1.1 Introduction

The principal reference for the development of roadside designs and the application of traffic barriers and crash cushions is the AASHTO Roadside Design Guide. This procedure will serve to supplement this reference with guidance specific to roadside design for WisDOT projects.

The Standards Development Engineer may be contacted for further guidance or information about the contents of this procedure (608) 266-2842.

1.2 Clear Zone Concept

Roadsides shall be designed to provide a reasonable opportunity for recovery of out-of-control vehicles. Ideally, this recovery area or “clear zone” should be free of obstacles and be reasonably flat. Width requirements for clear zones vary depending on traffic volume, design speed and side slope. Clear zone width requirements for new construction/reconstruction projects are included in FDM 11-15-1. The distances obtained from the curves and tables in this procedure represent the approximate center of a range of clear zone widths to be considered and are not precise distances to be held as absolute.

Clear zone width requirements for perpetuation and rehabilitation projects are included in FDM 11-15-1.13.1. The clear zone widths prescribed represent minimum values; wider clear zones should be provided on these projects when practicable.

Roadside design should focus on the area within the clear zone but should not exclude consideration of any significant hazards outside this area.

1.4 Special Situations

1.4.1 Short Radius

When there is insufficient space to provide the recommended length of beam guard between a structure and a side road (see Figure 1.2) consider the following:

1. If the structure is a box culvert with wing walls, provide a pipe grate between the wing walls to, and possibly beyond the theoretical clear zone. Provide about 2 ft of space between the flow line and the lowest pipe grate cross member to reduce nuisance maintenance cleaning.

2. If beam guard will be used then specify the standard bridge transition, SDD 14B20, with appropriate terminal treatment.

3. If beam guard is to be placed around the radius of an intersection (Refer to SDD 14B27).

![Figure 1.2 Beam Guard at Side Road](image-url)
intersecting roadway were not present. Its use in conjunction with an appropriate treatment at the bridge itself significantly reduces risk to a motorist by narrowing the angle at which the curved barrier or crash cushion can be hit.

**1.4.2 Beam Guard at Median Approach to Bridges**

There are four alternative layouts for median beam guard at approaches to bridges.

1. Thrie beam bullnose (SDD 14B26).
2. "Parallel" beam guard or concrete barrier (sheet "b" of SDD 14B18-b).
3. Special barrier terminals for beam guard.
4. Crash cushions and concrete barrier.

Most of the alternatives close access to the median. Closed median alternatives can cause more barrier to be installed in wider median, additional grading, drainage issues, or use more expensive barrier hardware. Some of the closed median options will make it more difficult to maintain areas behind the barrier system (e.g. tall grass, trees growth).

Parallel barrier installations do not typically close off the median. However, barriers with the correct length of need significantly reduce the chance of an errant vehicle getting between the median bridges and hitting other hazards. Parallel installations typical use hardware that staff are more familiar with.

Review guidance in other sections of this section, FDM 11-45-2 or SDDs for more information.

**1.4.3 Transitions to Bridges or Concrete Barrier Wall**

The transition and end treatment shall be used based on Table 1.2 for the proposed posted speed.

<table>
<thead>
<tr>
<th>Parapet or Barrier Wall Separates the Roadway from Sidewalk or Two-Way Shared Use Path. (See FDM 11-35 Attachment 1.1, Section CC.)</th>
<th>&gt; 45 mph posted speed</th>
<th>= 45 mph posted speed</th>
<th>&lt; 45 mph posted speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rural &amp; Undeveloped Transitional Areas.¹ (See FDM 11-35-1, Sections AA or BB.)</th>
<th>&gt; 45 mph posted speed</th>
<th>= 45 mph posted speed</th>
<th>&lt; 45 mph posted speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes, if no raised curb sidewalk/ path present. No, when a raised curb sidewalk/path is provided on approaches and structure, or when requested by community and agreed to by designer.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Urban &amp; Developed or Developing Transitional Areas.² (See FDM 11-35 Attachment 1.1 Sections AA or BB.)</th>
<th>&gt; 45 mph posted speed</th>
<th>= 45 mph posted speed</th>
<th>&lt; 45 mph posted speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No, when a raised curb sidewalk/path is provided on approaches and structure, or when requested by community and agreed to by designer.</td>
<td>No, when a raised curb sidewalk/path is provided on approaches and structure, or when requested by community and agreed to by designer.</td>
<td></td>
</tr>
</tbody>
</table>

¹ These areas are typically designed with a rural cross section and have a rural clear zone as provided in FDM 11-15 Attachment 1.9. Undeveloped transitional areas may have curb and gutter on the outside of the paved shoulder, however these areas will generally meet rural clear zone requirements.

² These areas have curb and gutter with a minimum lateral clearance of 2 feet from face of curb to the face of a fixed object. Typically, there are power poles, fire hydrants, or trees etc. located within the clear zone according to FDM 11-15 Attachment 1.9. When a raised curb sidewalk/path is not provided on the structure use roadside barrier to shield the blunt ends of the parapet.
When a raised curb sidewalk/path is provided on a structure and no approach sidewalk/path is provided, the designer shall install a temporary asphaltic height transition, or ramp, on the roadway approach from the top surface of the sidewalk/path down to the level of the adjacent ground surface to eliminate the blunt end effect of the sidewalk/path. This transition height is typically 6 to 8 inches and shall extend approximately 10 feet in advance of the end of the sidewalk/path. This guidance applies to all posted speeds and all project locations. White, 4-inch, cross hatch pavement marking should be considered to delineate the ramp area.

Sloped concrete end terminals are not acceptable for posted speed greater than 25 mph or greater than 3,500 AADT.

See FDM 11-35-1 for guidance on using roadside barrier to shield columns under structures.

1.4.4 Delineation of Roadways at Hazards

Marker posts, delineators and appropriate signing may be used to alert motorists of highway alignment or roadside conditions where roadside barrier is not cost-effective and yet a safety hazard remains. Document this situation in the Safety Certification Document (SCD) as well as the Design Study Report (DSR).

LIST OF ATTACHMENTS

Attachment 1.1  Beam Guard Terminal Earthwork

FDM 11-45-2 Roadside Barrier Design Guidance  May 15, 2019

2.1 (Blank)

2.2 Warrants

The following is a collection of warrants for various roadside design situations. Many of the warrants present are based on results from crash tests, computer modeling, crash analysis, cost benefit analysis, or a combination of them. It may be possible that an individual location may override a warrant. Limited project by project Design Justifications (DJ) to override a warrant may be granted by BPD. Document the DJs in the design study report (DSR).

2.2.1 Warrant Assumptions

Many of these warrants are based on an “average roadway”. An “average roadways” is:
- Built to the appropriate standard
- Has an average crash frequency
- Has an average crash severity
- Does not need to consider consequences of a collision
- Roadway is straight and level

Unless noted otherwise, warrants use the following assumptions:
- Roadway is a two-lane highway
- Roadway has a speed of 50 to 55 mph
- Warrants do not include interaction of hazards at a location. Some examples are (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 roadway and the hazardous object is non-recoverable.
- The roadside hardware or barrier system can be properly installed.
- The useful life of the barrier system is 20 to 25 years.
- The cost of installing a barrier system is near the state wide average cost.

2.2.2 Proper Application of Warrants

To properly apply 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 barrier system.
- Automatically allow for an exception to a standard.
- Automatically allow for “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 different assumptions to develop its warrant. It is possible that warrants presented may conflict with one another. If there is a conflict between warrants, it is recommended that designers:
- Consult with an engineer trained and experienced in roadside design issues.
- Error on the side of driver safety.
  - A Warrant that uses a more preferred roadside design treatment should be used prior to a less desirable treatment.
  - Two shielding warrants conflict each other, provide shielding.
  - Look for other hazards nearby
  - Review Attachment 2.5

If a situation does not match the assumptions in the warrant, error on the side of safety of the traveling public. Some examples are (list not all inclusive):
- A “Do Nothing” alternative for a lower speed roadway may not be appropriate for a higher speed facility.
- If a warrant for a two-lane roadway indicates that barrier system should be installed, it is likely that on a freeway and expressway would also warrant installation of a barrier system.
- If a two-lane roadway warrant indicates that that a hazard does not need a barrier system, installing a barrier system still may be appropriate on an interstate, freeway or expressway.

2.2.3 Median Barrier on New Freeway Construction
Attachment 2.10 is a warrant for installing median barrier on new freeway. It may not be appropriate to use this warrant to install barrier on new expressways. The need to have access for cross roads is not taken into account with this warrant (e.g. intersection spacing, sight distances…). For situations other than new freeway construction, evaluate the need for median barrier on a case-by-case basis.

Do not use Attachment 2.10 for determining allowable median width.

2.2.4 Barrier Installation for Foreslopes

2.2.4.1 Roadside Design Guide
Attachment 2.11 is a warrant for shielding foreslopes. Foreslopes that fall within the shaded area are more of a hazard than installing a barrier system. This warrant does not include the following issues:
- Fixed objects or other hazards are on the slope.
- A 3:1 slope lacks a flat run out area at the toe of the slope.
- Slope is poorly compacted, graded, saturated, or has ruts.
- The warrant is not intended to allow for a project to steepen an existing foreslope.

2.2.4.2 FHWA Barrier Warrant for Low Volume and Low Speed Roads Publication
Attachment 2.12 has warrants for shielding foreslopes based on Adjusted Traffic Factor (ATF), speed, slope rate, slope height, and offset from travel way. This warrant does not automatically eliminate slopes that are shorter than the distance given or flatter than the slope given from shielding. Slope flattening should be reviewed prior to the decision to shield.

Warrants in this subsection and in some other subsections are from an FHWA Central Federal Lands publication. The following information will discuss proper application of these warrants. These warrants were based off crash severity and frequency on low speed, low AADT roadways.
It would not be appropriate to use these tables on roadways with higher AADTs to justify leaving a hazard unshielded. However, if shielding is warranted in these tables, it is likely that shielding would be warranted on roadways with higher AADTs or speeds. In many high speed or higher AADT situations other roadside design methods would be more desirable (e.g. remove, relocate, make traversable, etc.).

These warrants use type of hazard, ATF (adjusted traffic factor), speed, and offset from roadway to determine if shielding is needed. The ATF value adjusts the vehicle encroachment rate for curves, traffic growth and grade. ATF is calculated as follows:

\[
ATF = AADT \times TG \times HC \times DG
\]

Where:
- AADT = AADT
- TG = Traffic Growth Factor (Attachment 2.12, Table A.1)
- HC = Horizontal Curve Adjustment Factor (Attachment 2.12, Table A.2)
- DG = Down Grade Adjustment Factor (Attachment 2.12, Table A.3)

Note: If project has projected AADT values, use projected AADT values and do not use TG Factor in calculations of ATF. If project does not have projected AADT value, use existing AADT and traffic growth factor.

The warrants have 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.

Shield hazards that fall within the Warranted column. Shield hazards that fall within the Possibly Warranted columns on projects where there is a ROR flag in Metamanager or if a Metamanager AK flag can be traced to ROR crashes.

Many roadways on the STH network have speeds greater than the maximum speed in the provided tables. Provide shielding on roadways when the speed is greater than 50 mph and the ATF value falls within the Possibly Warranted or Warranted columns.

These warrants were developed using older severity values for barrier impacts. Since the development of the warrants, research has shown that barrier impacts are less severe than previously thought (e.g. beam guard impacts are about 50% less severe than previously thought). It is possible that ATF ranges for the Possibly Warranted and Warranted columns will be lower than what is indicated.

In other locations, the Possibly Warranted column requires site and project specific information to conduct a more detailed analysis. Use Table 2.1 and Attachment 2.5 when considering shielding. Document decision making process for Possibly Warranted hazards within the DSR.
### Table 2.1 Factors to Consider

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Barrier is more warranted if:</th>
<th>Barrier is less warranted if:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjusted Traffic Factor</td>
<td>ATF is at the high end of range</td>
<td>ATF is at the low end of range</td>
</tr>
<tr>
<td>Roadway Cross Section</td>
<td>Section elements are more severe than assumed</td>
<td>Section elements are less severe than assumed</td>
</tr>
<tr>
<td>Size of hazard does not fit the assumption</td>
<td>Hazard is larger</td>
<td>Hazard is smaller</td>
</tr>
<tr>
<td>Hazard does not fit the description in the warrant table</td>
<td>Hazard is more severe</td>
<td>Hazard is less severe</td>
</tr>
<tr>
<td>Expected cost of Barrier</td>
<td>Expected costs will be low</td>
<td>Expected costs will be high</td>
</tr>
<tr>
<td>Multiple hazards exist at the site</td>
<td>Many additional hazards</td>
<td></td>
</tr>
<tr>
<td>Operating speed</td>
<td>Likely to exceed design speed</td>
<td>At or below design speed</td>
</tr>
<tr>
<td>Crash history</td>
<td>Clear crash pattern</td>
<td>No crash pattern</td>
</tr>
</tbody>
</table>

#### 2.2.5 Roadway Segment with High Rate of Tree Impacts

Attachment 2.13 has a threshold rate of tree impacts for various rural roads. If a roadway segment has a rate of tree impacts greater than the values in Attachment 2.13, take corrective action. Attachment 2.13 requires the roadway to be broken up into quarter mile segments and 5 years of crash reports.

#### 2.2.6 Shielding of Hazardous Trees

Attachment 2.14 is a warrant for shielding hazardous trees. Refer to FDM 11-45-2.2.4.2 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.

It is difficult to avoid impacting trees when the spacing between trees is less than 15 feet. Treat trees with spacing less than 15 feet as a group of trees.

Typically, removal of hazardous trees is less expensive than installing a barrier system and is a more desirable roadside design option. If a tree cannot be removed, or shielded, provide documentation in the DSR. Projects removing trees may need to include grubbing items to make sure that stumps are removed.

#### 2.2.7 Shielding Blunt End of Parapets or Railing

Blunt ends of parapets are significant hazards. In one study 58% of all fatal impacts into barrier system on a bridge involved an errant vehicle hitting the blunt end of a parapet or railing. Another study compared the safety performance of bridges with exposed blunt ends to bridges that had appropriate shielding. The bridges with exposed blunt ends had 4.5 times more K and A crashes than bridges with appropriate shielding.

Shield blunt ends of parapets on roadways with AADT of 400 or greater.

Review Attachment 2.5 for factors to consider when shielding blunt ends on roadways with AADTs between 150 and 399. Provide documentation of this analysis in the DSR.

Multiple research studies indicate that bridges that are narrower than the approaching roadway width are more likely to be struck. Shield the blunt ends of parapets on structures than are narrower than a roadway’s normal roadway width when AADT is between 150 and 399. Shield blunt end parapets that shield narrow drainage features or cattle passes on roadways with AADTs between 150 and 399.

Delineate blunt ends of parapets or railings on roadways with AADTs less than 150.

Review FDM 11-45-2.2.8 and 11-45-2.2.9 of this procedure for more information on about bridges and barriers that approach bridges. Review FDM 11-45-2.5.2.10 for more information about shielding blunt ends of parapets railing.

#### 2.2.8 Crashworthy Bridge Parapets and Railings

All bridge parapets and railings are to be NCHRP 350 compliant. Refer to Bridge Manual 30.1 for more information.

In some cases, it may not be practical to install a crashworthy parapet or railing on an existing structure. In
many of these cases, safety improvements can be made to the existing parapet or railing. Contact Bureau of Structures and Bureau of Project Development for assistance to improve existing parapets or railing that do not match current standards.

Review FDM 11-45-2.2.7 and 11-45-2.2.9 of this procedure for more information on about bridges and barriers that approach bridges. Review FDM 11-45-2.5.2.10 for more information about shielding blunt ends of parapets or railings.

2.2.9 Area with High Frequency of Run Off the Road Crashes by Bridges

Research in Wisconsin has indicated that cross median crashes (a specific subset of run off the road crashes) are more likely to occur near bridges. Research in Iowa indicates that 80 percent of the bridges have 2 or fewer parapet impacts in 10 years.xi

If a bridge's parapet or the barrier systems connected to the bridge has more than 2 impacts in 10 years, the location has an issue with run off the road crashes and additional steps should be taken to improve the roadside design in the area near this bridge. Provide documentation in the DSR.

This is not a warrant to provide median protection shielding.

2.2.10 Traversable Grate for Hazardous Cross Drains

Hazardous cross drains within the clear zone on roadways with AADTs of 750 or greater warrant traversable endwalls. Refer to discussion in FDM 11-45-2.6.

2.2.11 Traversable Grate for Hazardous Parallel Culverts

Hazardous parallel drains within the clear zone on roadways with AADTs of 100 or greater warrant traversable endwalls. Refer to discussion in FDM 11-45-2.6.

2.2.12 Shielding Hazardous Cross Drains or Cattle Passes

2.2.12.1 Shielding Hazardous Cross Drains or Cattle Passes on Perpetuation and Rehabilitation Projects

Attachment 2.15 is a warrant for shielding hazardous cross drains. Locations that are on or below the line for the given dimension warrant shielding.

Warrant was developed for S-1 projects. It is not appropriate to use this warrant to justify installing a new drainage feature or cattle pass than is narrow. (Refer to discussion in FDM 11-45-2.6). S-2 and S-3 projects should look to use other more desirable roadside treatments prior to shielding.

Warrant also assumes:
- Slopes near drainage feature or cattle pass are traversable
- Drainage feature or cattle pass is not considered a fixed object hazard (e.g. head wall is not a hazard).

2.2.12.2 Shielding Hazardous Cross Drains or Cattle Passes on Rural Local Roads

More recent research has indicated that shielding a hazardous cross drain can have a benefit cost ratio of 4 or more prior to 500 AADT. Some of these situations are:

Roadway width less than 36 feet
- Rural two lane or Rural one-lane roadway
- AADTs of 250 or greater
- Perpendicular slopes leading to the hazardous culvert are 2:1 or steeper

Roadway width less than 36 feet
- Rural two lane or Rural one-lane roadway
- AADTs of 450 or greater
- Perpendicular slopes leading to the hazardous culvert are 3:1 or steeper

Roadway width of 36 feet or greater
- Rural two-lane roadway
- AADTs of 400 or greater
- Perpendicular slopes leading to the hazardous culvert are steeper than 2:1

This research also indicates that shielding hazardous cross drains and cattle passes can have a benefit cost ratio of 2 or more in the following situations:

- Rural two lane or one lane roadway
- Roadway has AADT of 250 or greater.
- Slopes leading to the culvert are 2:1 or steeper

Provide shielding when projects match conditions that have a benefit cost ratio of 4 or more. Shield hazardous cross drains and cattle pass that match the conditions that have a benefit cost ratio of 2 or more on projects where there is a ROR flag in Metamanager, Metamanager AK flag can be traced to ROR crashes or when there is ROR history (e.g. high frequency or severity). Consequence of a collision in these situations may suggest shielding as well.

Review site and project specific information at locations that are similar to the benefit cost ratio 2 scenario. Use Table 2.1 and Attachment 2.5 when considering shielding. Document decision making process for these locations within the DSR.

This research assumed:
- That no other hazard is present
- Analysis was only done up to 500 AADT
- Highway’s functional class is a rural local roadway
- 3:1 slopes have flat traversable areas at the toe of slope

It is not appropriate to use this warrant to justify:
- Not to provide shielding for hazardous cross drains or cattle passes on higher AADT facilities or roadways that use a different highway classification.
- To install steeper slopes near a new cross drain or cattle pass.

It may be appropriate to use this warrant to justify shielding a hazardous cross drain or cattle pass on a higher AADT or functionally classified roadways in similar situations. However, other more desirable roadside design options should be investigated prior to shielding.

Even on roadways with low AADTs and traversable perpendicular slopes, traversable grates can be considered a viable option. In some situations, the benefit cost ratio can be 4 or higher.

2.2.13 Shielding Hazardous Water

Attachment 2.16 is a warrant for shielding hazardous water. Refer to FDM 11-45-2.2.4.2 on how to use this warrant.

This warrant assumes that the slopes between the water and the roadway are recoverable.

2.2.14 Shielding Fixed Objects

Attachment 2.17 is a warrant for shielding fixed object. Refer to FDM 11-45-2.2.4.2 of this procedure on how to use this warrant.

This warrant is not appropriate for considering consequence of a collision (e.g. dropping an overhead sign onto a roadway). For overhead sign supports, sign bridges, mono tube signs, and message boards follow guidance in FDM 11-55-20.

Shield or provide crash cushion for bridge piers and similar fixed objects when roadway’s posted speeds 55 mph or greater and bridge pier is within the desirable clear zone distance.

This warrant does not address the need for structural protection. See FDM 11-35-1.3.1 for guidance on structural protection.

2.2.15 Low-Volume Roadway

Barrier systems are generally not cost-effective for highways which have a current traffic volume under 400 AADT.xvii

However, barrier systems can be installed under the following conditions:
- Crash frequency warrants a barrier system.
- Crash severity warrants a barrier system
- Consequences of a collision warrant a barrier system.

Generally, other warrants presented in this section will override this warrant.

2.2.16 Strikes

If a fixed object has had 3 reportable crashes within a 5-year period, the object requires review. It would be desirable to have it removed.
2.2.17 Retrofit Cross Median Crash

Review crashes for cross median crash (CMC) events using the most current 5 years of crash data. A minimum of 3 crashes are required 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 11-45-2.8 for more information on Cross Median Crashes.

2.3 Proposed Hardware

To shield a hazard proper installation of barrier system is required. If a barrier system is not properly installed, the hazard can still be struck. The following contains basic guidance for almost all barrier systems. Specialty applications (e.g. long span beam guard, approach transitions to rigid barrier short radius system…) require additional engineering.

2.3.1 Design Criteria

2.3.1.1 Working Width

Working width is the combination of barrier’s width and either the maximum barrier deflection or the maximum distance a vehicle could extend behind the barrier (e.g. vehicle lean, see Figure 2.10). If working width in not provided an errant vehicle could interact with the hazard being shielded.

Provide working width for barrier systems. Limited project by project DJs for barrier systems without appropriate working width may be granted by BPD. Document in the DSR.

As working width 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).

In some cases, only a small segment of an overall barrier system may require reduced working width. Typically installing a small segment of barrier with reduced working width is more desirable than installing a whole barrier system with reduced working width (See Attachment 2.21).

Provide appropriate transition between barrier systems with significant differences in working width. Some examples are (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 2.21)
- Beam guard with half post or quarter post spacing to:
  - Short Radius System (SDD 14B27)
  - Energy Absorbing Terminals (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 type of barrier system being installed. Attachment 2.22 has a table of working widths for various barrier systems and where the working width is measured from. Figures 2.6 to Figure 2.10 show working width and Zone of Intrusion for single slope barrier. Most of the working widths are for TL-3 impacts using NCHRP 350 or MASH crash test criteria.

Some of the barrier systems listed in Attachment 2.22 are rare in Wisconsin and require approval by BPD prior to use. For barrier systems that are not typically used in Wisconsin, additional design effort, special details, individual construction details, special provisions and coordination with BPD is required. Additional documentation in the DSR will be required. It is recommended that this coordination occur early in the design process.

2.3.1.1.1 Working Width and Larger Vehicle Impacts

The majority of barrier impacts are from pick-up trucks or smaller vehicles; however, larger vehicles do strike barriers. Design barrier systems using working widths based on impacts from pick-up trucks or smaller vehicles unless:

- Crash history indicates larger vehicle impacts are frequent
- Consequence of a collision is severe (e.g. light pole or sign bridge drops across lanes of travel on a
National research, using nine years of crash data, indicates that 3% of reported barrier impacts involve vehicles larger than a pickup truck, SUV or van.\textsuperscript{viii} Locations with more than 3% heavy vehicle impacts into a barrier of fixed object within 9 years may be candidates for a barrier with a higher crash test level.

Typically, locations that do not meet the 3% in nine-year criteria and consequence of a collision is severe, designers can use standard detail drawings for single slope barrier and increase the height of barrier near the hazard (e.g. sign bridges, light poles). Although the standard barrier will not withstand a critical hit by a vehicle larger than a pick-up truck (i.e. a very rare event), a taller standard barrier will provide some additional shielding for less than critical impacts from a larger vehicle.

In some other situations, a higher test level barrier may be needed due to a combination of other issues. Adverse geometrics, large truck volume and significant consequence of collision may combine together at a location making it reasonable to install TL-5 or TL-6 barriers. Some examples are (list is not all inclusive):

- A roadway has a steep down grade 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 maintaining control when there is a large algebraic difference in cross slope (e.g. when a shoulder breaks in the opposite direction of superelevated lanes)\textsuperscript{xx}.

Coordinate with BPD prior to using higher test level barrier. Additional design effort, special details, individual construction details, and special provisions are required. Additional documentation in the DSR will be required. It is recommended that this coordination occur early in the design process.

Working widths for larger vehicles are significantly larger than what is typically used for vehicles that are the size of a pickup truck or smaller. Barriers that are designed for larger vehicle impacts are typically more expensive than barriers for vehicles that are the size of a pickup truck or smaller. The additional working width and cost of the barrier can have significant impacts on a project’s design and cost.

The guidance in this section for large vehicles does not apply to bridge substructures needing structural protection. See FDM 11-35-1 for guidance on structural protection for bridge substructures.

\textbf{2.3.1.2 Length of Barrier}

Do not use guidance in this section to install barriers that are shorter than what is required by Length of Need calculations or other factors. This section’s guidance is to indicate:

- when short installations of barrier require documentation.
- lengths of beam guard or similar barriers that should be avoided.

A barrier has a required minimum length to absorb impact loads or to prevent a vehicle from hitting the object being shielded. The minimum length of a barrier can depend on crash testing, direction of travel, expert opinion, computer modeling, or how other components of the barrier system work together. Some potential issues from installing a barrier that is too short could be (list is not all inclusive):

- Barrier failure
- Pocketing
- Soil tubes being pulled out of the ground
- Vehicles gating through terminal and hitting hazard
- Increased working width

\texttt{Attachment 2.21} and \texttt{Attachment 2.23} have some examples of how components of a barrier system or direction of travel can influence minimum length of a barrier system.

\texttt{Attachment 2.24} has “Recommended Minimum Barrier Lengths”. Barriers that are shorter than the “Recommended Minimum Barrier Lengths” require documentation in the DSR. Barriers that are shorter than the “Recommended Minimum Barrier Lengths” may not perform as expected.

Concrete barrier and cable barrier that are shorter than “Recommended Minimum Barrier Lengths” may be acceptable but requires documentation in the DSR.

For beam guard or thrie beam (not thrie beam bullnose or thrie beam transitions) installations there is a minimum length required to effectively use standard EATs and Type 2 terminals (see comment section of \texttt{Attachment 2.24}). Avoid installing beam guard that is shorter than what is in the comment section \texttt{Attachment 2.24}. Limited project by project DJs for beam guard installations that are shorter than the minimums may be granted by BPD. Document in the DSR.

