longer, more detailed messages regarding a work zone incident • Promotes diversion of traffic to alternate routes when appropriate • Traffic patterns may resume to normal patterns more quickly	• Limited range • Typically low utilization rates • Motorists may not be aware of the HAR
9	511 Traveler Information Website (project website, lane closures, motorist information, public information)	• Applicable to any work zone	• Provides motorists with current information • Information can be accessed whenever it is needed	• Can be distracting to the driver if used on the road • Road users must have these personal devices
10	Freight travel information/Lane Closure System (LCS)	• Applicable to any work zone	• Provides useful information to freight stakeholders	
11	Traffic Management Center (TMC)	• Applicable to any work zone	• Have access to real-time information on traffic and incidents and relay that to the traveling public through different media outlets • Integrate, maintain, operate, troubleshoot new equipment • Staffed 24/7, 365 days a year • Message Plan Development (DMS) • Operate and monitor permanent and temporary cameras	• Detectors may be difficult to maintain while the work zone is taking place

Transportation Management Plan (TMP) Strategy Matrix				
Incident Management Mitigation Strategies		**When to Consider**	**Potential Benefits**	**Potential Challenges**
1	ITS for Traffic Monitoring/Management	• Can be applicable to all situations – to convey messages that communicate accurate, timely, and pertinent information to motorists about prevailing and anticipated traffic conditions • Long project duration • Presence of permanent ITS deployment and/or STOC • High expected delay • Projects with multiple construction stages/phasing • Available detour routes exist • Frequent lane and/or ramp closures expected • Existing and potential high incident locations	• Provides real-time information to motorists • Enables agency to manage the transportation system in and around the work zone in real-time • Provides road users with information to divert or take other appropriate measures in response to an incident • Allows motorists to avoid hazards and delays, and respond properly to changing roadway conditions • Improves driver guidance and creates safer operations	• Cost • Needs accurate and reliable information that is dependable
2	Surveillance [closed-circuit television (CCTV), loop detectors, bluetooth, microwave detection]	• Long project duration • All situations - advanced warning/public information and signage is generally always beneficial	• Verifies the presence of traffic problems and incidents • Helps to determine appropriate response to address an incident • Contributes to saving both motorist and worker lives by aiding quick, appropriate response from local incident response agencies	• Cost
3	Traffic Screens/GAWK Screens/Glare Screens	• High traffic volumes • High crash rate • When headlight glare needs to be reduced • When construction is immediately adjacent to traffic	• Reduces driver distraction • Reduces rubbernecking, which can prevent congestion • Reduces headlight glare	• Cost
4	Mile-Post Markers (maintain or install temporary)	• Applicable to any work zone	• Provides the motorist with the location information critical for getting quick help • Aids in responding to incidents or breakdowns • Helpful in managing traffic records and subsequent analysis	
5	Freeway Service Team (FST)	• Long project duration • High public exposure/traffic volume • Where incidents can create significant delays • Where shoulder width reductions or closures are expected • High crash rate	• Reduces the time required to remove the incident from the roadway	• Cost
6	Incident/Emergency Management Coordinator	• Long project duration • Large complex project where on-going incident management is necessary • High public exposure/traffic volume	• Provides a dedicated, responsible person for managing incidents and ensuring that traffic safety and mobility goals are met	• Cost
7	Incident/Emergency Response Plan and Coordination with Emergency Responders	• Long project duration • Major/complex work zone projects where there is potential for recurring significant incidents • High public exposure/traffic volume	• Prompt and appropriate response and clearance of incidents	• Cost • Predicting and planning for potential incidents
8	Dedicated Law Enforcement	• Long project duration • High crash rate • In large and complex work zone locations where enforcement is an issue or incident support is desired	• Enhances safety of motorists and workers • Supports incident management • Promotes orderly traffic flow	• Cost

REQUEST FOR NON-STANDARD MITIGATION STRATEGIES APPROVAL

Complete this form for non-standard mitigation strategies before 90% TMP Submittal. Non-Standard mitigation strategies can be defined as any strategy not found in FDM 11-50 Attachments 5.8 – 5.10.

Requester Information:

Name: _____

Phone: _____

Email: _____

Region/Office: _____

Project Information:

Construction Project ID: _____ Mitigation Project ID: _____

Project Termini: _____ Project Length: _____

Highway: _____ County: _____

Affected Municipalities: _____

Anticipated Start Date: _____ Anticipated Completion Date: _____

Type of Strategy to be used: _____

Cost of Strategy: _____

Justification of Strategy: _____

Other Comments: _____

Follow up analysis is required to make sure strategy is effective and useful after 30 days.

Submit form through WisTMP.

Submittal Date: _____

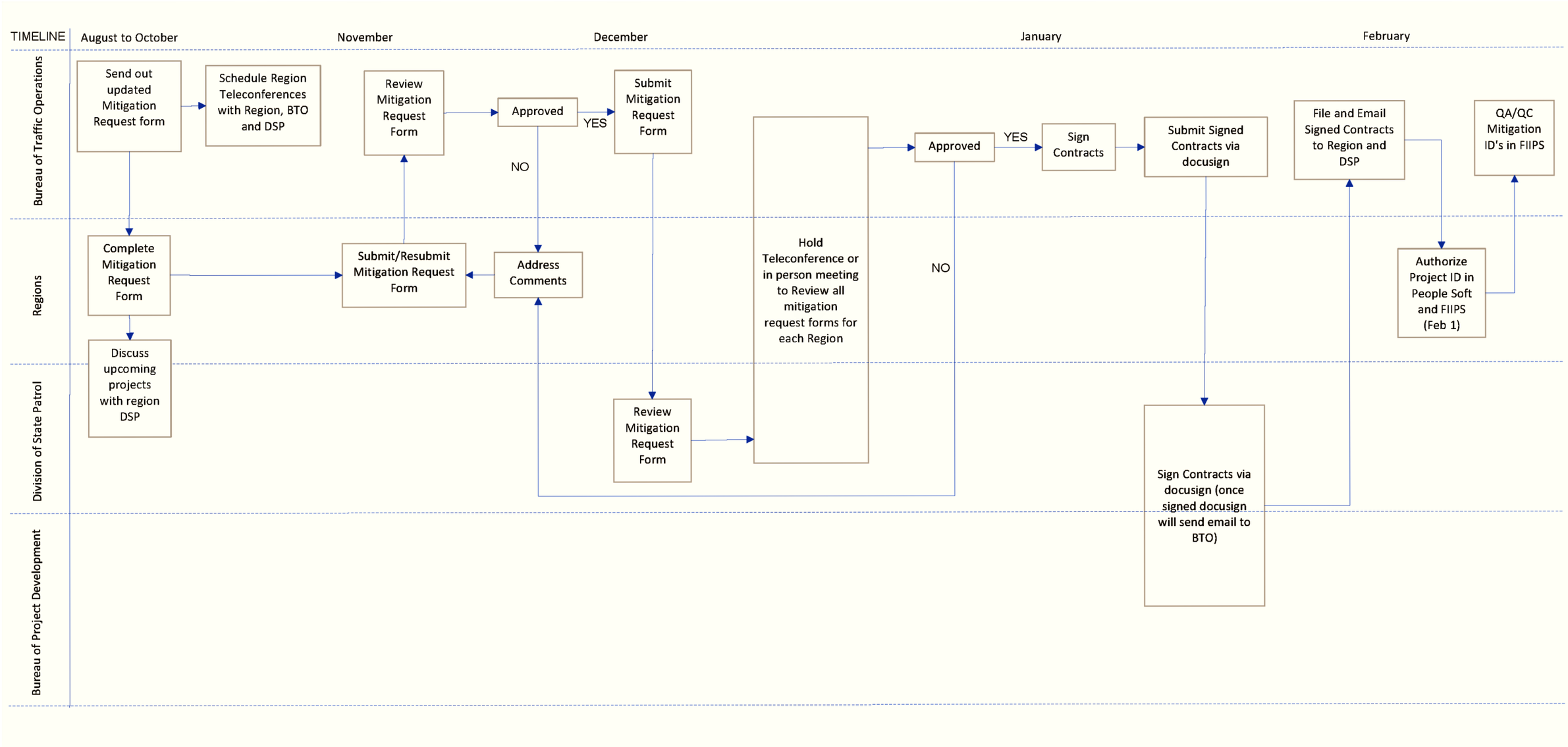
Four Approvers:

Bureau of Traffic Operations Director

Bureau of Traffic Operations, Traffic Engineering and Safety Section Chief

Two other Region Chief's not involved in project.

Approval Date: _____


TIMELINE
August to October
November
December
January
February
Bureau of Traffic Operations
Regions
Division of State Patrol
Bureau of Project Development
Send out updated Mitigation Request form
Schedule Region Teleconferences with Region, BTO and DSP
Review Mitigation Request Form
Approved
YES
NO
Submit Mitigation Request Form
Complete Mitigation Request Form
Submit/Resubmit Mitigation Request Form
Address Comments
Discuss upcoming projects with region DSP
Review Mitigation Request Form
Hold Teleconference or in person meeting to Review all mitigation request forms for each Region
Approved
YES
NO
Sign Contracts
Submit Signed Contracts via docusign
Sign Contracts via docusign (once signed docusign will send email to BTO)
File and Email Signed Contracts to Region and DSP
Authorize Project ID in People Soft and FIIPS (Feb 1)
QA/QC Mitigation ID's in FIIPS

SAMPLE "PUBLIC INFORMATION AND OUTREACH PLAN CHECKLIST"

A working copy of this file is at:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/programs/workzone/workzone.aspx

PIOP Checklist (Use for TMP type 2, 3 & 4 - save with project files)

1. Project Information	
Project ID: _____	Date: _____

2. Stakeholder Groups							
Stakeholders have been Identified in the plan:					☐	Yes	☐ No
Groups Identified:							
Motorists	☐	Pedestrians	☐	Bicyclists	☐	Transport Companies	☐
Businesses	☐	Residents	☐	City/County Officials	☐	Emergency Responder	☐
Bus Lines	☐	Ferries	☐	Mass Transit	☐	Law Enforcement	☐
Other: _____							

3. Communication Issues				
Communication needs have been identified:	☐	Yes	☐	No
Coordination with media/schools/businesses/emergency service/adjacent regions/state:	☐	Yes	☐	No

4. Communication Processes						
Scheduled delays and project duration:			☐	Yes	☐	No
Process meets schedule requirements:			☐	Yes	☐	No
Unscheduled delays and incident clearing:			☐	Yes	☐	No
Process meets response requirements:			☐	Yes	☐	No
Lane Closure and Roadway closures / detours:	☐	NA	☐	Yes	☐	No
Process meets response requirements:			☐	Yes	☐	No
Notification of alternate route to public:			☐	Yes	☐	No
Process meets response requirements			☐	Yes	☐	No

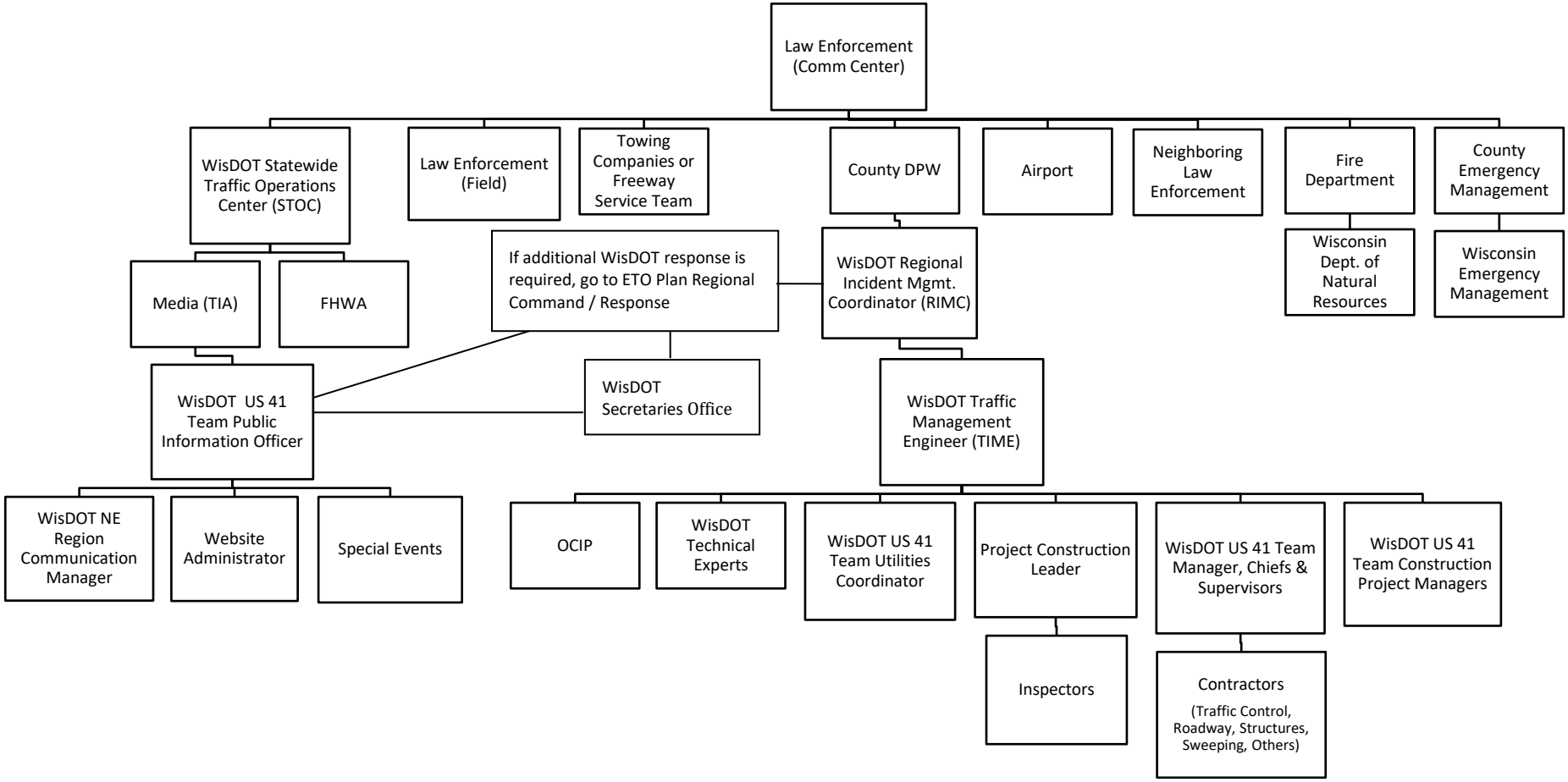
5. Communication Methods							
Brochures, Flyers	☐	Media Release	☐	Newspaper	☐	Radio	☐
Television	☐	Paid advertising	☐	Telephone Hotline	☐	Internet Website	☐
Public Meetings	☐	Traveler Info Sign	☐			Other	☐
Explain: _____							

6. Comments: _____

PIOP Developed by: _____ Date: _____/_____/_____

Example Communications Control Diagram

US 41 Freeway Incident / Crisis Communication Plan General Communication Flow Diagram



NOTE: This communication flow diagram **does not** represent a hierarchy for responding agencies. Rather, this communication flow diagram is meant to illustrate the initial flow of communication between agencies.

Entities not highlighted will be contacted depending upon location and scope of emergency.

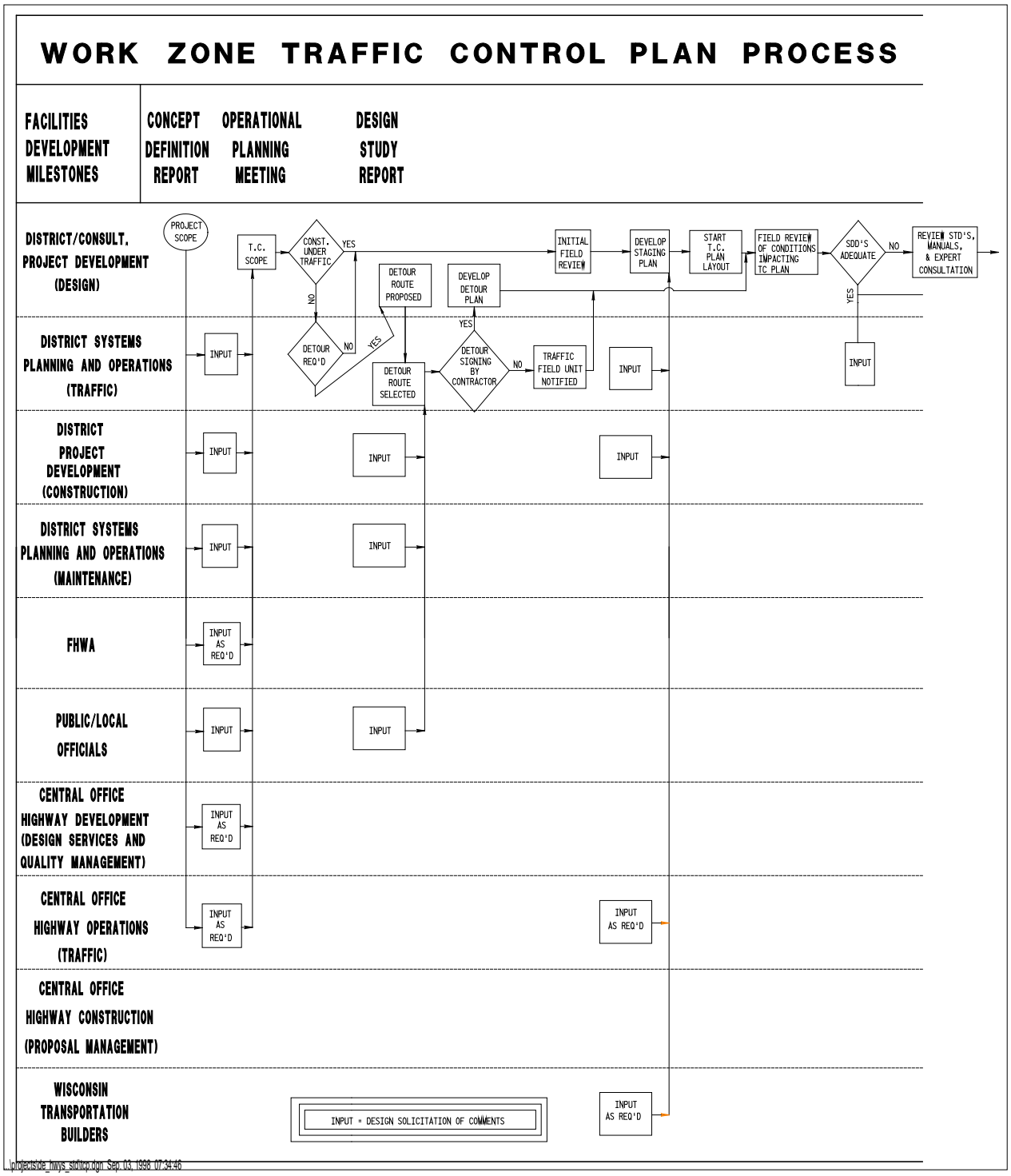
Example Emergency Alternatives Route Maps

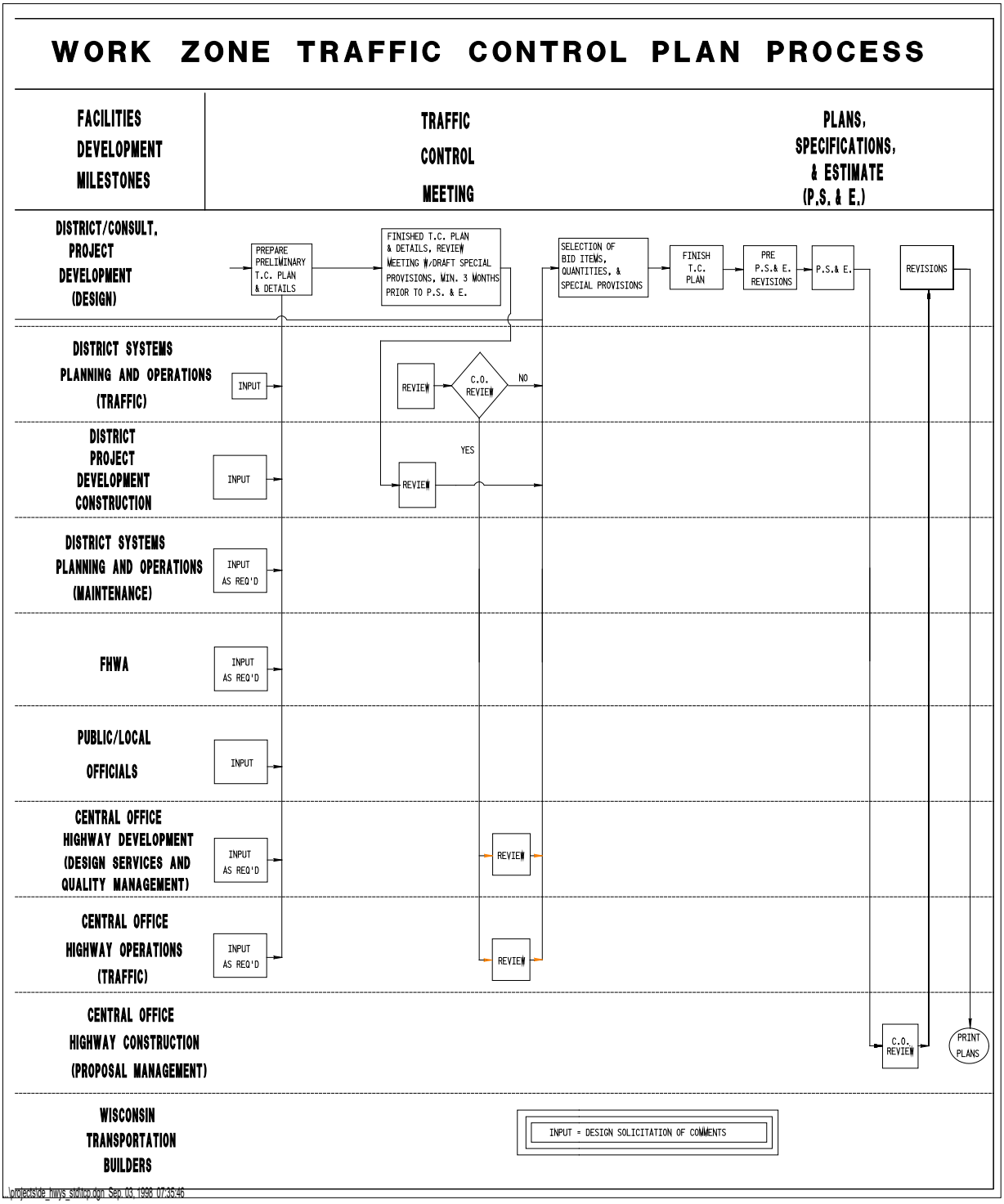
NB SEGMENT M.P. 175AB-171C

SB SEGMENT M.P. 171C-175AB

Example Emergency Access, Pullout and Traveler Information Equipment Locations Map

Provide a map of emergency access and pullout locations within the work zone and traveler information equipment, such as HAR, PCMS, DMS, and cameras within the project area.