Specialty barriers (e.g. concrete barrier transitions, concrete barrier integral to bridge piers, long span beam
guard, thrie beam bullnose, transitions from beam guard to rigid barrier...), have different length requirements that are not in Attachment 2.24. Review other portions of this sections or SDDs for more information.

Limited project by project DJs for specialty barriers that are shorter than the minimums may be granted by BPD. Document in the DSR. Additional engineering, DSR documentation, special details, and special provisions may be required. It is recommended that this coordination occur early in the design process.

### 2.3.1.3 Length of Need

The length of a barrier system needed to shield a hazard is termed "length of need" or LON. Length of need is dependent on the location and size of the hazard, lateral distance from the direction of traffic, design speed, design traffic volume, and how far the roadside barrier is away from the edge of the traveled way and horizontal curve. Typically, LON provides sufficient distance for an errant vehicle to stop (i.e. end of barrier need point in Figures B and C) prior to hitting an object being shielded.

Install barrier systems that provide Length of Need (LON) to shield the primary hazard. Review installation of barrier for secondary hazard. If there are secondary hazards that require shielding (see Figure 2.1), provide shielding. Proper hazard identification, both primary and secondary, is important by bridges.

Document in Design Study Report (DSR) when LON is not being provided at a given location. Document barrier installations that are significantly longer than LON. Minor adjustments of a barrier's location to accommodate for hardware, grading, and other issues does not need documentation in DSR.

After barrier lengths are designed, if there are short gaps, the barrier should be connected as one continuous run of barrier. In general, gaps of 400 feet or less should be avoided.

Length of need to shield fill embankments where the roadway cross section is transitioning from cut to fill should generally begin in the cut section to shut off vehicle access to severe fill slopes behind the approach end of the barrier.

![Figure 2.1 Hazard Identification](image)

Length of need is calculated using runout values from Table 2.2 and Equation 1. Equation 1 uses the parallel method from the Roadside Design Guide to calculate LON. The Roadside Design Guide has an equation that allows for a barrier to be flared away from the edge of lane. A flared barrier design typically reduces the amount of barrier being installed, but typically will require additional Right-of-Way and grading. The flared equation may be used under the following conditions:

- Grading from edge of lane to face of rail is 10: 1 or flatter slopes.
- Appropriate grading for the end treatment is provided (including runout areas").
- End treatments are flared at the same rate as the barrier system.
- Use of the flared equation is documented in DSR.
Using the LON equation, calculate the minimum distance from hazard to "end of barrier need (see Figure 2.2 and Figure 2.3). Depending on the barrier system and end treatment used the "end of barrier need" location may vary. Discussion of where the “end of barrier need” is located is in other sections of FDM 11-45-1 or FDM 11-45-2.
Table 2.2 Runout Lengths for Barrier Design (LR)¹

<table>
<thead>
<tr>
<th>Design Speed mph</th>
<th>AADT²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10,000 or more</td>
</tr>
<tr>
<td>80</td>
<td>470 ft</td>
</tr>
<tr>
<td>75</td>
<td>415 ft</td>
</tr>
<tr>
<td>70</td>
<td>360 ft</td>
</tr>
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<td>65</td>
<td>330 ft</td>
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<td>60</td>
<td>300 ft</td>
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<tr>
<td>55</td>
<td>265 ft</td>
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<td>50</td>
<td>230 ft</td>
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<td>45</td>
<td>195 ft</td>
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<tr>
<td>40</td>
<td>160 ft</td>
</tr>
<tr>
<td>35</td>
<td>135 ft</td>
</tr>
<tr>
<td>30</td>
<td>110 ft</td>
</tr>
</tbody>
</table>

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 2.2

\( X = \) LON = Minimum distance from hazard to 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 (e.g. water hazard, a stand of trees, non-traversable slopes, non-recoverable slopes without runout distances…).

Slopes that wrap around a bridge may increase the amount of barrier required. At bridges, use clear zone in the length of need calculation \((L_A = L_c)\) to protect water, roadway below or steep slopes that wrap around the structure. When shielding bridge piers or abutment near slopes that wrap around a structure, review if wrap around slope is a hazard. If the slope that wraps around is a hazard, use \( L_A = L_c \) in the length of need calculations.

In some situations (e.g. vehicle goes off cliff then enters body of water), extending the clear zone value for the barrier installed in the median of a high speed, high AADT facility with a narrower median may be feasible. See Figure 5-45 of the 2011 AASTHO Roadside Design Guide for an example. Review if a bullnose installation is feasible at this location prior to using a wider clear zone value in the length of need calculation. Provide documentation in the DSR about using a larger clear zone value in median installations.

Verify the location of a steep slope when calculating length of need. The transition between a traversable slope and a non-traversable slope may be adjusted during construction. This construction adjustment may relocate the beginning or end of the steep slope. Adding some additional length of barrier to allow for proper shielding may be appropriate.

¹ Table is based on 2011 Roadside Design Guide and linear interpolations.

² Use the greater of design AADT or current AADT.
For example, a steep slope is located at STA 10+00. A traversable slope is located at STA 11+00. It may be appropriate to assume that the barrier system needs to protect from STA 10+50 to the length of need point.

Figure 5-47 in the 2011 AASTHO Roadside Design Guide provides an example on how to shield a hazardous slope. This example also discusses selection of appropriate LA and LC 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 (LA = LC). The department does not use buried-in-backslope terminals.

Note that the example in the Roadside Design Guide is shielding a 3:1 slope. A 3:1 slope may not require shielding (see FDM 11-15-1.10).

On freeways, expressways and similar 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 auxiliary lanes are function more like through lanes.

### 2.3.1.3.1 LON on Curves

The length of need equation is intended for tangent sections of roadway. On the outside of curves errant vehicles tend to take a tangential path. To determine LON on the outside of curves do the following:

1. With the given speeds and AADT find $L_R$
2. Draw on the plan a line that is tangent to the edge of lane to the greater of back of hazard or edge of clear zone.
3. Measure the distance of line constructed in step 2
4. Use the smaller length of either the $L_R$ or the length of line constructed in step 2

On the inside of curves use $L_R$ to locate the LON point for the barrier system being used. See Attachment 2.4 for an example.

For examples of LON, see the following attachments:
- **Attachment 2.1**: Example Problem 1: West Side of Structure
- **Attachment 2.2**: Example Problem 2: Rock Wall
- **Attachment 2.3**: Example Problem 3: Outside of Curve Cattle Pass
- **Attachment 2.4**: Example Problem 4: Inside of Curve Cattle Pass

### 2.3.1.4 Individual Construction Detail Drawings

To minimize construction issues and errors, provide individual construction details when there is a close interaction between grading, drainage, barrier system, hazards, underground obstructions, structures, and changes in working width. Individual construction details will help ensure proper installation of a barrier system and to verify other components of the design can properly function. Providing individual construction detail drawings helps to communicate designer’s intent to field staff and contractor.

One of the most frequent calls that BPD receives are from construction staff on how to deal with conflict between barrier systems and other features. In many cases, these issues could have been dealt with during the design process. Dealing with design issues during construction leads to increase cost, delay, and in some cases barrier systems not being installed correctly (e.g. Figure 2.32 thrie beam is missing a post to install a flume, Figure 2.33 lacks appropriate grading near thrie beam transition, flumes have been installed that do not capture water, slope erosion near structures).

Some examples of when individual construction details are required are (list is not all inclusive):

- End treatments
  - Energy Absorbing Terminal (EAT)
  - Crash cushion
  - Sand barrel array
- Beam guard
  - Long spans
  - Short radius
  - Flared or taper applications
Anchor Post Assemblies
- Thrie beam bullnoses
- Approach transitions to rigid barriers

Some specific locations are more prone to requiring individual construction details (list is not all inclusive):
- Areas where there is limited post embedment or post rotation is restrained
  - Shallow fill box culverts (less than 4 ft of cover)
  - Large culverts that cross under semi rigid barriers
  - Inlets or flumes in close proximity to posts
  - Utilities in close proximity of posts
  - Footings below grade near structures
- 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

Some examples of a simple individual construction details are in Attachment 2.6.

Individual construction details are site specific. Generally, a generic construction detail in the front of the plan is not sufficient to make sure that the barrier systems and other component of the highway are installed properly.

Include the following in individual construction details when needed:
- Drainage structures (e.g. inlets, pipes, ditches)
- 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

Typically, contours are required for complicated grading situations (e.g. wrapping slopes around a structure that has a transition to rigid barrier installed nearby…).

Provide individual construction detail in plan. If project is not providing individual construction drawings provide documentation in the DSR.

2.3.2 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 considered crashworthy. See Figure 2.25 for an example of a low-tension cable barrier.

Currently, the Department is not installing cable barrier on the outside of roadways. Additional information about the performance of cable barrier on the outside of the roadways and proper installation is required. Contact BPD if considering installing cable barrier along a roadside.

Use SDD 14B52 when installing proprietary cable barrier systems (i.e. Type 1 cable barrier system). Use standardized special provisions (STSPs) for cable barrier (stp-613-010).

The cable barriers that the Department uses are proprietary. Because of the proprietary nature of the cable barrier systems, designing cable barrier is slightly different than designing other barriers (e.g. beam guard, concrete barrier…). The Department depends more on a manufacturer’s knowledge of their system. However, some of the guidance that is in the FDM, Standard Detail Drawings or in the Standardized Special Provision will
overrule manufacturer’s recommendations. Some examples of this are:

- Manufactures have tested cable barriers with very large lineost spacing, but the Department limits the maximum post spacing to 15 ft.
- Some manufactures have provided connection hardware that is weaker than the cable used in the crash tests. This can put a weak spot in the cable barrier and allow barrier failure.
- Some manufactures have crash tested cable barriers on steeper slopes than what is indicated in the design guidance. However, more recent research indicates that there are additional factors to consider, such as difficulties in cable/vehicle interaction.

The cable barrier market is very competitive. Manufacturers are constantly updating their systems. It is best to contact the manufacturer for the most current information on their system. It is best to get information directly from the manufacturers, but designers should verify with Bureau of Project Development (BPD) prior to implementing manufacturers’ recommendations.

2.3.2.1 Cable Barrier Selection
WisDOT’s policy is to have at least two different cable barrier manufacturers in each county to insure competitive bidding. See approved products list for what devices are available in each county. If a particular county is not listed contact BPD and BPD will provide you with guidance on what systems to use.

If the county has no approved cable barrier systems listed. Contact BPD early in the design process. BPD 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 provided contact BPD. BPD may require documentation on why a cable barrier system is no longer wanted in a county.

Design cable barrier installations using the “worst” features of either cable barrier system. Some examples are:

- “Cable Barrier System A” has a 25% greater working width than “Cable Barrier System B”, use “Cable Barrier System A” 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.

2.3.2.2 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 associated connection hardware. The reinforced concrete foundation and steel sleeve allow for quick removal and replacement of damaged posts. Steel posts are designed to hold the cables at the appropriate height to capture the vehicle and absorb some impact energy by fracturing or yielding on impact. Associated connection hardware assist in holding the cables at the appropriate height to allow for proper contact and are designed to allow for proper interlocking of the cable into the vehicle.

Cables and cable splice hardware transmits a large portion of the impact energy to the cable barrier end terminals.

Cable barrier end terminals are designed to transfer the impact energy to the ground. Cable barrier end terminals have additional crashworthy requirements (see FDM 11-45-2.3.2.5.1, and FDM 11-45-2.3.2.5.2).

2.3.2.3 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. In many cases mow strips have increased the project’s cost, made proper installation of the cable barrier more difficult, in some cases increased long term maintenance or created difficulties for future projects.

2.3.2.4 Cable Barrier to Beam Guard Connections
Avoid using cable barrier to EAT and beam guard connection. If project staff determines that the cable barrier to beam guard connections is required contact Project Oversight staff. Additional engineering and special provisions will be required.

Manufacturers have various designs to connect cable barrier to the beam guard. Although these connections have FHWA eligibility letters, many of these connections have not been crash tested. Manufacturers are basing their designs off of a generic low-tension cable barrier crash test.
Although the generic low-tension system passed crash testing, there are some concerns about stability of the vehicle. Adding more tension to the cable barrier would increase the vehicle instability.

Other states have noticed that cable barrier to beam guard connections has caused damage to the beam guard and difficulties repairing safety hardware. In addition, maintenance staff would need to stockpile additional parts and have additional training to maintain special connections.

### 2.3.2.5 Design Requirements

#### 2.3.2.5.1 LON Point for Cable Barrier End Terminals

Like EATs, errant vehicles can pass through the beginning of the cable barrier end terminal with little or no reduction in speed. Contact the manufacturers for the most current information on the LON point for their cable barrier end terminals.

When shielding a fixed object (see Attachment 2.25) cable barrier is designed using LON procedures in FDM 11-45-2.3.1.1. If using cable barrier at locations where CMC is an issue, desirably cable barrier terminals would overlap the LON of other barrier installations (see Attachment 2.25, 2.26, 2.27 for some examples) or extend cable barrier to a point beyond where CMC are less likely to occur.

#### 2.3.2.5.2 Shielding Cable Barrier End Terminals

Although cable barrier end terminals are designed to be crashworthy, it is desirable to shield cable barrier end terminals with other barrier systems when feasible (e.g. cable barrier runs up to a bridge and the cable barrier end anchors are behind the EAT/beam guard/thrie beam transition…). Impacts to a cable barrier end terminal can render a whole installation of cable barrier inoperative. Impacts to cable barrier end terminals can also cause expensive repairs (e.g. If cable connection plate gets bent during an impact, the whole concrete footing may need to be removed).

#### 2.3.2.5.3 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 their crash testing results. As distance between cable barrier end terminals increases, the working width increases. A typical roadway application of cable barrier is longer than most test installations. Consequently, real world cable barrier working width will typically be larger than what the manufacturer reports. For initial analysis to determine if cable barrier is a viable option assume a working with of 12 feet.

It is recommended that 12 feet is used for most design applications. However, in some locations a lower work width value from the manufacturer’s crash test report can be used with normal post spacing (see below). In other locations reduced post spacing may need to be used (see below).

Line post spacing is directly related to working width. The larger the distance between line posts the larger the working width.

The maximum line post spacing is 15 feet. This maximum distance between line posts is based on a FHWA memorandum from 2007. Do not use larger line post spacing because of concerns with increased working width, difficulties maintaining cable heights relative to the roadway profile, and increased likelihood of vehicle penetration of the cable barrier.

Most cable barrier manufacturers will use 15 feet for their normal line post spacing. Some manufacturers will use a line post spacing as low as 10 feet for normal line post spacing.

Reduced line post spacing may be used to reduce working widths at spot location (e.g. a long run of normal spaced cable barrier needs reduced post spacing near a sign bridge). See FDM 11-45-2.3.2.5.3.1 for information on how to design for reduced line post spacing by a fixed object.

Current crash tests with reduced line post spacing have shown significant damage to crash test vehicles (e.g. A-pillar of vehicle partially cut through, windshield cut through, tears in floor board). Avoid reducing line post spacing to less than 7 feet.

Impacts on the convex side of a curved cable barrier installation will cause a temporary loss of cable tension. This loss of tension will create a larger working width (See Figure 2.4). Provide more room to accommodate the increased working width on a curve by placing the cable barrier on the convex side of the median (See Attachment 2.26).

Avoid installing cable barrier curves with a radius of 1,300 feet or less when a vehicle can impact the convex side of the cable barrier. Review the use of other barrier system when the radius is 1,300 feet or less and a convex impact can occur. Limited project by project DJs for cable barrier installed on a radius of 1,300 feet or
For curve installations that cannot have a convex impact, the minimum radius to install cable barrier is 500 ft or the minimum radius that the manufacturer allows. Radii that are less than 500 ft or less than the manufacturer’s recommendation should use a different barrier system. Provide documentation in the DSR when installing a cable barrier that is less than 500 ft or the manufacturer’s recommendation.

Avoid median cable barrier installations where the cable barrier working width would allow the cable barrier to enter the lane of travel. Limited project by project DJs for cable barriers with working widths that enter lane of travel may be granted by BPD. Document in the DSR.

Provide working width for large fixed objects (e.g. piers, overhead sign supports, sign bridges, drainage features…). In some cases, other barriers with less working width will be required to shield large fixed objects or more than one installation of cable barrier may be required in a median (see Attachment 2.25 for some examples). Review the need for structural protection in FDM 11-35-1.3.1.1 for bridge piers.

Provide the following in the plan:
- Where working width is measured to (e.g. cable barrier to middle of shoulder, cable barrier to edge of lane, cable barrier to bridge pier…).
- Value or values of the cable barrier’s working width.
- Location or locations where working width is different (e.g. reduced post spacing is used near a particular sign bridge but the rest of the roadway will have a larger working width).

Desirably, small breakaway signs would be installed outside the working width of the cable barrier. However, small breakaway signs may have restrictions on where signs can be placed. Review small signs with region’s traffic staff to see if there are unnecessary signs or if signs can be moved outside the working width of the cable barrier.
2.3.2.5.4 Soils Information

Provide soils information on all projects with cable barrier installations. Manufacturers design their cable barrier end terminal foundations based on the soils information present and how their system absorbs or transmits energy. In many cases the cable barrier will not work correctly during an impact or will become a hazard if proper soils information is not provided. Projects that do not provide soils information can experience significant delay and cost increases.

It is recommended that soil boring information is provided on a plan sheet(s) for each cable barrier end terminal. In some cases, nearby cable end terminals may be able to use one soil boring (e.g. each side of a maintenance cross over requires a cable barrier end terminal, one soil boring may be sufficient).

However, if a regional soils engineer determines that an alternative source of information is adequate (e.g. soil boring for nearby bridge is representative of conditions near cable barrier terminal…), then this information can be made available to the contractor. Indicate in the plan, that other sources of soils information are available, and who to contact and contact information. It is recommended that the contact information is located on individual construction detail drawings for the cable barrier.

Attach soils engineer’s recommendation that an alternative source of soil information is adequate for designing cable barrier terminal end anchors to the DSR.

2.3.2.5.5 Cable Barrier and Curb

Avoid installing curb and gutter by cable barrier. Curb and gutter will change vehicle trajectory or could trip vehicle into cable barrier. Limited project by project DJs for curb installed in front of cable barrier may be granted by BPD. Document in the DSR.

If curb has to be used by a cable barrier, curb should be used in the following order (most desirable to least desirable)

1. driveway curb
2. 4” sloped curb at limited locations

2.3.2.5.6 Median Width for Installation of Cable Barrier

Cable barrier is normally placed in medians that are 40 feet or wider. Working width issues and cable barrier placement relative to ditch may make it difficult to install 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?).

In some cases, two runs of barrier may be required because of working with issues. For example, to get appropriate working width to a sign bridge, the cable barrier needs to be placed so close to the lane that the opposite side working width is within the lane of travel. Then a designer may need to install two cable barriers, one on each side of the median, to prevent opposite side impacts.

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 11-45-2.2.17).
- Department’s CMC Hotspot Analysis has indicated that there is a CMC issue at a particular location.
- Research has shown that CMC are likely to occur (See FDM 11-45-2.8.1)

2.3.2.5.7 Median Grading

It is complicated to predict the path of an errant vehicle in a simple “V” or flat bottom ditch. The more complicated the median cross section (e.g. a wide median with two near roadside ditches, a median with a berm in the middle, undulating median, median with large culvert pipes…), the more difficult it is to predict vehicle trajectory. If it is difficult to predict vehicle trajectory, it is difficult for any barrier system to capture an errant vehicle.

Install a single run of cable barrier on 6:1 slopes. Median ditch for a single run of cable barrier is to be a 6:1 to 6:1 traversable ditch.

In some cases, installing cable barrier or other barrier systems on both sides of the median may be a better option. Some examples are:

- Significant amount of earthwork is required to get appropriate slopes.
- Median ditch already has drainage problems.
- Drainage feature would require a significant amount of modification.
- Significant number of fixed objects are close together.

Consider using slopes flatter than 6:1 for cable barriers. Flatter slopes may allow future work on the roadway to proceed without requiring adjustments to the cable barrier.

If a project cannot get the appropriate median grading and other issues are making it difficult to properly install two barrier systems on both sides of the median, contact BPD. It is recommended that this is done early in the design process.

It is not recommended that slopes behind cable barrier installed at the edge of shoulder be steeper than 4:1.

Projects installing cable barrier are required to conduct field survey. Generate cross sections at a minimum of 100 ft intervals. Additional cross sections may be required near drainage features or other locations.

Projects that have relied on “As Built Plans” or Typical Sections have had significant construction problems and delays. Limited project by project DJs for not providing field survey may be granted by BPD. Document in the DSR.

Adjust drainage features to install cable barrier. This work typically includes:
- Grading around drainage features
- Re-grading of ditches.
- Adjusting the height of inlets.
- Installing traversable covers or traversable grates.
- Removal of 4” tall hazards on a 5 ft chord.

See FDM 11-45-2.6 for more discussion on roadside design for drainage features. If these issues are not taken care of it may be difficult for cable barrier to properly operate.

Pay attention to grading in curves, transitions to curves, narrow medians, other cross-sectional transitions, and special ditches. These areas may be steeper than what is indicated on previous plans due to drainage concerns or maintenance activities.

2.3.2.5.8 Placement in Median

Research conducted by FHWA has indicated that a vehicle can under ride a cable barrier when the cable barrier is placed too close to a median ditch. At a minimum, place cable barrier at least 8 feet up from a median ditch.

Cable barrier can be placed further than 8 feet up from a ditch. However, other factors (e.g. working width, the closer a barrier is to the roadway the more likely it will be struck, room for maintenance staff…) can influence how far away from the ditch a designer may want to place the cable barrier.

Placing cable barrier up the slope from the median ditch also keeps the cable from the wet or poor soils that are typically found in a median ditch. Installing cable barrier up a slope also lessens the likelihood that line post will freeze into line post footings.

Although it can be easier to measure from edge of lane or other feature in the plans, it is important that the actual cable barrier is no closer than 8 feet from the median ditch. If median ditch is hard to define or meanders either grade a ditch or move the cable barrier closer to the travel lane.

It is recommended that cable barrier is placed at a constant offset from the ditch. There has been no crash testing of tapered or flared cable barrier.

2.3.3 Beam Guard
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2.3.4 Thrie Beam
This section is blank.

2.3.5 Transitions to Rigid Barriers
This section is blank. At the time of publishing concrete barrier guidance, the following transition has not been fully developed:
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.

2.3.6 Concrete Barrier
Concrete barriers operate in a significantly different manor than flexible or semi-rigid barrier systems. Concrete barriers redirect impact energy verses absorbing energy.

The two main methods of redirecting impact energy are vehicle lift and vehicle deformation. During an impact, a vehicle will climb up the concrete barrier (i.e. converting kinetic energy into potential energy). Energy is also lost due to damage to vehicle components during impact (e.g. flattening or shattering body panels, bending vehicle frames, crushing of engine or drive train).

These two methods of redirecting energy cause impacts into concrete barrier systems to be more severe. (e.g. lifting a vehicle off the ground increases the chance of vehicle roll over, forces that cause vehicle deformation also can cause injury to vehicle 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 system has to match into an existing bridge or roadside barrier.

2.3.6.1 Shape
There are currently five different shapes of concrete barrier in Wisconsin: GM, NJ, F, Single Slope and Vertical (see Figure 2.4 for dimensions of GM, NJ, and F shapes). GM shaped barrier was originally designed in the 1970s, and tends to roll smaller, lighter cars.

No new runs of GM shaped barrier are to be installed. Spot replacement of GM barrier that has been damaged or removed to facilitate installation or repair is acceptable (e.g. inlet underneath GM barrier requires repairing).

![Figure 2.4 Barrier Shape](image_url)

NJ shaped barrier has been the standard style of barrier for both roadways 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 roadways.

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3 Frictional forces also are involved, but all barriers use frictional forces.
WisDOT has recently adopted the Concrete Barrier Single Slope (CBSS) design developed by Caltrans. The advantages of the CBSS design are:

- Lower maintenance cost
- Better crash performance
- More flexibility with overlay projects

Vertical shaped barrier may be found at various locations. For example, if removing an existing guardrail or thrie beam transition to concrete barrier, a vertical transition may be required to match the new CBSS into the existing concrete barrier. Minimize the use of vertical barrier.

Barriers that do not conform to: NJ, F, single slope, or vertical shapes are not acceptable. Changes to barrier shape to accommodate drainage, or placement of hardware on or near barrier is not desirable.

### 2.3.6.2 Concrete Barrier Height

Most existing installations of concrete barriers are 32 inches tall. Barriers that are 42 and 51 inches have been installed on some freeways and expressways (mostly SE region) and on various bridges.

The standard CBSS heights are in Table 2.3.

<table>
<thead>
<tr>
<th>Roadway</th>
<th>Standard Barrier Height (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeways and Expressways</td>
<td>42</td>
</tr>
<tr>
<td>STH</td>
<td>36</td>
</tr>
<tr>
<td>Local</td>
<td>36 *</td>
</tr>
</tbody>
</table>

*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 acknowledge that overlays should not be placed near 32-inch CBSS and that recent crash testing has indicated that taller vehicles (i.e. single unit van trucks) have gone over 32-inch barriers. Attach local unit of government’s written request to the project’s Design Study Report (DSR).*

Vertical-shaped barrier taller than 34 inches is acceptable between, and flush with, closely spaced bridge piers or other bridge substructures if there is not enough room to place a SSCB in front of the bridge piers or substructure. Vertical-shaped barrier taller than 34 inches is not desirable at other locations because of the increased risk of “head slap”.

In specific situations, a barrier that is taller or shorter than Table 2.3 may be used, but additional documentation in the DSR is required. Coordinate early in the design process with Bureau of Project Development (BPD) on the use of a non-standard barrier height. Minimize the use of taller barrier.

Other issues to consider when selecting the appropriate height of CBSS are:

- Sight Distances
  - Stopping Sight Distance
  - Intersection Sight Distance
  - Decision Sight Distance
- Working Width
- Zone of Intrusion
- “Head Slap”
- Crash history

#### 2.3.6.2.1 Sight Distances

Concrete barrier on the inside of a horizontal curve can obstruct stopping sight distance or decision sight distance (SSD or DSD). Taller barrier could possibly worsen the obstruction. If the available sight distance is less than the minimum required sight distance, then a Design Justification is required.

A barrier within the required clear sight window of an intersection can obstruct intersection sight distance (ISD). If it is necessary to install barrier that obstructs required SSD, DSD or ISD then provide mitigation (e.g. more signs, bigger signs, pavement marking, more delineation). See **FDM 11-10-5** for more discussion on sight...
distance.

2.3.6.2.2 Vacant
Guidance on Working Width has moved to FDM 11-45-2.3.1.1.

2.3.6.2.3 Zone of Intrusion
Figure 2.6 to Figure 2.9 show the differences between working width and Zone of Intrusion (ZOI). Table 2.4 has working width and ZOI values for various heights and types of barrier. ZOI is measured from the top, traffic side of barrier.

ZOI is a region within the working width where secondary hazards (e.g. breakaway signs) traditionally have been placed. Some recent crash testing has indicated that secondary hazards could intrude into the vehicle cab. It is desirable that secondary hazards are not placed within the ZOI of a concrete barrier (see Figure 2.5).

Many safety devices (sign poles, lights...) are designed to break away when a vehicle’s bumper (typically between 18 to 23 inches off the ground) engages the safety device. If a safety device is placed on the top of a barrier, the upper part of the vehicle engages the safety device. The safety device may not breakaway as intended. For example, a breakaway device may cause excessive deceleration to the vehicle (i.e. increasing the probability of a serious crash).

When making a decision to install objects on top of the barrier, early coordination with BPD is required. Additional design effort may be needed. Additional documentation will be required in the DSR.
Figure 2.6 Zone of Intrusion and Working Width

Figure 2.7 Example 1

Example 1: Pier is not interfering with barrier performance
Example 2:  
Pier is interfering with barrier performance.

*Figure 2.8 Example 2*

Example 3:  
Pier is interfering with barrier performance.  
Sign likely to be hit by vehicle or vehicle occupant.

*Figure 2.9 Example 3*
Figure 2.10 Example 4

Table 2.4 ZOI Dimensions

<table>
<thead>
<tr>
<th>Concrete Barrier</th>
<th>ZOI Width (Inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32” CBSS</td>
<td>21</td>
</tr>
<tr>
<td>36” CBSS</td>
<td>21</td>
</tr>
<tr>
<td>42” CBSS</td>
<td>21</td>
</tr>
<tr>
<td>56” CBSS</td>
<td>6</td>
</tr>
<tr>
<td>32” Vertical Concrete Barrier</td>
<td>24</td>
</tr>
</tbody>
</table>

2.3.6.2.4 Head Slap

"Head slap" is a condition where an occupant’s head is outside the cab of a vehicle during impact and contacts concrete barrier’s face (See Figure 2.11). Head slap becomes more of an issue when smaller vehicles impact taller barriers.
2.3.6.2.5 Crash History
Taller barriers may be warranted if crash history indicates smaller vehicles (i.e. cars, pick-up trucks, SUVs…) 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 warranted if there is a crash history of larger vehicles striking barrier.

2.3.6.2.6 Glare/Gawking Screen
Typically, glare screens should not be installed in medians wider than 20 feet, or in locations where there is ambient lighting. Ambient lighting includes roadway lighting, high-mast lighting, or neighboring properties provide significant lighting. If a median is greater than 20 feet, analysis is required.
Contact BPD early in the design process since they will review the installation of a glare or gawking screen on a case-by-case basis. Project staff will need to:
1. Document 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 an alternative at blocking glare or gawking?
   b. What is the cost of providing glare or gawking alternative?
3. Document the justification within the DSR.
If there is a counter directional traffic on a frontage road next to a main line, a glare screen may be appropriate.

2.3.6.3 Components of a CBSS System
CBSS systems have the following components:
- Standard Barrier Sections
- End Anchors
- Transitions
  - Shape
  - Height
Review barrier design for adequate space to use the different components of the CBSS system. (see FDM 11-45-2.3.6.4.6). If SDDs will not fit a given location, coordinate early in the design process with BPD. It is the
designer’s responsibility to develop crashworthy designs for unique situations.

### 2.3.6.3.1 Standard Barrier Sections

Of all the components of a concrete barrier single slope (CBSS) system, the standard barrier section (i.e. middle section of concrete barrier installation) is the most frequently used and simplest section. A standard section of CBSS requires less reinforcement steel than other components of concrete barrier system because impact forces are distributed in two directions (see Figure 2.12) and over long distances.

**Figure 2.12 Forces in Normal Barrier Section**

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. 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 next subsection FDM 11-45-2.3.6.3.2).

### 2.3.6.3.2 End Anchors

End anchors require additional vertical steel and footings to absorb impact loads and to prevent the anchor from rotating during an impact (in Figure 2.13 impact forces cannot travel in both directions). End anchors use a cold joint\(^4\) to connect to standard CBSS. When using SDDs, it is not necessary to detail the use of a cold joint.

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\(^4\) 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 impact energy.
There are two types of end anchors for CBSS: thrie beam anchors and normal end anchors. The department does not pay for anchors separately, because the anchor length is included in the length of the CBSS.

The thrie beam anchor is designed to prevent an errant vehicle’s front wheel from snagging the barrier. Do not install curb and gutter near a thrie beam anchor. 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. Indicate in plan (e.g. plan view) where thrie beam anchors are required and include appropriate SDD (SDD 14B33) in plan set.

Normal end anchors are used when there is an expansion joint needed in a barrier run (e.g. on both sides of the sign bridge) or on the downstream end of a one-way roadway. When using SDD 14B32, it is not necessary to indicate that a normal end anchor is needed. However, there could be a project specific need that would require the use of normal end anchor (e.g. an expansion joint is needed at a specific location, traffic control staging requires a normal end anchor…). In these situations, indicate on the plan were additional normal end anchors are needed.

Review grading and drainage near end sections. Although a particular location may satisfy the length of need for a barrier system, the location may not provide sufficient room for grading needed for other components of the barrier system (e.g. crash cushion, sand barrier array, or steel thrie beam structure approach), or may have other drainage issues that require additional work. This is a concern if the barrier is installed near a tall cut section, or in other areas where there is significant drainage needed near the barrier system. CBSS may have to be lengthened to provide appropriate space for proper drainage or other roadside hardware.

2.3.6.3.3 Transitions
CBSS may need to connect to taller or different shaped barriers. Typically, transitions require additional vertical steel and footings to absorb impact loads and to prevent the barrier from rotating during an impact.

It is important to review what transitions are needed for a given project early in the scoping or design phase. For example, if a new barrier is to match into a barrier that had an existing thrie beam transition, a vertical faced transition is required. Use “each” items to pay for shape transitions. Indicate in plan (e.g. plan view and MQ sheets) the location of shape transitions.

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. The double cold joint details allow impact force to be transmitted in both directions (i.e. the height transition acts like a normal barrier section). Double cold joint height transitions are included in the cost of normal CBSS. Indicate in plan (e.g. plan view) the location of double cold joint height transitions.

The expansion joint height transition designs, SDD 14B9 are intended for locations where it is not possible to transmit forces in both directions (e.g. the bridge has parapets of one height, and the roadway has barrier of a different height) or there is not sufficient length of barrier to absorb an impact. Pay for the expansion joint height transition as an each item. Indicate in plan (e.g. plan view and MQ sheets) the location of expansion joint height transition.
2.3.6.4 Unique Situations

2.3.6.4.1 Short Sections of Barrier

The minimum length for the standard CBSS is 40 feet (end of end anchor to end of the end anchor). Lengths shorter than 40 feet require the use of the CBSS Short Section (Concrete Barrier, Type B, SDD 14B34). These barriers are more robust and can absorb impact within the total length of the barrier.

The minimum length of installation of CBSS Short Section varies depending on the number and type of anchors required:

- If two thrie beam anchors are needed (e.g. bidirectional traffic), then the minimum installation length of CBSS Type B is 31 feet (end of the thrie beam anchor to the other end of the thrie beam anchor).
- If one thrie beam anchor is needed (e.g. one-way traffic), CBSS Type B then the minimum installation length is 21 feet.
- If no thrie beam anchor is needed (e.g. a sign bridge is close to a bridge), then the minimum installation length of CBSS Type B is 10 feet.

2.3.6.4.2 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 and fixed object require protection.

These details provide for extra steel, use of fill material and a small footing. Pay for fixed object protection using linear feet. Indicate in plan (e.g. plan view and MQ sheets) the location of fixed object protection. Include bid items for reflectors and brackets.

Other designs (e.g. integrating a sign bridge or light pole into the barrier run), have to integrate the impact forces into the structural design of the fixed object. Most impacts on a barrier are from vehicles of pick-up truck size or smaller (see FDM 11-45-2.3.6.4.6).

Taper rates in the transition at large or small fixed objects may be adjusted using Table 5.7 “Suggested Flare Rates for Barrier Design” in 2006 AASHTO Roadside Design Guide. Provide construction details and special provisions. Include special bid items for design. Include bid items for reflectors and brackets.

2.3.6.4.3 Median Widening or Narrowing a Hazard for a Crash Cushion/Array

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. Sections A-A and B-B of SDD 14B32-b can be used as a guide on how to narrow a hazard to allow for proper installation of a crash cushion or sand barrel array. Taper rates in the transition at large or small fixed objects may be adjusted using Table 5.7 “Suggested Flare Rates for Barrier Design” in 2006 AASHTO Roadside Design Guide.

Height of concrete at section where the crash cushion attaches should be 32 inches tall. Incorporate a height transition into the width transition to minimize the overall length of concrete needed. During an impact, a vehicle can lean over the top of a crash cushion and strike the hazard being shielded. Review guidance on crash cushions and arrays for back width and pad dimensions (FDM 11-45-2.3.6.4.4).

Structurally analysis and design is required (see FDM 11-45-2.3.6.4.6). End anchors will be required near the crash cushion location.

Provide individual construction details, special bid items and special provisions. Include bid items for reflectors and brackets.

2.3.6.4.4 Retaining Walls

There are two designs for retaining walls: median and roadside. Use median retaining wall design when the barrier is between two roadways of different height. The median design has a maximum wall height of 3 feet (see SDD 14B32). Indicate in plan (e.g. plan view and MQ sheets) the location of median retaining wall. 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 required height of median retaining walls is greater than 3 feet, a structural design is required. Design taller median retaining wall not only to retain soil and other loads, but also impact loads (see FDM 11-45-2.3.6.4.6).

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 require significant earthwork or special earthwork, include earthwork bid items. Include bid items for reflector and brackets.

The roadside retaining wall does not have a maximum fill height (see SDD 14B41). However, a soils or
A structural engineer is required to review the location to see if SDD 14B41 is appropriate. Indicate in plan (e.g. plan view and MQ sheets) the location of roadside retaining wall. Soils or structural engineer is to determine gradation of select borrow.

If SDD 14B41 is not structurally adequate for a given location, structural design is required (see FDM 11-45-2.3.6.4.6). Insert construction details, special provision, and special bid items for special roadside retaining walls.

It is not recommended that the median retaining wall barrier design is used on the outside of the roadway. Contact BOS and TSS soil staff for assistance.

A minimum length of barrier is required to resist impact and soil loads. If this is not accounted a barrier may overturn or slide after an impactxxx. In a study conducted by TTI indicated that a minimum of 35 to 60 feet of barrier was required to prevent barrier movement during an impact. xxx TTI’s analysis was not WisDOT’s design. A structural engineer or soils engineer review is required to verify that the barrier/retaining wall design eliminates or reduces the threat of overturn or slide during an impact.

Pay for associated earthwork for 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).

A standard retaining wall is not considered a vehicle barrier system. Retaining walls may not have a crashworthy surface (e.g. snag points, too rough of a surface) or strength to contain a vehicle without damaging the wall. A report by TTI using computer modeling of a TL-4 impact “indicated that panels alone cannot resist direct impact of such severity.”xxx

Repairing a damaged retaining wall may be difficult. Review the consequences if a retaining wall should fail because of an impact. Additional engineering is required when using a retaining wall as a barrier.

### 2.3.6.4.5 Use of Concrete Barrier Single Slope (CBSS) on Bridges

The CBSS may be used on a bridge in a non-outer parapet application (See SDD 14B32). An example of this situation would be when a barrier is required to separate an on or off ramp or CD lane from main line lanes on a bridge deck (see Figure 2.13). Separating vehicle travel lanes from a multi-use path or pedestrians still requires a crashworthy bridge parapet (see Figure 2.14).

When using a crashworthy barrier on a bridge, coordinate with BOS early in the design process. Indicate on plan the location of this barrier, use SDD 14B32, and insert a special provision, and special items for this barrier. Include bid items for reflectors and brackets.

![Crashworthy bridge parapet required](image-url)

**Figure 2.14 Crashworthy Barrier on Bridge**
2.3.6.4.6 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 vertical barriers

However, there may be other situations where the SDDs may not fit a given location (e.g. closely placed parallel bridges on super elevations, not enough room for the transitions) or fixed objects are incorporated into a barrier system (e.g. sign bridges, light poles). In these situations, barriers or fixed object designs are required to:

- Have sufficient reinforcement for:
  - Shrinkage and temperature steel
  - Contain a TL-3 impact 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 impact
- Provide clear cover for steel
- Provide working width (See FDM 11-45-2.3.6.2.2)
- Use crashworthy shape (See FDM 11-45-2.3.6.1)
- Allow for smooth redirection
- Be free of snag points
- Limit potential for vehicle vaulting
- Limit potential for flying debris

Coordinate early in the design process with BPD on the use of non-standard barrier. Structural analysis will be required. Place additional documentation in DSR justifying the use of special barriers or special transitions.

Provide constructible designs that are structurally and functionally adequate. Construction details, special provisions and special bid items will be needed.

2.3.6.5 Concrete Barrier Placement

The minimum required offset from edge of driving lane to face of barrier (at the toe) is the greater of shoulder width or the required horizontal clearance. WisDOT’s practice on some high-speed divided highways has been to place concrete barrier 2-feet beyond the edge of shoulder (i.e. shy distance).

Shy distance is desirable, but not required design criteria for barrier placement. If a designer has to choose between providing shy distance or working width (see FDM 11-45-2.3.6.2.2) provide working width.

2.3.6.6 Median Barrier

Concrete barrier is typically installed in medians that are 40 feet or less. It is desirable to install two runs of
concrete barrier. The advantages are:
- Fixed objects (e.g. signs, light poles, sign bridges, bridge piers…) can be located between the barriers and are less likely to be hit.\(^5\)
- Fixed object designs are not required to accommodate impact loads
- Snow storage
- It is less likely that a vehicle will penetrate or over top barriers and end up in opposing traffic.

In general, it is desirable to use two runs of barrier when:
- 4-lane A3 roadway’s median width is 19 feet or greater
- 6-lane A3 roadway’s median width is 31 feet or greater

A single run of concrete median barrier may be appropriate for some projects. Provide documentation within DSR for using one run of median barrier. Factor to consider include:
- Insufficient room for two runs (shoulder width, shy distance to barrier, width of hazard, working width)
- No or few fixed objects in median
- Construction staging and work zone traffic control.

### 2.4 End Treatments

Untreated ends of barriers, blunt objects or non-crashworthy end treatments exposed to oncoming traffic are significant hazards. These objects can cause excessive deceleration, spear into the cab of the vehicle, or launch a vehicle into the air. In some cases, the barrier system relies on the end treatments to provide strength for the entire barrier system. Review guidance in FDM 11-45-2.5.4.

End treatments may require individual construction details (see FDM 11-45-2.5) and cross sections. End treatments may not fit or function as intended if this information is not included in the plan. In some cases, improperly installed end treatments can degrade the strength of an entire barrier system.

Most end treatments are proprietary products and are on an approved products list. Avoid placing multiple end treatments in close proximity to each other (see discussion in FDM 11-45-2.4.1.2).

Current research indicates that beam guard terminal crashes are \(^{x011}\):
- 2.5 times more likely to cause driver injury when compared to impacts 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.

### 2.4.1 Energy Absorbing Terminals (EATs)

EATs are proprietary crashworthy end treatments that are attached to beam guard. With other appropriate hardware, a EAT can be used to shield the blunt end of a concrete barrier. EATs also provide structural strength for semi-rigid barrier systems.

Install EATs when an errant vehicle could have a head on impact with the blunt end of a semi rigid barrier. Install EATs, with additional hardware, when an errant vehicle could have a head on impact with the blunt end of a rigid barrier. If an EAT cannot be installed or it is not appropriate to install an EAT review other crashworthy options (sand barrel array, crash cushion, specialty terminals)\(^6\).

EATs may also be installed on the downstream end of a beam guard installation on a one-way roadway (e.g. where a Type 2 terminal is typically installed).

CMM 6-26 contains additional information on typical construction problem encountered when installing an EAT. This CMM section also has a link to an FHWA video on beam guard end treatments. The video discusses the history and design of many different types of end treatments. Although portions of the video cover hardware that WisDOT does not use, the video does discuss the operation of EATs.

During a head on impact, a EAT is capable of absorbing tremendous amounts of energy through the reshaping of rail over the entire length of the EAT. Angle hits between the head and post 3 will result in only a short section of rail being reshaped before the vehicle passes behind the EAT and barrier. Impacts beyond post 3 (e.g. post 4, 7), the EAT acts like the semi rigid barrier it is connected to. To properly shield a hazard the end of barrier

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\(^5\) See working width discussion in FDM 2.3.6.2.2

\(^6\) The use of a specialty terminal requires preapproval and coordination with BPD. Special provisions, special details drawings, public interest findings, additional engineering, and documentation will be required.
need (i.e. LON point) is post 3 of the EAT (see FDM 11-45-2.3.1.3).

**SDD 14B24** is the EAT SDD for Class A beam guard. **SDD 14B44** is EAT SDD for MGS beam guard. Use the appropriate EAT with the appropriate beam guard (e.g. MGS EAT with MGS, EAT with Class A). In the plans, identify EAT location by the station and offset of post 1 of the EAT.

Provide individual construction details for EAT installations (see FDM 11-45-2.5). Cross sections are required to properly install EATs and have the EATs properly operate. Not providing individual construction details and cross sections requires documentation in DSR. Provide station and offset of EAT Post 1 in plan.

In most cases, the department installs TL-3 EATs. In some situations, a TL-2 EAT could be installed. Limited site by site exceptions may be granted by BPD. Document the exception in the DSR. Special details and special provisions are required to install a TL-2 EAT. It is recommended coordination with BPD occur early in the design process.

EATs are not designed to accommodate the following situations (list is not all inclusive):

- Bending the rails to accommodate a radius.
- Post spacing that is smaller than what is indicated on the SDDs.
- Connecting to beam guard with significantly reduce working width without some intermediate beam guard (see FDM 11-45-2.5.2.8).
- Connecting to a rigid barrier without a transition.
- Connecting to a short radius system without a tangent section normal of beam guard prior to the EAT.
- Installing with nested rail within the EAT.
- Installing railing (e.g. railing or wooden planks) on the backside of the EAT for bike or pedestrian protection.

If there is a question on if an EAT can be modified to accommodate a situation, contact BPD.

### 2.4.1.2 Fixed Object Placement and EATs

**Figure 2.16** is a plot where test vehicles came to rest after impacting various end treatments at 62 mph. This figure also includes AASHTO’s Roadside Design’s recommended 75-foot by 20-foot area that should be traversable and free of fixed objects (i.e. yellow area). Crash testing for end treatments is performed on flat or near flat terrain. In real world applications, vehicles may travel further than what is indicated in **Figure 2.16**.

![Figure 2.16 Final Resting Position of Test Vehicle after Impacting End Treatments](image_url)
Avoid placing objects, even breakaway hardware, just behind an EAT (i.e. yellow box). The intent is to have the errant vehicle engage only one object during a collision (i.e. the EAT). Collisions into multiple objects are extremely complicated and are more likely to have negative consequences. In Figure 2.17, the rock face will likely be impacted by an errant vehicle after it gates through the EAT.

Avoid placing objects just upstream of an EAT (approximately 75 feet). Objects placed upstream of an EAT can “funnel” an errant vehicle towards the EAT or cause the errant vehicle to have a collision into multiple objects. Figure 2.18 has a breakaway sign that is too close to the beginning of the EAT. The sign could cause an errant vehicle to hit the EAT in a non-tracking mode. Non-tracking crashes into an end treatment are more likely to have negative outcomes.

In some situations (e.g. urban areas, low speed), the area that that AASHTO indicates be free of fixed objects
and traversable grading may be smaller. Document these locations in the DSR.

Review placement of objects near EAT prior to PSE submittal. If there are conflicts, adjust the placement of the object or EAT.

EATs, like many other end treatments, are intended to operate independently (See Figures 2.19 and Figure 2.20). Avoid placing two EATs, or other end treatments, in close proximity (e.g. narrow medians, gores). EATs are not designed for backside hits. Impacts into the first EAT may make it difficult for second EAT to function.

![Figure 2.19 End Treatment Placed in Close Proximity](image1)

![Figure 2.20 Results of Placing End Treatments in Close Proximity](image2)

Other end treatments (e.g. thrie beam bullnoses, crash cushions, a specifically designed end treatment for semi-rigid barriers) are more appropriate where there is a narrow width between barrier installations.

Contact BPD for assistance at locations where end treatments are in close proximity (typically 25 feet or less). Additional engineering, DSR documentation, special details, special provisions may be required. In some cases,
proprietary product finding may be required. It is recommended that this coordination occur early in the design process.

2.4.1.3 EAT Grading

In 2004, FHWA released a memorandum that emphasized the importance of advance, adjacent and run-out grading (see Figure 2.21). Advance grading is provided to allow a vehicle to avoid hitting the EAT or allows the vehicle to properly engage the EAT. Adjacent grading helps to provide vehicle stability during the moment of impact and provide structural strength to the whole barrier system. Run-out grading provides an area for a damaged vehicle to come to a stop prior to impacting a fixed object that the barrier system is trying to shield. Note that the tree in Figure 2.21 may get impacted by errant vehicle that passes behind the EAT.

![Figure 2.21 EAT grading Locations](image)

AASTHO indicates that the desirable grading would be the whole traversable area in Figure 2.16. WisDOT does allow modification 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 is not required for the additional area indicated in the 2011 AASHTO Roadside Design Guide (see Figure 2.15), but it is considered a best practice.

Insert cross sections at posts 1, 5, 9 and at the beginning of approach taper into plan. Review how various slopes blend into each other near EAT. The transitions from one slope to another should be smooth as practical. Blending of slopes will help minimize vehicle instability prior to and after impact with the EAT.

Eliminating or reducing the amount of earthwork at an end treatment may have a significant impact on performance of the barrier system (see FDM 11-45-2.4.1.5). Grading and shaping barrier system item may be used to grade EAT (see FDM 11-45-2.5).

The quality of the soil outside the roadway’s core may not be suitable material to build a fill on. Review the need to bench the EAT’s earthwork into existing roadway slopes or if material needs to be removed prior to constructing fill for an EAT. If benching is required, show benches in the cross sections provided for the EAT. If soil is needed to be removed, show the removal in the cross sections as well.

Review drainage and right-of-way near EAT early in the scoping or design process to see if additional right of way is required. If EAT grading interferes with ditch drainage, review installing a parallel culvert pipe (see FDM 11-45-2.6) to maintain drainage. In some situations, a parallel culvert pipe may also reduce the need for right of way and allow for proper grading adjacent to the EAT. Additional right-of-way may be required to install an EAT.
with appropriate grading.

### 2.4.1.4 Extending Barrier Installation for EAT Grading

Minor shifts in EAT locations to account for transitions and rounding up to get an even number of rail sections do not require additional documentation. Shielding of a secondary hazard, or to avoid having fixed objects within the area near the EAT require some documentation. Installing an EAT without grading requires a designer to evaluate and document the moving the EAT to a different location.

If it is not possible to get the preferred grading for an EAT, use the following options (in order of preference):

1. Provide alternative grading at initial 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 location where alternative grading can be provided.
4. Install EAT with substandard grading.

In some situations, flaring a barrier system may allow for a shorter overall barrier length. This may allow for appropriate grading. Note that thrie beam transitions to rigid barrier cannot be flared.

When barrier is being extended to accommodate grading, use one of the following methods (in order of preference):

1. Length Factor.
2. Cost Ratio.
3. Other Factors.

#### 2.4.1.4.1 Length Factor

If has been determined that 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 that the barrier system may be extended using the length factor method.\(^7\)

**Example:**

Given:
- Barrier run length is 312.5 feet
- Extension factor 1.6
- The designer has determined that 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 = \(312.5 \times 1.6 = 500\). Any location from 312.5 to 500 feet in front of the hazard being shielded that allows for grading may be selected.

When using the length factor, provide documentation in the DSR.

#### 2.4.1.4.2 Cost Ratio

If grading for the EAT cannot be provided within the length factor range, the barrier may be extended beyond the length factor range using the cost ratio. If the total cost of EAT installation at the desirable location divided by the total cost of the additional length of barrier to provide grading is greater than 6, extend the barrier to provide grading. The ratio is based on the relative crash cost of impacting a barrier system verses impacting an EAT.\(^{xxxvi}\)

**Example:**

Given:
- Barrier run length is 312.5 feet
- Length Factor 1.6

---

\(^{7}\) 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.
The designer has determined that it is not feasible to provide grading for the EAT at the desirable location (i.e. 312.5 feet prior to the hazard).

Maximum length of barrier using length factor method is 500 feet prior to the hazard.

If it has been determined that it is not feasible to provide grading at any location from 312.5 feet to 500 feet prior to the hazard being shielded.

Find:

Does a location 650’ prior to the hazard being shielded satisfy the cost ratio requirements?

The cost to provide additional barrier and EAT measured from the desirable location (i.e. 312.5 feet prior to the hazard) to 650 feet prior to the hazard = $5,000

The cost of providing EAT and grading at desirable location (i.e. 312.5 feet prior to 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 prior to hazard.

Document cost information and analysis in the DSR.

### 2.4.1.4.3 Other Factors

In some situations, there may be significant impacts that prevent appropriate grading or relocating a terminal. Careful consideration of the operation of the barrier system must be made in conjunction with the other needs of the roadway and its surroundings.

Designers wishing to use one of these other impacts to justify not installing grading for an EAT should contact BPD early in the design process. Additional analysis is required within the DSR. Analysis is to indicate the scope of the impact to provide grading of the EAT and analysis of the other previously stated methods for altering an EAT location.

Avoid aesthetic reasons to justify not installing a barrier system correctly. Review FDM 11-45-2.5.6.

Approvals to install EATs without grading because of other factors will be done on a case-by-case basis by BPD.

### 2.4.1.5 Substandard Grading

There may be situations where moving and providing acceptable grading for an EAT is not feasible. In these cases, providing a crashworthy end treatment with substandard grading is more desirable than providing a down turned end or non-crashworthy end treatments.

Installing substandard grading can only be considered after previous options of providing alternative EAT locations has been reviewed. Provide documentation in DSR when reducing the grading. Eliminate grading in the following order of preference:

1. Reduce or eliminate 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 steepen run out path slopes.
4. Reduce slope beyond the hinge line to 3:1.