WORK ZONE TRAFFIC CONTROL PLAN PROCESS
FACILITIES DEVELOPMENT MILESTONES
CONCEPT DEFINITION REPORT
OPERATIONAL PLANNING MEETING
DESIGN STUDY REPORT
DISTRICT/CONSULT. PROJECT DEVELOPMENT (DESIGN)
DISTRICT SYSTEMS PLANNING AND OPERATIONS (TRAFFIC)
DISTRICT PROJECT DEVELOPMENT (CONSTRUCTION)
DISTRICT SYSTEMS PLANNING AND OPERATIONS (MAINTENANCE)
FHWA
PUBLIC/LOCAL OFFICIALS
CENTRAL OFFICE HIGHWAY DEVELOPMENT (DESIGN SERVICES AND QUALITY MANAGEMENT)
CENTRAL OFFICE HIGHWAY OPERATIONS (TRAFFIC)
CENTRAL OFFICE HIGHWAY CONSTRUCTION (PROPOSAL MANAGEMENT)
WISCONSIN TRANSPORTATION BUILDERS
PROJECT SCOPE
T.C. SCOPE
CONST. UNDER TRAFFIC
YES
NO
DETOUR REQ'D
NO
YES
DETOUR ROUTE PROPOSED
DETOUR ROUTE SELECTED
DEVELOP DETOUR PLAN
YES
DETOUR SIGNING BY CONTRACTOR
NO
TRAFFIC FIELD UNIT NOTIFIED
INITIAL FIELD REVIEW
DEVELOP STAGING PLAN
START T.C. PLAN LAYOUT
FIELD REVIEW OF CONDITIONS IMPACTING TC PLAN
SDD'S ADEQUATE
NO
YES
REVIEW STD'S, MANUALS, & EXPERT CONSULTATION
INPUT
INPUT AS REQ'D
INPUT AS REQ'D
INPUT = DESIGN SOLICITATION OF COMMENTS
\projects\de_hwys_stdtcp.dgn Sep 03, 1998 07:34:46


WORK ZONE TRAFFIC CONTROL PLAN PROCESS
FACILITIES DEVELOPMENT MILESTONES
TRAFFIC CONTROL MEETING
PLANS, SPECIFICATIONS, & ESTIMATE (P.S. & E.)
DISTRICT/CONSULT. PROJECT DEVELOPMENT (DESIGN)
PREPARE PRELIMINARY T.C. PLAN & DETAILS
FINISHED T.C. PLAN & DETAILS, REVIEW MEETING W/DRAFT SPECIAL PROVISIONS, MIN. 3 MONTHS PRIOR TO P.S. & E.
SELECTION OF BID ITEMS, QUANTITIES, & SPECIAL PROVISIONS
FINISH T.C. PLAN
PRE P.S.& E. REVISIONS
P.S.& E.
REVISIONS
DISTRICT SYSTEMS PLANNING AND OPERATIONS (TRAFFIC)
INPUT
REVIEW
C.O. REVIEW
NO
YES
DISTRICT PROJECT DEVELOPMENT CONSTRUCTION
INPUT
REVIEW
DISTRICT SYSTEMS PLANNING AND OPERATIONS (MAINTENANCE)
INPUT AS REQ'D
FHWA
INPUT AS REQ'D
PUBLIC/LOCAL OFFICIALS
INPUT
CENTRAL OFFICE HIGHWAY DEVELOPMENT (DESIGN SERVICES AND QUALITY MANAGEMENT)
INPUT AS REQ'D
REVIEW
CENTRAL OFFICE HIGHWAY OPERATIONS (TRAFFIC)
INPUT AS REQ'D
REVIEW
CENTRAL OFFICE HIGHWAY CONSTRUCTION (PROPOSAL MANAGEMENT)
C.O. REVIEW
PRINT PLANS
WISCONSIN TRANSPORTATION BUILDERS
INPUT = DESIGN SOLICITATION OF COMMENTS
\projects\de_hwys_stdtcp.dgn Sep. 03, 1998 07:35:46

Directions for use: The answer to each of these questions should be yes (Y) or not applicable (NA). If the answer is no (N), then modifications should be made to the plan. Refer to the text of this procedure or the region traffic section for guidance in making modifications.

No.	Design Plan Review Checklist for Work Zone Traffic Control	Y	N	N/A
	GENERAL			
1.	Is the vehicle path vs. the work area clearly delineated?			
2.	Can cross street traffic identify the vehicle path?			
3.	Do intersection staging details allow for construction?			
4.	Has the work zone traffic control been field reviewed during the design process? (e.g., visibility of signs, devices, crossovers)			
5.	If the speed limit is reduced from 65mph, has a temporary speed zone declaration been completed and submitted to BTO?			
	CAPACITY CONSIDERATIONS			
6.	Is turning traffic at intersections provided for?			
7.	Can the mainline handle the traffic volume?			
8.	Do the special provisions address work restrictions? (time of day, weekend, holidays, etc.)			
9.	Are the necessary parking restrictions shown in the plan?			
10.	Have the appropriate traffic personnel (Region, City, County, etc.) been consulted about special traffic control mitigation measures, e.g. temporary signals?			
	PLAN AND SPECIAL PROVISIONS			
11.	Are SDD's and typical drawings used only when appropriate for the field conditions? NOTE: If SDD's and typical drawings are not appropriate, project specific drawings must be included.			
12.	Are all of the appropriate SDD's listed in the plan?			
13.	Do the special provisions include a "Traffic" article?			
14.	Are incidental items related to traffic control provided for under a "Traffic Control" special provision?			
15.	Is "Traffic Control" included in the estimate?			
16.	Are miscellaneous quantities for each WZTC item included?			
17.	Are the general notes and legends shown on the traffic control sheets?			
18.	Will the WZTC Plan be legible when reduced to "D" size?			

No.	Design Plan Review Checklist for Work Zone Traffic Control	Y	N	N/A
	WORK ZONE SIGNING			
19.	Are the sign dimensions shown in the plan or indicated in the general notes?			
20.	Are warning signs which are typically manufactured in yellow, properly shown as "WO"?			
21.	Are advisory speed signs, WO 13-1, if needed, shown only in conjunction with a warning sign?			
22.	If a WO1-2 or WO1-4 sign is shown with an advisory speed (WO13-1), is the advisory speed greater than 30 MPH?			
23.	If a WO1-1 or WO1-3 sign is shown with an advisory speed (WO13-1), is the advisory speed 30 MPH or less?			
24.	Are the advance warning sign messages more specific as the driver gets closer to the beginning of the work zone?			
25.	If width restriction less than 15 feet exists, are the appropriate width restriction signs shown?			
26.	If the project length is more than 2 miles, are "ROAD WORK NEXT XX MILE" sign shown on each end of the project?			
27.	Is the sign spacing in accordance with Table 6C-1 in Part 6 of the MUTCD?			
28.	If flags are to be installed on signs, is a 16"x16" flag size indicated?			
29.	Are flags shown on all temporary stop signs?			
30.	If existing signs need to be moved due to traffic staging, are they noted in the traffic control plan and special provisions with the appropriate bid item included?			
31.	If a milled or loose surface will exist, are the "GROOVED PAVEMENT" or "LOOSE GRAVEL" signs provided for?			
32.	If project specific fixed message signs are to be installed by the contractor, are they bid separately and are sign details included in the plan?			
33.	If Type I or Type II signs require modification or covering by the contractor, are they bid separately and are details included in the plan?			
34.	Have Region Traffic personnel been consulted about the use of portable changeable message signs?			
35.	Are individual sign codes shown on the plan?			

No.	Design Plan Review Checklist for Work Zone Traffic Control	Y	N	N/A
	CHANNELIZING			
36.	Are Type C lights shown on drums in "taper" areas?			
37.	Do the taper lengths match Tables 6C-3 and 6C-4 of Part 6 of the MUTCD?			
38.	For counter-directional traffic, have Region Traffic personnel been consulted about the separation devices?			
39.	Is the spacing of channelizing devices shown on the plan as specified in Section 6F.63 of Part 6 of the MUTCD?			
40.	Is a buffer space provided as shown in Table 6C-2 of Part 6 of the MUTCD?			
	WORK ZONE MARKINGS			
41.	When temporary pavement marking is required, is the appropriate material specified for Temporary Pavement Marking? (Temporary Marking Paint vs. Temporary Marking Removable Tape vs. Temporary Pavement Marking Epoxy)			
42.	Is the proper width and method of payment specified for Temporary Pavement Marking? (e.g. 8" channelizing line must be a separate bid item)			
43.	If existing markings conflict with traffic handling or staging, is removal or covering provided for in the plans? (edge lines, centerlines, lane lines, channelizing lines, stop lines, arrows, words)			
44.	When removal is necessary, are the limits for the removal of existing or staged markings shown on the plans? NOTE: Various widths of pavement marking removal should be paid for separately per line width.			

FDM 11-52-1 Intelligent Transportation Systems (ITS) Guidance

August 15, 2019

The purpose of the Wisconsin DOT Intelligent Transportation Systems Design and Operations Guide is to familiarize engineers with ITS elements and the process and information necessary to design and implement Intelligent Transportation System (ITS) elements for WisDOT. The intended audience for the guide is WisDOT regional traffic staff, regional project development staff, and consultants. The guide is written at a level that assumes working knowledge of signal design, roadway signing design, and electrical design as it applies to roadway design and installation elements. Information about the following ITS elements are included in the guide:

- ramp meters,
- system detector stations
- closed-circuit television cameras
- dynamic message signs
- portable message signs
- dynamic trailblazer signs
- ramp gates
- crash investigation sites
- law enforcement pads
- roadside weather stations
- smart work zones

The Division of Transportation System Development - Bureau of Traffic Operations (DTSD-BTO) Traffic Engineering Section, maintains the guide. The developer is required to contact WisDOT BTO for any ITS inquiries after determining the need for such ITS devices.

The ITS Design and Operations Guide can be found at:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/its/its.aspx

FDM 11-52-5 Traffic Engineering, Operations and Safety Manual (TEOpS)

August 15, 2019

The Traffic Engineering, Operations and Safety Manual (TEOpS) contains policy, guidelines and procedures related to traffic engineering and related functions as practiced within the Wisconsin Department of Transportation. More specifically, the region field and office forces of the Division of Transportation Systems Development, the staff of the Bureau of Traffic Operations, and other agencies of the Department which may be involved in traffic engineering. Traffic engineering functions include the installation and maintenance of traffic control devices, highway lighting facilities, traffic regulations, safety analyses, and support for the improvement program.

The TEOpS manual can be found at:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/teops/default.aspx

FDM 11-52-10 Traffic Signal Design Manual (TSDM)

March 4, 2009

The guidance supplied by the Traffic Signal Design Manual (TSDM), is based on established practices of the Wisconsin Department of Transportation and is supplemented by research. It is applicable to all types of new traffic signal installations and revisions. The TSDM does not describe all possible situations; rather, it is intended to promote sound engineering and uniformity in the design process and operational aspects of traffic signals on the State Trunk Highway system in the State of Wisconsin. This document does not constitute a legal standard, specification, or regulation.

The TSDM can be found at:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/tsdm/tsdm.aspx

FDM 11-55-1 Boat Ramps

May 15, 2019

1.1 Site Layout

The layout of facilities such as access roads, parking lots, ramps, piers, etc., will depend greatly on the size, shape, and contour of the site, and on the location of existing vegetations. Each case will be different, but some general guides can be given.

One of the most desirable attributes of a site is its natural beauty. Ramps should be located and designed so as to blend in with and maintain the natural beauty of the shoreline. Parking lots should be set into the landscape so as not to disrupt it. Existing trees and shrubs should be preserved if at all possible. Before deciding to retain a tree, however, consideration should be given to the length of its remaining lifespan. Generally, protective islands can be employed to retain trees and shrubs in parking lots. It is not generally practical to plant or retain trees without these islands, because they are frequently hit by automobiles. Native trees or shrubs retained or planted along the shore, between the ramp or parking lot and other properties, and between the parking lot and any roadways that may be nearby will enhance the natural beauty of the access site and aid in controlling erosion.

It is recommended that a buffer strip of trees at least 40 feet wide be used between any parking lot and the shore (see Attachment 1.3 and Attachment 1.4).

In locating parking lots, sufficient room should be provided for future expansion. A typical method of doing this is shown in Attachment 1.1. In general, there should be no more than one car-trailer stall per ten acres of water to be served by the site. The aisle serving automobile and trailer parking should be aligned as straight as possible with the ramp to reduce the amount of turning required in backing up the rig. If this is not possible, the ramp should be offset to the left of the aisle, as one faces the lake. In this way, the driver may back down the ramp while viewing the maneuver from the operator side of the car rather than from the blind side. When backing around corners is required, the corners should not turn more than 90 degrees. In placing the parking lot and ramp on the site, both should be centered as much as possible to provide an equal buffer zone for each adjacent property owner. Some typical layouts of access points are shown in Attachment 1.3 and Attachment 1.4.

1.2 Launching Ramps

A typical plan and profile view and typical cross sections of a launching ramp are depicted in Attachment 1.1 and Attachment 1.2, respectively. Several items are worth noting here.

For grades more than 15 percent, it is difficult to obtain good traction on wet ramps; therefore, ramp grades should not exceed 15 percent. Desirably they should be at least ten percent or greater, especially for shorter boats. To aid in keeping the upper portion of the ramp as dry as possible, grades on the approach road or parking lot just above the ramp may be warped to prevent storm water from running down the ramp.

Quite often fill slopes, especially steep ones with light soils, will erode in heavy rains. As noted in Attachment 1.2, this can be minimized by inverting the ramp crown to eliminate runoff from the approach roadway. While this is contradictory to the previously mentioned consideration of keeping the water off the ramp, it should take precedence where erosion is a potentially serious problem. In some cases, riprap or a similar type of protection can be provided at the toe or side of the ramp to prevent erosion.

In most cases it is advisable to surface the ramp and the ramp approach. The surface may consist entirely of coarse gravel, but a combination of P.C. concrete planking on the ramp and bituminous concrete on the approach is preferred. Bituminous concrete surfacing should not extend into the water but should end where the P.C. concrete planking begins. Details for P.C. concrete plank are given in Attachment 1.2. These details outline the dimensional and material characteristics of the preferred plank. However, where these are not readily available, or a cost savings could be affected, comparable planks may be used at the designer's discretion.

Base course requirements are shown in the typical cross sections in Attachment 1.2. If the ramp is not surfaced, it is important to use a coarse material (maximum aggregate size of two inches) to prevent it from becoming too slippery when wet.

Piers should be provided where adequate maintenance is available and where ramp usage warrants them. The recommended placement of a pier with respect to a ramp is shown in Attachment 1.1. Where a high degree of resiliency is desired, wooden Piers are best. Details for two types of simple wooden piers (permanent

installation) are given in Attachment 1.2. Where ice damage is the primary consideration, a removable pier is recommended. Any of the various commercially sold floating piers with either a steel or wooden treadway would be best in this instance, but a semi-permanent pier with removable supports and deck could be employed also. Floating piers can also be used to good advantage where water levels fluctuate greatly. Cleats and padding should be added to piers to protect the boats.

Ramps should be provided on the basis of approximately one per 20 parking spaces. The optimum width of top for a single-lane ramp is about 16 feet. This will permit the use of the normal 10-foot concrete plank with 3-foot gravel shoulders on each side. When a pier is included, this could be reduced to 14 feet as shown in Attachment 1.1, with a 3 feet shoulder on one side and a one-foot shoulder between the plank and the pier. When multiple installations are required, the recommended method is to build a series of single-lane ramps side by side with piers separating them in the manner depicted in Attachment 1.1. For the most part piers can then be used to service two ramps.

1.3 Parking Lots

It is preferable to pave parking lots whenever feasible, although gravel surfaces have proven satisfactory. The planting or retention of native trees and shrubs in the parking lot is optional but is very much preferred. Plantings that are susceptible to damage by turning vehicles should be protected with posts or enclosed with islands formed by a concrete curb at least six inches high. On a surfaced lot where plantings are omitted, required island areas can be adequately delineated with paint. Where there is a single row of car-trailer parking, it may be desirable to omit bumper blocks and permit the rigs to pull out the front of the parking stall; otherwise, bumper curbs of any acceptable material are recommended for delineating the front of vehicle parking spaces. Plastic and fiberglass curbs have been used but are not durable enough to withstand vehicle loading. Wood and concrete curbs are preferred. Since parking stalls cannot be easily delineated on gravel lots, their sizing and arrangement are more difficult to plan for. Somewhat wider stalls may be necessary under these conditions.

Desirable parking angles, aisle widths, and turning radii are all depicted in Attachment 1.1. An automobile requires a 10' x 20' parking space and an auto-trailer-boat combination requires a 10' x 40' area.

1.4 Miscellaneous Design

When practical, toilet facilities, picnic tables, grills, trash containers, and drinking facilities should be included as part of the access site improvement, especially if the site is remote from other such facilities. This should be conditioned, however, on the existence of adequate space and maintenance services. Toilet facilities are particularly desirable on many sites and possibly necessary on heavily used ones. In planning for them, a review should be made of DNR and Department of Health regulations.

Some projects will require only very short access roads. When longer ones are required, typical cross sections should be prepared to show the applicable significant requirements of the access roads. An example of a typical access road cross section is given in Attachment 1.2.

Since many of the items of work are not covered by the Standard Specifications, it will be necessary to include the description of work in the Special Provisions, listed as 90000 bid items. Some examples are Grade and Shape Parking lot, Grade and Shape Access Road, Grade and Shape Ramp, Install Concrete Ramp and Pier, Install Bumper Blocks, etc.

LIST OF ATTACHMENTS

Attachment 1.1	Boat Ramp Details
Attachment 1.2	Pier Details
Attachment 1.3	Boat Ramp Example Parking Layouts
Attachment 1.4	Boat Ramp Example Parking Layouts

FDM 11-55-3 Timber Management

June 18, 1999

WisDOT is committed to the preservation or proper management of trees within the highway right-of-way. As such, the designer is encouraged to regard the forest/timber as a resource having both aesthetic and commercial value.

Aesthetically, the existing trees and vegetation present an opportunity and basis for sculpting a pleasing and efficiently maintainable roadside. In this regard, the landscape architects in the Bureau of Highway Operations should be consulted.

When new right of way is acquired, the seller is compensated for the value of the marketable timber on that

property. The Department expects to recover that value in some form, nominally in the contractor's competitive bid. Unless otherwise specified in DOT contracts, the merchantable timber removed in clearing the right of way becomes the property of the contractor. The contractor is required to make the timber available for commercial or fuel use before disposing by other means. Contractors will generally make a good effort to market the timber and give consideration to anticipated revenue in preparation of their bid.

However, timber management in the form of advanced timber sale by the Department should be considered. This requires that right of way acquisition be completed sufficiently in advance of construction to allow for the sale and harvest; and that there be a desirable species of timber in sufficient concentration to be attractive to logging contractors.

Advance marketing of timber assures that the resource is properly utilized and, if properly undertaken, may expedite the construction contractor's operations. Active management also provides a response to the public, which occasionally perceives clearing operations as a waste of valuable resources.

FDM 11-55-5 Retaining Walls

March 28, 2014

5.1 General

Retaining structures are used to hold back earth where an abrupt change in ground elevation is required. They are useful in cases of restricted right-of-way or where existing features must be avoided.

The Bridge Manual (https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/strct/bridge-manual.aspx) contains guidance on all aspects of incorporating a retaining wall into a highway project. It is important that the designer be familiar with this guidance. That guidance will not be duplicated here, but will be briefly described:

Chapter 2 - *General*.

Section 2.5 (Bridge Numbers) shows the criteria for assigning structure numbers. Retaining walls receive R numbers which are assigned by the region in the same manner as bridge numbers. Only retaining walls with R numbers require structure survey reports. These are prepared using the Separation Structure Survey form and sent to the Structures Design Section. Also, as a rule, all retaining walls with R numbers will require a geotechnical analysis.

Chapter 14 - *Retaining Walls*.

Section 14.1.1.1 (Wall Numbering System) states the criteria for assigning an R number to a retaining wall.

Section 14.2 (Wall Types) lists the proprietary and non- proprietary wall systems considered for use on WisDOT projects.

Section 14.3 (Wall Selection Criteria) and Section 14.15 (Construction Documents) describe the process for selecting a suitable wall system for a given wall location and for incorporating the design for that wall into the construction contract documents respectively.

WisDOT may provide a complete design of one of the following types of walls on a project:

- Cast-in-place walls
- Gabion walls
- Post and panel walls
- Sheet piling walls

For a proprietary wall system (except as described below under "Minor Retaining Wall), WisDOT will provide a conceptual design including location (horizontal and vertical). The wall supplier is then responsible for the structural design and furnishing of complete design plans. Only one wall system shall be specified from the list of suitable systems.

All proprietary wall systems must be pre-approved by the Bureau of Structures (BOS) prior to being considered or used on WisDOT projects. Design all systems in accordance with the procedure specified by the WisDOT Bridge Manual and the appropriate Standardized Special Provisions (STSP 532-030 through 532-035, Item 90031) or Special Provisions (refer to BOS website) must be inserted into the contract. See the Approved Products List for pre-approval wall systems.

For proprietary walls (except as described below under "Minor Retaining Wall") BOS is responsible for reviewing the structural aspects of the design and construction plans provided by the wall company before construction can begin. Note that the structural design of proprietary wall systems is the responsibility of the wall supplier

(vendor).

Within 25 days after the award of the contract, the contractor must provide the region project engineer with the name of the vendor who will be supplying the proprietary wall system. A wall submittal package shall be submitted electronically to the project engineer and BOS no later than 30 days prior to beginning construction of the wall.

WisDOT will consider cost reduction incentive (CRI) proposals per the WisDOT Standard Specifications, provided the proposal is equivalent both functionally and aesthetically and does not violate any usage restrictions as stated in the WisDOT Bridge Manual.

Wall systems which are designed in compliance with the procedures specified by the WisDOT Bridge Manual are considered functionally equivalent. Aesthetic equivalence may vary from project to project because of public perception and site specifics and can best be determined by the designer involved in the project. See Chapter 14 of the WisDOT Bridge Manual for more details.

Bid each wall separately by the type of wall and either the R-X-XXX number or the sta.- sta. Limits, LT or RT. Include each wall in a list on the plan's miscellaneous quantity sheets.

Note: All retaining walls assigned an R number (such as R-XX-XXXX) are to be included in the 8.X sheet section of the plan set. Submit preliminary plans, final plans and shop drawings to BOS for review and acceptance.

5.2 Minor Retaining Wall

A "Minor Retaining Wall" is a proprietary MSE wall with a modular block face that is less than 5.5 feet tall or a proprietary modular block gravity wall that is less than 4.0 feet tall as measured from the bottom of wall or top of the leveling pad to the top of the wall.

Minor retaining wall details are to be included in the 2.X sheet section of the plan set and quantities in the 3.X sheet sections of the plan set under Miscellaneous Quantities". The minimum required details to be included in a minor retaining wall plan include: a plan view layout, an elevation view, estimated soil parameters, and a typical cross section view of the wall. See BOS LRFD Standard Detail Drawing 14.03 for a sample plan and WisDOT Bridge Manual 14.15.2 Special Provisions for bid items. This information constitutes a minor retaining wall plan.

Note: "Minor Retaining Walls" are not intended to support vehicle traffic or slopes equal to or steeper than 2.5H:1V. Additionally, tiered walls are not considered "Minor Retaining Walls" and should be assigned a structure number. In most cases, a geotechnical analysis is not required for "Minor Retaining Walls"; however, it is the designer's responsibility to determine if an analysis is required. Contact the BOS region liaison, regional soils engineer, or Bureau of Technical Services Geotechnical Unit for more information. Submit shop drawings to BOS for review and acceptance.

5.3 Barriers on Top of Retaining Walls

When designing a retaining wall, determine if vehicles, bicycles, pedestrians or children are likely to be present near the top of the wall. Install a barrier at the top of any wall which is over 1 foot tall if the top of the wall is to be adjacent to a sidewalk, trail, parking lot or stairway landing. Walls located farther from human or vehicular activity may be higher before a barrier is considered necessary. In any case, provide a barrier if it is determined to be necessary, regardless of the height of the wall.

The barrier on top of a wall could be a fence, beam guard, or a railing. Coordinate the selection, location and installation details of a proposed barrier with the structural designer. Consider aesthetics of any barrier, especially in urban areas where the wall and barrier are located adjacent to private property.

5.4 Right-of-Way Requirements

All segments of a retaining wall system must be under the control of WisDOT. This includes the area behind a MSE type wall containing the soil reinforcing elements. This area is considered part of the wall. Do not allow permanent improvements, including utility construction, in this area.

Fee simple purchase of the right of way is the best option. A permanent easement may be used, but this is not recommended. If sufficient right of way cannot be obtained for a particular type of wall, then specify a different type of wall.

Mature trees or structures on private property can also affect the choice of wall type. Wall types having tie backs may require clearing vegetation that would affect adjacent properties. Also, consider buildings that are near the right of way that could be undermined.

Sometimes a right-of-way estimate is needed before the wall type is selected. In these cases, estimate the R/W need at 6 feet from the back of the proposed wall, or use the height of the wall, whichever is greater. This

estimate is for planning purposes only. The exact distance must be determined after a geo-technical investigation is completed. This investigation may reveal the need for even more right-of-way at the site.

FDM 11-55-10 Cattle Pass Design

August 17, 2020

10.1 General

A stockpass is defined as any structure which allows domestic animals to cross a highway without interfering with traffic. In Wisconsin, the applicable domestic animal population ranges in size from sheep to llama to buffalo. While the general principles of this policy are applicable to all livestock, the policy will be directed and referenced to cattle and cattle passes.

A cattle pass is generally considered to be either a land service facility or a highway service facility. The land service facility is for the benefit of a business or non-public land owner, whereas the highway service facility benefits highway users. FHWA generally considers a cattle pass to be a land service facility; therefore, it is up to the state to document that a proposed cattle pass is for the benefit of the traveling public.

Public funds designated for the improvement of highways are limited to that purpose. Highway funds used for the installation of a cattle pass and related appurtenances on the highway right of way must be in the public interest and for the benefit of highway users. The benefits accruing to the landowner or occupant whose stock uses these highway service facilities are considered incidental. A landowner may request that the Department provide a cattle pass for his convenience or safety (i.e., a land service facility). In such instance, the Department can reasonably recognize that any installation results in some benefit to the highway user (although likely not sufficient to justify the total cost of the installation). Highway funds could therefore participate to the limit of public benefit perceived, and the remaining cost would be the responsibility of the requester.

Refer to FDM 11-45-30 for the definition of hazardous cross drain or cattle pass, treatment options, and warrants for various treatment options.

10.2 Criteria

Past, present, and potential future use of the lands may demonstrate the need to provide for or perpetuate the circulation of stock and therefore the need to provide for the safety and convenience of the highway user. Designers should meet with stock owners to discuss their need for and willingness to use the facility as well as any restrictions which require that the facility be used.

New construction, or reconstruction involving grading, allow the opportunity to design in safety features in a more cost-effective manner. A retrofit situation, which would be initiated in response to a changed land use or evolving hazard, will likely be costlier and hence more difficult to justify, and may also probably provide less-than-ideal service.

10.2.1 On New Grading Sections

Highways warranting design criteria A2 or above should provide cattle passes at locations where herds of 20 or more will cross the highway on a regular (daily) basis.

On highways of lower volumes or function, cattle passes may be considered if sight distance limitations make an at-grade herd crossing hazardous or if herd size causes lengthy delays to highway traffic. These installations must be justified and supported on the basis of cost effectiveness and safety.

The separation of livestock from designated freeways and expressways is always warranted regardless of conditions, by definition of the access. This restriction should be recognized during the real estate phase of project development, preferably through payment of damages or whole takings but also by land exchanges. A cattle pass on this type of facility would likely be of such length and size and resultant cost as to justify a change in land use.

Designers should note that if a cattle pass is provided as a real estate consideration, it becomes part of the value of the property and therefore cannot be taken away without compensation. Example; if lands are taken with payment based on acreage taken, and the remnant has diminished value due to severance, and that diminished value is not compensated with dollars but rather restored to value by a cattle pass, then the cattle pass becomes a compensable part of that property (until such time as ownership and use of the remnant changes or becomes unrelated to the rest of the property.)

10.2.2 Non-grading Situations:

The Department may respond to a request from an abutting owner for a cattle pass in the same manner as any other land service facility request.

Proper attention to visibility, adjusting the location of an at-grade crossing, and the use of advance warning

signs are often the most cost-effective and feasible treatment.

10.2.3 Documentation

Prior to committing resources to the design and construction of a cattle pass, the "Documentation for Cattle pass" worksheet (Attachment 10.1) should be completed, accepted by the designated region authority, and filed both in region and central office project files. The 'Basis for Consideration' portion of the worksheet is meant to identify such items as a private request, an identified safety problem, new construction of a high-volume facility, combination of the above or other. Note that the worksheet may also be used to document the decision not to include a considered, or to turn down a requested, cattle pass. The inclusion and location of each cattle pass should be discussed in the "Unique Features" section of the Design Study Report.

10.3 Design Guidelines

Cattle passes, due to lower minimum size requirements, are expensive to construct and shield. The most expensive cattle passes, however, are those that are not used due to inadequate design, or subsequently abandoned due to avoidable deterioration. Therefore, if a cattle pass is warranted, it should be sized and located to be attractive for use and should be designed to avoid bog ends.

In most cases a structure should be built to accommodate either livestock or drainage, not both. In some cases, however, a combined facility may be unavoidable. This includes river crossings being lengthened to accommodate a stock path on the bank or in the case of a dry run or overflow structure. When a combined facility is being considered, it should be designed to carry water only when runoff exceeds that expected from a 10-year storm.

The cattle pass and its approach path should never be placed at a drainage low point; there must always be drainage away from the facility. In addition, aprons or paved walkways will aid in preventing bogs or mudholes. Placement and drainage influence the attitude of the user; a stockowner will make a greater effort to use a well-drained structure than a poorly drained one. Bogs resulting from poor drainage conditions can become breeding grounds for disease, a factor which is critical to dairy farmers.

Placement of the cattle pass as high up in a fill section as possible, considering cover and clearzone, will result in the shortest length.

The longer a cattle pass is in relation to its size, the more hesitant stock are to pass through it. For that reason, the opening size may be varied, depending on cattle pass length and size of herd. A lower minimum usable opening of 4' x 6' may be acceptable for lengths up to 75 feet. Beyond that, sizes of 6'x 6' to a practical maximum of 7' x 7' can be considered, the larger for lengths in excess of 150 feet passing herds of more than 70 head.

The cattle pass should always have a lower minimum gradient of 1%, desirable 3%, sloped one way to allow flushing, but not so steep that the stock will slip. Gradients steeper than 5% should be textured.

Fences should be constructed to the highway right of way as part of the facility.

As with the consideration of necessity and location, the design of the facility should be discussed with the stockowner.

10.4 Other Considerations

As part of the highway, the physical facility on the right of way is maintainable by the state. To that end the installation should be designed, constructed, and maintained so that it is functional and serviceable, with due consideration to minimizing erosion, providing adequate drainage, and with walkways sufficiently stable to permit the passage of the livestock without undue soft and muddy conditions developing on the right of way.

The owner or occupant of the property served shall be required to maintain practical and serviceable fences along the stockpath approach with due regard to not impairing surface water drainage or the function of the structure. Such owner or occupant shall also be responsible for cleaning the structure floor and walkway approach.

An understanding of cooperation and responsibilities should be reached and documented for the protection of all concerned. It must be further understood that the state will have the right to gate or remove the facility at such time as it may no longer be needed for livestock operations or if the facility becomes a nuisance.

If the cattle pass is provided at the request of an abutting owner, the basis of participation should be included in the above agreement.

Existing cattle passes within a proposed improvement project should be reviewed to determine usage and condition. If it is determined that a stockpass is unused, the property owner is informed by letter that the department proposes to either abandon or remove it. The property owner should be allowed ample time to

respond. A desire on the part of the property owner to perpetuate the cattle pass should carry with it some tangible evidence of legitimate future need. If no response is received from the property owner, it is assumed they have no further interest in the facility. Experience would suggest that a second notification effort is desirable to avoid misunderstanding.

If the cattle pass is to be perpetuated it should be evaluated for structural condition, improvements if needed, or replacement.

If no longer needed as a cattle pass, its condition and effect on safety is evaluated. If in good condition, it is normally abandoned by removing the end sections and filling with earth. If in poor structural condition, it must be removed. In instances where the stockpass also serves as a drainage facility, determination is made as to the cost effectiveness of retaining it for that purpose, or replacing it with a smaller, safer drainage pipe.

It is currently accepted that the presence or absence of a cattle pass has little bearing on the value of farm property as this item is only of value to a single use of the land. However, each cattle pass should be reviewed to determine that any action by the Department is appropriate, fair to the property owner, and to the benefit of the traveling public.

LIST OF ATTACHMENTS

Attachment 10.1 Documentation for Cattle Pass

FDM 11-55-20 Overhead Sign Structures *August 17, 2020*

The provisions within this section (11-55-20) take effect for projects with an August 1st, 2020 PS&E with November letting. If final design has already begun for a project on or after this date, please contact the Bureau of Structures Design Section for how best to proceed, as project-by-project exceptions may be granted.

20.1 General

20.1.1 Introduction

Overhead Sign Structures (OSS) are structural supports for mounting signs over roadways. OSS configurations include cantilever and butterfly structures with a single vertical support post and full-span structures with vertical supports at each end of the structure. OSS superstructure configurations include monotube, (one horizontally spanning member), 2-chord planar trusses, and 4-chord space trusses. See attachment 20.1 for a graphical description of the various types. All OSS are required to be structurally designed per the applicable provisions of the AASHTO LRFD Design Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (LRFDLTS-1) and the Wisconsin Department of Transportation (WisDOT) Bridge Manual (BM). All OSS are assigned a structure number and inventoried in the WisDOT Highway Structures Information (HSI) System.

Roadside sign supports are ground mounted posts supporting signs adjacent to roadways. Roadside sign supports are not considered OSS, not assigned a structure number nor inventoried in the HSI system.

20.2 OSS Selection and Usage Criteria

20.2.1 General

The following criteria and guidance are used for determining the sign structure type to be used in a given situation. In general, the selection is determined by one of the following controlling criteria:

- Required Cantilever Arm or Full-Span Length
- Maximum Sign Panel Height
- Maximum Total Sign Panel Area
- Maximum DMS Dimensions
- Maximum DMS Weight

Based on the above parameters, the smallest sign structure type for the controlling parameters is selected for use at a given location. Use the figure in sections 20.2.3 (static signs) and 20.2.4 (DMS) to determine which sign structure type is appropriate. The sign structure types are arranged from most economical at the top to least economical at the bottom. Once the OSS type is selected, making note of whether it is *Contractor Designed*, *Standard Design* or *Non-standard Design*, follow the appropriate design and plan submittal process discussed in section 20.3. For Contractor Designed OSS, a standard foundation also needs to be selected. Refer to section 20.2.5.

Due to the variability of factors that can influence the selection of structure type, designers are encouraged to contact the WisDOT Bureau of Structures Design Section for further assistance when structural layout geometry, sign sizes or total sign area are in question or to address any unique or special situations. See section 20.4.3 for examples of unique situations.

20.2.2 Bridge Mounted Sign Supports

When space or other constraints prohibit the use of an overhead sign structure and no practical alternatives exist, signs may be mounted on the side of grade separation bridges over the undercrossing roadway. These are considered non-standard designs that require individually designed structural mounting brackets to attach the sign to the side of the grade separation bridge. Bridge mounted sign support brackets are assigned a sign structure number and inventoried in the WisDOT HSI system. Refer to Chapter 39 of the WisDOT Bridge Manual for further guidance.

20.2.3 Overhead Sign Structure with Static Signs

OSS Selection and Usage Criteria - OSS with Type I and / or Type II Static Signs:

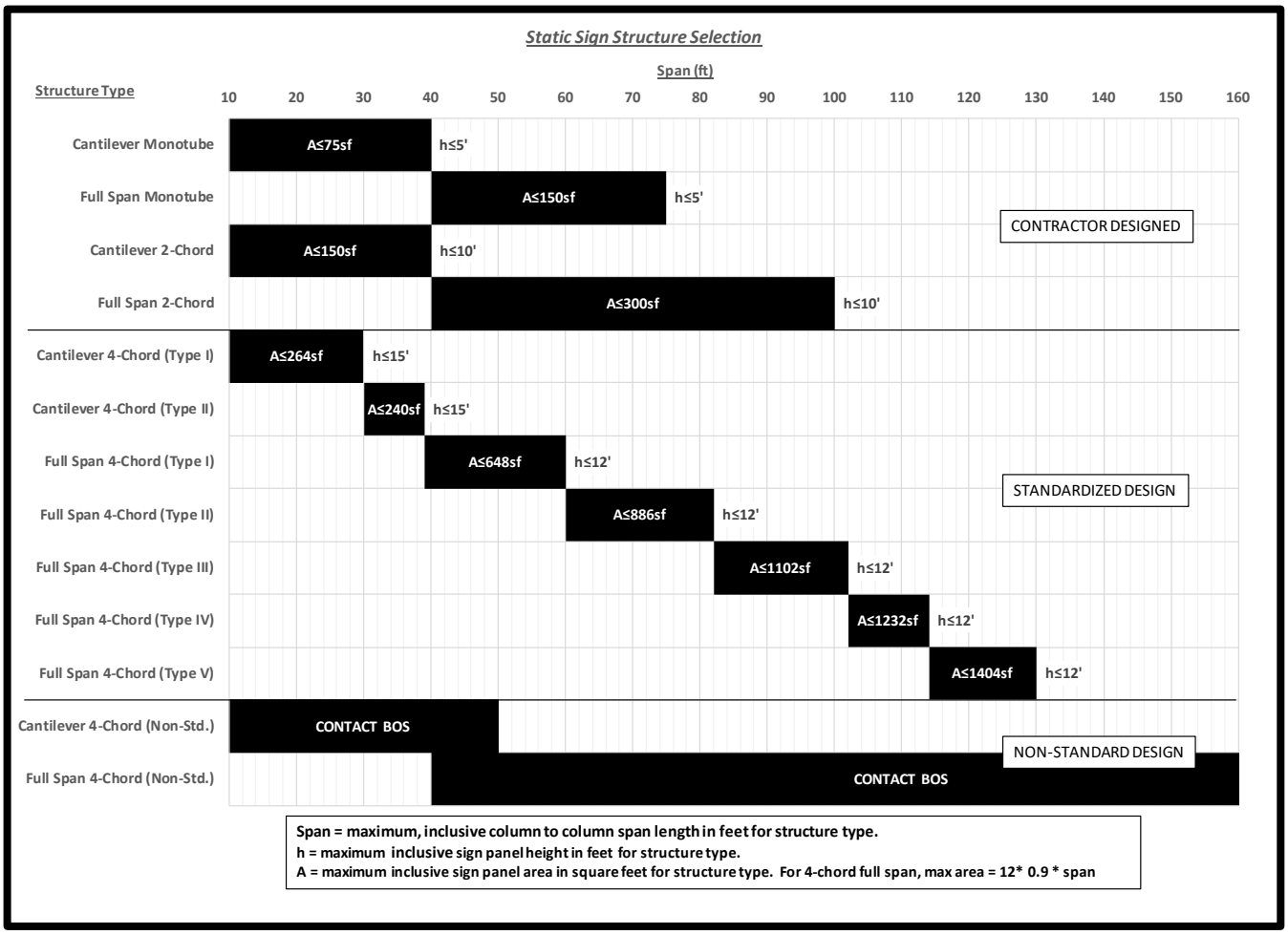


Figure 20.2.3
OSS Type Selection for Static Signs

Notes:

1. An example demonstrating the use of the chart for sign structure selection is provided in attachment 20.2
2. The sign areas shown for the *Full Span 4-Chord* types are maximums. The actual allowable sign area will be less and is limited to 90% of the span length x max sign height (12') – see attachment 20.2 example.
3. Standard foundations are included with all *Standard Design*s. Standard foundations are also available for *Contractor Designed* OSS but must be selected using Figure 20.2.5.
4. The overall structure height should be checked and is limited to the values shown in the WisDOT Bridge Manual 39.1.5 and 39.1.6. Generally, it is not an issue with typical roadside embankments.