Reducing or eliminating EAT flare is discussed in FDM 11-45-2.4.1.6.

Reducing the grading between the EAT head hinge point may make it more difficult for a vehicle to maintain stability during or just after an impact. Reducing grading to less than 2 feet can weaken the whole semi-rigid barrier system.

Research conducted by MwRSF indicates that providing the recommended grading reduces the chances of rollover after impacting an EAT. In the same report, MwRSF indicated that 3:1 slopes may be used in runoff areas so long as the soil was firmly compacted to prevent rutting. Use of 3:1 slopes may reduce flexibility for future projects to adjust profile and require the use of a flat run out area beyond the 3:1 slope. Review 3:1 slopes for flat spot at the toe of ditch and fixed objects on the slopes or at the toe of slope.

Approach taper may be steepened to 4:1.

### 2.4.1.6 Curb and Gutter near EAT

In areas with curb and gutter, it is desirable to install driveway curb from post three of the EAT to 100 feet out in
advance of the guardrail extruder head. A minimum of 25 feet in front of the guardrail extruder head is needed in confined locations. Extend driveway curb to post three of the EAT. Review drainage near EAT.

Provide information on the plan where the driveway curb is located (i.e. individual construction detail). If this is not provided, there can be conflicts and delays during construction. If providing paving details or curb and gutter detail, locate driveway curb on these details. Typically, one contractor will install curb and gutter, and another will install the EAT.

2.4.1.7 Flare EAT

EATs can be installed tangent or flared from a roadway. If beam guard is installed tangent to the roadway, the maximum flare rate for an EAT is shown on SDD 14B24 or SDD 14B44.

If the beam guard is flaring away from the roadway prior to the EAT, install the EAT without additional flare measured from the beam guard (e.g. if the beam guard is at flared 15:1 from the roadway the EAT should be flared at 15:1 from the roadway).

In urban and suburban/transitional areas where it is difficult to acquire space for EATs, the rail offset from flow line of curb can be reduced down to 1 foot. Any offset less than 1 foot will more than likely lead to additional hits by snow plows because some of the EAT heads will extend beyond the flow line of curb. It is not recommended to reduce the flare rate in rural areas. Discuss with local government and regional maintenance staff about the use of reducing the flare rate prior to final design.

Provide information on the plan where a reduced or no offset is provided for in the plan (i.e. individual construction detail).

2.4.2 Downturned Ends, Sloped Concrete End Treatments or Blunt Ends

Downturned end treatment (see FDM 11-45-2.5.4), sloped concrete end treatments (see FDM 11-45-2.5.6) or blunt ends (see FDM 11-45-2.5.4) are not considered crashworthy. These end treatments can launch vehicles into the air, decelerate a vehicle too quickly or spear into the cab of the errant vehicle.

Department’s policy is to not install downturned ends, slope concrete end treatments or blunt ends when other crashworthy end treatments are other viable alternatives.

Limited project by project DJs for downturned ends, sloped concrete end treatments may be granted by BPD. Document in DSR the use of a downturned end treatment and why other more desirable end treatments are not feasible at a particular situation. BPD is aware of some situations that would allow the use of a downturned end or sloped concrete treatment. These situations are:

- A project is using a non-standard barrier system and the only end treatment that can be attached is a downturned end or a sloped concrete end treatment.
- A combination of unique topography and roadway geometry allows for the installation of a downturned end or sloped concrete end treatment.\(^8\)
- New sloped concrete end treatments are acceptable on roadways with posted speeds of 25 mph or less.

Coordinate early in the design process with BPD to determine if a downturned end or sloped concrete end treatment is appropriate. Document in DSR the use of why other more desirable end treatments are not feasible at a particular situation. Avoid using aesthetical concerns to justify the installing a downturned end or sloped end treatment.

Additional design effort, special details, individual construction details, and special provisions are required. Structural design will be required for a sloped end treatment (see FDM 11-45-2.3.6.4.6).

For most beam guard and concrete barrier installations, do not install a blunt end were an errant vehicle can have a head on impact to the blunt end. If installing a blunt end that can be hit head-on coordinate with BPD. Locations where blunt ends can be hit head on will be approved on a case by case basis.

2.4.3 Type 2 End Treatments

These end treatments are installed at locations where an errant vehicle cannot have a head on impact with the end treatment (e.g. downstream end of a beam guard on a one-way road) or in locations where it is unlikely to be hit (i.e. downstream end of a beam guard installed in a wide median on a freeway or express way). Type 2 end treatment can be found on SDD 14B16 (class A) and SDD 14B47 (MGS).

\(^8\) BPD is aware of only one such location in the state.
Computer modeling and recent crash testing with the MGS Type 2 has indicated that vehicle will gate through the end treatment (see Figure 2.22).

Options available to designer are:
- For hazards placed close to the beam guard, extend beam guard 39.5 feet beyond the hazard and place a Type 2 end treatment.
- For hazards placed further away from the beam guard the Type 2 end treatment can be placed closer to the hazard (see Figure 2.22).

For example, if a fixed object (e.g. pole) is 15 feet behind the beam guard it may be possible to have the end post of the Type 2 end treatment flush with the end of the fixed object hazard (i.e. Both the Type 2 and the hazard being protect would have the same stationing but different offsets).

Some situations where it is not appropriate to install a Type 2 end treatment within 39.5’ of a hazard are (list is not all inclusive):
- Steep slopes,
- Water,
- Cliffs,
- Areas of Concern for Pedestrians,
- Areas with High Consequence of Collision,
- Areas where gating through the Type 2 terminal will allow a different fixed object be struck.

If a hazard has to be placed in the area where the Type 2 will gate or within the working width of the Type 2, provide documentation in the DSR.

Provide working width for MGS Type 2. Document in Design Study Report (DSR) when working width cannot be provided.

Indicate the location of end post of a Type 2 in the plan.
If curb and gutter is being used, transition from typical curb and gutter to driveway curb and gutter between post 6 and 7 in Figure 2.22. Install driveway curb and gutter 32 feet downstream of the end posts.

2.4.4 Crash Cushions and Sand Barrel Arrays

Where fixed objects cannot be removed, relocated, made breakaway, or shielded adequately by roadside barrier a WisDOT approved crash cushion or sand barrel array may be appropriate. Typically, other barrier systems (e.g. thrie beam plus EAT) should be looked at prior to selecting a crash cushion or sand barrel array. However, sand barrel arrays and crash cushions are often the only effective ways to shield narrow rigid hazards from impacts.

A crash cushion is a manufactured product designed to absorb impact energy by deforming the components of the crash cushion. Crash cushions redirect errant vehicles that impact the side of them. Depending on the severity of the initial impact and the type of crash cushion used, a crash cushion may have the potential to shield a second impact or be put back into service relatively quickly.

An array is a series of barrels filled with a mixture sand and salt. During an impact, an errant vehicle’s momentum is dissipated by impacting various weighted drums in the array. Arrays typically do not allow for redirection of an errant vehicle during a side impact. Typically, after an initial impact an array has limited to no capability to shield a second impact.

Crash cushions and arrays are proprietary devices. Typically, arrays can have barrels from different manufacturers intermixed, while crash cushions cannot intermix parts from different manufacturers.1

In temporary work zones, if the approach end of a temporary barrier terminates within a clear zone and the posted speed is 30 mph or greater provide a crash cushion or sand barrels. If site conditions prevent the proper installation of a crash cushion or pad during a temporary work zone, provide documentation in the DSR.

Designers are to discuss selection of permanent crash cushions or arrays with local maintenance staff. Proper long-term operation of these systems depends on proper maintenance. It becomes more difficult, although not impossible, for local agencies to maintain multiple systems. Maintenance input may influence final design of a location, or the selection of a system. However, maintenance concerns should not be the only factor in the selection process for a given location or project.

2.4.4.1 Design Criteria

The fundamental design criteria for designing a 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 and direction of traffic. Include information previously listed in the miscellaneous quantities requirements for each installation.

Length on need point for most crash cushions is within 2 feet of the crash cushion nose or first metal diaphragm. In many cases, the location of the length of need point may not matter (e.g. Crash cushion is protecting blunt end of two barriers in a gore). Cases that the length of need point may matter are when the barrier is protecting a hazard that extends along the direction of travel (e.g. concrete barrier is shielding a steep slope and is going to have a crash cushion attached to it).

Length of need point for arrays is the first barrel.

Provide individual construction details drawings for each crash cushion or array installation. In the individual construction detail drawing provide information on grading near crash cushion or array, width and length available for installation and what the array or crash cushion is shielding.

Standard bid items will indicate system maintenance requirements for crash cushions. It is recommended that projects do not use special provisions for crash cushions. In the past, there have been the following problems with special provisions for crash cushions (list is not all inclusive):

- critical component missing from contract documents
- problems with consistency between special provisions
- standard bid items or other project's special provisions
- specifying a product that is not required/allowed.

These issues and similar issues have caused delays, increases in project costs, and have led to less than desirable installations.

It is recommended that the designer contact manufacturers for the most current design information on their product. Manufacturers’ contact information can be found within the Department’s Approved Product List.
2.4.4.1 Sand Barrel Considerations

Department policy is to limit the installation of permanent sand barrel arrays to locations where crash cushions cannot reasonably be installed. In general, sand barrel arrays are typically more expensive to maintain, and in certain impacts not as safe as a crash cushion (arrays will allow the vehicle to gate through, vehicles can hit the heaviest barriers first…). Document the decision to install a sand barrel array in DSR. See system maintenance discussion.

The barrels typically vary in height based on design function and manufacturers. The use of an array and may affect the site distance of turning vehicles in the vicinity of the array. Review sight distance near the array. Indicate if the array is to be 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, indicate the crash test level for each array. See the Roadside Design Guide Chapter 8, for additional guidance on placement of sand barrels.

Arrays are to be placed on asphalt or concrete pads, unless manufacturer’s specification state otherwise. Show a pad for the array on the plan sheet, but it is the responsibility of the manufacturer to provide the actual design of the pad. Designer’s responsibility is to provide sufficient room to install an array.

When providing space for an array using the following guidance:
- Provide minimum offset from last few rows of barrels and end of hazard (see Figure 8-40 of 2011 Roadside Design Guide)
- 6 inches of space between barrels
- Barrels are 3 ft wide

Desirable new arrays would also include the following features:
- For Bidirectional installation of arrays install some barrels to reduce severity of reverse direction impacts (see Figure 8-41 of 2011 Roadside Design Guide).
- Angle arrays toward traffic (see Figure 8-42 of 2011 Roadside Design Guide).

Indicate in the plan that the array should be installed with additional barriers to reduce reverse direction impacts or if array is angled towards traffic.

2.4.4.2 Crash Test Condition

Table 2.5 indicates what crash test levels are to be used for various Design Speeds for crash cushions and arrays.

<table>
<thead>
<tr>
<th>Speed (MPH)</th>
<th>Crash Test Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤25</td>
<td>NA –Concrete Sloped End Treatment</td>
</tr>
<tr>
<td>&gt;25 to 45</td>
<td>TL-2</td>
</tr>
<tr>
<td>≥45</td>
<td>TL-3 *</td>
</tr>
</tbody>
</table>

* In confined locations, a TL-2 system may be installed for speeds of 45 MPH.

2.4.4.3 Area Requirements

Figure 2.23 and Table 2.6 provides two sets of dimensions for providing a crash cushion. The majority of crash cushions on the Department’s Approved Products list will fit within the desirable dimensions. Manufacture’s crash cushions are required to be anchored into the ground by use of a concrete/asphalt pad or a backing block. Designers using the standard specifications do not need to provide details for pads and backing block or payment items.

Not providing sufficient space for the concrete pad or backup block may not allow for proper operation during an impact (i.e. the N dimension in Figure 2.23 is an approximation for concrete pad width). Typically, the pad dimensions are bigger than the actual crash cushion.

Review pad location for underground conflicts. Most manufactures can use an 8-inch deep concrete footing to anchor a crash cushion. Some manufacturers allow the use of asphalt for temporary crash cushions, but if the hazard is 4 or more feet in width most manufactures require a concrete pad for a temporary crash cushion.

Minimum dimensions should not be used in areas where there is reduced shoulder width, because there will be limited room to install the crash cushion or to allow for maintenance of the crash cushion. Some manufactures’
systems may not fit within minimum dimensions. Designer is to review manufactures’ information to verify that a system can fit within a location.

![Diagram of crash cushion installation](image)

*No curbs, raised pavement, or pavers to be built or to remain in the area surrounding or occupied by the crash cushion.*

**Figure 2.23 Area Requirements for Crash Cushions**

**Table 2.6 Area Requirements for Crash Cushions**

<table>
<thead>
<tr>
<th>Design Speed (MPH)</th>
<th>Minimum (FT)</th>
<th>Desirable(FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>L</td>
</tr>
<tr>
<td>30</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>35</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>40</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>45</td>
<td>6</td>
<td>15</td>
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<tr>
<td>50</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>55</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>60</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td>65</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>70</td>
<td>6</td>
<td>28</td>
</tr>
</tbody>
</table>

Note: Intermediate values in Table 2.06 are linear interpolations of data from AASHTO Roadside Design Guide Figure 8.4.

When proposing to use minimum area dimensions, document the impacts of using the desirable dimensions and provide justification for use of the minimum area in DSR or as an amendment to the DSR. When proposing to use the minimum dimension, designers are to consider the use of a low-maintenance crash cushion. Document why a low maintenance system is not being used in areas were minimum area is being provided.

It is desirable to use minimum area requirements for crash cushions installed in construction zones. If the minimum area cannot be provided at a construction zone installation, document why. Type of work going on near the crash cushion or overall area available by a crash cushion or pad may limit the effectiveness of a crash cushion. However, installing a crash cushion may be the best available option.

**2.4.4.1.4 Back Width Requirements**

Back width is the dimension of the hazard that requires protection. Typically, crash cushions are as wide or wider than the hazard they are intending on protecting.

Dimension F in Figure 2.23 should be adequate for most crash cushion installations. However, with some projects, typically retrofit projects, the back width may be larger than what is indicated in Table 2.6. Manufacturers can provide wider crash cushions, or an array can be used. Get BPD approval to use wider crash cushion or array.

Wider crash cushions will cost more to repair than standard sized crash cushions. Limit the use of wider crash cushions to locations where it is not feasible to install other barriers system to narrow up the back width (e.g.
concrete taper or beam guard). Generally, the department would use concrete barrier that tapers to the widths indicated in Table 2.6 to minimize the cost of future repairs. See FDM 11-45-2.3.6 for guidance on narrowing a hazard with a concrete barrier. Beam guard or thrie beam transitions to larger hazards are typically only acceptable if the barrier system shielding the hazard is beam guard or thrie beam. If planning to use a beam guard transition for wider hazards, contact BPD.

Using the minimum back with may limit what systems can be installed. It is recommended that the desirable distance for dimension “F” in Table 2.6 be use even if the other minimum dimensions are used.

When determining the back width of a hazard, use the outermost limits of the hazard. If there are two barriers in close proximity, use the outside toe of barrier to outside toe of the other barrier as the measurement of back width. If there is a hazard that is near a barrier, use the distance from the outer toe of the barrier to the outside edge of the hazard for back width dimension.

Where the crash cushion attaches to concrete barrier the concrete barrier shall be 32” tall. Height transitions and width transitions may need to be used to get the crash cushion properly installed.

2.4.4.1.5 Grading

Grading in the leading to or alongside a crash cushion or array is not to be greater than 10:1. Curb and gutter will make it more difficult for crash cushions or arrays to perform as intended. Curb and gutter is not to be installed on the approaches to or alongside new crash cushions or arrays installations.

It is desirable to remove curb and gutter near an existing crash cushion or array. 4-inch sloped face curb and gutter may remain in place if the crash cushion does not have a history of poor performance. If there is a history of poor performance, it is desirable to remove curb and gutter. If curb is taller than 4-inch or vertical shaped, replace with 4-inch slope faced curb.

For existing installations, analyze the need for existing curb and gutter, consequences of removing curb and gutter, existing crash cushion or array performance, and other alternatives considered. Include analysis in DSR.

As crash cushions or arrays are installed further away from the roadway edge, it become more and more difficult to integrate the crash cushion or array’s grading with other grading needs. Cost of the grading may be more expensive than installing a crash cushion. A different barrier system may be more easily integrated into the overall design.

2.4.4.1.6 Maintenance Requirements

Some crash cushions are designed specifically to be easier, faster, or less expensive to repair. Typically, these systems cost more to install than a standard crash cushion. 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.

If there is no crash data available or the crash data indicates that an existing crash cushion has 4 or more years between impacts use (in order of preference):

1. Desirable maintenance criteria tables in Attachment 2.20.
2. Less than desirable maintenance criteria tables in Attachment 2.20.

If a crash cushion is experiences less than 4 years between impacts or if there are other issues factoring into the selection a low maintenance crash cushion may be used. Some of the other issues factoring into the selection of a crash cushion are:

User delay;
Roadway facility is operating at capacity and it would not be feasible to repair cushion during the off-peak time or at night.

Exposure to the traveling public or maintenance staff;
Geometric or cross-sectional issues present near the crash cushion (e.g. there is little to no shoulder, a high-volume ramp gore requires a crash cushion, areas where there is little to no shoulder).

Violation of driver expectations;
Geometric issues are present (e.g. left-hand off-ramp, curve hidden by hill).

Figure 2.23 indicates that a “12:1 taper (Min)”. Flatter tapers (e.g. 20:1, 15:1…) are acceptable.
If a location is being struck at such a high frequency that it is difficult for maintenance staff to maintain using a crash cushion with some residual capacity may be appropriate (i.e. one or more impacts within a week). Contact Bureau of Project Development for assistance. Special provisions will be required. A proprietary product finding may be required. Provide documentation on the criteria used when select maintenance requirements for a given crash cushion installation in the DSR.

Provide discussion in DSR when selecting a crash cushion from the less than desirable tables, installing a low maintenance crash cushion because of crash frequency or other issues. Provide a summary of police reports or maintenance repair records in the DSR to justify frequency of crash cushion impacts.

2.4.4.1.7 Object Marking Pattern

Indicate in the miscellaneous quantities, the object marking pattern required for a given installation. Manufacturers will provide the appropriate marking on the front of their specific systems to conform to the marking pattern indicated.

For permanent installations:
- When the installation is on the left side of a one-way road, indicate the use of marking pattern OM-3L (W5-58L sign plate).
- When the installation is on the right side of a one-way or two-way road, indicate the use of marking pattern OM-3R (W5-58R sign plate).
- When the installation is in the median or a gore between a ramp and the main line, indicate the use of 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, indicate the use of marking pattern OM-3L (WO5-58L sign plate).
- When the installation is on the right side of a one-way or two-way road, indicate the use of marking pattern OM-3R (WO5-58R sign plate).
- When the installation is in the median or a gore between a ramp and the main line, indicate the use of marking pattern OM-3C (WO5-58M sign plate).

In both situations, manufacturers will provide the black and orange marking pattern as required by MUTCD. Include appropriate WisDOT sign plates in the plan set.

2.4.4.1.8 Direction of Travel

There are two traffic directions: unidirectional direction (e.g. outside shoulder of a one-way roadway, gores between ramp and mainline) or bidirectional (e.g. temporary barrier divides north and south bound 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. If this information is not communicated to the contractor an installation may not perform as intended. For example, bidirectional traffic can require the use of a transition from temporary barrier to crash cushion.

2.4.4.1.9 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.

2.4.4.1.10 Object Crash Cushion Shields

The type of hazard can influence what hardware or layout is needed. Typical hazards are blunt end of temporary barrier and blunt end of permanent barrier. There may be some other hazards as well (e.g. permanent concrete barrier and bridge pier). Object being shielded may also influence crash cushion hardware. Provide information on what is being shielded and where the crash cushion is located in plan.

2.4.4.2 Miscellaneous Quantities Sheet

Below is a sample of the miscellaneous sheet for crash cushions and sand barrel arrays.
### Table 2.7 Crash Cushion Miscellaneous Quantity Sheet

<table>
<thead>
<tr>
<th>Location</th>
<th>614.0800 Crash Cushions Permanent</th>
<th>614.0805 Crash Cushions Permanent Low Maintenance</th>
<th>614.0905 Crash Cushions Temporary</th>
<th>Back Width FT</th>
<th>Object Marking Pattern</th>
<th>Crash Test Level</th>
<th>Traffic Direction</th>
<th>Traffic location</th>
<th>Crash cushion shields</th>
</tr>
</thead>
<tbody>
<tr>
<td>354+13, 30' R</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>4</td>
<td>OM-3C (W5-58M)</td>
<td>TL-3</td>
<td>Unidirectional</td>
<td>L and R</td>
<td>permanent concrete barrier in ramp gore</td>
</tr>
<tr>
<td>50 °c +67 10' L</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>2</td>
<td>OM-3C (W5-58M)</td>
<td>TL-2</td>
<td>Bidirectional</td>
<td>L and R</td>
<td>permanent concrete barrier in median</td>
</tr>
<tr>
<td>10 “temp” +15 R</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>OM-3R (W05-58R)</td>
<td>TL-3</td>
<td>Bidirectional</td>
<td>L and R</td>
<td>gore between temporary lanes single temporary barrier</td>
</tr>
<tr>
<td>357+80 45 L</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>2</td>
<td>OM-3L (L5-58L)</td>
<td>TL-3</td>
<td>Unidirectional</td>
<td>L</td>
<td>permanent concrete barrier on shoulder</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 2.4.4.3 Other Crash Cushion Considerations

There are times when at the end of a project a crash cushion has to be left in place because of traffic control issues and a future project will remove the crash cushion. It is recommended that the permanent crash cushion items are used to install the crash cushion that a future project will use.

Temporary crash cushion bid item uses some older crash cushions or crash cushion that may have high repair costs. During the time between projects, county forces will be responsible for maintenance. Repair crews are more familiar the crash cushions on the permanent crash cushion list and have easier access to replacement parts. The second project can remove the crash cushion when not needed.

The standard special provisions are designed to require the contractor to attach the crash cushion to the object being shielded. There could be situations where it is not feasible to attach the crash cushion to the object being shielded (e.g. traffic is temporarily closer to a metal pole during construction). In situations like this use a special provision to indicate the contractor is to follow the standard specifications except for connecting to the object being shielded.

Avoid placing crash cushions in close proximity to each other or having fixed object installed in close proximity of a crash cushion (see discussion in FDM 11-45-2.4.1.2).

#### 2.5 Existing Barrier System Evaluation

A significant amount of research has been invested into making barrier systems as safe as practical. However, there can be collisions into a barrier system that have serious consequences. Because of this, it is important to review the need and quality of existing barrier systems.

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10 A barrier system is all of the components needed to prevent an errant vehicle from impacting a hazard. A simple example of a barrier system would require all hardware shown on the standard detail drawings for beam guard, end treatments (separate SDD drawings), proper placement of the barrier relative to hazard and grading. Installing beam guard without all the other components (e.g. EAT, grading...) may degrade the beam guard’s performance.
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.”

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.”

Document in the Design Study Report (DSR) the following:

- The quantity of existing barrier systems,
  - Where are existing barrier systems located?
  - What type of barrier systems are on the project?
- The need for the existing barrier systems:
  - Can other roadside design methods be used to reduce the severity or frequency of collisions?
- 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 judge what action is appropriate (e.g. remove, spot improvement or replace existing barriers systems). Except for certain preventative maintenance (see PM Agreement) projects, not reviewing existing barrier systems is below minimum standards. Limited project by project DJs for barrier systems may be granted by Bureau of Project Development (BPD). Document in the DSR.

After determining that a barrier system is required, analyze the existing barrier system. Use Attachment 2.5 Roadside Design Factors to Consider and guidance provided in this sub-section to determine if spot improvements or full replacement of a barrier system is required.

It can be difficult to determine what action is appropriate (e.g. do I modify this barrier or replace it?). BPD has tried to provide clear guidance when it can (e.g. remove beam guard with 12-foot 6 inch post spacing). Many situations will require the professional judgment of an experienced engineer trained in roadside design. In general, BPD recommends:

- Installing barrier systems as indicated in the Standard Detail Drawings (SDDs) and Facility Development Manual (FDM).
- Fully replace barrier systems instead of performing a significant amount of spot improvements.
- Flexibility for an existing barrier system does not apply to newer installations of the same type of barrier system. Some examples are:
  - Existing beam guard has a range of acceptable heights. It is not appropriate to use this range of heights for new Midwest Guardrail System (MGS) beam guard installations.
  - Retrofitting a concrete sloped end treatment to shield an existing blunt end has more flexibility than installing a new concrete sloped end treatment for a new hazard.
- Remove barrier systems that are no longer needed.
- Remove or modify curb on approaches to or adjacent to a barrier-systems.
  - It is desirable to do the following (in order of preference):

11 Limited project by project DJs allowing modification of barrier system may be granted by BPD. Document in the DSR.

12 Barriers are hazards and require maintenance.

13 Some modifications may allow a barrier system to be installed by curb. See SDDs and FDM for details.

14 Contractors have access to equipment that makes removal of the head of curb easier to do.
- Remove curb and gutter.
- Use driveway curb and gutter.
- Use 4-inch sloped face curb.
- Shorten barrier installations that are longer than what is required to shield hazard or hazards.\(^{15}\)

Some of the design guidance for new barrier systems can be used to judge existing barrier systems (e.g. length of need, grading, working width\(^{16}\)). Additional guidance on existing barrier systems can be found in the following sub-sections. Guidance in this sub-section is applicable to roadside barriers systems. Some of the guidance may be applicable to parapets on or attached to structures. Contact Bureau of Structures (BOS) for guidance when working with parapets attached to structures or barriers used for structural protection.

A significant number of crashes occur in work zones. Replace or perform spot repairs on existing barrier systems that are in marginal condition prior to shifting traffic closer to or increasing traffic adjacent to existing barrier systems.

Document the following in the DSR:
- Not reviewing existing barrier systems.
- Leaving a barrier system that is no longer needed in place.
- Installing a “modified” barrier system to fit a given location.\(^{17}\)
- Not applying spot improvements or replacing a substandard barrier system.
- When applicable, not modifying existing curb or installing 4-inch sloped face curb.

Other items within this sub-section may require additional documentation within, as an attachment, or as an amendment to the DSR.

An individual construction detail for the installation of a barrier system may be required\(^{18}\). Typically, an individual construction detail is required when there is close interaction between grading, drainage, barrier system, hazards, underground obstructions, or structures. If these interactions are not addressed during the design, a barrier system or other features may not be installed correctly or perform as intended (e.g. Figure 2.31 Thrie beam is missing a post to install a flume). Figure 2.32 lacks appropriate grading near thrie beam transition). A construction project may experience delay or costly change orders. An example of an individual construction detail is in Attachment 2.6. See following sub-sections or SDDs for more information.

Individual construction details are site specific. Include the following in individual construction details: drainage structures (e.g. inlets, pipes, ditches) cross section/contours, hinge points, slope intercepts, structures (e.g. bridges, box culverts, retaining wall…) and underground obstructions (e.g. utilities, rock…). Typically, contours are required for complicated grading situations (e.g. wrapping slopes around a structure that has a transition to rigid barrier installed nearby…). Other items that may be in individual construction details are: post location and embedment, curb and gutter changes, radius of shop bent beam guard, fixed object, changes in working width, installations near driveways, etc.

Some barrier systems may have components that can be salvaged and reused. Coordinate with regional operation staff if components are to be salvaged. Provide local unit of government contact within plan.

Both removal and salvage items for barrier systems include language requiring the contractor to restore the site. For example, no additional items are required for filling holes left by old posts being removed or salvaged. Earthwork items may be required if performing modification to a site to install a new barrier.

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.

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\(^{15}\) This assumes that the barrier was not lengthened to shield other hazards or to allow for proper grading for the EAT.

\(^{16}\) Working width is the combination of barrier width and either the maximum barrier deflection or the maximum distance a vehicle could extend behind the barrier. If a barrier does not provide working width, an errant vehicle may engage the fixed object that the barrier was intended to shield.

\(^{17}\) Limited project by project DJs allowing modification of barrier system may be granted by Bureau of Project Development (BPD). Document in the DSR.

\(^{18}\) This guidance is recommended for both new barrier systems and retrofitting old barrier system installations.
When using the grading and shaping standard bid item, use a table like Table 2.8. Add note to miscellaneous quantities indicating that the other items are for bidding purpose only. It is not recommended to include other items into the grading and shaping bid item. Typically, other items (e.g. installing a pipe, erosion control…) require additional design.

<table>
<thead>
<tr>
<th>Location</th>
<th>Excavation Common*</th>
<th>*Borrow</th>
<th>*Salv. Topsoil</th>
<th>*Fert. Type (-)</th>
<th>*Seeding</th>
<th>*Mulching</th>
<th>Each</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sta.__ to Sta.__</td>
<td>C.Y.</td>
<td>C.Y.</td>
<td>S.Y.</td>
<td>CWT.</td>
<td>L.B.</td>
<td>S.Y.</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* = Items & Quantities listed for Bid Information Only. Show the quantities and units clearly in the table.

Provide termini for each individual location where grading item is being used. Use discrete locations to identify where grading and shaping. For example, a given EAT location or a whole barrier system (EAT, beam guard, transition to rigid barrier.) The standard bid item for grading and shaping can be used with all different types of barrier systems.

### 2.5.1 Flexible Barriers

Replace low-tension cable barrier systems installed in non-median locations (See Figure 2.24). Typically, these systems are not crashworthy, have fixed objects within a barrier’s working width or have grading issues.

Typically, median cable barrier installations are installed at cross median crash locations. Coordinate with BPD prior to removing or working near median cable barrier. Grading, cable barrier placement, drainage structures, and soil conditions can influence cable barrier performance. Some modifications of the cable barrier may be required.

Working width of cable barrier is measured from the traffic side of the cable. Many variables can impact the working width of a given installation. Discuss cable barrier working width with BPD.

It is recommended that curb and gutter near cable barrier systems is removed.

Forward questions about cable barrier to BPD. Special provisions and construction details are required when working on cable barrier. Typically, individual construction details are needed for interaction with drainage structures, and areas of reduced working width.

![Figure 2.24 Strong Post Low-Tension Cable Barrier to be Replaced](image-url)
2.5.2 Semi-Rigid Barriers

Non-MGS beam guard (See SDD 14B15, SDD 14B25), MGS beam guard (See SDD 14B42, SDD 14B43), transitions to rigid barrier\(^{19}\), bullnoses and curved beam guard are considered semi-rigid barrier systems.

General guidance (e.g. damaged components, missing components, washer between rail and bolt head, working width, LON…), can be applied to almost all semi-rigid barriers systems. However, there are some differences between systems (e.g. depending on speed, non-MGS beam guard requires modification and specific types of curb. MGS does not require modifications or special types of curb). What will work with one barrier system may not work with a different system. Know what barrier systems are within a project.

Working width for semi-rigid barrier installations is measured from traffic face of rail to front of hazard. Special applications of semi-rigid barrier may have different or additional requirements.

Some situations that require individual construction details are (See FDM 11-45-2.5):
- Installation of beam guard (non-MGS and MGS) next to or on top of underground obstruction, drainage features, or box culverts.
- Installation of beam guard (non-MGS and MGS) near retaining wall.
- Installation of beam guard (non-MGS and MGS) near a spot location with reduced working width.
- Installation of long span beam guard (non-MGS and MGS).
- Installation of transitions to rigid barrier systems (non-MGS and MGS).
- Installation of thrie beam bullnoses.
- Installation of curved beam guard.
- Installation of short radius beam guard.

Show post location and embedment on individual construction details when working next to or on top of an underground obstruction, drainage feature, or structures. Individual construction detail may be required to show dimensions of mow strip and changes of working width changes.

Only runs of semi-rigid barrier systems that do not require any grading, including end treatments, do not need individual construction details.

CMM 6-25 has examples of semi-rigid barrier that requires repair. Table 2.9 is an example of a miscellaneous quantity sheet using semi-rigid repair items. Use the limits of semi-rigid barrier installation to identify where work is required (e.g. from post number one of an EAT to post number one of an EAT, or post number one of an EAT to end of thrie beam transition). Additional location accuracy is not required.

### Table 2.9 Example Miscellaneous Quantity Sheet

<table>
<thead>
<tr>
<th>Location</th>
<th>204.0165 Removing Guardrail (LF)</th>
<th>614.0400 Adjusting Steel Plate Beam Guard (LF)</th>
<th>614.0920 Salvaged Rail (LF)</th>
<th>614.0950 Replacing Guardrail Posts and Blocks (Each)</th>
<th>614.0951 Replacing Guardrail Rail and Hardware (LF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2+00 to 3+00 LT</td>
<td>35</td>
<td>--</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3+00 to 7+35 RT</td>
<td>150</td>
<td>75</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8+00 to 10+50 LT</td>
<td>250</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15+00 to 19+00 RT</td>
<td>600</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>250</strong></td>
<td><strong>185</strong></td>
<td><strong>600</strong></td>
<td><strong>75</strong></td>
<td><strong>125</strong></td>
</tr>
</tbody>
</table>

2.5.2.1 Adjustment of Steel Rail Height

Top of rail for existing non-MGS beam guard is between 27 3/4 to 29 inches.\(^{xiii}\) Top of rail for existing MGS

\(^{19}\) Rigid barriers include bridge parapets and concrete roadway barriers.
beam guard is between 27 3/4 to 32 inches. Top of thrie beam rail is plus or minus 1 inch of the rail height indicated 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 locations. Do not measure rail height on damaged rail sections or at locations where erosion or other grade abnormalities would cause errors and height measurements.

Document in DSR that rail heights have been reviewed. Adjustment item (614.0400) may be used by itself or with other spot improvement items.

2.5.2.2 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). Indicate in plan when thrie beam is being replaced using the replacement of steel rail item. If Shop bent rail is needed, provide radii in plan (See FDM 11-45-2.5.2.12). Do not use steel rail replacement item on EATs because they are proprietary products.

2.5.2.3 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). 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

2.5.2.4 Straightening Blocks or Posts

Straighten posts or blocks that are out of plumb. Straighten posts that are more than 6 inches out of plumb. Use the adjust item (614.0400) for straightening blocks or posts.

2.5.2.5 Other Hardware Issues

The following issues require special provisions:

- Remove washers installed between the head of a bolt and traffic side of steel rail. A washer in this location can cause semi-rigid barrier to fail.
- Replace delineators that are missing.
- Rails are not lapped in the proper direction (see SDD 14B15).

2.5.2.6 Use of Salvage or Removal Bid Item

Use salvage and removal bid items separately. Use removal item (204.0165) if contactor is to dispose of all components.

Use salvage item (614.0920) to reclaim metal components. It is not the intent of the standard specification to reclaim wood materials. Once a post is installed and cut to proper height, it may be difficult to reuse the post in another installation. Exposure to the elements may weaken a wood post.

Use a special provision in the following situations:

- Reclaiming all semi-rigid barrier components (e.g. metal and wood components).
- If the contractor is to remove hardware, others are to select what hardware is to be reclaimed, and then have the contractor remove the remaining hardware from the construction site.

Removing semi-rigid barrier can facilitate other work or can allow for a better finished product. For example, an overlay project can add a significant amount of shoulder material. Removing the beam guard can allow proper compaction of new shoulder material and proper compaction can reduce shoulder erosion.

Review grading near soil or foundation tubes. These tubes provide strength for a whole semi-rigid barrier system.

2.5.2.7 Grading for Semi-Rigid Barriers

All semi-rigid barrier systems use soil to absorb impact energy. Some semi-rigid barrier systems can be modified to accommodate locations with reduced grading. Other semi-rigid barrier systems do not have the same flexibility. Grading options for semi-rigid barrier systems can be found on the appropriate SDD or
discussed in the following sub-sections. See discussion in FDM 11-45-2.5 on providing earthwork in plans near barrier systems.

Visual gaps between soil tubes (or foundation tubes) and soils around the tube reduce the amount of force the anchors can absorb. Small gaps should have soil replaced around the tube and compacted. Replace soil tubes when a soil gap is one inch or more. If there are issues with gaps around soil tubes, provide special provision to either reset soil tubes or replace soil around post.

2.5.2.8 Beam Guard

Beam guard is one of the most frequently encountered barrier systems. Use Excel analysis program (Attachment 2.7), Table 2.10 and Table 2.11 to determine if replacement or spot improvements are required. Issues in Table 2.10 require new beam guard. Other issues not in Table 2.11 may impact the decision to install new beam guard. Replace non-MGS beam guard with most current standard. Table 2.10 Issues that Warrant New Barrier System.
### Table 2.10 Issues that Warrant New Barrier System

<table>
<thead>
<tr>
<th>Situation</th>
<th>Issue</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project</strong></td>
<td>A new hazard requires shielding.</td>
<td>Install the most current standard.</td>
</tr>
<tr>
<td></td>
<td>Other work on the project requires removal of beam guard.</td>
<td>Install the most current standard.</td>
</tr>
<tr>
<td><strong>Beam Guard Installation</strong></td>
<td>Current beam guard has 12-foot 6 inch post spacing.</td>
<td>This type of installation is not crashworthy.</td>
</tr>
<tr>
<td></td>
<td>Beam guard has had poor past performance.</td>
<td>A new barrier system may have better performance.</td>
</tr>
<tr>
<td></td>
<td>Beam guard has a w-beam backup plate installed at posts.(^\text{22})</td>
<td>W-beam backup plate may prevent rail separation from post during impact (see Figure 2.16).</td>
</tr>
<tr>
<td></td>
<td>Beam guard has washer installed between the bolt head and the front face of the rail (see Figure 2.21).</td>
<td>A washer in this location may reduce the effectiveness of the beam guard.(^\text{23})</td>
</tr>
<tr>
<td></td>
<td>Top of steel rail is less than 21 3/4 inches tall.</td>
<td>It is not possible to adjust rail to acceptable height.</td>
</tr>
<tr>
<td></td>
<td>Cost of spot improvements is greater than the depreciated value of the existing barrier system (see Excel analysis program).</td>
<td>It is less expensive to install a new barrier system.</td>
</tr>
<tr>
<td></td>
<td>Total installation length (end treatments plus beam guard) is 75’ or less.(^\text{24})</td>
<td>Barrier systems with shorter lengths have not been crash tested. In addition, fixed objects that are shielded by short beam guard still can be hit by vehicles gating through treatments (see FDM 11-45-2.4).</td>
</tr>
<tr>
<td></td>
<td>Beam Guard Class B is installed</td>
<td>Connecting beam guard directly to a 6x8 wood post allow for too much tire snag during an impact. Post spacing for Class B is 12.5 feet 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 impact.</td>
</tr>
</tbody>
</table>

\(^{22}\) The last time that the w-beam backup plate was included in a standard detail drawing was 1981.

\(^{23}\) The last time that the washer was included in a standard detail drawing was 1985.

\(^{24}\) 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.
Table 2.11 is a list of situations that would require at least spot improvements and may require replacement. Replacement of beam guard depends on the magnitude and accumulated effect of spot improvements. Other issues not in Table 2.11 may influence the decision to upgrade or to replace beam guard.
### Table 2.11 Issues that Warrant Spot Improvements of Beam Guard

<table>
<thead>
<tr>
<th>Situation</th>
<th>Issue</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Guard Installation</td>
<td>Non-MGS beam guard has curb and gutter installed near it (see backside of SDD 14B15 for alternatives).</td>
<td>Curb and gutter have a detrimental influence on beam guard performance.</td>
</tr>
<tr>
<td></td>
<td>Beam guard posts are pinned in asphalt, millings, or concrete (see backside of SDD 14B15 for alternatives).</td>
<td>Pinned posts increase the likelihood of beam guard failure (See SDD 14B28)</td>
</tr>
<tr>
<td></td>
<td>Beam guard has insufficient working width (see Figure 2.26).</td>
<td>Beam guard can direct an errant vehicle into the fixed object (see Figure 2.27) or vehicle can lean over barrier and strike a fixed object.</td>
</tr>
<tr>
<td></td>
<td>Lack of the 2 feet of grading behind beam guard with 6-foot 3 inch post spacing.</td>
<td>Lack of soil behind posts increase the likelihood of beam guard failure (see backside of SDD 14B15 for alternatives).</td>
</tr>
<tr>
<td></td>
<td>Steel rail or wooden planks are used to control erosion or water (see Figure 2.28)</td>
<td>Steel rail or wooden planks limit post rotation</td>
</tr>
<tr>
<td></td>
<td>Non-MGS Beam guard is flared at a rate steeper than the values in 2006 Roadside Design Guide Table 5.7.</td>
<td>Flaring barrier steeper than what is recommended increases the likelihood that the barrier will not function as intended.</td>
</tr>
<tr>
<td></td>
<td>Beam guard posts or blocks are missing, out of plumb, or damaged.</td>
<td>Missing or out of placed hardware can influence barrier performance.</td>
</tr>
<tr>
<td></td>
<td>Steel rail is Weathering or Cor-Ten steel.25</td>
<td>This type of steel makes it difficult to perform maintenance on.</td>
</tr>
<tr>
<td></td>
<td>Total installation length (end treatments plus beam guard) is 175' or less.26</td>
<td>Beam guard is typically crash tested using 175' length. However, fixed objects that are shielded by shorter section of beam guard may be hit by vehicles gating through end treatments (see FDM 11-45-2.4). Review for approximate length of need.</td>
</tr>
<tr>
<td></td>
<td>Beam guard installed without terminals that transmit impact energy to the ground.</td>
<td>Beam guard uses the soil tubes, anchor cables, ground struts or anchors in rigid barrier to absorb impact energy.</td>
</tr>
<tr>
<td></td>
<td>Steel rail is damaged.</td>
<td>Weakened rail may not function as intended.</td>
</tr>
</tbody>
</table>

---

25 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.

26 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.
More than likely, the beam guard was installed to shield the bridge pier. If the beam guard was not there, the errant vehicle, more than likely, would have missed the utility pole.
The following situations require additional engineering to determine what action should be taken:

- Beam guard is on slopes steeper than 10:1.
- Beam guard is over a drainage feature (e.g. bridge, box culverts, culverts, pipes).\(^{28}\)
- Beam guard is shielding an errant vehicle from going over the top of a retaining wall or other structure.\(^{29}\)
- The majority of a barrier installation requires the maximum height adjustment.
- If a project has a service life greater than 15 years (see duration discussion in Attachment 2.5).

To determine working width for normal non-MGS beam guard installations, add 19.25 inches (i.e. 8-inch post, 8 inch block, 3.25 inch rail thickness) to the lateral distance values in FDM 11-45-1.5.2. Adjust working width if additional blocks are added to beam guard installation. See SDD 14B25 for working width requirements for non-mgs long span application.

Provide individual construction detail showing reduced working width in spot locations. Identify the beginning/end of reduce working width, fixed object that has reduced working width and overall length of barrier requiring reduce working width. Reduce working width is to be provided 25 feet prior to hazard and along hazard. For unidirectional traffic, provide reduce deflection 12 1/2 feet beyond hazard. Bidirectional roadways have two approaches.

If working width is being reduced by one method (e.g. standard post spacing to half post spacing) no additional design is required. If working width is being reduced by two or more method (e.g. standard post spacing to half post spacing, half post spacing to quarter post spacing), provide 25 feet of each intermediate method to reduce working width prior the next method to reduce working width (e.g. 25 feet half post spacing between the standard post spacing and the quarter post spacing). This procedure would be followed on the approach and departure of the installation. Provide individual construction detail for a working width reduction of 2 units or more.

Lack of sufficient working width can cause a barrier installation to increase in length. For example, it is not possible to reduce working width for end treatments. A hazard along a unidirectional roadway requires 12 1/2 feet of reduced post spacing longitudinally beyond a hazard. After the 12 1/2 feet of reduced post spacing, then

\(^{28}\) A previous construction project may have installed shorted posts, used other methods to mount the beam guard to the drainage structure or used a long span beam guard design. Consult with BOS and a structural engineer.

\(^{29}\) 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 impact loads. Consult with BOS and a structural engineer.
a type 2 end treatment is installed. Other specialty applications typically do not permit modifications to reduce working width.

Use special provisions to pay for non-MGS beam guard with reduced deflection (e.g. half post spacing, quarter post spacing).

2.5.2.9 MGS

Much of the guidance for non-MGS beam guard can apply to MGS beam guard (MGS). In some situation, MGS may be installed with curb and gutter. If MGS lacks appropriate grading behind the post, install MGS type K. Working width information for MGS systems will be provided for on future SDDs. Although it is possible, BPD does not recommend intermixing of MGS and Non-MGS systems.

MGS system may be flared at a maximum rate of 5:1. However, additional working width is required when flaring MGS.

2.5.2.10 Treatments Near Rigid Barrier-Transitions

There are 3 types of treatments near beginning and end of existing rigid barriers:

- Unconnected beam guard (see Figure 2.29)
- Beam Guard Transition to Rigid Barrier (See Figure 2.30)
- Thrie beam transitions (See SDD 14B20, and Figure 2.31)
There are different options to modify barriers near a rigid barrier. The options depend on: type of treatment (see Figure 2.29 through Figure 2.31), direction of travel, what deficiencies are present, speed, and 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. If parapet is not shown on: standard detail drawings, WisDOT’s Bridge Manual, or within BOS’s standard detail drawings, coordination with BOS and BPD is required. There may be crashworthiness issues with the parapet. For example, parapet designs prior to 1964 may not have sufficient strength to contain an impact.\textsuperscript{lix} Parapets designed after 1964

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{beam_guard_transition.png}
\caption{Beam Guard Transition to Rigid Barrier\textsuperscript{30}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{three_beam_missing_post.png}
\caption{Thrie Beam Missing Posts}
\end{figure}

\textsuperscript{30} Installation is not crashworthy. Installation lacks sufficient strength.
may have sufficient strength, but the parapet may have other issues (e.g. snagging, pocketing).

Additional design effort may be needed to evaluate the parapet or develop alternative retrofit designs. It is recommended that this coordination occur early in the design or scoping process. The crashworthiness of a parapet can have a significant impact 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. 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 sufficient right of way, provide 2 feet of grading behind the posts.
2. If there is not sufficient right of way or there is a restriction preventing the use of the right of way, install a retaining wall. Or extend rigid barrier to a location that would allow for proper grading for the transition to rigid barrier.

A retaining wall may have to be designed to accommodate impact loads (See AASHTO LRFD Bridge Design Guide Chapter 13 for load information). Post location may also influence type of retaining wall. For example, the reinforcement straps for MSE wall may conflict with post placement. Consult a structural engineer to determine type of retaining wall and if wall has to accommodate impact loads.

If required, a structural engineer is to design retaining wall for impact loads. Use TL-3 impact loads on roadways with design or operating speeds of 45 mph or greater. Use TL-2 impact loads on roadways with design or operating speeds less than 45 mph.

Use semi-rigid barrier system’s working width for transition to rigid barrier’s working width. Review guidance on providing individual construction details (See FDM 11-45-2.5 and FDM 11-45-2.5.2).

Use standard semi-rigid barrier adjustments bid items to provide spot improvements or replacement on transitions (See FDM 11-45-2.5.2). Some special SDDs have been developed to assist in the retrofitting of transitions to rigid barriers (SDD 14B48, SDD 14B49, SDD 14B50, and SDD 14B51). Depending on situation and location special provisions may be needed. Transitions to rigid barrier may also use the grading shaping item.

Figure 2.32 Problematic Thrie Beam Transition to Rigid Barrier

Figure 2.32 has a thrie beam transition to rigid barrier that has the following issues: post pinned into position by asphalt, lack of grading behind posts and insufficient post embedment.

31 Delineating a roadside hazard is the least desirable roadside design option and requires documentation in DSR.
Transitions to rigid barrier were not designed to be curve or to flare away from the roadway. Installations that are installed with a curve or flare from the roadway require additional coordination with BPD. Additional engineering and special bid items may be required.

2.5.2.10.1 Unconnected Beam Guard

Unconnected beam guard near a rigid barrier is a significant hazard (i.e. Figure 2.29). Not only is the blunt end of the rigid barrier a concern, but the beam guard installed 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 in a similar manner as Figure 2.29 will allow a vehicle to hit the blunt end of a rigid barrier. An example of end treatment allowing a vehicle to impact a blunt end of a rigid barrier is in Figure 2.33. The end treatment in Figure 2.29 is a potential spearing hazard for an errant vehicle. An end treatment, similar to one pictured in Figure 2.29, may not provide the whole beam guard installation with sufficient strength to contain a vehicle.

Figure 2.33 Unconnected Beam Guard Gated or Directed Errant Vehicle in to Blunt End

Desirably, shield blunt end with a crash cushion or sand barrel array. A sloped end treatment may be used (see FDM 11-45-2.5.6). If guard rail is required to shield other hazards, desirably a thrie beam transition to rigid barrier would be used. In certain circumstances, a beam guard transition to rigid barrier may be used (see FDM 11-45-2.5.9.2).

2.5.2.10.2 Beam Guard Connected to Rigid Barrier

Connecting beam guard to a rigid barrier is an improvement over an unconnected beam guard installed near a rigid barrier. However, critical impacts may allow an errant vehicle to impact the end of the rigid barrier. Beam guard connections may experience pocketing during an impact (see Figure 2.34) or other failures during an impact.
However, there may be situations where a special beam guard transition to rigid barrier could be used (See SDD 14B46). A beam guard transition to rigid barrier is more than just connecting standard beam guard to a rigid barrier. The beam guard transition uses additional posts and nested beam guard to stiffen the connection to rigid barrier similar to a thrie beam transition.

A beam guard transition to a rigid barrier is not as desirable as installing a thrie beam transition to rigid barrier. BPD is trying to strike a balance between allowing minor projects (e.g. overlays, projects with less than 10 years of service life) to proceed and providing an improvement to roadside safety (i.e. providing at least some shielding for minor impacts).

To determine if a beam guard transition is a suitable alternative, review the following variables: existing site conditions, speed, AADT and duration (i.e. how long an installation will be in service).

Some existing site conditions where a beam guard transition would be appropriate are:
- Beam guard is already attached to the structure.
- Rigid barrier has holes in it that allows beam guard transition to attach to the rigid barrier.
- Projects with 10 or fewer years of service life.
- Roadway segment does not have ROR flag in metamanager.
- Installation is in a location where ROR is not likely.

Some existing site conditions where a beam guard transition would not be appropriate are:
- New rigid barrier is being installed.
- Rigid barrier has holes for thrie beam transition to rigid barrier.
- Roadway segment has ROR flag in metamanager.
- Installation is in a location where ROR is more likely (e.g. curves, areas that violate driver expectations…).
- Projects with more than 10 years of service life.

Table 2.12 provides guidance on speed, AADT, and some existing site conditions. If roadway does not match criteria listed in Table 2.12 or other criteria within this sub-section replace with most current thrie beam transition.

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32 If a barrier contains a vehicle, as in figure 2.5, the occupants can experience excessive deceleration forces. Excessive deceleration forces can cause significant injuries or fatalities.
Table 2.12 Roadway Conditions for Beam Guard Retrofit 33

<table>
<thead>
<tr>
<th>Design or Operating Speed&lt;sup&gt;34&lt;/sup&gt;</th>
<th>AADT</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;45 mph</td>
<td>Any</td>
<td>If rigid barrier ends abruptly (i.e. blunt end), a beam guard transition may be a permanent application.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If rigid barrier has a “sloped concrete end section” (see SDD14b20-c), the beam guard transition is only to be used on projects with 10 or fewer years’ service life.</td>
</tr>
<tr>
<td>≥45 mph to ≤50 mph</td>
<td>≤20,000</td>
<td>Use beam guard transition on projects with short service life of 10 years or less.</td>
</tr>
<tr>
<td>&gt;50 mph to ≤55 mph</td>
<td>≤4,000</td>
<td>Replace beam guard with most current thrie beam transition.</td>
</tr>
<tr>
<td>&gt;55</td>
<td>All</td>
<td>Replace beam guard with most current thrie beam transition.</td>
</tr>
</tbody>
</table>

Other conditions for the beam guard transition are:
- Rigid barrier is NJ, F or vertical shaped.
- Bridge does not have brush curb (see Figure 2.35).
- Top of beam guard rail can be attached to rigid barrier at 27 3/4 inches.
- Bridge rail is not W or M.

Follow guidance in the introduction of this sub-section on curb and gutter (FDM 11-45-2.5). Review SDD 14B4 (SDD being developed) or additional information on the beam guard transition to rigid barrier.

Figure 2.35 Brush Curb

Provide documentation in DSR when using beam guard transition. Projects with long service life are to install thrie beam transitions (See Duration discussion in Attachment 2.5). If a designer cannot determine if a beam guard or a thrie beam transition is appropriate, BPD recommends installing the thrie beam transition.

2.5.2.10.3 Thrie Beam Transitions

Since 1990, thrie beam transitions to rigid barriers have been installed by the department. Since its inception, the thrie beam transition drawings have had various changes. The preferred alternative 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:

33 Table adapted from: Keller, Eric, Faller, Ronald, Sicking, Dean, Polivka, Karla, Rohde, John: “Guideline for Attachments to Bridge Steel Beams and Median Barriers” Midwest State’s Regional Pooled Fund Research Program, MwRSF Research Report No. TRP-03-98-03, February 2003

34 Select the higher of the two.
- 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 feet 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 desirable to replace missing posts within the thrie beam transition. Posts may conflict with drainage structures. BPD is conducting research on this issue. Until the research is published, relocate drainage structures to allow for post installation. Provide justification in DSR if missing posts cannot be installed.