5. Prior to initiating design, contact the Bureau of Structures Design Section for questions regarding OSS selection or if the signage demands warrant a *Non-standard Design*.

20.2.4 Overhead Sign Structure with Digital Message Signs

OSS Selection and Usage Criteria - OSS with DMS:

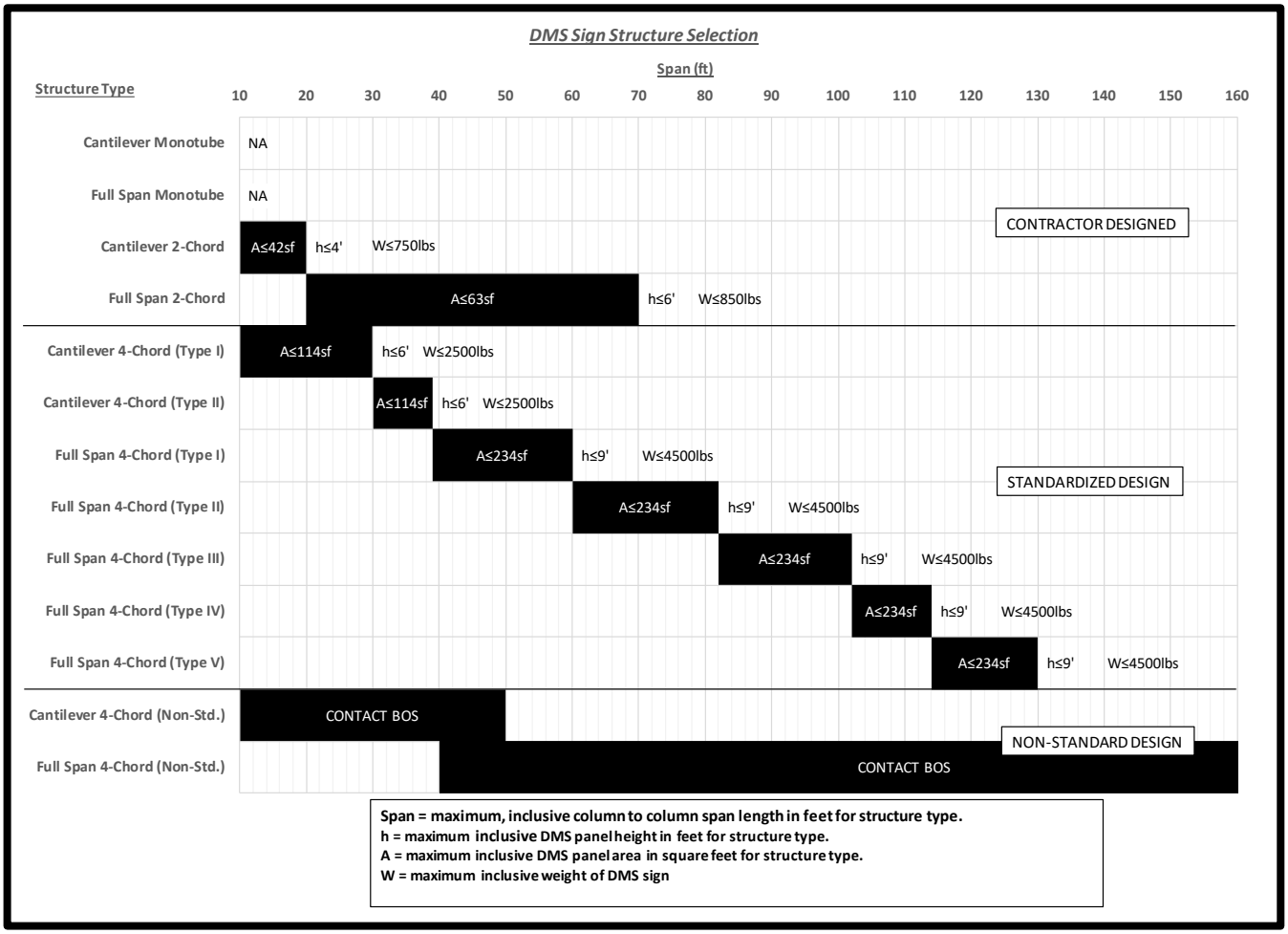


Figure 20.2.4
OSS Type Selection for DMS

Notes:

1. Standard foundations are included with all *Standard Design*s. Standard Foundations are also available for *Contractor Designed* OSS but must be selected using Figure 20.2.5.
2. The overall structure height should be checked and is limited to the values shown in the WisDOT Bridge Manual 39.1.5 and 39.1.6. Generally, it is not an issue with typical roadside embankments.
3. Prior to initiating design, contact the Bureau of Structures Design Section for questions regarding OSS selection or if the signage demands warrant a *Non-standard Design*.

20.2.5 Standard Foundation Selection for Contractor Designed OSS

Standard Foundation Selection and Usage Criteria:

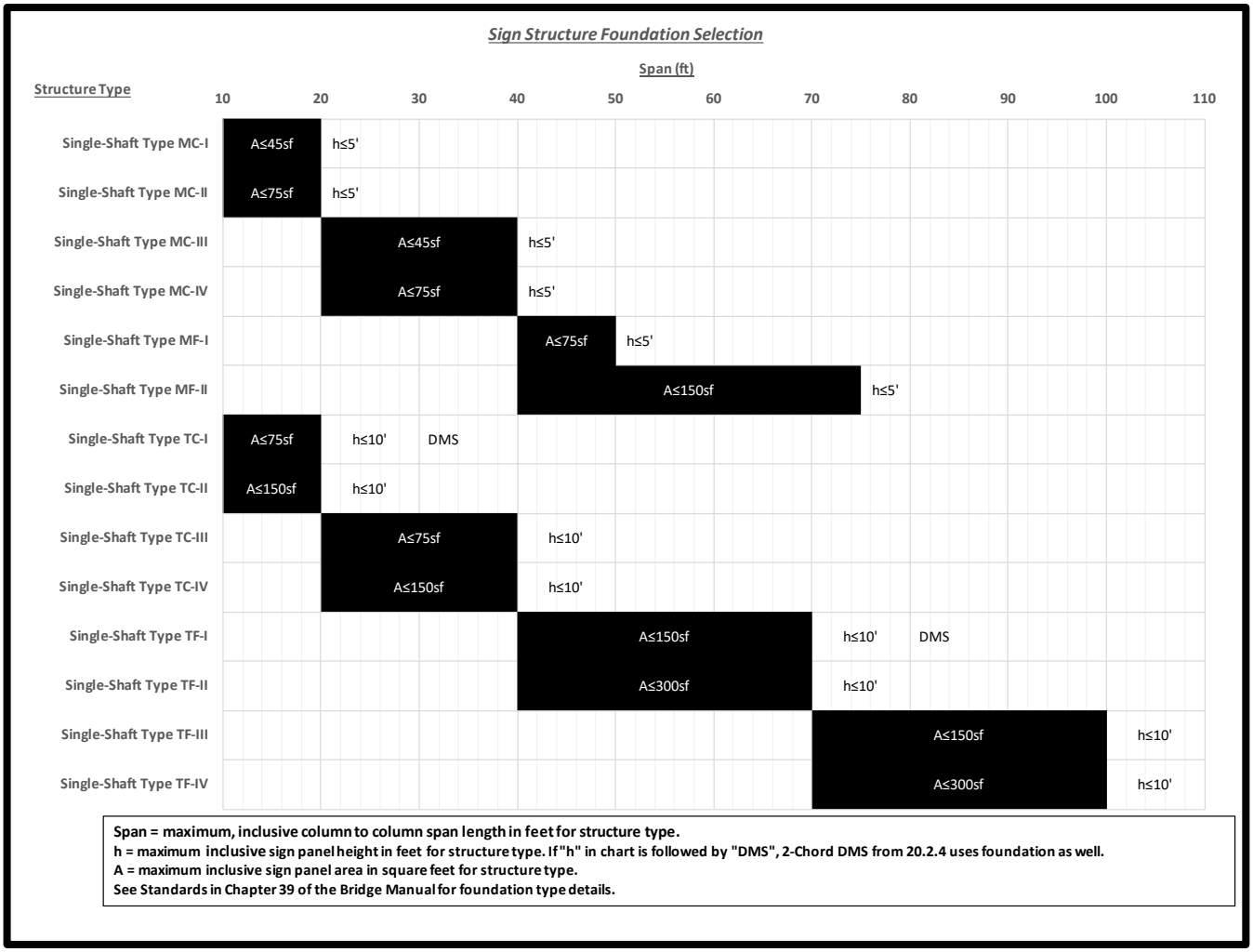


Figure 20.2.5
Standard Foundation Selection for Contractor Designed OSS

Notes:

1. An example demonstrating the use of the chart for foundation selection is provided in attachment 20.2
2. The progression of foundations within each type provide additional capacity to match increased signage demands. Only a single foundation option for each 2-chord OSS type is available for OSS carrying a DMS.

Type (structure)(span)-(design) *Example: a foundation for a standard WisDOT-designed cantilever monotube is Type MC-III*					
STRUCTURE		SPAN		DESIGN	
M	Monotube	C	Cantilever	I	Standard WisDOT designs
T	Two-chord truss	F	Full-span	II	
F	Four-chord truss			III	
				IV	
				V	
				NS	Non-standard

Figure 20.2.6
Standard Foundation Type Encoding

20.3 OSS Design and Plan Submittal Process

Identification of the need for a sign structure occurs at the preliminary design phase in conjunction with development of the initial signing plan. Based on the sign requirements for the project, the Region traffic engineer selects the type of sign structure needed, considering the appropriate subsections of 20.2. As most sign structure types come with standard foundations, the Regional soil engineer should be consulted to verify foundation constructability (see section 20.5 for more information). Regional or consultant staff initiate the design process by requesting a structure number from the Region Ancillary Project Manager, then completing a Grade Separation Structure Survey Report (DT1694), checking "sign structure" on the form, and submitting to the Bureau of Structures via the structure e-submit process.

When submitting the SSR, indicate the type of sign structure in the "preference for structure type" field (e.g. Cantilever Monotube). For those *Contractor Designed* or *Standard Design* OSS types, no supporting documents or additional information is required with the SSR submittal. For non-standard designs, butterfly or bridge mounted type, or for reasons listed in 20.4.3, submit the supporting information (plan and profile, layout, etc.) with the SSR.

The design and plan submittal process depend on the sign structure design type (Contractor, Standard or Non-standard). For Contractor Designed or Standard Design OSS types, without special or unique requirements, the Region or their consultant prepare final contract plans, utilizing available BOS Standard Design Drawings. A flow chart illustrating the different processes is shown in attachment 20.3. Additional information is provided in 20.4.

All OSS contract plans are included in the series 8 structure section. Standard Design Drawings and templates for the lead sheets are available on the BOS website. The lead sheets shall provide the following information:

- The assigned structure number (S-XX-XXX).
- The sign sizes and location on the structure as well as their relation to the traffic lanes below.
- The high point of roadway elevation and the top of concrete foundation elevation or the relative difference in elevation between the two.
- The required lower minimum vertical clearance from the high point of the roadway to the low point on the sign/structure. Refer to WisDOT Bridge Manual and FDM 11-35 Attachment 1.8 for more details on lower minimum vertical clearance requirements. Show signs centered vertically on the horizontal arm.
- Horizontal dimensions of the roadway typical section, including cross slopes.
- The location of the structure by station and, if applicable, by highway and crossroad.
- The detail views should depict the correct OSS superstructure type (monotube, 2-chord, or 4-chord truss), and match the associated OSS pay item.
- For DMS, show the length x width x thickness and its weight.

20.4 OSS Design Types

20.4.1 Contractor Designed OSS

These smaller sign structures carry type II directional signs, limited amounts of type I signs and small dynamic message signs (DMS).

Using figures 20.2.3 and 20.2.4, the appropriate contractor designed OSS type is identified during the design phase based on the required sign structure configuration and length, maximum design sign height, and total design sign area to be supported by the structure. Beginning with monotube and moving to 2-chord planar truss OSS, the designer identifies the smallest sign structure type suitable for the intended use. If the range of applicability for any design parameter (cantilever arm or full-span length, maximum sign size, total sign area) is exceeded for the sign structure type under consideration, the designer must check the next larger type with design ranges of applicability that meet or exceed the required values for the intended use. If any of the ranges of applicability for the 2-chord planar truss are exceeded, a contractor designed OSS cannot be used and use of a 4-chord truss must be considered.

Things to keep in mind while selecting a structure type in addition to the structure limits are:

- Check the available room at the installation site for the structure foundation. For example, check the proposed foundation diameter against the available room between a curb section and a sidewalk.
- Consider the distribution of signing in the case of full-span overhead structures. Do not leave a relatively large portion of horizontal span "unsigned" with signs only at the end of the span.
- See FDM 11-35-1 and Chapter 39 of the WisDOT Bridge Manual for design considerations and

requirements for vertical clearance.

Standard bid items for monotube and 2-chord planar truss OSS include structural design and detailing of these structures in addition to supplying and erecting these sign structures within the construction contract. Design is typically done by the contractor's sign fabricator / supplier or another party on behalf of the fabricator or supplier.

However, the foundation design is not the responsibility of the contractor. A standard foundation must be selected for Contractor Designed OSS types using figure 20.2.5. See Chapter 39 of the WisDOT Bridge Manual for information regarding the use of standard detail drawings in contract plans.

20.4.2 Standard Designed OSS

4-chord truss OSS are larger sign structures that are generally used to carry Type I signs with large total sign areas or large DMS and are capable of spanning over multi-lane highways and interstate routes.

Using figures 20.2.3 and 20.2.4, the appropriate standard design OSS is identified during the design phase based on the required sign structure configuration and length, maximum design sign height, and total design sign area to be supported by the structure.

With Standard Designed OSS types both the structure and foundation are pre-designed and detailed. See Chapter 39 of the WisDOT Bridge Manual for information regarding the use of standard detail drawings in contract plans.

20.4.3 Non-Standard Designed OSS

A unique design must be provided by Bureau of Structures or by a structural design consultant for all non-standard designs. The following circumstances warrant a non-standard design:

1. The OSS type is Butterfly, Butterfly Truss, or Bridge Mounted
2. The OSS type falls outside the limits of span length, sign area, DMS weight, or sign height in figures 20.2.3 and 20.2.4.
3. Region soil engineer advises that subsurface conditions at the site are expected to negatively differ from assumed soil profile and design parameters of standard foundations (e.g. soft soil or shallow bedrock).
4. Excessive sign structure height (e.g. sign structure behind MSE wall) or requires the use of concrete column (designed for impact load)

20.5 Subsurface Investigation and Information

Standard foundation designs are available for use with *Contractor Designed* and *Standard Design* OSS types within the OSS Standard Design Drawings. The standard foundation designs are based on conservatively assumed subsurface soil parameters that are intended to underestimate the actual subsurface soil strength at most sites across the state of Wisconsin. No subsurface investigation/information is necessary for any of the sign structures that meet the limitations for allowing the use of WisDOT standard foundations. When weaker soil strength or other conditions such as the presence of near surface bedrock is known, or suspected, appropriate subsurface information is necessary to confirm that soils strength parameters meet or exceed the assumed soil parameters used for the standard foundation designs. If weaker subsurface soil parameters are confirmed, an individually designed and detailed foundation is required in which case the design and plan submittal process would proceed as a non-standard design. Refer to Chapter 39 of the WisDOT Bridge Manual for further guidance on the use of standard OSS foundations, assumed soil parameters, and the individual design of non-standard OSS foundations.

20.6 Roadside Design Guidelines

Provide shielding (e.g. crash cushion or barrier, transitions, end terminals, grading…) for an OSS installation when the design or off-peak operating speed is 45 mph or greater. Shielding is required even if the sign structure is placed outside the clear zone of the roadway because the consequences of a crash (not only for the individuals in the errant vehicle, but other users of the roadway network and pedestrians) are severe.

If the design or off-peak operating speed are less than 45 mph but are greater than or equal to 35 mph it is optional to provide shielding for sign structures installed outside the clear zone. However, individual site analysis is required. If the design or off-peak operating speed are less than 45 mph but are greater than or equal to 35 mph and the sign structure is within the clear zone, provide shielding unless individual site analysis indicates otherwise.

For design or operation speeds that are less than 35 mph, shielding is not typically required, unless an individual site analysis indicates otherwise. Designers are required to perform an individual site analysis for speeds less than 35 mph.

Individual site analysis includes:

- Review of existing crash data
- Review of the alignment and cross-sectional elements near installation
- Traffic volumes
- Character of traffic
- Impact of installing barrier systems, (e.g. grading required, purchase of R/W, drainage needs…)
- Consequences of not installing barrier system, (e.g. Could the sign fall onto the road or pedestrians, if sign does not fall but is taken out of service, what is the impact to the road network?)

Some examples that would tend to lead designers to install barrier would be:

- Segment of roadway has run-off-road (ROR) flag in metamanager.
- Less than lower minimum alignment or cross-sectional elements exist near the proposed installation.
- Installation is near or in a weave, merge or diverge section of roadway.
- Roadway violates driver expectation (e.g. hidden curves, entrance/exit ramps on left side of roadway).
- Installation is in areas where ROR crashes are more likely to occur (e.g. tapers, outside of curves…).
- High AADT in area of installation (i.e. High AADT increases the probability of a vehicle leaving the roadway).
- Majority of traffic is unfamiliar with the roadway.
- Impact to roadway and users if the overhead sign support was damaged or destroyed.

Some examples that would lead a designer to not install barrier are:

- Not possible to install barrier according to design criteria (e.g. LON would cause the closure of side streets)
- Accident history does not indicate a problem with ROR accidents.
- No less than lower minimum features are present
- Installation is on tangent section.
- Low AADT

Document decisions to provide or not to provide barrier or crash cushions at a given location. Provide barrier systems with appropriate Length of Need (LON), adequate deflection distance from barrier to front face of sign bridge support, appropriate end terminals and grading. Document why it is not possible to provide adequate LON, deflection distance, end terminals, and grading. Documentation is to include what other alternatives were reviewed, and why a particular alternative was selected.

See FDM 11-15-1 and FDM 11-20-1 for guidance on clear zones. See FDM 11-45 for guidance on barrier systems. FDM 15-1 Attachment 5.14, page 1 shows a sample permanent signing plan sheet for freeways and ramps.

LIST OF ATTACHMENTS

Attachment 20.1	WisDOT Overhead Sign Structure Types
Attachment 20.2	Overhead Sign Structure Selection Examples
Attachment 20.3	Overhead Sign Structure Design Process Flow Chart

FDM 11-55-25 Ramp Gates

August 15, 2019

25.1 Background

To enable the physical closure of freeway on-ramps, the Wisconsin Department of Transportation (WisDOT) has installed ramp gates at numerous Interstate interchanges and on-ramps for selected highways around the state. Ramp gates utilize a mechanical gate arm that are manually lowered to provide a physical barrier prohibiting motorists from accessing the Interstate and highways. The gates are used as a safety feature to help mitigate severe congestion caused by incidents or severe weather. The gates restrict access to the roadway and allow first responders to work in a safer environment while clearing an incident. This also provides for the quicker clearance of an incident and reduces the possibility of secondary incidents.

The ramp gate design and the details were originally developed by the State of Wyoming. This gate can be installed within the clear zone because the base is designed as a breakaway component and the above ground components are designed to rotate over the vehicle during an impact.

25.2 Deployment and General Considerations

The situations in which closure methods are to be applied are summarized below:

- *Barricades* - Type III barricades are recommended for deployment on entrance ramps along interstate corridors with an average annual daily traffic (AADT) along the mainline of less than 45,000. These barricades are to be safely stored within the freeway interchange when practical. Ramp closure barricade rack(s) (refer to STSP 662-015) shall be included for storing the barricades.
- *Ramp Gates* - are recommended for deployment on freeway entrance ramps along interstate corridors with the mainline AADT of more than 35,000 and criteria of the 'Other Deciding Factors' section. These gates are manually operated.

The overlap in AADT ranges is intended to allow for flexibility in selecting which closure method to implement at a location. Deployment recommendations are based on AADT, crash history and Law Enforcement input; however, other factors should be evaluated before prescribing the gate treatment.

Other Deciding Factors:

- *Site-Specific Conditions* - Site-specific conditions need to be considered when selecting a closure method. Some issues to consider include availability of a safe barricade storage location, expected personnel availability during a road closure event, crash frequency in the area, geometric deficiencies, sight distance and expected frequency of use. Also, some locations may require a combination of gates and barricades. For example, at signalized intersections a gate may be used to close the entrance of the ramp and barricades may be used to close left turn lanes that approach the ramp. In addition, closure devices must be placed in locations that do not trap vehicles. Engineering judgment must be exercised when selecting a closure method.
- *Corridor Consistency* - In some locations the AADT guidelines may not be followed to select a closure method that maintains consistency within a corridor.
- *Barricade Storage* - Barricades should be pre-positioned on-site when practical. Consideration must be given to placement outside of the clear zone, right of way availability, site topography, snow storage needs, and locations that do not obstruct sight lines. Steps should also be taken to limit weathering of the barricades' reflective sheeting.
- *Maintenance* - A maintenance plan must be followed to inspect barricades and ramp gates to ensure proper functionality. Barricades should be inspected a minimum of once per year, prior to the winter driving season. Special attention should be given to the condition of barricade stands and retroreflective barricade/sign sheeting. Ramp closure gates and associated signing should be inspected a minimum of twice per year, prior to and after the winter driving season. Maintenance should follow the procedures outlined in the *Wisconsin Ramp Gates Maintenance and Inspection* graphic (refer to Attachment 25.1). A maintenance log for ramp gates should be reported to the regional maintenance coordinator (Attachment 25.2).
- *Stakeholders* – Consider input and feedback from the stakeholders in the location, including law enforcement, fire service personnel, and other state/county/local responders, who are involved in WisDOT's Traffic Incident Management Enhancement (TIME) Program.

Additional Considerations:

- *System to System Interchanges* - System to system interchanges should be closed with multiple devices brought to the site in accordance with procedures outlined in the MUTCD. Drop down gates and stored on-site barricades are generally not feasible to close system to system interchanges because of the higher vehicle speeds and resulting roadway geometries, both of which require greater closure visibility than a gate or small number of barricades can provide.
- *Roundabouts* - Roundabouts are generally amenable to closure with gates or barricades.
- *Signage* - Properly placed signs are an important tool in notifying the public of closures. Flip down signs should be installed in conjunction with drop down gates. For especially high-volume areas, these signs could be augmented with active warning flashers to be made more effective.

25.3 Guideline Compliance Documentation

If it is not feasible to follow the gate placement guidelines, document why a location was selected, what alternatives were reviewed and why an alternative was selected.

25.3.1 Gate Placement

Placing gates is a complex design process that must consider many, often competing, factors. These factors are listed below in relative order of importance and are discussed in more detail in the remainder of this section.

- Grading

- Curb and Gutter
- Gate Knockdowns
- Vehicle Trapping
- Single vs. Multiple Gates
- Adjacent Roadway Features
- Pedestrians
- Sightlines and Driver Reaction Time
- Control Boxes and Power Supplies

25.3.2 Grading

Breakaway designs require the vehicle to properly engage the pole assembly. Proper engagement is dependent on the vehicle's bumper being close to its normal position during impact, and the mounting hardware/base being properly traversable. Place gates in locations that adhere to the following guidance:

Approach Grading:

Provide grading that is 10:1 or flatter within the approach grading area (refer to Figure 25.1).

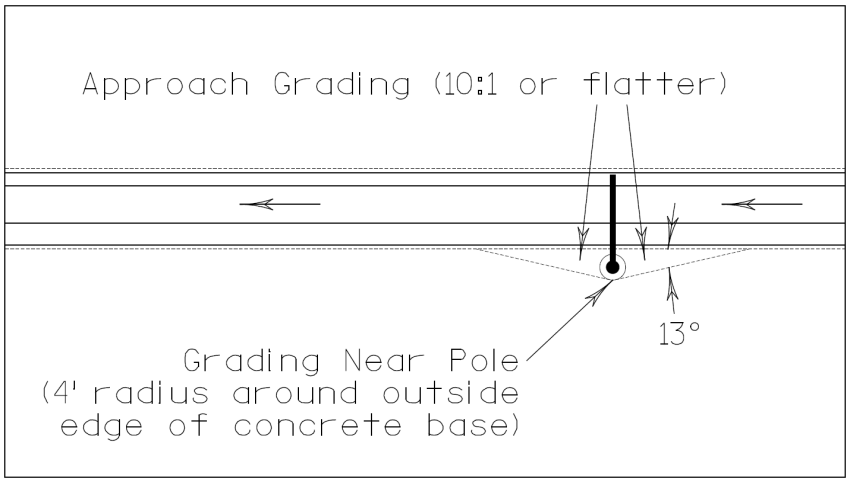


***Figure 25.1* Horizontal Grading at Ramp Gate**

Grading less than 10:1 may not allow for proper activation of the breakaway features of the pole or may cause the pole to contact the roof of the vehicle after initial impact. Figure 25.2 shows failure to properly break away when a vehicle did not engage a pole at the correct height.

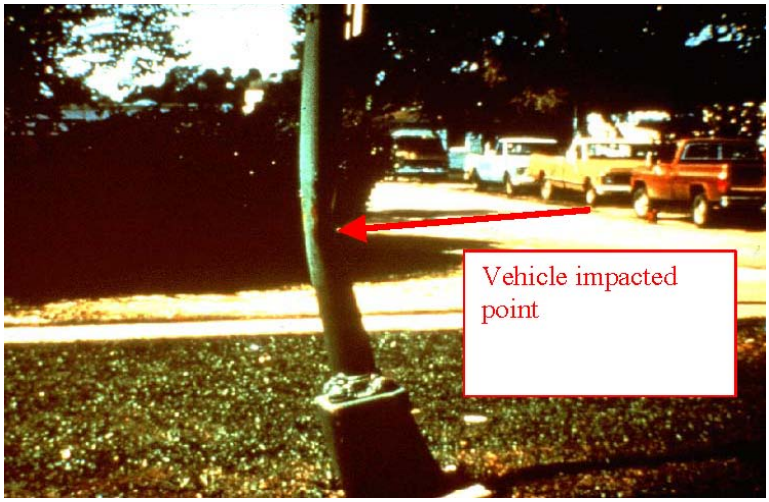


***Figure 25.2* Improper Grading Causing Pole Not Breakaway [1]**

Vertical Grading at Pole:

For a vehicle to effectively traverse the pole mounting hardware or concrete footing, the stub height of the gate's breakaway support is required to be less than 4" on a 5-foot chord (see Figure 25.3). If the stub height is greater than 4" on a 5-foot chord, a vehicle may decelerate too rapidly or be tripped by the stub. Provide 10:1 or flatter grades near the pole to make sure the vehicle does not snag on the stub or concrete footing.

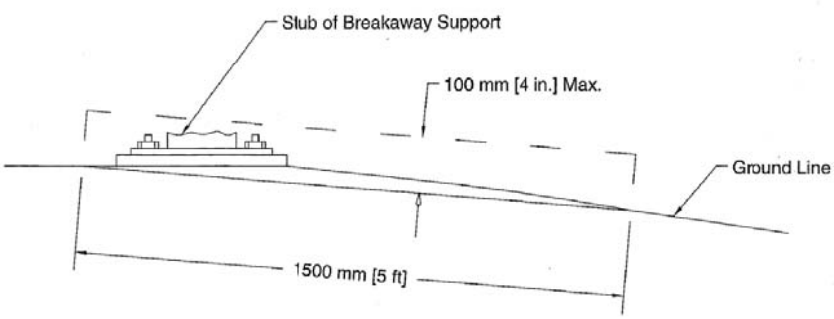


***Figure 25.3* Grading Profile [2]**

Figure 25.4 shows an installation where the concrete footings for a breakaway road sign are too far out of the ground, resulting in a roadside hazard even though the sign has breakaway hardware.

[1] NHI Roadside Design Presentation, 2009
[2] AASHTO Roadside Design Guide, 2006

***Figure 25.4* Improperly Installed Concrete Footing [3]**

25.3.3 Curb and Gutter

After impact with a 6" high barrier curb, it is difficult to predict the vertical trajectory of a vehicle's bumper. Thus, impact with a curb increases the probability that a vehicle will not engage a ramp closure gate correctly. Crash testing has indicated that a distance of 8' is needed from the flow line of a curb and gutter to the face of rail so that a vehicle properly engages beam guard [4]. This crash testing serves as a basis for gate placement guidance in the presence of curb and gutter. In the area of approach grading shown in Figure 25.1, ensure the following conditions are met:

- For operating speeds ≥ 35 MPH - three options are recommended:
- Place gate 8' from the flow line of the ramp curb and gutter (see Figure 25.5)
- Remove curb and replace with mountable curb less than 2" high (driveway entrance curb, per SDD 8d1, less than 2" high is exempt from the 8' requirement)
- Provide shielding per FDM 11-45
- For operating speeds < 35 MPH - there are no restrictions on the use of curb.

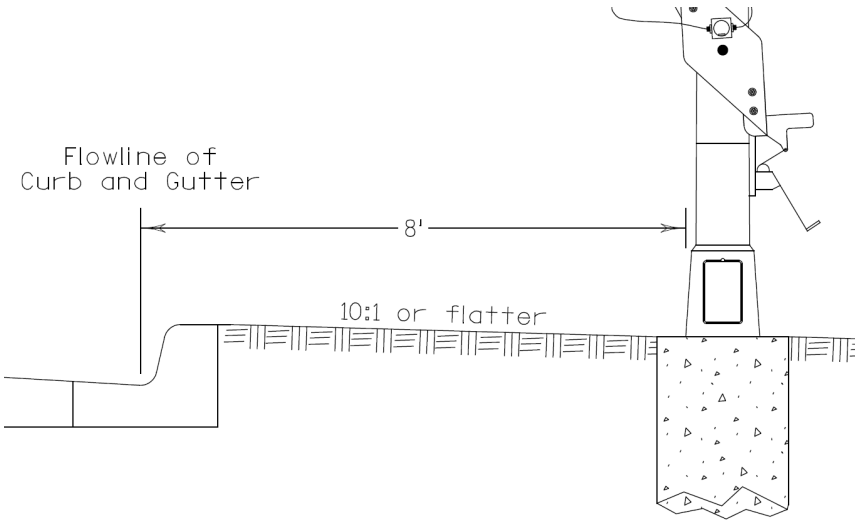


***Figure 25.5* Footing**

[3] NHI Roadside Design Presentation, 2009
[4] Zhu, L., Reid, J.D., R.K., Lechtenberg, K.A., Brenner, C.D. and Bielenberg, R.W., "Draft Performance Limits for 152-mm (6-inch) High Curb Placed in Advance of the MGS using MASH 08 Vehicles - Part 1: Vehicle-Curb Testing and LS-DYNA Analysis", TRP-03-205-08

25.3.4 Gate Knockdowns

Special considerations should be made regarding the potential for gate knockdowns from errant mainline vehicles and oversize vehicles, especially when the mainline roadway is a designated long truck route. To lessen the chance of a knockdown from an errant mainline vehicle, gates should be located outside the mainline roadway's clear zone. Locating gates at the edge of or outside mainline clear zones will also lessen the chance of an errant mainline vehicle spearing a deployed gate arm.

As previously indicated, place gates 8' from the flow line of a ramp curb and gutter (see Figure 25.5). In locations without curb and gutter, place gates 6' from the edge of ramp pavement (see Figure 25.6). Analysis of long truck turning movements indicates that gates located within the infield of a typical diamond interchange are less likely to be struck by a trailer than gates placed to the outside of the interchange. Thus, consider placing gates within the infield of a typical diamond interchange (see Figure 25.7). Make similar considerations for other types of interchanges.

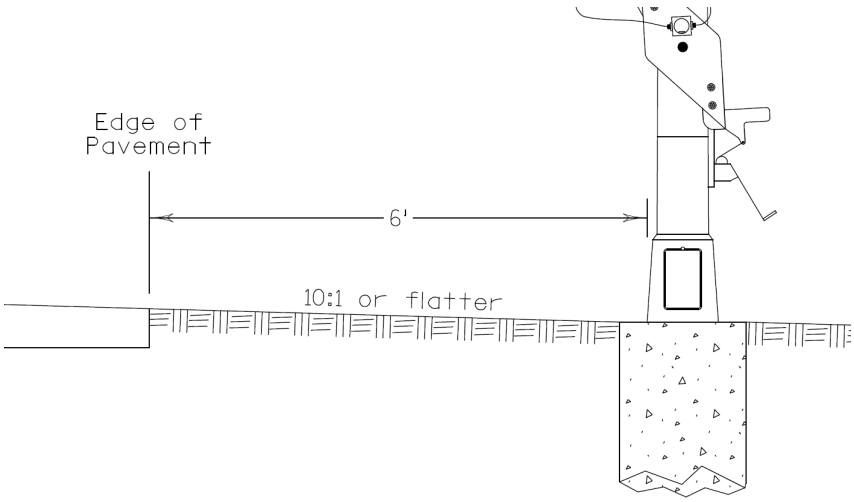


***Figure 25.6** Footing*

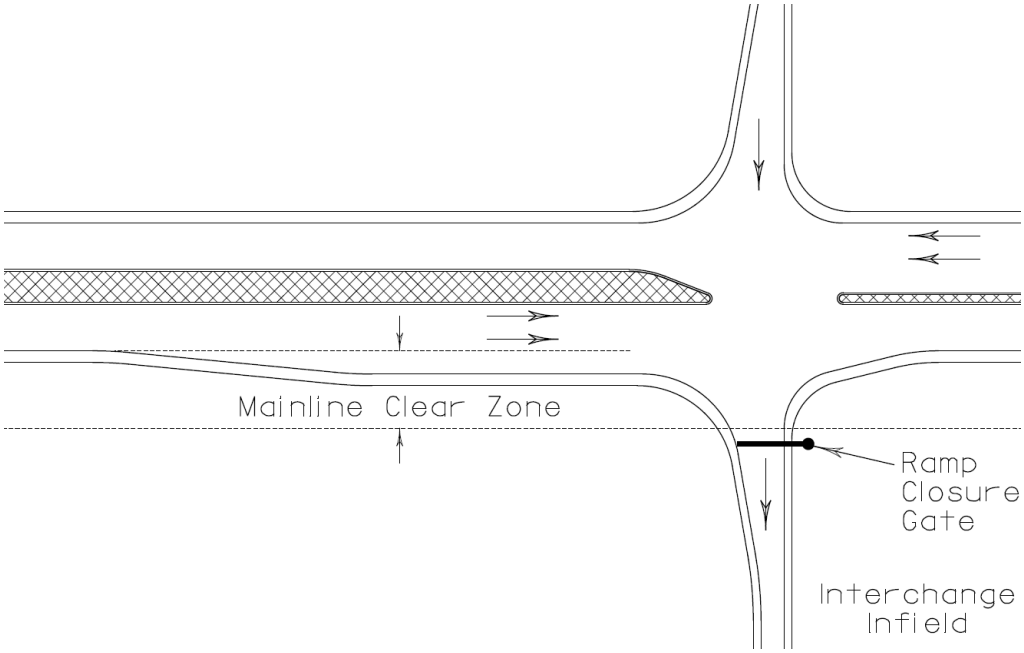


***Figure 25.7** Ramp Gate Placement at Diamond Interchange (Typical)*

25.3.5 Vehicle Trapping

If possible, gates should be located outside the mainline roadway's clear zone. However, gates should be placed close enough to the intersection to prevent "trapping" vehicles between the gate and the intersection.

Gates located near the downstream ramp curb return (or a similar edge of pavement return for ramps without curb and gutter) will often put a gate outside the mainline roadway's clear zone while keeping the possibility of trapping vehicles to a minimum (refer to Figure 25.8).

25.3.6 Single vs. Multiple Gates

Using a single gate to close a ramp is highly desirable, as installation costs, maintenance costs and the possibility of a gate being struck all increase with the placement of multiple gates. Choose a gate arm length to cover at least the distance between the mounting pole and a point three feet from either the opposite side curb face or opposite side edge of shoulder to prevent drivers from maneuvering around the gate structure (refer to Figure 25.8). The lower minimum gate arm length is 24' while the maximum gate arm length is 40' (gate arm lengths are measured beginning at a point offset approximately 1.33' from the center of the mounting pole).

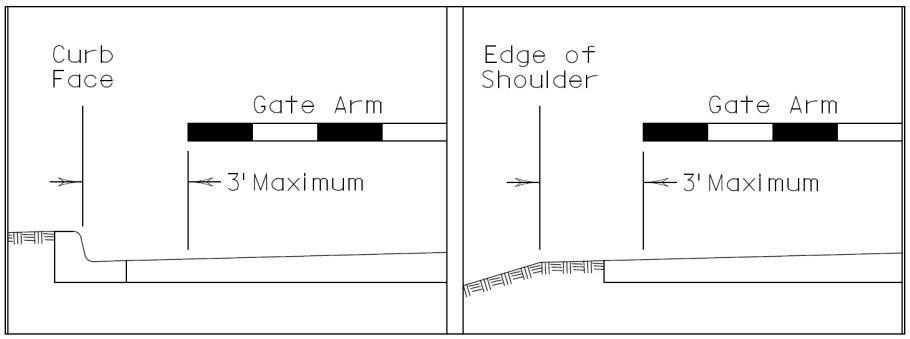


Figure 25.8 Ramp Gate Arm Lengths

If closing a ramp is not feasible with a single gate while adhering to gate placement guidelines, consider positioning the gate slightly downstream to take advantage of the ramp tapering to a narrower width. In positioning the gate slightly downstream, be careful not to create a situation in which vehicles can become trapped as described in the previous section. Depending on ramp geometry, closing a ramp with only a single gate may not be feasible. If more than one gate is needed to span the ramp, locate gates to minimize the likelihood of an impact on one gate striking the other.

25.3.7 Adjacent Roadway Features

If gates adhering to the above gate placement guidelines conflict with utilities, traffic signals, lighting, beam guard or other adjacent roadway features, shifting the gate location may be required. Increasing the offset from the ramp and moving a gate slightly downstream or to the opposite side of the ramp are the simplest measures for reducing conflicts with adjacent roadway features.

Always ensure that gates are not in conflict with the indications on traffic signal heads. Placing a gate along a ramp downstream from an adjacent traffic signal standard and mast arm should avoid such conflicts.

On a ramp lined with beam guard, place gates 6' behind the face of the beam guard to allow for deflection (refer to Figure 25.9).

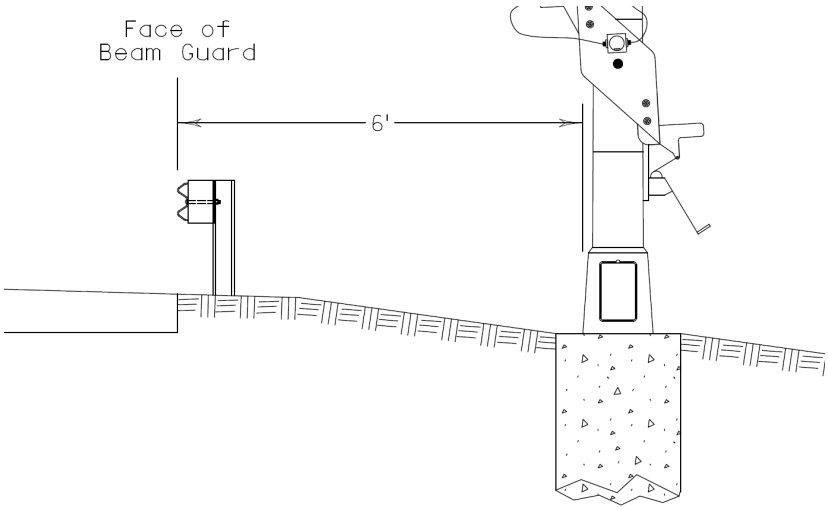


***Figure 25.9* Ramp Gate Offset behind Conflict**

Ensure the gate pivot assembly is installed at a proper height on the mounting pole to allow for free gate arm movement above the beam guard (see Figure 25.10).