Existing curb and gutter may remain in place. Review guidance provided in SDD 14B20.

Some thrie beam transitions to single slope barrier have been installed without 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 that requires the installation of the connector plate and resetting the thrie beam transition.

### 2.5.2.11 Bullnoses

WisDOT has used at least three different bullnoses designs. Only the thrie beam bullnose design has been successfully crash tested. The three systems are:

- Downturned end treatment bullnose (See Figure 2.36)
- Bent beam guard bullnose (See Attachment 2.8)
- Thrie beam bullnose (SDD14B26)

Replace downturned end treatment bullnoses and bent beam guard bullnoses. Limited project by project DJs to allow downturned end treatments and bent beam guard bullnose may be granted by BPD. Document in the DSR.

Review thrie beam bullnose installations for other issues that may impact performance (e.g. grading, working width, curb and gutter, fixed objects too close to rail 1 of bullnose). Review guidance provided in SDD 14B26. Review guidance on providing individual construction details (See FDM 11-45-2.5, FDM 11-45-2.5.2, and SDD14B26)

For existing installations, follow guidance in the introduction of this sub-section on curb and gutter (See FDM 11-45-2.5).

![Figure 2.36 Downturned Bullnose Design](image-url)
2.5.2.12 Curved Beam Guard

Curved beam guard is any beam guard that has to be shop bent. 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 permit the use of a curved beam guard. For example, a collision into curved beam guard may be more desirable than a collision with a hazard.

Replace curved beam guard with radii 36 feet or less with the short radius system (see SDD 14B27). If curved beam guard with radii of 36 feet or less is not going to be replaced with short radius system document in DSR.

Desirably, radii greater than 36 feet would be removed or the location would be modified to use the short radius system. If it is not feasible to install short radius system, document in DSR.

On existing curved beam guard installations, follow guidance in the introduction of this sub-section on curb and gutter (See FDM 11-45-2.5). For grading and curb guidance for new installations of the short radius system, review the backside of SDD 14B27. Review guidance on providing individual construction details (See FDM 11-45-2.5, FDM 11-45-2.5.2, and SDD 14B26).

The short radius system may require additional right of way. Review right of way needs early in project’s design.

![Figure 2.37 Problematic Short Radius with installation Problems](image)

The installation in Figure 2.37 has the following issues: not using CRT post in radius, insufficient length of tangent beam guard along the low volume road, wrong end treatment, and use of curb and gutter.

2.5.3 Concrete Barriers

WisDOT has used various shapes of concrete barriers (See FDM 11-45-2.3.6). Issues in Table 2.10 require new concrete barrier. Other issues not in Table 2.13 may also impact the decision to install new concrete barrier.

---

35 Radii 150 feet or less require shop bending.
### Table 2.13 Issues that Warrant New Concrete Barrier

<table>
<thead>
<tr>
<th>Situation</th>
<th>Issue</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project</strong></td>
<td>A new hazard requires shielding.</td>
<td>Install the most current standard.</td>
</tr>
<tr>
<td></td>
<td>Other work on the project requires removal of a whole run of concrete barrier.</td>
<td>Install the most current standard.</td>
</tr>
<tr>
<td></td>
<td>Structural protection is required (FDM 11-35-1).</td>
<td>LRFD impact loads require special barrier designs.</td>
</tr>
<tr>
<td><strong>Concrete Barrier</strong></td>
<td>Barrier is GM shaped.</td>
<td>GM shaped barrier has not passed NCHRP 350 criteria.</td>
</tr>
<tr>
<td></td>
<td>Concrete barrier does not match NJ, F, single slope or vertical shapes (See FDM 11-45-2.3.6).</td>
<td>Barrier shape is a non-crash tested design.</td>
</tr>
<tr>
<td></td>
<td>Concrete barrier is flared at a rate steeper than the values in 2006 Roadside Design Guide Table 5.7.</td>
<td>Flaring barrier steeper than what is recommended increases the likelihood that the barrier will not function as intended.</td>
</tr>
<tr>
<td></td>
<td>Overlays greater than 3 inches have been placed adjacent to a NJ, and F shaped barrier (see Figure 2.29).</td>
<td>NJ and F shaped barriers were designed to accommodate up to 3 inches of overlays.</td>
</tr>
<tr>
<td></td>
<td>Single slope barrier has a height less than 32 inches (see Figure 2.29).</td>
<td>Single slope barrier less than 32 inches may have difficulties redirecting larger vehicles.</td>
</tr>
</tbody>
</table>

**Figure 2.38 Overlays near NJ, F, Single Slope Barriers**

Reducing barrier height can make it more likely that a vehicle could vault over concrete barrier or hit objects just behind the barrier. From a roadside design perspective, it is more desirable to steepen paved shoulder slopes near concrete barrier because it does not reduce the overall height of the barrier\(^{36}\). It may not always be possible to steepen shoulder slope to avoid reducing the overall height of the barrier. Overlays directly adjacent to a barrier (Left side of Figure 2.38) may also cause drainage issues.

The recommend minimum height for single slope concrete barrier on freeways or expressways with design or operating speeds greater than 45 mph is 36 inches. Single sloped concrete barriers with height of the barrier 32 inches may acceptable on other facilities. Document changes in barrier height in DSR.

---

\(^{36}\) Review other sections of FDM about maximum shoulders slopes and maximum algebraic difference in slopes.
Avoid reducing barrier height in the following locations:
- Fixed objects are placed close to the barrier.
- Consequences of a collision are severe.
- Pick-up trucks or smaller vehicles have ridden on top of, hit fixed objects on the barrier or vaulted over the barrier.
- Collision history of large vehicle impacting a barrier.

*Table 2.14* is a list of situations that would require at least spot improvements and may require replacement. Replacement of concrete barrier depends on the magnitude and accumulated effect of spot improvements. Other issues not in *Table 2.14* may also impact the decision to use spot improvements or fully replace concrete barrier.

**Table 2.14 Issues that Warrant Spot Improvements**

<table>
<thead>
<tr>
<th>Situation</th>
<th>Issue</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
<td>Project requires the partial removal of concrete barrier installation to facilitate work on project.</td>
<td>Replace long sections of concrete barrier with most current concrete barrier standard.</td>
</tr>
<tr>
<td>Concrete Barrier Installation</td>
<td>Police reports indicate that vehicles are vaulting over, riding on top of, or striking objects behind/on top of barrier.</td>
<td>See discussion below.</td>
</tr>
<tr>
<td></td>
<td>Concrete barrier has open cracks that extend through the barrier (see Figure 2.42, 2.43 and 2.44).</td>
<td>Concrete barrier with open cracks may fail during an impact or launch projectiles at other vehicles or pedestrians.</td>
</tr>
<tr>
<td></td>
<td>Concrete barrier has exposed or rusted reinforcement.</td>
<td>Concrete barrier is structurally weak and may fail during an impact.</td>
</tr>
<tr>
<td></td>
<td>Concrete barrier is tipping over or faulting (see Figure 2.39).</td>
<td>Concrete barrier may snag a vehicle during an impact.</td>
</tr>
<tr>
<td></td>
<td>Individual panels are more than 2 inches offset (See CMM 1-45.12.5.9 for examples).</td>
<td>Concrete barrier may snag a vehicle during an impact.</td>
</tr>
<tr>
<td></td>
<td>Concrete barrier has opening greater than 4 inches long (See CMM 1-45.12.5.9 for examples).</td>
<td>Concrete barrier may snag a vehicle during an impact.</td>
</tr>
<tr>
<td></td>
<td>Concrete barrier has open gaps (see Figure 2.41).</td>
<td>Concrete barrier may snag a vehicle during an impact or fail during an impact.</td>
</tr>
<tr>
<td></td>
<td>Concrete barrier has abrupt changes in cross sectional area (see Figure 2.40).</td>
<td>Concrete barrier may cause rapid deceleration of vehicle or launch vehicle into opposing lanes or air.</td>
</tr>
<tr>
<td></td>
<td>Curb and gutter is placed in front of concrete barrier.</td>
<td>Curb can have negative influences on barrier performance.</td>
</tr>
<tr>
<td></td>
<td>Concrete barrier has a blunt end.</td>
<td>This is not a crashworthy end treatment.</td>
</tr>
</tbody>
</table>

Some issues in *Table 2.14* may not improve overall concrete barrier performance. Addressing these issues limit negative influences on concrete barrier. For example, repairing cracks on concrete barrier (damage similar to Figure 2.42 through Figure 2.44), may not provide structural strength for critical impacts. Repairing cracks may help reduce future deterioration of the barrier, limit snag, or limit size of barrier fragments from an impact. Additional design effort may be required when designing spot improvements.

Issues similar to Figure 2.42 through Figure 2.44 may be only a few feet long and more than likely not provide structural capacity. Other issues, such as Figure 2.39 or the need to provide working width may be 100’s of feet long and more than likely provide structural capacity.
Some issues, such as Figure 2.39, will require limited engineering effort (i.e. remove barrier and replace with new). Other issues, similar to Figure 2.40, Figure 2.42, Figure 2.44 and barrier openings (see CMM 1-45.12.5.9), will require more engineering effort. Coordinate with BPD early in the project development.

Follow guidance in the introduction of this sub-section on curb and gutter (see FDM 11-45-2.5). Review FDM 11-45-2.3.6 for additional guidance on concrete barrier design.

Depending on work being performed, special provisions and construction details may be needed.
Figure 2.41 Opening in barrier that can snag a vehicle

Figure 2.42 Cracked Concrete Barrier Needing Repair
2.5.4 End Treatments
Review guidance provided in FDM 11-45-2.4.

Upgrade approach blunt ends (see Figure 2.45 and Figure 2.46), all BCT’s (Figure 2.47), and all downturned ends (Figure 2.48) to EATs.

Limited project by project DJs for downturned ends may be granted by BPD. Document in the DSR. In many cases, an EAT can be designed to accommodate a location. BPD is aware of two situations that would allow
the use of a downturned end treatment. These situations are:

- A project is using a non-standard beam guard system and the only end treatment that can be attached is a downturned end.
- A combination of unique topography and roadway geometry allows for the installation of a downturned end.\(^\text{38}\)

Coordinate early in the design process with BPD to determine if a downturned end is appropriate. Additional design effort, special details, individual construction details, and special provisions are required.

MELT terminals (Figure 2.49) are acceptable in locations where: the design speed or operating speed is 45 mph or less, the terminal is installed correctly, and the MELT is in working order\(^\text{39}\). If one of these conditions is not met, remove the MELT and replace with EAT. SRT-350 terminals (Figure 2.50) may remain in place provided that they are in good working order and installed correctly.

\(^{37}\) In many cases an EAT without proper grading is more desirable than a downturned end. However, not providing grading for EAT would require documentation in DSR.

\(^{38}\) BPD is aware of only one such location in the state.

\(^{39}\) Note the MELT requires a “parabolic flare” from the edge of shoulder.
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 2.48 Downturned Ends

Multiple breakaway holes and ground strut (strut hidden by debris)

Figure 2.49 MELT
Review existing EATs for proper grading, hardware, steel rail height, reflective sheeting and EAT marker posts. EAT height and height tolerance is the same as semi-rigid barrier’s it is attached to. Review backside of SDD 14B24 and SDD 14B44 for grading and other design information on EATs.

EATs attached to flared barrier installations should be installed tangent to the flared barrier. For example, the barrier is flared at 16:1 the EAT should use a 16:1 flare. Steepening the flare rate of the EAT (e.g. 16:1 barrier flare plus an additional 2:1 for the EAT) may increase the likelihood of EAT not functioning as intended.

Replace EATs and other end treatments that are near another (see FDM 11-45-2.4). Other end treatments should be installed. Contact BPD for assistance at locations where end treatments are in close proximity. Additional engineering, DSR documentation, special details, special provisions may be required. In some cases, proprietary product finding may be required. It is recommended that this coordination occur early in the design process.

EATs that can have backside hits are to be reviewed. Different hardware may need to be installed.

In situations where an EAT is being retrofitted, follow guidance in FDM 11-45-2.4.1 on curb and gutter placement. Desirably driveway curb will be used. Note contractors can get sawing equipment that can cut the head off a curb.

Review FDM 11-45-2.4.1 for guidance locating curb and gutter near EATs. Follow guidance in FDM 11-45.2.5 on existing curb and gutter.

EAT’s are proprietary devices. Write special provision to have the contractor provide replacement parts made by the manufacture.

Provide individual construction detail for EATs (See FDM 11-45-2.5 and FDM 11-45-2.5.2).

Extend beam guard sufficiently far enough downstream to prevent vehicle from gating through Type 2 and hitting hazard being shielded (see FDM 11-45-2.4.3)

Broken post in end treatments may limit the effectiveness of a barrier system because the system may not transfer energy into the ground or allow the rail to go into tension during an impact.

**2.5.5 Crash Cushions and Sand Barrel Arrays**

Issues in Table 2.15 require new crash cushions or sand barrel arrays. Other issues not in Table 2.15 may also impact the decision to install a new crash cushion or sand barrel array.
### Table 2.15 Issues that Warrant New Crash Cushion or Sand Barrel Array

<table>
<thead>
<tr>
<th>Situation</th>
<th>Issue</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project</strong></td>
<td>A new hazard requires shielding.</td>
<td>Install the most current standard.</td>
</tr>
<tr>
<td></td>
<td>Other work on the project requires removal of crash cushion or array.</td>
<td>Install the most current standard.</td>
</tr>
<tr>
<td><strong>Crash Cushion or Sand Barrel Array Installation</strong></td>
<td>Crash cushion is a GREAT system (see Figure 2.51 and Figure 2.52).</td>
<td>This system does not meet current crash test standard.</td>
</tr>
<tr>
<td></td>
<td>Crash cushion or array was installed prior to October 1, 1998.</td>
<td>Systems older than this date are not to current crash test standards.</td>
</tr>
<tr>
<td></td>
<td>Crash cushion or array has had poor past performance.</td>
<td>A newer system may have better performance.</td>
</tr>
</tbody>
</table>

**Figure 2.51 GREAT Crash Cushion**

![Diagram of GREAT Crash Cushion](image)
Table 2.16 is a list of situations that would require at least spot improvements and may require replacement. Replacement depends on magnitude and accumulated effect of spot improvements. Other issues not in Table 2.16 may also impact the decision to provide spot improvements or fully replace and crash cushion or array.

**Table 2.16 Issues that Warrant Spot Improvements Crash Cushion or Array**

<table>
<thead>
<tr>
<th>Situation</th>
<th>Issue</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash Cushion or Sand Barrel Array Installation</td>
<td>Cushion or array is not on a paved surface.</td>
<td>Systems are required to be on a paved surface.</td>
</tr>
<tr>
<td></td>
<td>Crash cushion is not mounted to a backup block or anchored into a paved surface.</td>
<td>Without one of these attachments the crash cushion may not absorb impact energy.</td>
</tr>
<tr>
<td></td>
<td>Curb and gutter is on the approach or adjacent to a crash cushion or array.</td>
<td>Curb can have negative influences on performance.</td>
</tr>
<tr>
<td></td>
<td>Grading from edge of lane to crash cushion or array is steeper than 10:1.</td>
<td>Vehicle may not engage the crash cushion or array correctly.</td>
</tr>
<tr>
<td></td>
<td>Array is 10 or more years old.</td>
<td>Older barrels are more likely to have a non-impact failure because of exposure to UV rays. (e.g. yellow barrels look more like gray barrels or barrels are very brittle)</td>
</tr>
<tr>
<td></td>
<td>Crash cushion or array has missing, improperly installed, or damaged components.</td>
<td>Systems may not function as intended.</td>
</tr>
</tbody>
</table>

Review [FDM 11-45-1.7](#) for additional guidance on crash cushions or arrays.

Discuss with crash cushion manufacturer the need for a backup block or pad for crash cushion. If needed, update delineation of crash cushion.

Older arrays may not be designed to most current crash testing standards. Review existing layouts by using procedures in 2006 Roadside Design Guide, or manufacture’s most current array layouts. Replace arrays that are not to current crash test standards. If it is not possible to fit a new array into an existing location, review if a crash cushion could be installed.
If array is designed to current crash test standard, review arrays for: minimum distance between barrels, minimum distance from barrels to fixed object being shielded, correct number of barrels, correct weight of sand at the correct barrier location, and that rock salt is mixed with sand. Existing barrels have a tendency to warp over time and may not accept new lids. Older warped barrels may have to be replaced. If the majority of barrels in an array require replacement, replace whole array.

If feasible, modify existing arrays using the following guidance:

- For Bidirectional installation of arrays install some barrels to reduce severity of reverse direction impacts (see Figure 8-41 of 2011 Roadside Design Guide).
- Angle arrays toward traffic (see Figure 8-42 of 2011 Roadside Design Guide).

If array cannot be modified document as indicated above, document in DSR.

Figure 2.53 Problematic Sand Barrel Array

Figure 2.53 is a problematic array installation. This installation has the following issues: use of curb and gutter, barrels are not on a pad, and a damaged barrel.

Use special provisions to refurbish crash cushions. Include name of manufacture, the name of the specific system and indicate what work is required in special provisions. If multiple systems are within a project, use different special provisions for each system. Provide individual construction details when grading, installing pad or back up block, or modifying curb near crash cushion.

Use special provision to repair individual barrels within an array. Provide individual construction details indicating which barrel is to be replaced, its location, and weight. When using a special provision reference WisDOT’s Product Approval List (PAL).

Use standard bid item to replace whole array. Provide individual construction details when grading, installing pad or back up block, or modifying curb near array.

2.5.6 Sloped Concrete End Treatments

No known concrete sloped end treatment has passed all crash testing requirements. In general, the department does not want to install sloped concrete end treatments. Guidance provided below is for retrofitting a concrete sloped end treatment into an existing location on minor projects (i.e. projects with less than 15 years of service life).

Approval of Bureau of Project Development is required to install a concrete sloped end treatment. Approvals will be rare. In many cases, it is possible to install crashworthy hardware (e.g. crash cushions, sand barrel arrays,
transition to rigid barrier with EAT...)\(^{41}\). Avoid using aesthetical concerns to justify the retrofitting of a sloped end treatment.

AASHTO indicates the following:

“While aesthetics are a concern, they should not be the controlling factor in 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”\(^{viili}\)

There could be existing site specific or project related issues that may allow a sloped end treatment (i.e. slope end treatment is better than an exposed blunt end). Retrofitting in a new sloped end treatment into an existing facility requires the following:

- Design or operating speeds are 40 mph or less.
- Other roadside features prevent the proper installation of crash tested hardware.
- Barrier has sufficient LON to protect roadside hazards or the only hazard is the blunt end of a rigid barrier.
- 10:1 or flatter grading is present leading to an adjacent to the sloped end treatment.

Desirably no curb or gutter should be installed leading into or adjacent to the sloped end treatment. Follow guidance in the introduction of this sub-section on curb and gutter (See FDM 11-45-2.5).

**Attachment 2.9** has an acceptable sloped concrete end section. Other “sloped” concrete sections that do not match the barrier design in **Attachment 2.9** (e.g. such as **Figure 2.54** or **SDD 14B 20 sheet c**) are considered blunt ends. Shield, replace, or delineate blunt ends of concrete barrier.\(^ {42}\)

**Attachment 2.9** is a concrete sloped end treatment designed to match into a 32-inch F shaped barrier. To match into a taller barrier, extend slope to reach appropriate height. To match into a different shaped barrier, use similar geometry and transition to desired shape. Generally, the length of the barrier will be 20 feet or longer (depending on height of barrier matching into). Provide overall geometry details, overall steel details, cross sections, and bent bar details. See FDM 11-45-2.3.6.4.6 for more information.

---

\(^{41}\) In some case, it may be better and EAT without grading than to install a sloped end treatment.

\(^{42}\) Note that delineating a hazard is the least desirable roadside design option. Provide documentation in DSR when delineating a roadside hazard.
Coordinate with BPD when retrofitting a sloped end treatment. Construction drawings and special provisions will be required.

2.6 Drainage Features and Cattle Passes

Drainage features like (list not all inclusive): culverts, bridges, large drainage conduits have unique challenges that can make it difficult to select an appropriate roadside treatment option. Cattle passes can have many of the same roadside design issues as drainage features and will be discussed in this section.

Drainage features or cattle passes can be a hazard depending on orientation, 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 2.17 Drainage Feature or Cattle Pass Size

<table>
<thead>
<tr>
<th>Pipe Orientation to Roadway</th>
<th>Number of Culverts</th>
<th>Culvert diameters or box culvert opening width (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perpendicular</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>2 or more</td>
<td>30</td>
</tr>
<tr>
<td>Parallel</td>
<td>1</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>2 or more</td>
<td>All multi-culvert runs are hazards</td>
</tr>
</tbody>
</table>

A drainage feature or cattle pass can become a hazard, regardless of size of drainage feature or cattle pass, if a portion of the structure can snag the undercarriage of an errant vehicle (e.g. 4-inch object on a 5-foot chord) or the vehicle bumper can impact the structure (e.g. headwall, pipe sticks out of slope, etc.).

Drainage features that are equal to or smaller than the values listed in Table 2.17 are not considered roadside hazards. However, treatment of smaller parallel drainage features can be considered. In many cases treating smaller parallel drainage features could be considered a best practice.

In addition, other objects near a drainage feature or cattle pass can be hazards (refer to Figures 2.56 and Figure 2.57). Some examples are:
- Water 43
- Slopes
  - Leading to and departing from drainage feature.
  - Slopes that blend into drainage feature.
- Ditches
  - Non-traversable roadway’s ditches.
  - Drainage ditches’ slopes (i.e. non-roadway ditches).
  - Blending slopes:
    - Roadway backslopes and drainage ditch slopes.
    - Foreslopes and drainage feature or cattle pass.
- Other fixed object hazards.
- Overall drop from structure to ditch bottom.44

Other hazards typical increase the traveling public’s crash exposure (refer to Figure 2.55).

![Figure 2.55 Likely Exposure Limits for Errant Vehicles to Hazards (one direction of travel only)](image)

43 Water 2 feet or deeper.

44 Vertical drops of 8 feet or more are hazardous. Vertical drops of 6 feet or more combined with other hazards (e.g. rip rap or water) are hazardous.
The following subsections are written assuming the drainage feature or cattle pass is in good structural condition. When reviewing structural adequacy, it is important to review where safety hardware or a barrier system will attach to the drainage feature. If there are questions about the structural condition of the drainage feature or cattle pass contact Bureau of Structures.

Some of the alternatives to treat hazardous drainage features and cattle passes may require hydraulic analysis. See FDM Chapter 13 for more information and requirements.

Provide individual construction details for installing a barrier system or safety hardware near hazardous drainage features or cattle passes (refer to discussion in FDM 11-45-2.5). If cross sections are not provided, the barrier system or safety hardware may not work as intended.
FDM 11-45-2.6 is written for 3R, 4R, or new construction projects. The provided guidance may be applicable to some Preventative Maintenance (PM) projects. Typically, the type of work being performed in the PM project will influence what roadside treatment is being used. Some examples are listed in Table 2.18 (list is not all inclusive).

**Table 2.18 Potential Roadside Treatment Options for Hazardous Drainage Features or Cattle Pass for PM Projects**

<table>
<thead>
<tr>
<th>Type of PM Project or Work Being Performed</th>
<th>Traversable Grate</th>
<th>Extend, Remove or Relocate</th>
<th>Shield</th>
<th>Delineate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Restoration Project</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Restoring grading near drainage feature or cattle pass</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Restoring or installing Rip Rap</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>A barrier system shielding a hazardous culvert can be removed by installing a traversable grate without acquiring additional R/W</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project is crack sealing and upgrading signage</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

It is recommended that Regional staff review the PM project with Bureau of Project Development Project Services Section early in the scoping phase or design phase. If a hazardous condition for a drainage feature or cattle pass cannot be adequately addressed as within a PM project, then a future project should be program to correct this hazard.

### 2.6.1 Cross Drainage Features and Cattle Passes

This section deals with drainage features and cattle passes that are installed perpendicular or skewed to the direction of mainline travel. Options available for cross drainage features and cattle passes (in order of preference are):

1. Traversable grates
2. Extending removing or relocating cross drain
3. Installing a barrier system
4. Delineate

#### 2.6.1.1 Traversable Grates

From a roadside design perspective, traversable grates are the most desirable option. In general, traversable grates have lower installation and crash costs than other alternatives. Traversable grates can have a lower maintenance cost than a barrier system.

Traversable grates can have issues with clogging, requiring right of way, or grading. Issues with clogging can be minimized by installing a traversable grate on the upstream end of the drainage feature. If a traversable grate is not installed on the upstream end of the drainage feature, it is difficult to detect if the cross drain is clogged with debris. It is also more difficult to clean out debris from inside a cross drain.

Not installing traversable grates because of maintenance concerns requires additional coordination with Bureau of Project Development (BPD). Document the decision not to install a traversable grate because of maintenance concerns in the DSR.

Do not install traversable grates on cattle passes or cross drains for navigable waterways.

Review hydraulic capacity of cross drains prior to installing traversable inlet. Not installing a traversable inlet because of hydraulic concerns requires documentation in DSR.

Refer to FDM 11-45-2.2.10 traversable grates for the warrant on traversable inlet.
Generally, it is not possible to intermix cross drain traversable culvert grates with parallel traversable grates because the number of bars, bar orientation, and spacing for the bars are different.

For most cross-drain culverts, the traversable grate details can be found on SDD 8F8. Concrete culverts are to use steel traversable culvert grates (refer to Steel Adapter Sleeve for Concrete Pipe drawing on SDD 8F8). Inlets Median 3 and 4 Grate may be modified to provide the correct slope to allow it to be traversable (refer to SDD 8C5). Larger box culverts, mortar rubble masonry endwalls (SDD 8F9), or concrete masonry endwalls (SDD 8F10), may require special provisions, special construction details and coordination with BPD.

Concrete inlets may require additional information in the plan to allow the contractor to construct the inlet and associated slopes.

Provide grading for traversable grates. Installation of traversable grate may require a site-specific construction detail or cross sections (refer to Attachment 2.18 for an example). Do not rely on a generic drawing similar to Attachment 2.18 as the sole source of grading information.

2.6.1.2 Extend, Remove or Relocate Cross Drain or Cattle Pass

In general, extending cross drains or cattle passes will have higher initial construction costs and will result in lower crash costs. Extending smaller hazardous cross drains or cattle passes is simpler than extending a larger drainage features or cattle passes. Extending a large cross drain or cattle pass is more likely to require coordination with a structural engineer, environmental work, review of hydraulic capacity, right of way and grading.