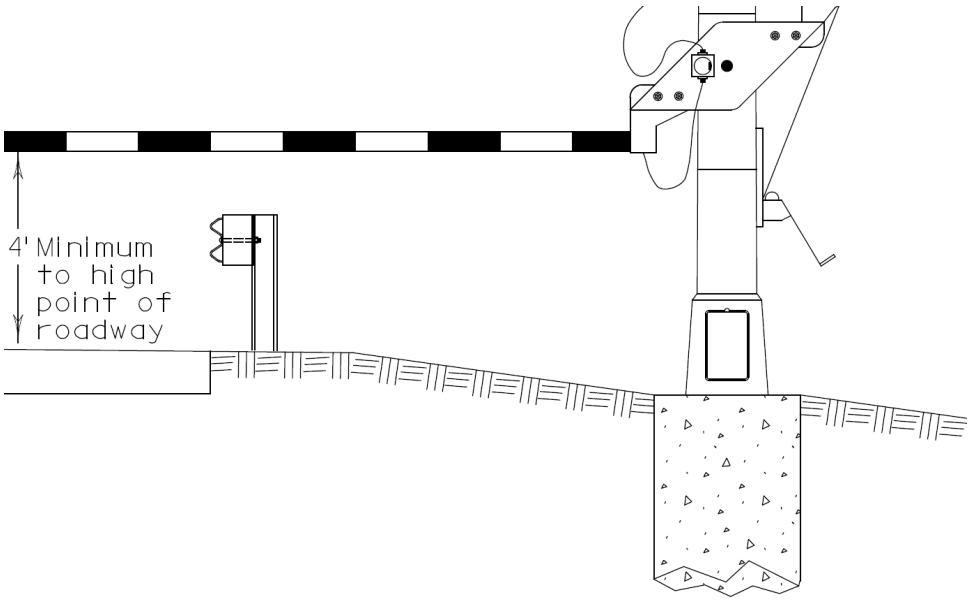


***Figure 25.10* Ramp Gate Height behind Conflict**

25.3.8 Pedestrian

Place gates to not block a pedestrian sidewalk or crosswalk when the gate arm is deployed.

If gates must be placed in areas of significant pedestrian traffic, the potential exists for pedestrian injuries due to a knockdown. Several options should be considered for mitigation:

- If possible, place the gate in an area where there is less pedestrian exposure
- Place the gate in an area where knockdowns are less likely
- As a last resort, provide beam guard shielding to prevent a vehicle from hitting the gate

If beam guard is needed to shield a gate, it is required that the barrier is of sufficient length to protect the gate (i.e. length of need), has appropriate end terminals and appropriate grading is provided for the barrier and end terminals.

25.3.9 Sightlines and Driver Reaction

Consider sightlines and driver reaction time when locating gates. Ideally, drivers would be able to observe a deployed gate arm far enough in advance to avoid entering a closed ramp and becoming trapped.

25.4 Other Design Considerations

25.4.1 Operating Speeds

Operating speeds on the ramp near a gate may be lower than the design speed used for the mainline roadway due to vehicles turning onto the ramp. Use acceleration tables from *AASHTO's A Policy on Geometric Design of Highways and Streets* to calculate operating speeds near a gate as this will influence run out length for barrier (if needed due to pedestrian concerns), clear zones and potentially grading leading up to a gate base.

25.4.2 Signing

The designer should supplement the visual cues of the ramp gate arm and attached flashers by installing WisDOT Standard Sign R11-54F (Folding "RAMP CLOSED USE ALT ROUTE") on or near each approach to the ramp to be closed by the gate to reinforce a closure. Include these details on the signing plan and in the signing quantities.

Guidance for the R11-54F sign installation:

- For two-lane rural crossroads, the folding R11-54F sign shall be placed at the ramp gate or barricade rack. If possible, a folding R11-54F sign should be placed in advance for traffic turning onto the ramp (see Attachment 25.3).
- For multi-lane crossroads, the folding R11-54F sign shall be placed at the ramp gate or barricade rack. Advance folding R11-54F signs should be considered at roundabout bypass lanes and look ahead left turn lanes, left turn lanes and right turn lanes (see Attachment 25.3).

25.5 Identification Plaques

Ensure proper installation of structure identification plaques per SDD 12a4.

25.6 Barricades in Conjunction with Ramp Closure Gates

Where slotted turn lanes create the potential for a vehicle virtual trap, and ramp closure gate deployment is not feasible, type III barricades should be deployed (see Figure 25.11).

Refer to the "Deployment and General Considerations" section for additional barricade guidance.

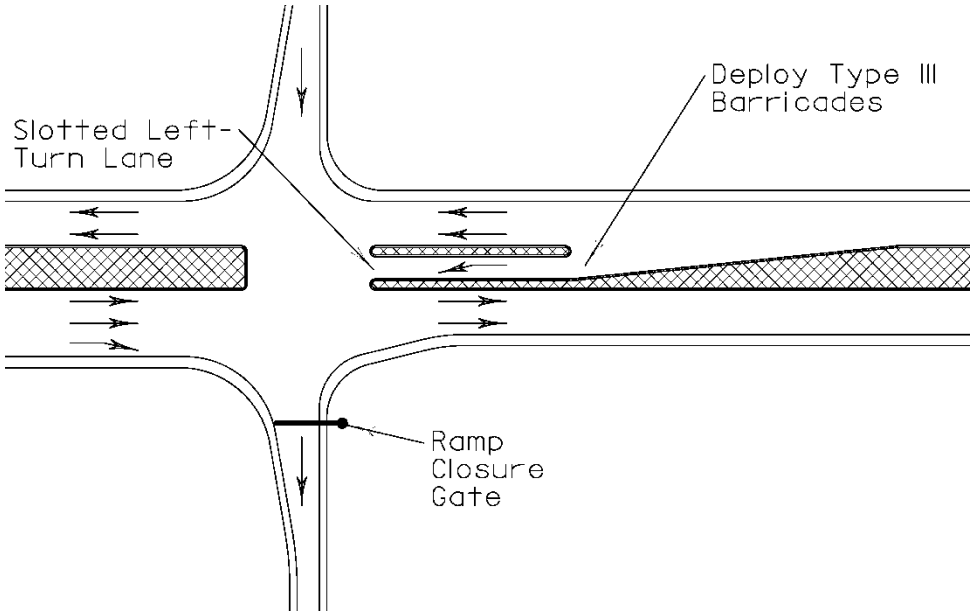


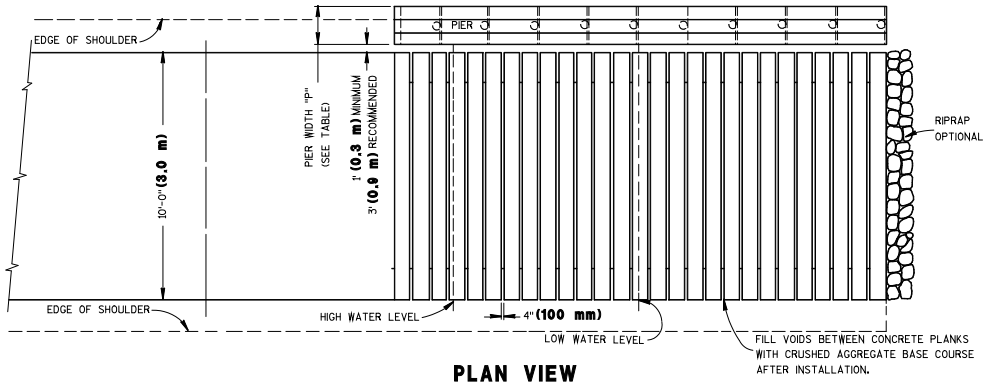
Figure 25.11 Barricades in Conjunction with Ramp Closure Gates

25.7 Additional Information

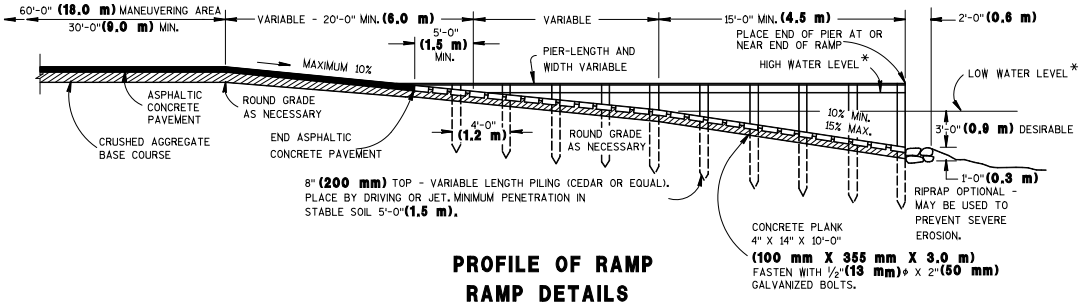
In 2018, WisDOT suspended installation and maintenance of the electrical components on ramp gates, new and existing. Designers should refer to standard detail drawings (SDD 12a4, 15d35 (a-c)) and standardized special provisions (refer to http://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnsltrsrces/tools/stsp.aspx) ramp gates and barricade racks.

LIST OF ATTACHMENTS

Attachment 25.1 Wisconsin Ramp Gate Maintenance and Inspection Guideline
Attachment 25.2 Inspection Form for Manual Ramp Gates
Attachment 25.3 Example Ramp Closed Use Alternative Route (R11-54F) Sign Details



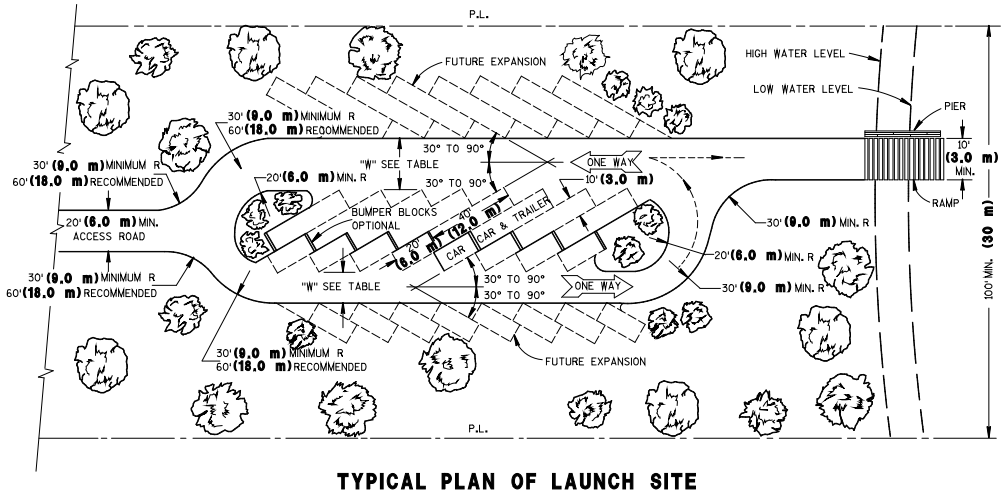
PLAN VIEW



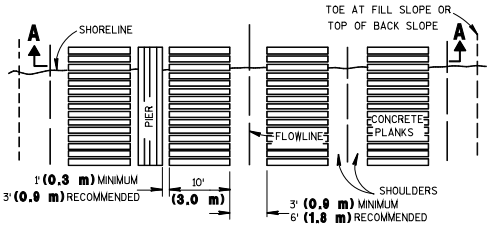
PROFILE OF RAMP

RAMP DETAILS

*WHERE WIDE FLUCTUCATION BETWEEN HIGH AND LOW WATER LEVELS CAN BE EXPECTED, SUCH AS OCCURS AT BOAT RAMPS ON RIVERS, IT MAY BE PREFERABLE TO CONSTRUCT TWO INDIVIDUAL RAMPS, ONE FOR HIGH WATER AND ONE FOR LOW WATER, INSTEAD OF ONE LONG RAMP.



TYPICAL PLAN OF LAUNCH SITE

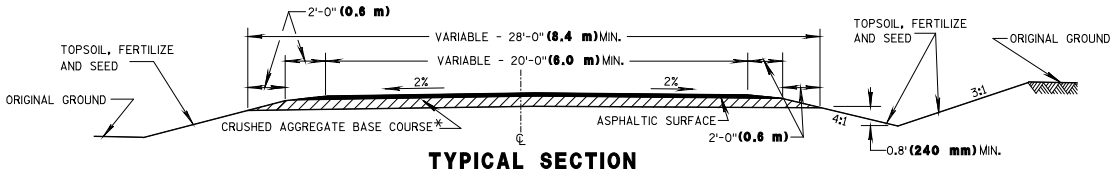


PLAN VIEW

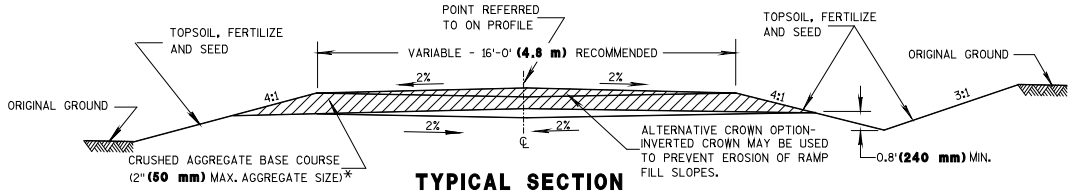
SECTION A-A

MINIMUM AISLE WIDTHS "W"	
NO PARKING ON EITHER SIDE	
ONE - WAY	15' (4.5 m) MIN.
TWO -WAY	20' (6.0 m) MIN.
CAR PARKING ONLY	
30° ANGLE	15' (4.5 m) MIN.
45° ANGLE	20' (6.0 m) MIN.
90° ANGLE	30' (9.0 m) MIN.
CAR & TRAILER PARKING	
30° ANGLE	25' (7.5 m) MIN.
45° ANGLE	30' (9.0 m) MIN.
90° ANGLE	60' (18.0 m) MIN.

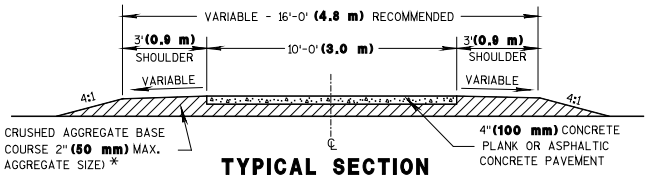
MULTIPLE RAMP INSTALLATION DETAILS



TYPICAL SECTION
ACCESS ROAD

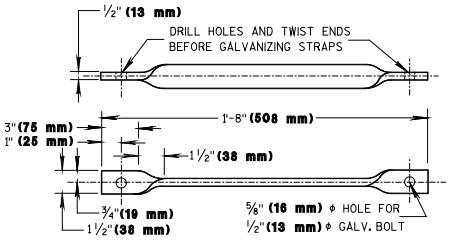


TYPICAL SECTION
CRUSHED AGGREGATE RAMP APPROACH



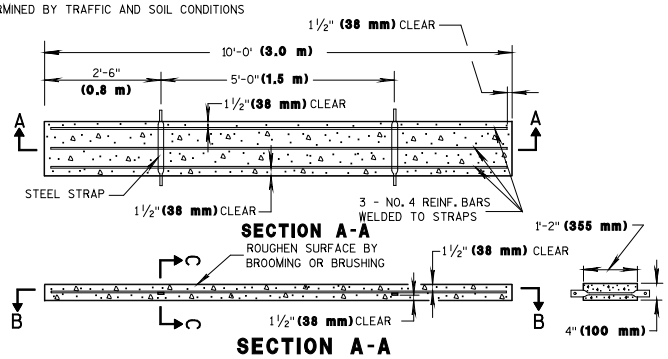
TYPICAL SECTION
CONCRETE PLANK RAMP OR PAVED RAMP APPROACH

* DEPTH TO BE DETERMINED BY TRAFFIC AND SOIL CONDITIONS



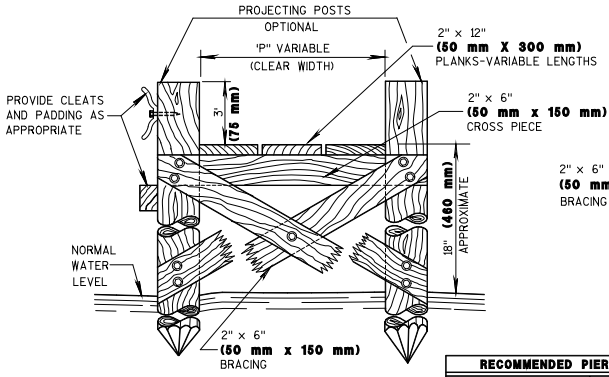
ACCESS ROAD

NOTE: ALL METAL STRAPS, BOLTS, NUTS AND WASHERS SHALL BE GALVANIZED IN ACCORDANCE WITH ASTM A153.

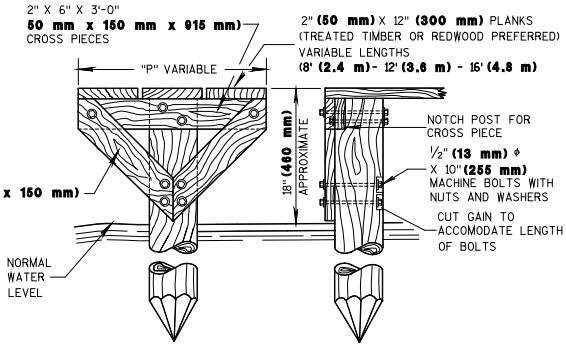


PRECAST REINFORCED CONCRETE BLOCK

(APPROXIMATE WEIGHT 580 LBS.) (263 kg)



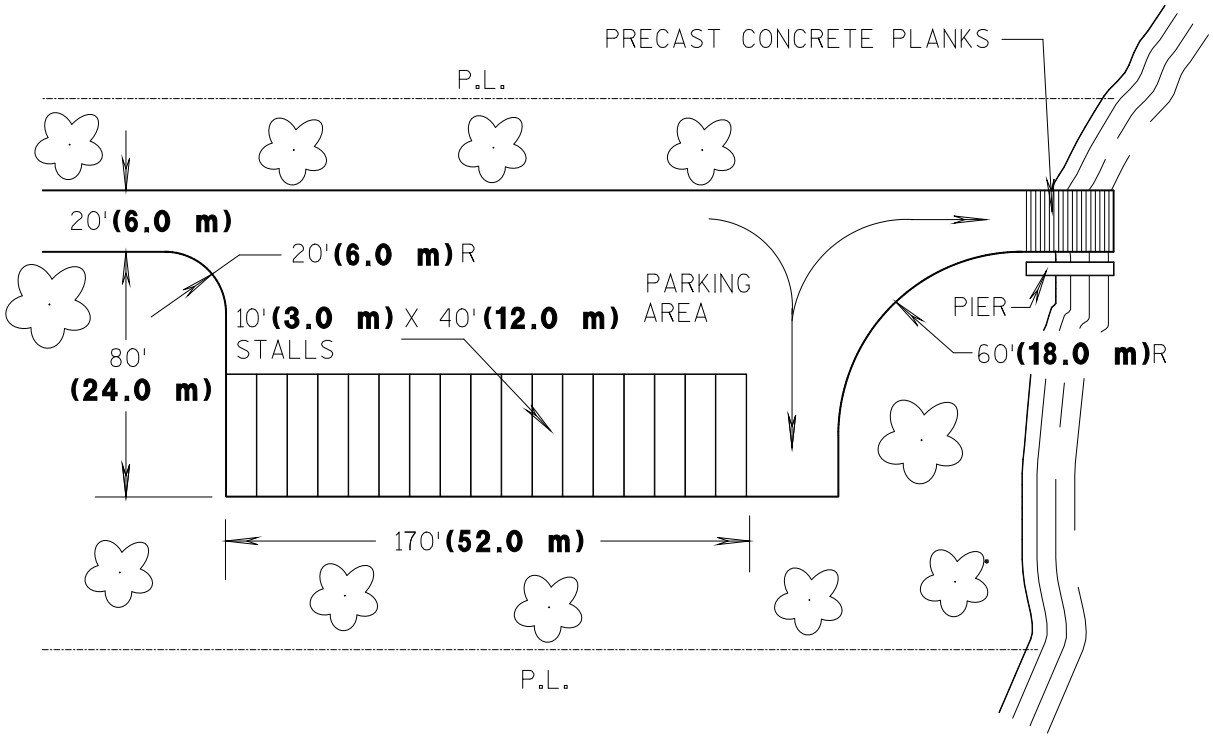
DOUBLE POST PIER

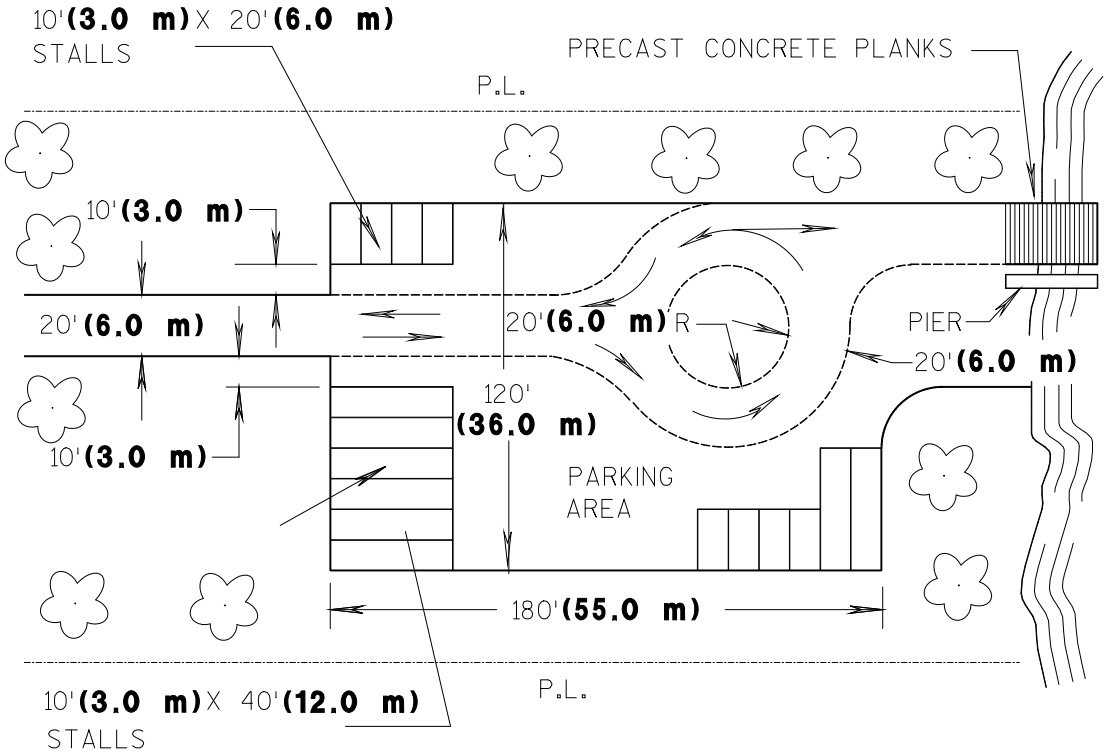


SINGLE POST PIER

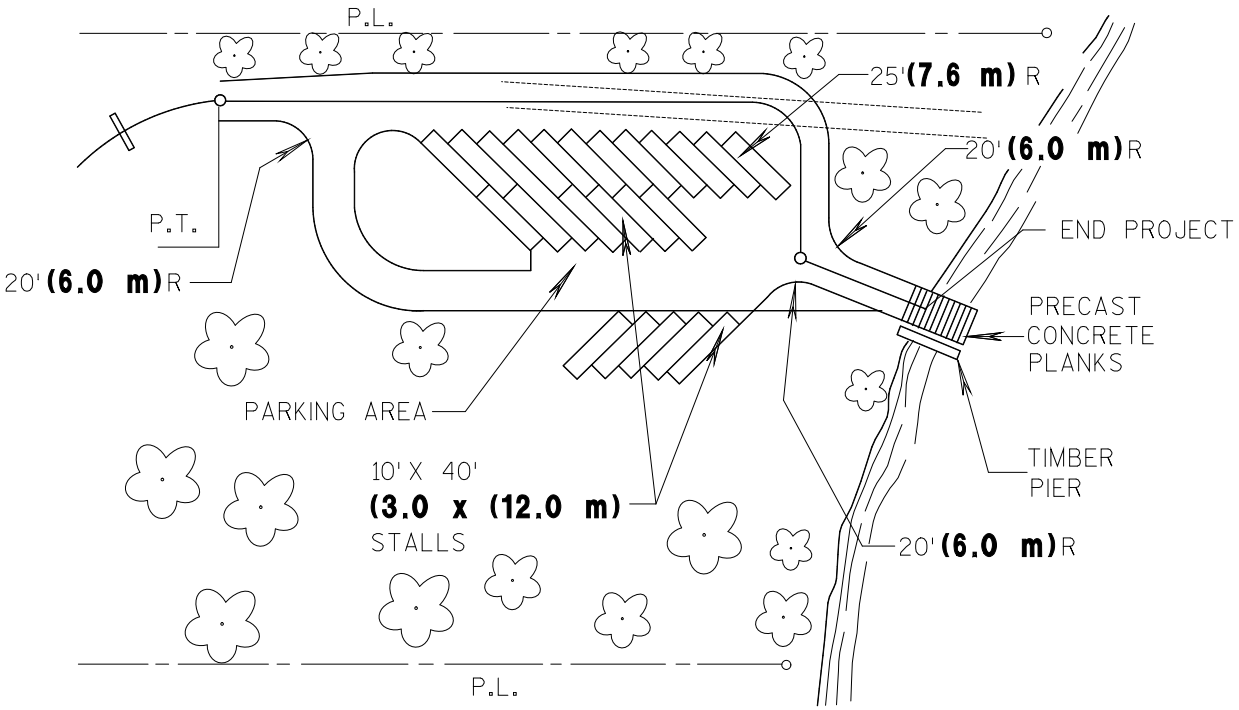
RECOMMENDED PIER WIDTHS "P"		
CONDITION	MINIMUM	DESIRABLE
RAMP ON ONE SIDE	2' (0.6 m)	3' (0.9 m)
RAMP ON BOTH SIDES	3' (0.9 m)	4' (1.2 m)

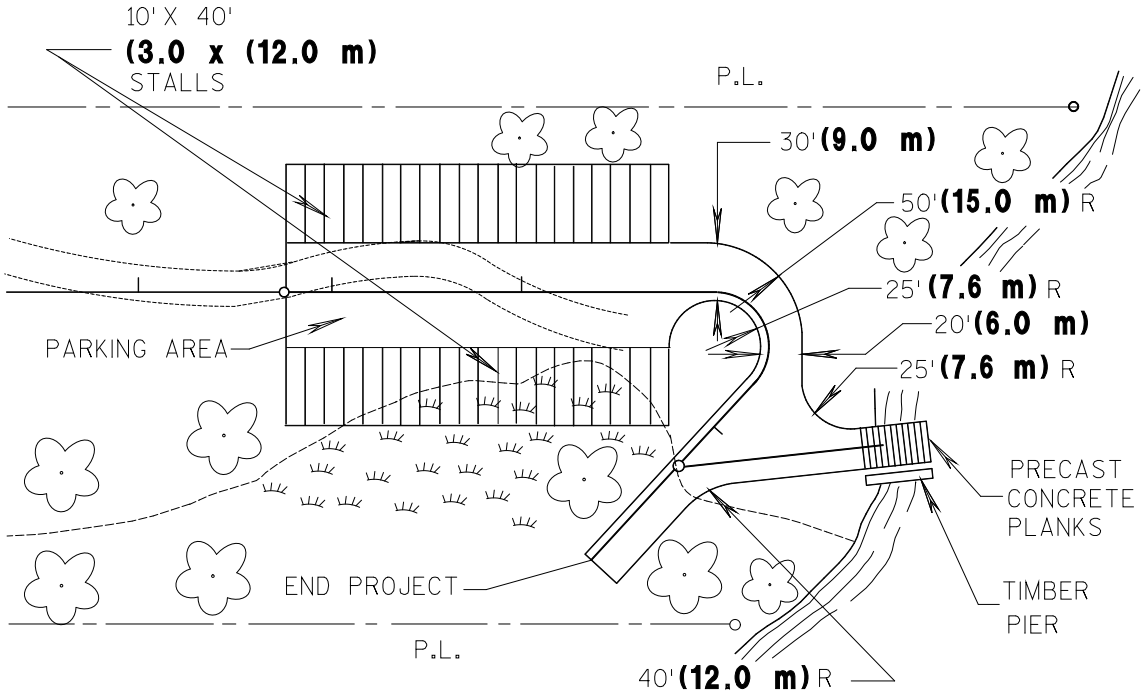
PIER DETAILS





EXAMPLE LAYOUTS





EXAMPLE LAYOUTS

DOCUMENTATION FOR CATTLEPASS

HIGHWAY _____, LOCATION _____
COUNTY _____
RELATED PROJECT ID (if any) _____

BASIS FOR CONSIDERATION:

LIVESTOCK OPERATION

Owner _____-
Size of Herd _____; Milk Cows _____; Young Stock _____; Beef _____
Size of Farm _____Acres

Building Side	owned	rented	Opposite Side	owned	rented
Acres cultivated	_____		Acres cultivated	_____	
Acres pasture	_____		Acres pasture	_____	

Water ? yes / no

Present Operation

Existing cattlepass? yes / no

Herd driven across highway: Daily? _____ Occasionally? _____

HIGHWAY INFORMATION

ADT _____

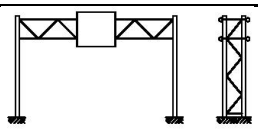
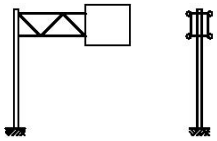
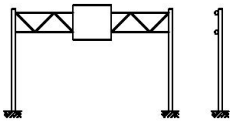
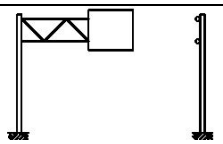
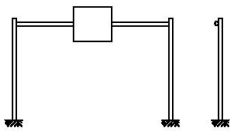
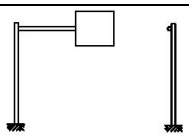
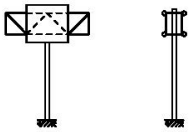
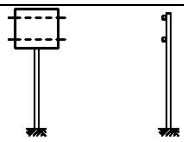
Visibility / Alignment (each approach) _____

_____

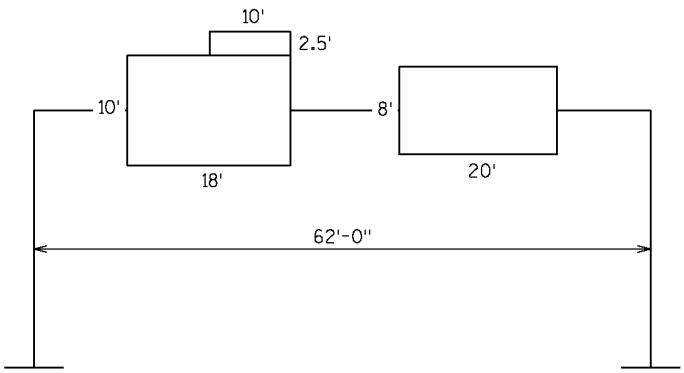
Accident experience:

DISCUSSION / RECOMMENDATION:

BY _____ ACCEPTED _____

Overhead Sign Structure Type	Description	Standard Structure Design	Standard Foundation Design
 Full Span 4-Chord Truss	A 4-chord space truss with dual, trussed vertical support posts at each end. Used to support large Type I static highway sign panels and Dynamic Message Signs (DMS). Typically used over multi-lane state highways and interstate routes.	Yes	Yes
 Cantilever 4-Chord Truss	A 4-Chord space truss with a single vertical support post. Used to support large Type I static highway sign panels and DMS. Commonly used to span over the outside lanes of multi-lane state highways and interstate routes to delineate exit lanes and ramps.	Yes	Yes
 Full Span 2-Chord Truss	A 2-chord planar truss with single vertical support posts at each end. Used to support Type II and smaller Type I static signs and DMS over roadways and state highways.	No	Yes
 Cantilever 2-Chord Truss	A 2-chord planar truss with a single vertical support post. Used to support Type II and smaller Type I static signs and DMS over roadways and state highways.	No	Yes
 Full Span Monotube	Similar to a Full Span 2-Chord Truss but with only a single horizontal sign support member. Used to support small Type II static signs.	No	Yes
 Cantilever Monotube	Similar to a Cantilever 2-Chord Truss but with only a single horizontal support member. Used to support small Type II static signs.	No	Yes
 Butterfly Truss	A 4-Chord space truss with a centrally located single vertical support post used to support DMS. Typically used in the medians of multi-lane interstate routes.	No	No
 Butterfly	Similar to a Butterfly Truss but with multiple monotube horizontal sign support members.	No	No
Bridge Mounted Sign Support	Sign support brackets to mount signs to the sides of grade separation highway bridges over the underpass roadway. These are typically used in special circumstances where other OSS types cannot be used.	No	NA

Example #1: Selection of Overhead Sign Structure using Figure 20.2.3 of FDM 11-55-20.

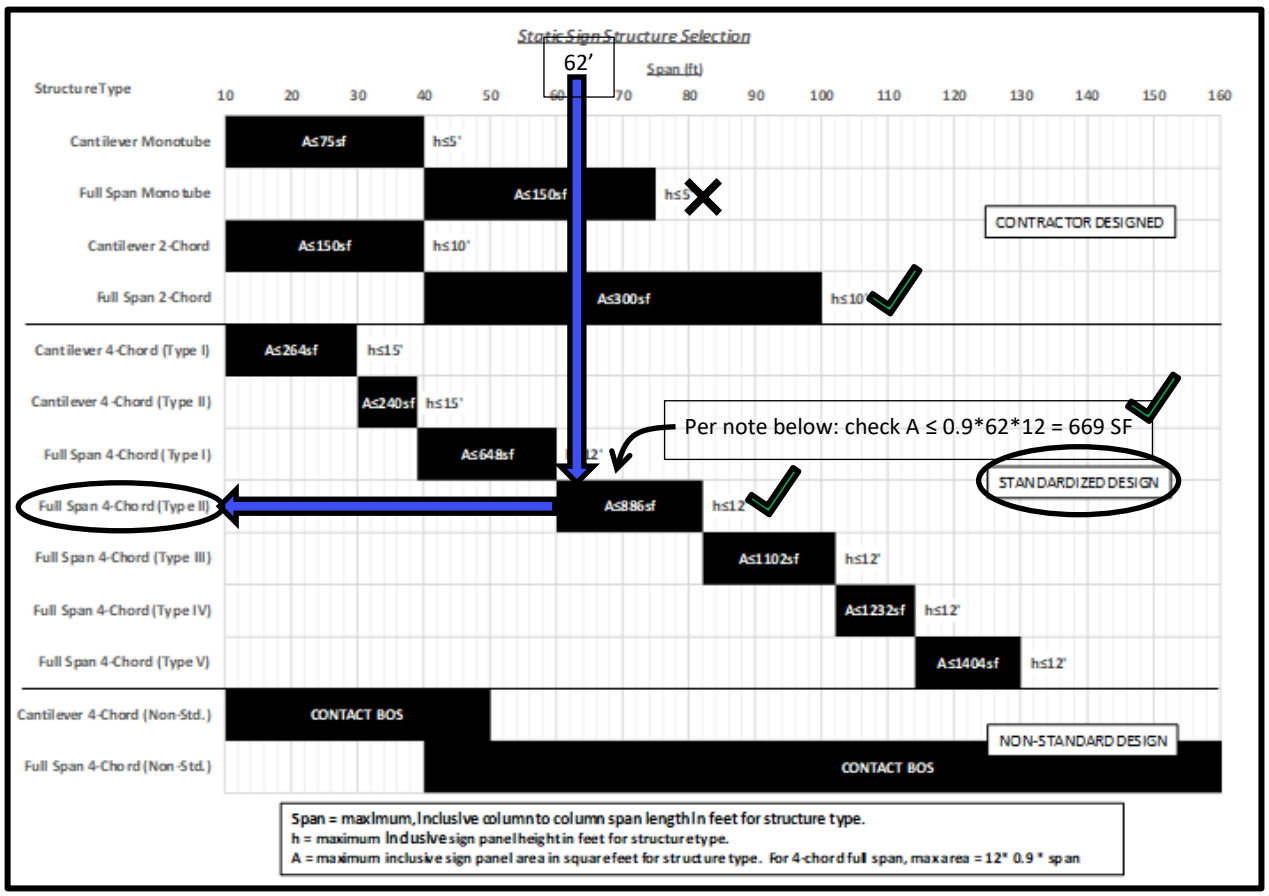


Total sign area, A = 365 SF
(10x18 + 2.5x10 + 8x20)

Max sign height, h = 10'
(small signs mounted above the main sign are not considered to contribute to "h" unless 4'-0" or greater)

Span, S = 62 feet

Directions: Beginning with span length, move down the chart and check the parameters where the line intersects with a black box. The total sign area, A, and max sign height, h, must fit within the listed parameters. The *first* point at which both parameters are satisfied, moved left on the chart to determine the OSS type. Note which category the OSS type belongs (e.g. Contractor Designed, Standardized Design or Non-standard Design)

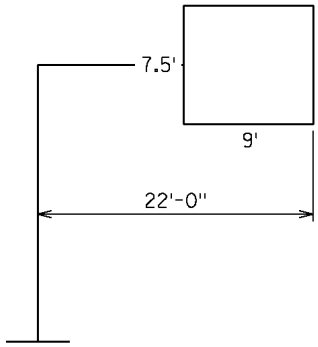


OSS Type = Full Span 4-Chord Type II

OSS Category = Standardized Design (Foundations are included with the standard design type)

Follow the design process detailed in section 20.3.

Example #2: Selection of Overhead Sign Structure using Figure 20.2.3 and 20.2.5 of FDM 11-55-20.

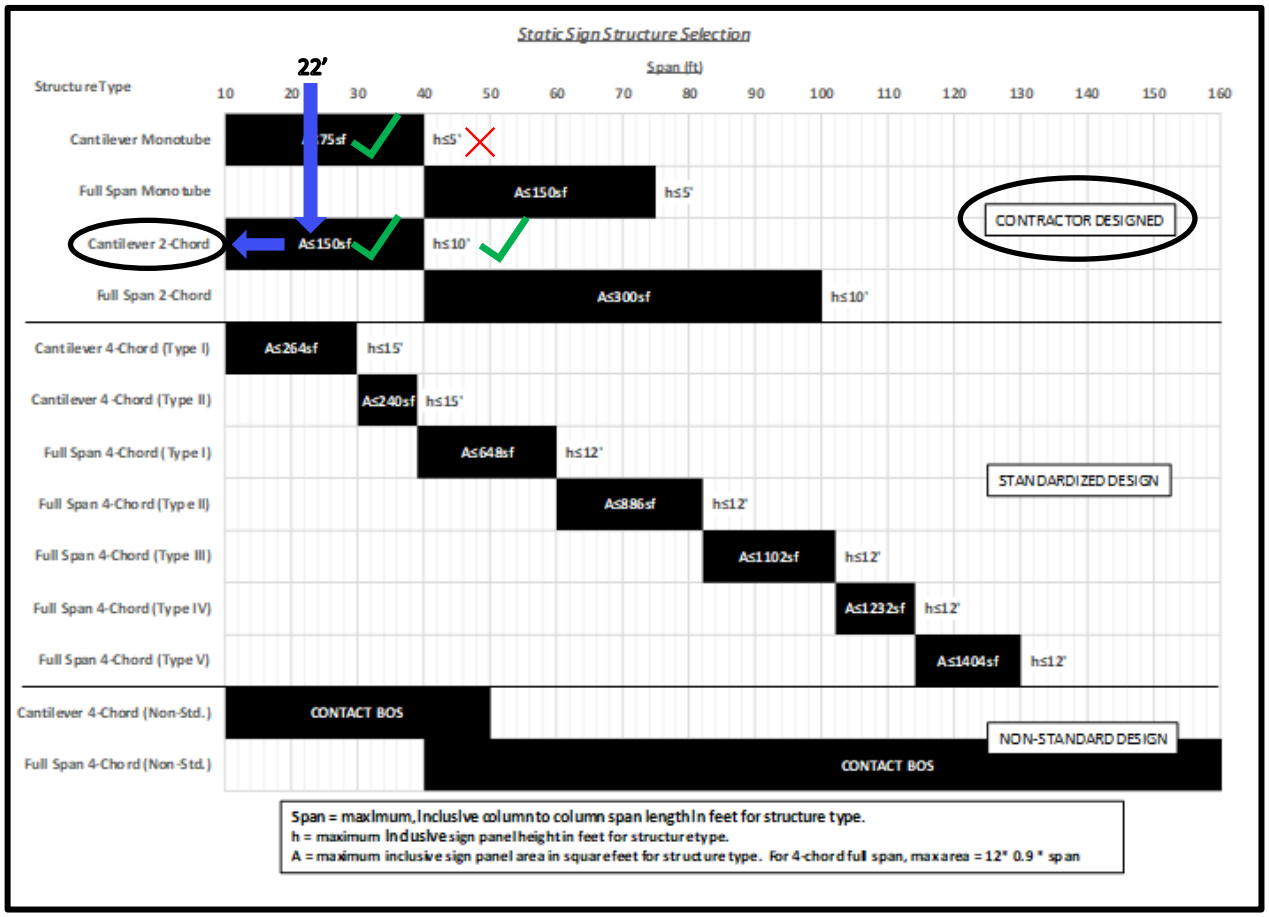


Total sign area, A = 68 SF

Max sign height, h = 7.5'