Review the use of a traversable grate prior to extending a cross drain. Extending a culvert or cattle pass may be the best option when installing a new cross drain or cattle pass or performing a significant amount of work on an existing cross drain or cattle pass. However, other hazards may limit the effectiveness of extending a cross drain or cattle pass (e.g. overall drop, water, rip rap, etc.).

Extend hazardous cross drain or cattle passes to the desirable clear zones values adjusted for AADT, speed and curvature in the following situations (see FDM 11-15 Attachment 1.9 and 1.10):

New construction of:
- Roadway project near cross drain or cattle pass
- Cross Drain or cattle pass

Reconstruction of:
- A roadway and the project are purchasing right of way near cross drain or cattle pass
- Cross drain or cattle pass

Areas with run off the road crash history.

On 3R projects, extend existing hazardous cross drains, or cattle passes to the minimum of the following: desirable clear zone values adjusted for AADT, speed and curve or 30 feet.

Not extending hazardous cross drains or cattle passes requires documentation in the DSR. Not extending hazardous cross drains or cattle passes to the distances above requires documentation in the DSR.

Provide grading for cross drain or cattle pass extension. The extension of a box culvert or cattle pass may require a site-specific construction detail or cross sections (refer to Attachment 2.18 for an example). Do not rely on a generic drawing similar to Attachment 2.18 as the sole source of grading information. Check drainage and traversability of slopes, ditches and blending slopes. When designing the grading be careful that a non-traversable hump of soil where the pipe extension is. Review traversable slope requirements for slopes that are perpendicular to the direction of travel in FDM 11-45-2.6.2.1.

In some rare situations, cross drains or cattle pass that are no longer required and can be removed. FDM 11-55-10 contains design guidance on what to do with a cattle pass that is no longer in use.

In some rare situations, cross drains or cattle pass that are no longer required and can be removed. There could also be situations where a drop inlet could be installed to “remove” a cross drain. FDM 11-55-10 contains design guidance on what to do with a cattle pass that is no longer in use.

In some rare situations, cross drains or cattle passes can be relocated. Relocate a cross drain or cattle pass to a location where run off the road crashes are less frequent (e.g. move the cattle pass out of a curve and into a tangent section). When relocating a cross drain or cattle pass, extend the new cross drain or cattle pass to the desirable clear zone distance.

2.6.1.3 Barrier Systems

Typically, barrier systems increase crash frequency and decrease crash severity. If other roadside design
alternatives are not feasible then a barrier system may be a viable alternative. Barrier systems can be designed to shield other roadside hazards that previous alternatives cannot address.

Refer to FDM 11-45-2.2.12 for warrants to shield larger culverts.

Some difficulties with installing barrier systems are:
- Lack of cover over the cross drain or cattle pass.
- Lack of room between posts for drainage feature of 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.
- Being able to maintain a barrier system.

Lack of cover becomes a concern when there is less than 5 feet of fill over the top of a cross drain or cattle pass. Options for low fill situation could be:
- Long Span Beam guard
- Attaching to the structure
- Rigid barrier system

Lack of room between posts becomes a concern in a low fill situation and the width of the cross drain or cattle pass is close to the span length between posts. Depending on cross drain or cattle pass width and skew it may not be possible to install standard semi-rigid barrier. Options for this situation could be:
- Long Span Beam guard
- Attaching to structure
- Rigid barrier system

Barrier systems require length up station and down station of a cross drain or cattle pass in order to shield the hazard or hazards. If there are driveways or side roads within 125 feet of the cross drain or cattle pass it may be difficult to properly install a barrier system. Options for this type of situation are:
- Move driveway or cross street
- Taper semi rigid barrier (refer to FDM 11-45-2.3.1.3 for length of need discussion)
- Install a short radius system.

If these options cannot fit a given location, additional design and coordination with BDP is required. Documentation in the DSR is required.

Almost all barrier systems require some grading (even if it is just for end treatments). In case of semi-rigid barriers, grading provides structural strength to the barrier system. Grading near the cross drain or cattle pass may prevent the use of a given barrier system (e.g. designer cannot get grading near post for proper installation of Midwest Guardrail System (MGS K)).

In some cases, adding a barrier system on top of a box culvert or cattle pass may require contact with Bureau of Structures. A barrier system may influence the structural rating; attaching or bolting through the deck of a box culvert may require structural analysis; condition of box culvert or cattle pass may not allow for proper connection. Additional engineering will be required.

Do not bolt through a cross drain with permanent water in it without discussing with maintenance staff. Provide documentation of maintenance staff discussion in DSR. Contact BPD when bolting through the deck of a box culvert for crashworthy details. Special provisions will be required.

2.6.1.4 Delineate

If other alternative roadside design are not feasible, delineate a hazardous cross drain or cattle pass with the clear zone (refer to SDD 15A7). Also refer to MUTCD sections 2C.63 and 2C.65. Provide documentation in DSR when using delineating a hazardous cross drain or cattle pass.

Use flexible marker post for culvert pipe (SDD 15A3) for nonhazardous cross drains and cattle passes.

2.6.2 Parallel Drainage Features

Parallel drainage features are typically located at an access point (e.g. driveway, side road, median crossover, etc.). Other locations may also have slopes that are perpendicular to the direction of travel and have a parallel drainage feature (e.g. a median berm near a thrre beam bullnose installation).

Options available for parallel drainage features are (in order of preference):
1. Traversable Grates
2. Relocate or remove structure
3. Installing a barrier system
4. Delineate

2.6.2.1 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 grates installed on cross drains (refer to FDM 11-45-2.6).

Parallel drainage features are less likely to experience difficulties with clogging as cross drains. If a traversable grate is installed on downstream of a drainage feature, install a traversable grate on the upstream end of the drainage feature. Not installing a traversable grate or inlet because of hydraulic concerns requires documentation in DSR.

Generally, it is not possible to intermix cross drain traversable culvert grates with parallel traversable grates because the number of bars, bar orientation, and spacing for the bars are different.

Do not install traversable grates on parallel drain for navigable water ways. Refer to FDM 11-45-2.2.11 (Traversable Grate for Hazardous Parallel Culverts) for warrant to install traversable grates on hazardous parallel culverts.

Refer to SDD 8F7 for information on traversable grates for most parallel culverts. Type 8,9,10 inlets may be modified to provide the correct slope to allow traversability (refer to SDD 8C5). Larger box culverts, mortar rubble masonry endwalls (SDD 8F9), or concrete masonry endwalls (SDD 8F10), may require special provisions, special construction details and coordination with Bureau of Project Development and Bureau of Structures.

Provide grading for proper installation of a traversable grate. Installation of traversable grate may require a site-specific construction detail or cross sections (refer to Attachment 2.19 for an example). Do not rely on a generic drawing like Attachment 2.19 as the sole source of grading information. Select the appropriate traversable grate and transverse slope based on the following table:

<table>
<thead>
<tr>
<th>Posted Speed (mph)</th>
<th>Maximum Parallel Slope to the Direction of Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;35</td>
<td>4:1</td>
</tr>
<tr>
<td>≥ 35 to &lt;60 *</td>
<td>6:1</td>
</tr>
<tr>
<td>≥60 *</td>
<td>10:1</td>
</tr>
</tbody>
</table>

* 20:1 are more desirable for freeways and expressways.

Grade slopes near the traversable grate to the values shown in the above table. Flatter slopes are permissible. Not installing a traversable grate or providing appropriate grading requires documentation in DSR.

2.6.2.2 Relocate or Remove Structure
In some rare situations, a parallel drainage feature is no longer required and can be removed. If an access point is removed, remove the drainage feature and its associated grading. One possible way of “removing” a parallel drainage features is to combine closely spaced parallel drainage features into one feature.

In other situations, it may be possible to relocate a parallel drainage feature. Relocate the new parallel drainage feature to a location where run off the road crashes are less likely to occur (refer to Figure 3-11 of 2011 Roadside Design Guide).

2.6.2.3 Barrier Systems
It can be difficult to install a barrier system to protect a parallel drainage feature and its associated slopes. In some situations, a short radius system (SDD 14B27) can be used to wrap beam guard around the parallel drainage feature and its transverse slopes.
If a short radius system is not feasible, it may be possible to provide a “break” in the barrier system. However, this break would allow some errant vehicles to hit the hazards. Designing a break in the barrier system requires discussion in the DSR.

2.6.2.4 Delineate
Guidance for this section is to be added at a future date.

2.7 Safety Edge
Safety edge is a sloped wedge of pavement added to the outside edge of a lane (assuming no paved shoulder) or outside edge of a paved shoulder (refer to Figure 2.58 below).

![Figure 2.58 Cross Section of Safety Edge](image)

Safety edge can mitigate run off the road crashes due to edge drop between the paved surface and the gravel shoulder. An edge drop as little as 2.5 inches can cause a driver to over steer in an attempt to reenter the pavement. Eventually, when the vehicle's tires climb up the edge, the vehicle will shoot abruptly across its lane and enters into oncoming traffic.

Many states are reporting better pavement performance near the safety edge. Some of the pavement benefits are: reduced edge line cracking, better compaction, less damage to pavement edge due to construction traffic. Safety edge can be installed on HMA and concrete pavements. Currently, WisDOT is installing safety edge on various HMA projects through the state. Safety edges are created by adding a wedge maker to the paver. CMM 6-70 has additional information about safety edge.

2.7.1 Policy
Install safety edge on HMA pavements (e.g. HMA overlay, new construction, reconstruction) with no paved shoulder or HMA paved shoulder of 3 feet or less. Install safety edge on temporary roads that are in-service over the winter or will be in-service for a year or more.

Provide documentation in the DSR when not installing safety edge on a roadway that matches the previous criteria. 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.

2.7.2 Design Information
Standard Spec 450.3.2.11 contains language on where to install safety edge. SDD 14b29 contains information on how to construct safety edge. No additional information is needed in the plan for standard application of safety edge. Special provisions are required when using safety edge on wider paved shoulders or when not installing a safety edge.

The “top” of the safety edge is to be located at edge of paved shoulder or lane. If the safety edge is not properly located the widths of the shoulder or lane may be too narrow.

Review stability of shoulder. Soft shoulders or poorly graded shoulders may need additional work to provide stability for safety edge and new pavement. If the project is not building a new pavement, review FDM 19-7-1.2 on preparing foundation and shaping shoulders bid items. Use these items if applicable.

45 Instead of designing one continuous barrier system, there would be two independent barrier systems with a gap between them.
Calculate additional HMA quantities for safety edge and add the quantity to the overall quantities. Typically safety edge adds less than 1 to 2% to the overall HMA quantities.

2.8 Cross Median Crash (CMC)

A cross median crash (CMC) is a crash where 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.

Although installing a barrier system can be effective in limiting CMCs, other methods should be used to limit the likelihood an errant vehicle would strike a median barrier system. Barrier system can increase overall crashes, barrier systems have to be maintained, and barrier systems may need to be removed to accommodate future work. Some potential mitigation treatments to reduce the severity of a median encroachment or the frequency of a median encroachment are (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
- Speeds reduction techniques
- Repairing edge drops from lane to paved shoulder and shoulder to gravel
- Safety Edge

* These options are typically only available for new or reconstruction projects.

If a significant number of CMCs are occurring during wet weather, ice or snowy conditions review:

- Superelevation
- Pavement cross slope
- Faulting pavement
- Pavement ruts
- Standing water on roadway
- Maintenance activities in poor weather

Review the potential mitigation strategies above to mitigate CMC crashes. If installing a barrier system to prevent CMC, document what other mitigation techniques are going to be used with the barrier system. If installing a barrier system without using other mitigation techniques, provide documentation as an attachment to the DSR.

NCHRP 790 Appendix D has some guidance on the effectiveness of some of the potential mitigation strategies for CMC.

The Department uses two methods to determine when a segment of roadway should be reviewed for CMC issues:

- Locations where CMC crash that are statistically likely to have CMC (See FDM 11-45-2.8.1)
- Locations where existing crash history indicates action should take place (See FDM 11-45-2.8.2)
2.8.1 Likely CMC Locations

Cross median crashes are most likely to occur at the following locations\textsuperscript{lxiv, lxv}:

- Downstream of bridge\textsuperscript{*}
- Downstream of on-ramps\textsuperscript{*}
- In curves with a radius of 3,000 ft or less
- Curves to the left\textsuperscript{*}
- Downgrades of 4\% or greater
- Closely spaced on and off ramps between interchanges

\* Locations proven to be statistically significant based on Wisconsin data. Other locations are from NCHRP Report 790

Install median barrier systems at locations indicated above on 3R, 4R, reconstruction, and new construction. If a project is not installing a barrier system at the location indicated above provide documentation in the DSR. Installing barriers at these locations is a proactive measure to prevent future CMC.

Attachment 2.26 and 2.27 provide information on how to install barrier to prevent CMC crashes at locations where CMC crashes are more likely.

Note that because CMC crash are likely at these locations, it is likely that other run off the road crashes are likely here as well. Use caution placing fixed objects or other hazards in locations were CMC crash are likely.

2.8.2 Department’s CMC Hotspot Analysis or CMC Warrants

CMC locations can also be identified based on actual rate of crashes. This can be based on the warrant in FDM 11-45-2.2.17 or the Department’s CMC Hotspot Analysis (see Regional Safety Engineer for more information).

Once a segment of roadway has been identified, it can be difficult to identify where to terminate the treatment of CMC crashes. Use the following methods to determine where to terminate the treatment of CMC crashes.

2.8.2.1 Logical Termini

Logical termini are highway features such as:

- Interchanges
- Grade separations
- Median openings
  - Median intersections
  - Maintenance crossovers
  - Permanent crossovers
  - Roadway transitions to urban lower speed roadway
- Medians wider than 70 feet or AADT less than 90,000 AADT\textsuperscript{*}.

\* If the median is 70 feet or wider and has a CMC crash history, then a median barrier can be installed. If the existing AADT is greater than 90,000 then median barriers can be installed.

If a segment of roadway has been identified by Department’s CMC Hotspot Analysis or CMC warrants in the FDM, and the segment of roadway is within 2,000 feet of a logical terminus, extend CMC shielding to logical terminus.

2.8.2.2 Roadway Similarity

In some cases, median barrier can be extended in areas where the roadway has similar roadway characteristics (e.g. number of lanes, width of lanes, width of shoulder, median width and traffic characteristics to a logical terminus (see FDM 11-45-2.8.2.1).

2.8.6 Median Opening

If a particular segment of roadway has a history of CMC crashes or research has shown that CMC crashes are more likely, a review of existing median openings or crossings is required. Each median opening left in place after the median is shielded can allow a CMC crash.

Avoid placing new median openings in locations where there is a history of CMC crashes, or research has shown the CMC crashes are likely to occur.

If a median opening must remain or be installed, provide documentation on why it is required. What would be the impact if the median opening was closed or not provided? Include this documentation as an attachment to
the DSR.

The desirable way of designing a median opening to limit CMC crashes is in Figure 6.16 in the 2011 AASHTO Roadside Design Guide on how to design a median opening to minimize the likelihood of CMC crash. Attachment 2.28 shows how a cable barrier opening can be designed for maintenance cross over.

If placing a barrier system for CMC near a permanent cross over, contact BPD.

**2.8.7 Barrier Systems for CMC**

Many of the attachments in section 2.8 use a single run of cable barrier to prevent CMC. Although a single run of cable barrier can be effective at limiting CMCs other barrier systems can be used or a designer may need to install two runs of cable barrier.

These other barrier systems typically must be installed on the roadway shoulders (e.g. semi rigid barriers, concrete barrier), are not designed for backside hits (e.g. single faced beam guard) or need median grading that is 10:1 or flatter to allow for proper engagement of the barrier system (e.g. grading causes the vehicle to go over the top of barrier or roll over prior to contact with the barrier).

A design team may decide to install a barrier system besides cable barrier because (list is not all inclusive):

- Grading disrupts median drainage
- Excessive grading is required
- Fixed object density and placement require a barrier with reduced working width for a significant length of a barrier installation

Other sections of the FDM or SDDs should be reviewed when looking at installing another barrier system. Attention may be required when selecting barrier end treatments.

Some specialty barriers could be used in some situation (e.g. double face semi-rigid barrier). If interested in using specialty barriers contact BPD early in the design process. Additional design, special details and special provisions will be required.

**LIST OF ATTACHMENTS**

<table>
<thead>
<tr>
<th>Attachment</th>
<th>Description</th>
</tr>
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### 3.1 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 accurate estimates during scoping or preliminary design.
- Limit the amount of redesign in later stages of the design process.
- Allow for more time to get technical assistance.
- Allow for implementation technical solutions into projects.
- Allow a quicker and more systematic review of roadside design decisions.
- Allow more experienced staff to assist less experienced staff.
- Assist in determining what clear zone is practical for a project or given location within a project.

There are three phases to RHA:

1. Scoping/Preliminary Design/SCP,
2. Design Study Report, and
3. Final Design.

The scoping/preliminary design phase identifies roadside hazards and areas of concern that can have a significant influence on the type of project and what resources a project requires.

The DSR phase has two steps. The first step generates a list of roadside hazards or locations of concern. The second step documents what roadside design methods to be used on a particular hazard or area of concern.

The final design phase is a holistic review of the overall final design. This phase determines if new hazards are being installed or less than desirable situations are being created. This phase also identifies and discusses the use of non-standard barrier systems or safety hardware.

This section will discuss the following:

- What project will need to use the RHA process?
- What is a hazard?
- What is an Area of Concern?
- How far from the roadway do I need to look for hazards or Area of Concern?
- What documentation is required for RHA and where does this documentation belong?

### 3.2 Project Applicability

A PM project may have to use the RHA process. Typically, the type of work being performed on a PM project will influence the extent of the RHA process. Some examples for PM projects are (examples are not all inclusive):

- A PM project is replacing roadway signs because of poor retro reflectivity. Signs that have the correct retro reflectivity but are missing breakaway features would have breakaway supports installed.
- A PM project is working on drainage features (e.g., culvert pipe restoration, culvert pipe replacements, installing culvert pipe liners, rebuilding inlets/manholes). Drainage features that are roadside hazards would be identified and corrective action would be taken.
- A PM project has an Area of Concern. The Area of Concern would be identified and reviewed.
- A PM project that was sealing cracks would not likely install traversable culvert grates. However, this
It's recommended that Regional staff review the PM project with Bureau of Project Development Project Services Section early in the scoping phase. Discuss the extent of the RHA process for a given PM project.

Modernization projects would not have to identify existing hazards because most existing hazards should be treated using the standard roadside design process. However, S-2 and S-3 projects would need to identify new barrier systems that are non-standard, review the final plan to make sure that roadside features are properly located, identify new hazards (e.g. new design is creating a non-traversable slope) and areas of concern (e.g. roadway is being relocated near a school).

Projects that work on retaining walls, bridges, box culverts, or other structures are to conduct a RHA (see FDM 11-45-3.3.3). If retaining walls, bridges, box culverts, large culverts or large drainage conduits are adjacent to or within a road project’s termini, include these features in the project's RHA. Some examples are (list is not all inclusive):

- A roadway project has a "net project length exception" for a bridge (i.e. the bridge is not part of the road project) the bridge is to be included in the roadway project’s RHA process.
- A roadway project terminus is near a bridge or beam guard installation that connects to the bridge. The bridge and associated beam guard would be included in the roadway project’s RHA.

Research has shown that crashes near these features are more severe and more likely to occur, it is important that safety hardware at these locations is installed appropriately. Even though a roadway project was planning to "skip past" a bridge, box culvert, retaining wall or large culvert a barrier system may be required to connect to these structures. Because of the need to connect barriers to these structures or shield hazards associated with these structures, a roadway project is required to review these structures.

### 3.3 Roadside Hazard

As stated previously, one of the key functions of the RHA process is to identify and determine how roadside hazards are handled. This section discusses some of the most common roadside hazards. Not all possible hazards are listed.

The following subsections are roadside hazards and require documentation in the RHA process. Unless noted otherwise, hazards identified in this section do not need to be documented in the scoping/preliminary design phase. However, in some situations it may be a benefit to early review what would normally not be reviewed in scoping. Some examples would be (not all inclusive):

- A significant quantity of work is required on a particular item (e.g. many culvert pipes require traversable grates).
- Work on a particular item will add significant cost (e.g. extend large culvert pipe(s)...).
- Right of Way may be required.

If an issue is identified during scoping/preliminary design, it is to be documented in the DSR phase.

#### 3.3.1 Slopes

Identify hazardous slopes during the scoping/preliminary design phase. Grading may require additional right-of-way, drainage or environmental work. Slopes are either perpendicular to the direction of travel (i.e. foreslope and backslopes) or parallel to the direction of travel (e.g. driveway slopes, side road slopes, median crossovers, ditch checks).

Perpendicular slopes steeper than 4:1 are hazards because an errant vehicle will travel to the bottom of the slope. An errant vehicle on a foreslope steeper than 4:1 will engage the backslope, or any fixed objects on or at the bottom of the foreslope.

Perpendicular 3:1 foreslopes that lack the flat runout area are hazards (see FDM 11-15 Attachment 1.10 page 2). Any ditch at the bottom of a 3:1 foreslope will have the vehicle’s bumper snag on the backslope of the ditch.

For perpendicular backslopes see the discussion on ditches in the culverts and other associated drainage items section.

Parallel slopes that are too steep for a given speed will launch an errant vehicle into the air and in some cases caused the vehicle to flip over (rear bumper rotated over front bumper). Information in FDM 11-45-2.6.2 contains information on acceptable speed and maximum perpendicular slopes.
Figure 3.1 Parallel Slope Hazard

Figure 3.2 Good Parallel Slope and Traversable Endwall
On some projects, it may be possible to determine if slopes are hazards from reviewing as built plans. However, unrecorded construction/maintenance activities, utility work, or natural erosion may have steepened slopes. Conduct a field review to verify what slopes are present along a roadway.

Initially, an on-site visual survey with spot checks with a 4-foot carpenter level (or similar device) can be sufficient on projects that will have future survey work. Projects without future survey work will need to check perpendicular slopes with a 4-foot carpenter level (or similar device), and tape measure. Include slope break points (e.g. barn roof sections), extent of hazardous slope (e.g. station to station, distance perpendicular from roadway) and ditches when reviewing perpendicular slopes.

Slope measurements for the RHA process are not intended to be used as survey for a project. These slope measurements are intended to identify if hazardous slopes are present and to roughly quantify the extent of the
hazard (e.g. How many feet long is the hazardous slope? How tall is the hazardous slope? How steep is the hazardous slope? Are there other hazards on or near the hazardous slope?). Without this information it is difficult to determine an appropriate course of action. Use the following guidance when measuring the slopes with a 4-ft carpenter level on projects without future survey:
- Once every 500 feet
- Spot locations (e.g. driveways, near structures, drainage features, and transitions from cut to fills…).
- Parallel slopes require at least one measurement in the direction of travel.

In some situations, parallel slopes can be approached from two directions (e.g. a driveway on a two lane road has two approaches…) and would require two measurements.

### 3.3.2 Drainage Features

#### 3.3.2.1 Culverts

Working on culverts and associated drainage items may require grading, right of way and modification to existing barrier systems. Coordination with Bureau of Structures or environmental work may also be required.

Identify large culverts or culverts that require a significant amount of grading early in the scoping/preliminary design phase.

See FDM 11-45.2.6 for guidance on hazardous culverts and other typical hazards near culverts.

Other openings wider than 24 or 36 (depending on opening orientation to the roadway) inches are roadside hazards\(^{46}\). Some examples could be (list is not all inclusive):
- Inlets or manhole with no cover
- Three 12-inch culverts placed in close proximity
- Basins, drop structures, channels, (see Figure 3.5)

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\(^{46}\) Opening smaller than 24 or 36 inches may be hazards for pedestrians and bikes.

\(^{47}\) Wall of basin is approximately 1 foot tall. In the direction of travel, the inside dimensions of the basin are 10 feet. Contact with the wall caused excess decelerations.
Improperly installed pipe grates (See Figures 3.7, Figure 3.8, and Figure 3.9) are hazards. For a traversable grate to be effective, the pipes of the traversable grate need to be perpendicular to the direction of travel. Pipe grates that do not have the appropriate hardware (e.g. scheduled 40 pipes with a minimum diameter of 3 inches…) may not have enough strength to support an errant vehicle. Review SDD 8F7 or SDD 8F8 for appropriate spacing and orientation between pipes within a pipe grate.

If a pipe grate is installed like Figure 3.8, it is a hazard. The horizontal bar in the foreground is too far off the ground. An errant vehicle can roll over after its wheel traverses the lower horizontal bar.
3.3.2.1 Ditches

Ditches that fall outside the desirable ditch cross sections in FDM 11-15 Attachment 1.12 pages 1 and 2 are considered 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 hazard (Figure 3.4).

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50Head and sidewalls of the box culvert are 4-inch hazards on a 5-ft chord
3.3.2.2 Other Drainage Related Hazards

Identify water with a normal depth of 2 feet or more in the scoping/preliminary design phase. If a vehicle rolls into water this deep, occupants may drown.

Medium, heavy, and extra heavy riprap is a hazard. Riprap of this size can trip a vehicle or cause excessive deceleration.

![Figure 3.10 Rip Rap is a Hazard](image)

3.3.3 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. Research conducted on Iowa local bridges indicated that are bridges that narrower than the roadway are more likely to experience more vehicle impacts than bridges as wide as the approaching roadway.

Review box culverts, bridges, retaining walls, large drainage conduits and other similar features during the scoping/preliminary design phase. Review the interaction of grading, drainage features, and barrier systems near these features.

Box culverts, bridges, retaining walls, large drainage conduits and other structures require additional coordination with Bureau of Structures (BOS) and Bureau of Project Development (BPD). Structural issues may limit options available to modify hazards (e.g. blunt ends, bridge parapet...), what barrier systems can be used near or on structures.

Work to replace or modify structures should be coordinated with other roadway projects to limit impact on roadway users. Doing the roadwork with the bridgework allows for the correct installation of hardware verses cobbng barrier systems together.

Pay attention to the slopes that wrap around a structure and blend into perpendicular roadway slopes. These slopes may increase the length of barrier needed to shield because they are hazards.

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51 Individual rocks are 4-inch hazards on a 5-ft chord
3.3.3.1 Bridge Parapets

Use only approved bridge parapet or roadway 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 it is not feasible to install an approved parapet or barrier system, it is typically possible to improve the performance of an existing parapet or barrier system. BOS and BPD will determine if an approved parapet design or modifications to the existing parapet or barrier systems are required.

If the parapet is not on standard detail drawings or within BOS’s standard detail drawings, coordination with BOS and BPD is required. There may be crashworthiness issues with the parapet. Parapet designs prior to 1964 may not have sufficient strength to contain an impact. Parapets designed after 1964 may have sufficient strength, but the parapet may have other issues. Some of the typical problems that parapets can have are (list is not all inclusive):
- Brush curb is present.
- Elements of the parapet can allow snag during impact.
- Elements of the parapet can spear into the vehicle cab.
- Elements of the parapet are missing or in poor condition.
- Joints between elements of the parapet are not connected.
- Parapet design prevents smooth redirection.
- Parapet is not sufficiently strong enough to absorb impact load.
- 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.

Some situations may require the professional judgment of an experienced engineer trained in roadside design and a structural engineer to determine if an existing parapet is crashworthy.

Figure 3.12 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.

52 Note that this bridge parapet lacks appropriate thrie beam transition to beam guard.
- Structural strength of parapet elements and connections to bridge may not be sufficient.
- Parapet has an insufficient transition from parapet to semi-rigid barrier system.

Review the quality and condition of the top, sides and bottom of a deck that have parapets mounted to them. A deck that looks good on top may have issues on the sides or bottom of the deck that can impact the performance of the parapet (see Figure 3.13). Provide photos of the parapet and deck (e.g. top, bottom and side of deck) to assist BPD and BOS.

Figure 3.12 Brush Curb

Figure 3.13 Damage to Side of a Deck that May Impact Parapet Performance
Some sources of information that can assist in the evaluation of an existing parapet are:

- Chapter 6 of the 2006 Roadside Design Guide has pictures of inadequate parapets.
- **FDM 11-45-2.5.3** has discussion on concrete barrier issues that can apply to parapets (structural strength, smooth transitions...).
- **FDM 11-45-2.5.2.10** discusses transitions to parapets.
- **CMM 1-45.12.5** has discussion and photos of potential snag issues and damage to temporary barrier that 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.

If there is a driveway or intersection close to the structure, it can be difficult to fit crashworthy hardware. Identify these situations, early in the scoping/preliminary design phase.

### 3.3.3.2 Blunt Ends

Blunt end can be on barrier systems, end of retaining walls, parapets and even some “sloped” bridge parapets are actually blunt ends. All blunt ends are significant hazards. Identify blunt ends that an errant vehicle can hit head on during scoping/preliminary design phase. See **FDM 11-45-2** for more discussion on blunt ends.

### 3.3.3.3 Bridge Piers

Impacts into bridge piers can have serious consequences for the errant vehicle. In some cases, the bridge itself may be damaged. Identify piers as hazards early in the scoping or design process. See **FDM 11-35-5** and **FDM 11-45-2** for more information on piers.

### 3.3.3.4 Retaining Walls

Retaining walls are typically not designed for impact loads. An impact can cause damage to the retaining wall and could cause significant repairs or in the worst case, wall failure. In addition, walls with a ruff face or edges can cause excessive vehicle compartment deformation, rollovers, and large deceleration forces.

Identify retaining walls as a hazard when:

- Errant vehicle can leave the roadway and fall off an unshielded retaining wall.
- Barrier system on top of a retaining wall is in poor condition or substandard.
- Errant vehicle can leave the roadway and strike an unshielded retaining wall.

A chain link fence is not considered a barrier system for errant vehicles.

### 3.3.3.5 Pedestrian Rails

Pedestrian railings using steel pipes with diameters of 2 inches or more are hazardous. Crash testing of a road

---

53 Crash testing has indicated that sand blasted textures with a relief 3/8 of an inch or more can negatively crashworthiness of a concrete barrier system.
sign using 2-inch diameter steel pipe caused excessive vehicle deceleration. Also, pedestrian rails can spear into a vehicle’s passenger compartment. In Figure 3.15 the pedestrian rail is a hazard to an errant vehicle and can prevent a pedestrian from evading an errant vehicle (see FDM 11-45-3.4.1 for discussion of Areas of Concern - Pedestrian).

Figure 3.15 The Pedestrian Rail is a Hazard

Figure 3.16 Pedestrian Rail Entered Cab of Vehicle

3.3.4 Signs and Poles

Signs and poles are some of the most frequent fixed objects that engineers decide to install along a roadway. In this section, traffic signals and railroad crossing warning devices are not considered to be hazards.

In some situations, luminaires may use non-breakaway hardware. However, these poles are to be identified during the RHA process as hazards.

54 Top of railing is typically at 42 inches. Average eye height of a vehicle’s occupants is 42 inches.

55 See 2011 AASHTO Roadside Design Guide for more information

56 Non-breakaway pole may be used in locations where dropping a pole on pedestrians, other roadway users or buildings is not desirable.
Table 3.1 contains a list of conditions where a sign or pole would be identified as a hazard.

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<tr>
<th>Issues</th>
<th>Condition</th>
<th>Discussion</th>
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</thead>
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<tr>
<td><strong>Breakaway Feature</strong></td>
<td>Type I signs missing post clips, post clip bolts, washers or nuts) are hazards (see Sign Plate A4-6 and A5-2)</td>
<td>Post clip hardware allows the overhead sign to detach from the posts during an impact. If a sign does not detach from a post during an impact, the sign may fall on top of the vehicle or cause the vehicle to decelerate too quickly.</td>
</tr>
<tr>
<td><strong>Breakaway features</strong></td>
<td>Breakaway features are missing or are not installed correctly (see Figure 3.17 to Figure 3.23) are hazards.</td>
<td>Sign or pole may not breakaway as intended (see discussion below).</td>
</tr>
<tr>
<td><strong>Breakaway features</strong></td>
<td>A sign is a hazard if the sign is heavier or has dimensions greater than what was crash tested. Adding hardware to a crashworthy pole design or relocating hardware on a pole can make the pole a hazard.</td>
<td>Signs that are heavier than what was crash tested can prevent the breakaway hardware from functioning or allow the sign to impact the errant vehicle. Signs that are larger than what is crash tested may enter a vehicle cab. Additional mass or relocating a mass can change the rotational inertia of a pole or sign. If the rotational inertia is changed, a sign or pole may lock into place versus rotating over the top of an errant vehicle.</td>
</tr>
<tr>
<td><strong>Breakaway features</strong></td>
<td>Signs or poles that use weathering or Cor-Ten Steel are hazardous (See Figure 3.23).</td>
<td>This type of steel can cause breakaway features to rust shut and become non-functional</td>
</tr>
<tr>
<td><strong>Breakaway features</strong></td>
<td>Steel poles with a diameter of 2 inches or more are hazards.</td>
<td>Without modifications that weaken the pipe or the use of breakaway features, pipes this size can cause a vehicle to decelerate too quickly.</td>
</tr>
<tr>
<td><strong>Placement and Breakaway Features</strong></td>
<td>Signs that do not conform to WisDOT’s Sign Plates A3-1, A4-1, A4-2, or A4-3 are hazards.</td>
<td>Signs that do not follow these details have issues with proper sign placement or the sign is not using breakaway hardware.</td>
</tr>
<tr>
<td><strong>Placement</strong></td>
<td>Breakaway features for a sign or pole is more than 4 inches tall on a 5-foot chord are hazards (See Figure 3.17, Figure 3.18, and Figure 3.20).</td>
<td>Grading near a sign or pole can cause the breakaway feature to become a snagging hazard.</td>
</tr>
<tr>
<td><strong>Placement</strong></td>
<td>Sign or poles installed in poor soils or wet soils are hazardous. Signs or poles installed near the bottom of a ditch can be hazards.</td>
<td>Poor or wet soils may not allow breakaway features to engage. Ditch slopes can steer an errant vehicle into a sign or pole. Signs and pole installed within 3 feet of the ditch bottom are hazards.</td>
</tr>
<tr>
<td><strong>Placement</strong></td>
<td>Signs or poles are within the working width or the zone of intrusion of a barrier system are hazards.</td>
<td>Errant vehicle may engage the barrier system and engage the sign or pole behind the barrier (see working width discussion in other sections of FDM 11-45-2).</td>
</tr>
<tr>
<td><strong>Placement</strong></td>
<td>Signs or poles are installed within 70 feet of an EAT (See figure in CMM 6-26).</td>
<td>Errant vehicle may try to avoid the sign or pole and steer into the EAT. An errant vehicle may gate through an EAT and then hit the sign or pole.</td>
</tr>
<tr>
<td><strong>Placement</strong></td>
<td>Guy wires and poles are near the roadway.</td>
<td>Guy wires are significant hazards. (See Figure 3.25 and Figure 3.26).</td>
</tr>
<tr>
<td><strong>Placement</strong></td>
<td>Grading leading to or around object can prevent object from working correctly</td>
<td>If vehicle engages breakaway pole too high, the pole may not work as designed (Figure 3.27)</td>
</tr>
</tbody>
</table>

Overhead sign supports, sign bridges, message board do not conform to shielding requirements of FDM 11-55-20 are hazards.
Figure 3.17 Light Pole using Non-Breakaway Hardware 57

Figure 3.18 The Footing is a 4-inch Hazard 58

57 Footing is a 4-inch tall object on a 5-foot chord hazard

58 This fixed object serves no purpose and should be removed.
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.

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59 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 3.22 Breakaway Holes in Wrong Location

Figure 3.23 Cor-Ten/Weathering Steel Prevented Breakaway Hardware from Working

Figure 3.24 Pole with Cabinet did not Breakaway
Figure 3.25 Utility Poles are Hazard

Figure 3.26 Guy Wire Cut Car into Two Pieces
3.3.5 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 3.29 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 noted as fixed object hazards because of the 4-inch on 5-foot chord criteria. In some cases, it may not be possible to install a sign or pole without violating the 4-inch on 5-foot chord criteria, but care should be taken to minimize these situations.

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60 Concrete foundation is a 4” tall hazard on 5’ 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 3.29 4-inch tall hazard on 5-foot chord

Figure 3.30 Rock is a Fixed Object Hazard
3.3.5.1 Trees

Preliminary results from NCHRP Project 17-43 indicate the following:\textsuperscript{xxx}

- 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 (i.e. Hit tree at 22 mph and came to 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 roadways are associated with an increase in crash frequency and crash severity.\textsuperscript{lxxxiii}

A tree with a diameter of 4 inches or more or will grow to be more than 4 inches in diameter is a hazard.\textsuperscript{lxxxii}

Bushes or groups of closely spaced, small trees with a group diameter of 4 inches or more are hazards.\textsuperscript{lxxxiii}

Measure a tree’s diameter 4 inches from the ground.\textsuperscript{lxxxiv} Include stumps in hazardous tree identification.
Figure 3.33 is an example of what a vehicle impact looks like on a tree. Review existing trees for similar scars. Woody limbs can become spearing hazards. For an example in Figure 3.34, even though the small trees are behind a barrier (more than likely the trees are within the working width of the barrier), a branch fatally speared an occupant of an errant vehicle.
Roadside landscaping and aesthetic issues can conflict with roadside design concepts. Planting a small tree near a traffic lane may not seem to be a big issue during the design of a project. However, the tree will grow into a long-term hazard that can cause significant injury or fatality.

Typically, removing existing trees is inexpensive, reduces ROR frequency and ROR severity. It may not be practical to remove all hazardous trees. Some examples when it may not be practical to remove a tree would be (list is not all inclusive):

- A tangent section of a PM project within a suburban setting that does not have ROR history.
- A tree or grove of trees is:
  - A documented “Witness Tree” for surveying
  - Where a historically significant event took place
  - A memorial to an important person, group, or historical event
  - A endanger/threatened tree species or habitat for endanger/threatened species
    - A documented rare or exceptional example of a tree species
- The roadway is:
  - A rustic roadway
  - On the Great River Roadway network
- Other locations that it may be difficult to remove trees are:
  - Scenic overlooks
  - Historical properties
  - Parks

If a hazardous tree or groves of trees are to remain in place, provide additional discussion in the RHA process.

3.3.5.2 Mail Boxes

FDM 11-15-1.9.4 provides guidance on how designers are to treat hazardous mail boxes. See CMM 3-15.5 for a handout on mailboxes. Identify hazardous mail boxes during the RHA process.

3.3.5.3 Fences

Chain link fences with a top rail are hazard. Top rails can be pipe or steel channels.

61 In these locations the trees are part of the original historical setting.

62 For an example, a given tree is the third largest white pine in the state.

63 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).
3.3.5.4 Barrier Systems
Barrier systems\textsuperscript{64} are hazards. Identify barrier systems during the scoping/preliminary design phase. See FDM 11-45-2.5 for additional information on reviewing barrier systems.

3.3.5.5 Vertical Drops
Vertical drops noted in this section should be noted early in the scoping or early design process as hazards for vehicles. Drops of lesser height may be hazards for other users of a facility (e.g. bike and pedestrians).
Vertical drops of 8 feet or taller are hazardous (see Figure 3.36)\textsuperscript{65}.
Drops of 6 feet or more combined with other hazards (e.g. water with a normal depth of 2 feet or more, rip rap, drainage ditch or channel slopes…) are hazards.
Vertical drops with high consequence of collision (see FDM 11-45-2 Attachment 2.5)

\begin{figure}
\centering
\includegraphics[width=\textwidth]{vertical_drop.png}
\caption{Vertical drop and water hazards are hazards}
\end{figure}

3.3.5.6 Planters, Monuments and Similar Objects
Planters, monuments, and similar objects are hazards that need to be identified early in the scoping and design of a project.
Planters, monument, and similar objects may not be structurally strong enough to absorb impact loads, allow a vehicle to have a blunt end impact, snag a vehicle, occupant interaction with objects within the planter/monument, excessive vehicle compartment deformation, rollovers, and large deceleration forces.

\textsuperscript{65} Vehicles have a tendency to flip or rollover when they traverse vertical drops of 8 feet or more.
3.4 Areas of Concern

As stated previously, one of the functions of the RHA process is to identify and place emphasis on Areas of Concern. Areas of Concern are locations where ROR crashes are more likely to occur, crash severity is high, or the consequence of a collision is severe (See FDM 11-45-2 Attachment 2.5 for more discussion). Identify Areas of Concern during the scoping/preliminary design phase of a project.

The list of areas of concern in the following sections is not all inclusive. Individual locations may require the professional judgment of an experienced engineer trained in roadside design.

In some cases, it may not be possible to address an Area of Concern with a project (e.g. it may not be reasonable to shield an Area of Concern). However, it may be possible to minimize risks (e.g. move bus stop out of a curve, remove hazards that are likely to be hit, provide signing, remove visual obstructions...).

3.4.1 Areas of Concern - Pedestrians

Areas of Concern with pedestrians are:

- Locations where pedestrians would have no escape route or little time to react to an errant vehicle (See Figure 3.15 and Figure 3.38).
- Locations where there is frequently a high concentration of pedestrians (See Figure 3.39).\(^{67}\)
- 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 roadway.).

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\(^{66}\) Planter has various other roadside design issues. Curb and gutter in front of the planter can cause a vehicle to not properly engage the planter. Texture of planter may cause excessive decelerations or vehicle rollover.

\(^{67}\) The presence of a sidewalk does not indicate that there is a high pedestrian concentration.
Other areas that could have frequent high pedestrian concentrations are (list is not all inclusive):

- Memorials
- Parks
- Scenic outlooks
- Trail crossing
- Athletic fields
- Playgrounds
- Transit shelters
- Schools
- Senior centers
- Medical facilities

The presence of these types of facilities does not automatically indicate that there is a high pedestrian concentration (e.g. a road may run along a school property but be far from the main entrance).

Consider the abilities of the pedestrians using the facility. For an example, children in a playground may not be as focused or have the same ability to escape an errant vehicle as a group of college students waiting to cross a street.

3.4.2 Areas of Concern - Locations with High Run Off the Road Crashes

Areas of Concern with high run off the road crashes are:
- Areas with known high ROR crash rates
  - Roadway segments with Metamanager ROR Flags
  - Other spot locations where crash reports indicate a ROR problem
- Areas where research indicates ROR accidents are more likely to occur

Review FDM 11-45-2 Attachment 2.5.

3.4.2.1 Curves
Research has shown that curves are more likely to have run off the road crashes. In one study 70% of all fatal crash occurred on or near the outside of horizontal curves. Other studies have also indicated that the probability of leaving the roadway is greater on curves. Curves that are likely to experience run off the road crashes are:
  - An entrance curve that leads into a series of curves
  - 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)
  - Compound curves that have a ratio of 1.5 or more between radii.88 Curves with advisory speed signs that are significantly lower than the approach tangent’s speed
  - Sharp curves within or at the bottom of a steep grade.

3.4.2.2 Other Locations
Other areas that are likely to experience run off the road crashes are (list is not all inclusive):
  - Top of the “T” of a T intersection
  - Areas adjacent to or downstream of a merge/diverge area
  - A roadway segment where there is weaving
  - Upstream of taper, taper and gore area of a off ramp
  - Gore area, taper and downstream of taper of an on ramp
  - Upstream and adjacent to a major fork
  - Upstream and downstream of a bridge
  - Areas with inadequate sight distance.

3.4.2.3 Areas of Concern-Locations that Violate Driver Expectation
Locations that violate a driver’s expectations are likely to experience ROR. Some potential locations are (list is not all inclusive):
  - Left hand off or on ramps
  - Sharp curves hidden by profile changes

Figure 3.40 and Figure 3.41 show a roadway where driver expectation is violated. In Figure 3.40, a driver expects the roadway to go straight. However, Figure 3.41 shows that the "straight" road is a side road and not the mainline.

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88 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.
3.4.2.4 Areas of Concern—Locations with High Consequence of a Collision

Review discussion in FDM 11-45-2 Attachment 2.5 on Consequence of Collision. For errant vehicles or other users of the roadway network are the following are considered areas of Concern (list is not all inclusive):

- See Vertical Drop section of this procedure
- Overhead sign or sign bridge or other similar structure
- Message board

Other areas of with high consequence of collision for the whole community are (list is not all inclusive):

- Power plants/substations
- Chemical plants/storage areas
- Natural gas/petroleum facilities

3.5 Area of Analysis

Identify all hazards and Areas of Concern within the area of analysis. The width of the area of analysis for RHA
is measured similar to clear zone (i.e. measure edge of lane of travel toward the right of way). However, if the edge of lane is not defined or other lanes act as through lanes, measure from the outside edge of his type of lane. Some examples 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
- Desirable 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 acquiring right of way, use existing right of way to limit the area of analysis. If a property or portion of a property cannot be purchased within the project that is purchasing right of way (e.g. environmental, cultural resource, historical property…), then the existing right of way may be used to limit the area of analysis at that specific location. Document why existing right of way was used to limit analysis when desirable clear zone should be used in DSR.

Include significant hazards that are just beyond the area of analysis. If a cliff were 1 foot outside the area of analysis, it would be documented in the RHA process.

Break the roadway into segments with similar geometrics (e.g. number of lanes, lane width, shoulder width…), AADT and speed when documenting hazards. Segmenting a project this way allows for a reasonable comparison of exposure and crash severity without complicated analysis.

Median divided roadway may be treated as two roadways (e.g. one roadway running north, one running south) or as one roadway (e.g. northbound and southbound roadways together). If documenting median divided highways as two roadways, note which roadway will document the median hazards.

3.6 Roadside Hazard Analysis (RHA) Documentation

3.6.1 Scoping/Preliminary Design

Use Attachment 3.1 during scoping and preliminary design. If items are discovered during the early scoping or preliminary design, modification of project scope may be required.

If a hazard is identified during the scoping/preliminary design, it is to be listed in the DSR phase of the RHA.

BPD is in the process of integrating RHA process into the PMP process.

3.6.2 DSR Phase

A Form has been developed to assist in the documentation of hazards. Include this form as an attachment to the DSR. An example of this form can be found in Attachment 3.2.

The preferred roadside hazard treatment process is (in order of desirability):

1. Remove hazard.
2. Make hazard traversable.
3. Relocate hazard to a location where the hazard is less likely to be hit.
4. Use breakaway hardware.
5. Shield hazard with a barrier system, crash cushion, sand barrel array if hazard cannot be eliminated relocated or use breakaway hardware.
6. Delineate hazard if none of the above alternatives are feasible.

Provide justification when shielding, delineating or not acting on a particular hazard. Address why the other more preferred methods of treatment are not being used.

Use caution when using construction or right away cost to justify what type of treatment or lack of treatment is being used. Cost justifications are to review maintenance and crash cost. Use Attachment 2.5 to assist in decision-making.
3.6.3 Final Design
During the Final Design process, designer should review plans looking for the following issues:
- Plan has adequate 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 function of safety hardware or other features.

By following the RHA process, and properly installing safety hardware, few of the situations listed above should be discovered during the final design process. However, given the complexity of plans and the number of people involved in the development of a plan it is possible that the above situation can happen.

Designers should strive to eliminate issue identified above. If it not possible to eliminate issue identified above, the designer should coordinate with Region and provide an amendment to the DSR. The amendment should address why these issues cannot be eliminated.

LIST OF ATTACHMENTS
Attachment 3.1 Scoping/Preliminary Roadside Hazard Design Review List
Attachment 3.2 Roadside Hazard Analysis Sheet Template
Attachment 3.3 Roadside Hazard Analysis Sheet Example

FDM 11-45-4 Roadside Design Application – Improvement Strategy

4.1 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 11-45-2 - Roadside Barrier Design Guidance
- FDM 11-45-3 - Roadside Hazard Analysis

FDM 11-45-4 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.

Roadside hazards analysis and treatment requirements will be categorized under three pavement treatment service lives as described under FDM 11-45-4.2. Follow FDM 11-45-4.3 for roadside hazard analysis and treatment guidance.

Refer to FDM 11-45-4.4 for guardrail hardware evaluation and treatment requirements.

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 11-45-2.4.1.3.

A flowchart has been developed to assist designers in addressing roadside hazards and guardrail hardware evaluation and treatments for Perpetuation and Rehabilitation projects. Refer to Attachment 4.1 for the flowchart.

Follow FDM 11-45-1, FDM 11-45-2 and FDM 11-45-3 guidance for Modernization improvement projects.

4.2 Application of Improvement Strategy
Roadside hazard analysis (RHA) will be performed and treatments recommended based on the project improvement strategy:
Refer to the project’s Final Scope Document for the expected improvement strategy.

4.3 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. Additionally, refer to the supplemental decision tree guidance under Attachment 4.1.

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 11-45-3.

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).

4.3.1 Roadside Hazard Analysis/Treatment – Perpetuation Improvement Strategy

A roadside hazard analysis (RHA) will not be required for this strategy. Re-evaluate roadside fixed objects and their potential removal/relocation with the next improvement project.

4.3.2 Roadside Hazard Analysis/Treatment – Rehabilitation Improvement Strategy

At locations using S-2 Applications - Perform RHA per FDM 11-45-3 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 with the S-2 area(s) that qualify for removal under the RHA. An RHA 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 11-45-3 qualify for removal. Refer to FDM 11-45-3.6.2 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.

4.3.3 Roadside Hazard Analysis/Treatment – Modernization Improvement Strategy

Perform RHA per FDM 11-45-3. Remove existing roadside hazards that qualify for removal per the analysis. Refer to FDM 11-45-3.6.2 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).

4.4 Guardrail Hardware Evaluation and Treatments

Perform field/as-built plan assessment of existing guardrail system (including hardware) per FDM 11-45-2.5 on all Perpetuation and Rehabilitation projects. All improvement projects will replace existing downturned or blunt terminal ends, including breakaway cable terminals (BCTs) and MELT systems, with new EAT end treatments. Apply the following guardrail hardware guidance for all Perpetuation and Rehabilitation improvement projects:

- Replace/restore existing guardrail system or hardware where determined to be deficient/missing.
- Replace guardrail where the remaining service life is less than the improvement’s pavement treatment service life. If the existing guardrail has a reasonable service life remaining, it is not mandatory to replace it.
- Install or replace any guardrail 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 guardrail system is replaced, install new beam guard Midwest Guardrail System (MGS) per FDM 11-45-2. Determine guardrail length of need (LON) per FDM 11-45.2.3.1.3.
- Replace unconnected or non-compliant beam guard transitions to rigid barriers per FDM 11-45-.
2.5.2.10.
- Replace existing non-EAT end treatments with EATs. Existing EATs may be left in place if determined to be in good condition.
- Attain preferred EAT grading for S-1 applications as described in FDM 11-45-2.4.1.3. Where preferred EAT grading is not possible, refer to FDM 11-45-4.4.1 for guidance on end treatment grading for S-1 applications.
- Attain preferred EAT grading for S-2 applications as described in FDM 11-45-2.4.1.3. Acquire right-of-way, if necessary, to accommodate preferred EAT grading for S-2 applications. See FDM 11-45-4.4.2 for additional right-of-way acquisition guidance. Refer to FDM 11-1-10 for S-1 and S-2 application definitions.

4.4.1 Guardrail and End Treatment Considerations for S-1 Applications
Evaluate whether preferred EAT grading installation is attainable per FDM 11-45-2.4.1.3. 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 11-45-2.4.1.4. 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 11-45-2.4.1.5 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.

4.4.2 Right of way Acquisition Considerations
Right-of-way acquisition to accommodate EAT grading will not be required with Perpetuation and Rehabilitation improvements using S-1 Applications. However, acquire new right-of-way with the project to accommodate preferred EAT grading if new right-of-way is being acquired elsewhere (e.g. intersections and other spot improvements) within the project limits. In this situation, improve all existing end terminals with new EATs and preferred grading per FDM 11-45-2.4.1.3 along the entire project length (i.e. inclusive of all S1 and S-2 areas).

LIST OF ATTACHMENTS
Attachment 4.1 Roadside Hazard and Guardrail Decision Flowchart for Perpetuation and Rehabilitation Highway Improvement Projects

FDM 11-45-5 Fencing August 31, 2006

5.1 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.

In very rare instances 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.

5.2 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.

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.

5.3 WisDOT Policy for Expressways
Department policy is to generally not fence expressways 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.

5.3.1 Exceptions to 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:
   - 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.

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69 The clear zone for a multi-use path is normally 3 feet minimum beyond the edge of traveled way.

70 Expressways are generally defined as divided highways with at-grade intersections and usually having a posted speed of 50 mph or greater.
- 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.

5.3.2 Location of Expressway Fencing

Department policy is to generally not fence expressways, including expressways with multi-use paths, and to minimize fencing in those locations where it is deemed necessary. If an exception to this policy is needed 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 path71. 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 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.

5.4 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.

5.4.1 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.

71 The clear zone for a multi-use path is normally 3 feet minimum beyond the edge of traveled way.
5. Along steep embankments or drop offs such as a box culvert opening adjacent to a sidewalk.

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.

5.4.2 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.

5.5 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.

5.6 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.

5.7 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.
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