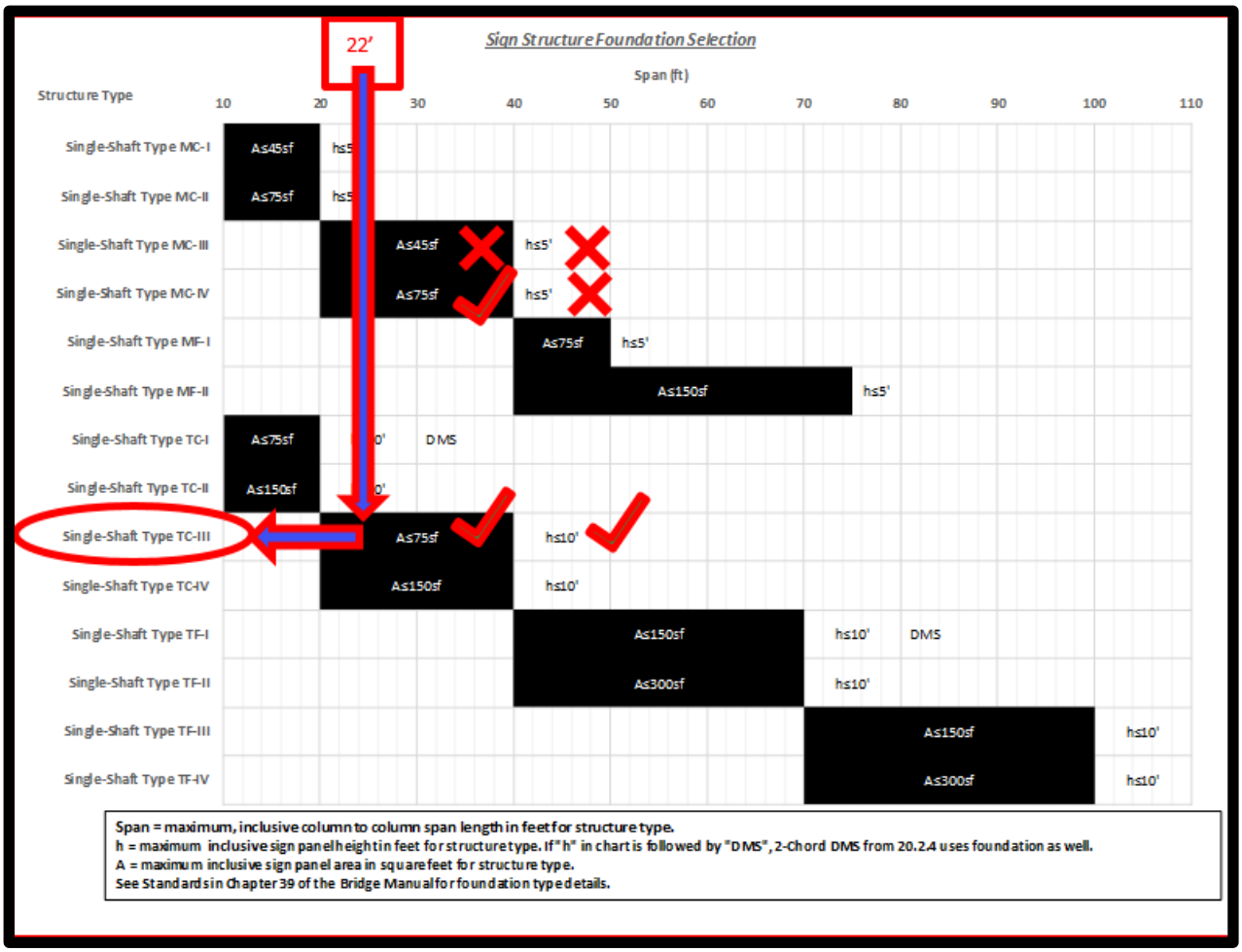
Span, S = 22 feet

Directions: Beginning with span length, move down the chart and check the parameters where the line intersects with a black box. The total sign area, A, and max sign height, h, must fit within the listed parameters. If both limits are satisfied, moved left on the chart to determine the OSS type. Note which category the OSS type belongs (e.g. Contractor Designed, Standardized Design or Non-standard Design)



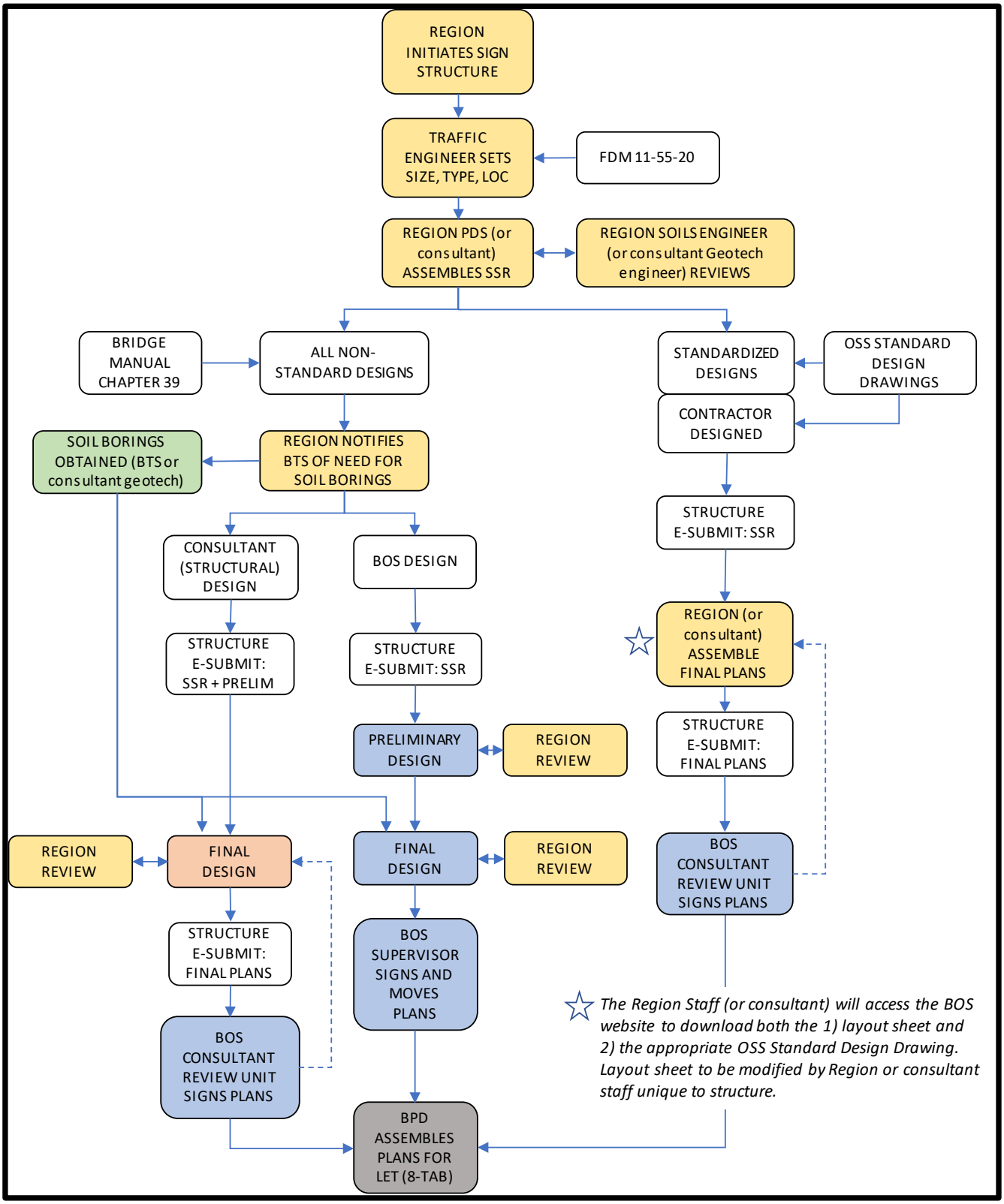
OSS Type = Cantilever 2-Chord

OSS Category = Contractor Designed
(Foundations are NOT included, use the following figure to select the appropriate foundation)



OSS Foundation Type = Single Shaft Type TC-III

Follow the design process detailed in section 20.3.


REGION INITIATES SIGN STRUCTURE
TRAFFIC ENGINEER SETS SIZE, TYPE, LOC
FDM 11-55-20
REGION PDS (or consultant) ASSEMBLES SSR
REGION SOILS ENGINEER (or consultant Geotech engineer) REVIEWS
BRIDGE MANUAL CHAPTER 39
ALL NON-STANDARD DESIGNS
STANDARDIZED DESIGNS
OSS STANDARD DESIGN DRAWINGS
CONTRACTOR DESIGNED
SOIL BORINGS OBTAINED (BTS or consultant geotech)
REGION NOTIFIES BTS OF NEED FOR SOIL BORINGS
STRUCTURE E-SUBMIT: SSR
CONSULTANT (STRUCTURAL) DESIGN
BOS DESIGN
STRUCTURE E-SUBMIT: SSR + PRELIM
STRUCTURE E-SUBMIT: SSR
REGION (or consultant) ASSEMBLE FINAL PLANS
PRELIMINARY DESIGN
REGION REVIEW
STRUCTURE E-SUBMIT: FINAL PLANS
REGION REVIEW
FINAL DESIGN
FINAL DESIGN
REGION REVIEW
BOS CONSULTANT REVIEW UNIT SIGNS PLANS
STRUCTURE E-SUBMIT: FINAL PLANS
BOS SUPERVISOR SIGNS AND MOVES PLANS
BOS CONSULTANT REVIEW UNIT SIGNS PLANS
The Region Staff (or consultant) will access the BOS website to download both the 1) layout sheet and 2) the appropriate OSS Standard Design Drawing. Layout sheet to be modified by Region or consultant staff unique to structure.
BPD ASSEMBLES PLANS FOR LET (8-TAB)

Wisconsin Ramp Gates Maintenance and Inspection

1.

General Inspection:

Make a general visual inspection of the ramp gate system, noting any damage, deterioration or vandalism.

2.

Prior to Lowering Gate Arm:

Ensure gate arm guides are properly aligned and will allow arm to lower freely without binding. Verify shear pins are present.

3.

Lower Gate Arm:

Follow WisDOT Ramp Gate Utilization visor card instructions. Ensure bumper rod is operational and free to deploy.

Check polyester strap for deterioration or damage as the gate arm is lowered. Polyester strap will likely require replacement if internal red yarn is visible. Inspect the condition of the reflective sheeting on the gate arm.

4

Raise Gate Arm:

Ensure arm returns to slots on gate arm guides with relative ease.

5.

Lubrication:

Lubricate winch components. Lubricate lock{s) if presented.

Here is the working file for the Inspection Form for Manual Ramp Gates.

Inspection of Manual Ramp Gates

(to be done twice a year)

County: _____

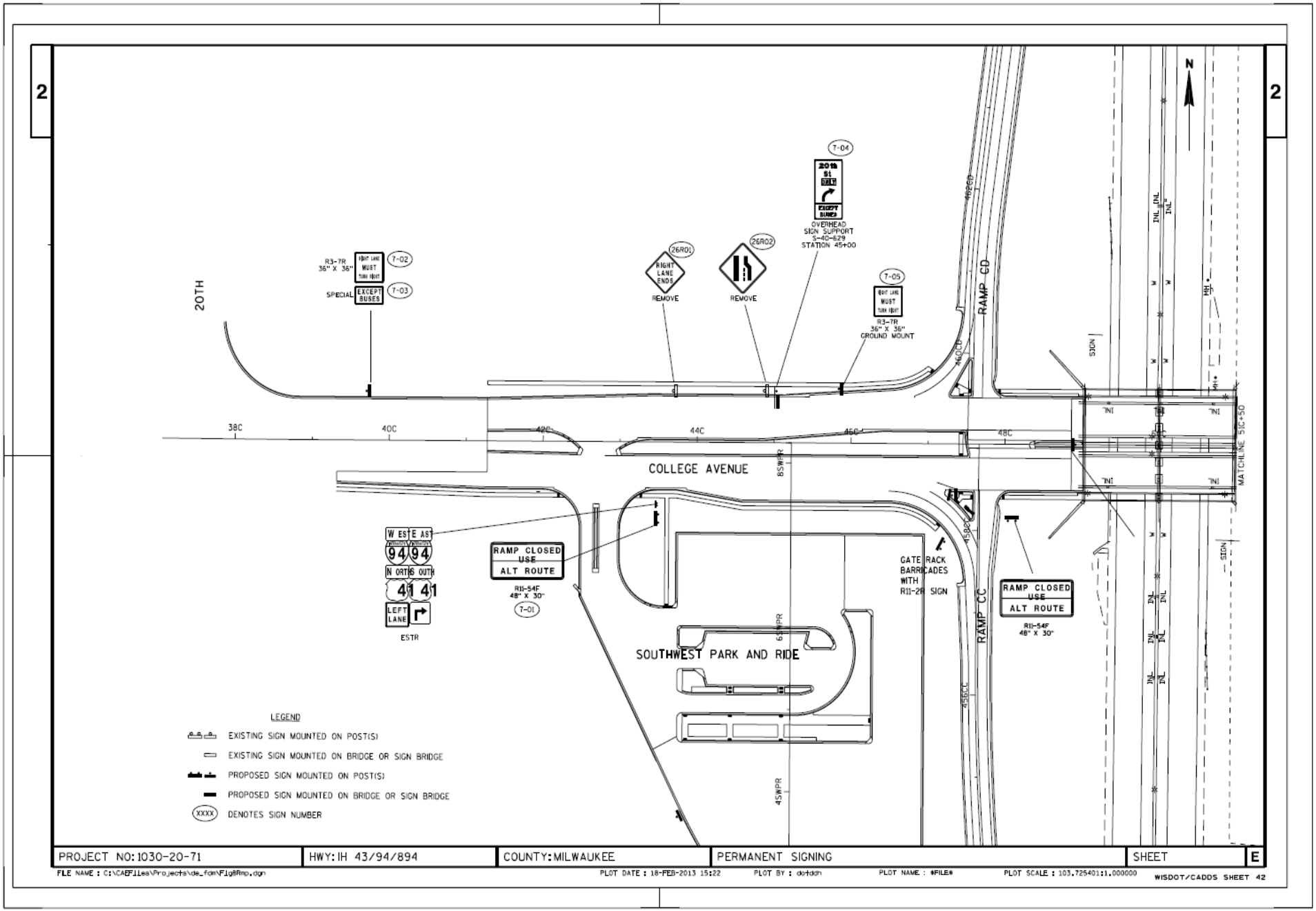
Date	Location of Gate	Gate	Lights	**Lock	Signs	Strap	Problems	Inspected by:

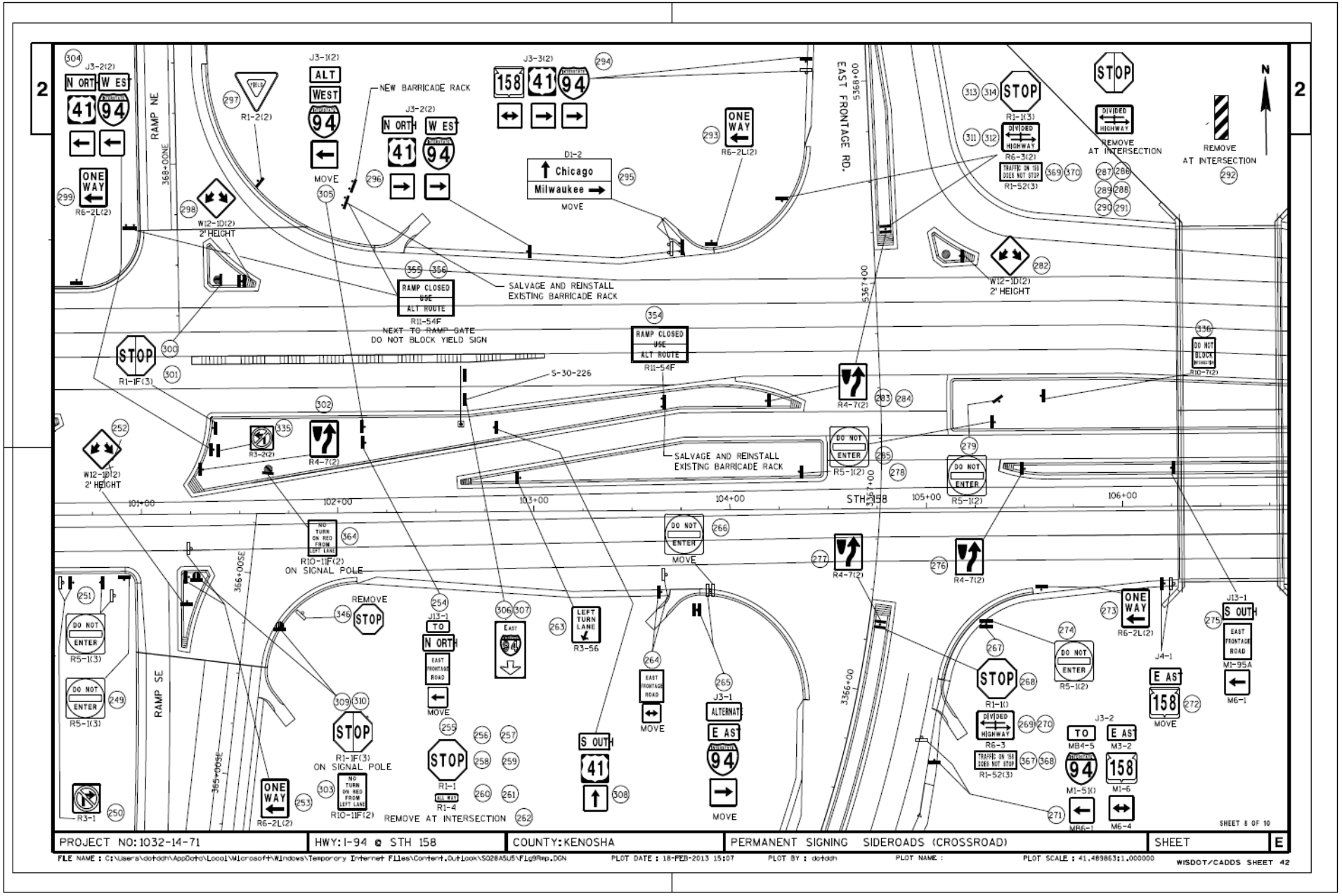
Gate = OK if gate is smooth through at least one cycle

**Lock = OK if lock unlocks smoothly

Signs = OK if signs are posted and not worn Strap = OK if no wear is visible

****Note: Only if the lock is present.**


2
2
N
20TH
R3-7R
36" X 36"
SPECIAL
EXCEPT BUSES
7-02
7-03
26R01
RIGHT LANE ENDS
REMOVE
26R02
REMOVE
7-04
OVERHEAD SIGN SUPPORT S-40-629 STATION 45+00
7-05
R3-7R
36" X 36"
GROUND MOUNT
RAMP CD
38C
40C
42C
44C
46C
48C
COLLEGE AVENUE
85WPR
65WPR
45WPR
MATCHLINE 51C+50
WEST
EAST
94
94
NORTH
SOUTH
41
41
LEFT LANE
ESTR
RAMP CLOSED USE
ALT ROUTE
R11-54F
48" X 30"
7-01
SOUTHWEST PARK AND RIDE
GATE RACK BARRICADES WITH R11-2R SIGN
RAMP CC
RAMP CLOSED USE
ALT ROUTE
R11-54F
48" X 30"
LEGEND
EXISTING SIGN MOUNTED ON POST(S)
EXISTING SIGN MOUNTED ON BRIDGE OR SIGN BRIDGE
PROPOSED SIGN MOUNTED ON POST(S)
PROPOSED SIGN MOUNTED ON BRIDGE OR SIGN BRIDGE
XXXX DENOTES SIGN NUMBER
PROJECT NO:1030-20-71
HWY:IH 43/94/894
COUNTY:MILWAUKEE
PERMANENT SIGNING
SHEET
E
FILE NAME : C:\CAEFiles\Projects\de_fdm\Fig8Rmp.dgn
PLOT DATE : 18-FEB-2013 15:22
PLOT BY : dotddh
PLOT NAME : $FILE$
PLOT SCALE : 103.725401:1.000000
WISDOT/CADDS SHEET 42


RAMP NE
RAMP SE
EAST FRONTAGE RD.
STH 158
NEW BARRICADE RACK
SALVAGE AND REINSTALL EXISTING BARRICADE RACK
RAMP CLOSED USE ALT ROUTE
R11-54F
NEXT TO RAMP GATE
DO NOT BLOCK YIELD SIGN
S-30-226
ON SIGNAL POLE
REMOVE AT INTERSECTION
REMOVE
MOVE
Chicago
Milwaukee
PROJECT NO:1032-14-71
HWY:I-94 @ STH 158
COUNTY:KENOSHA
PERMANENT SIGNING SIDEROADS (CROSSROAD)
SHEET
SHEET 8 OF 10
WISDOT/CADDS SHEET 42