# TABLE OF CONTENTS

**Chapter 13: Drainage**

### Section 13-1 Drainage Practice

<table>
<thead>
<tr>
<th>13-1-1</th>
<th>Drainage Practice Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Introduction</td>
</tr>
<tr>
<td>1.2</td>
<td>General</td>
</tr>
<tr>
<td>1.3</td>
<td>Basic Statewide Practice</td>
</tr>
<tr>
<td>1.4</td>
<td>Design Responsibility</td>
</tr>
<tr>
<td>1.5</td>
<td>Common Drainage Law</td>
</tr>
<tr>
<td>1.6</td>
<td>Statutory Drainage Law</td>
</tr>
</tbody>
</table>

**Attachment 1.1** | Glossary of Terms |

<table>
<thead>
<tr>
<th>13-1-5</th>
<th>Major Drainage Guidelines and Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Definition</td>
</tr>
<tr>
<td>5.2</td>
<td>General Guidelines</td>
</tr>
<tr>
<td>5.3</td>
<td>Surface Data Collection</td>
</tr>
</tbody>
</table>

**Attachment 5.1** | Drainage Data Requirements, Design Aids and Computer Software |

**Attachment 5.2** | Major Drainage Summary Sheet |

<table>
<thead>
<tr>
<th>13-1-10</th>
<th>Documentation of Hydrologic/Hydraulic Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1</td>
<td>Introduction</td>
</tr>
<tr>
<td>10.2</td>
<td>Bridge and Box Culvert Design</td>
</tr>
<tr>
<td>10.3</td>
<td>Stormwater Report Applicability</td>
</tr>
<tr>
<td>10.4</td>
<td>Design Documentation</td>
</tr>
<tr>
<td>10.5</td>
<td>Stormwater-Drainage-WQ Report Spreadsheet Instructions for Drainage Design</td>
</tr>
</tbody>
</table>

**Attachment 10.1** | Stormwater-Drainage-WQ Report Spreadsheet: Drainage - Summary Worksheet |

**Attachment 10.2** | Stormwater-Drainage-WQ Report Spreadsheet: Drainage - Data Worksheet |

<table>
<thead>
<tr>
<th>13-1-15</th>
<th>Culvert Material Selection Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.1</td>
<td>Application</td>
</tr>
<tr>
<td>15.2</td>
<td>Selection Standard</td>
</tr>
<tr>
<td>15.3</td>
<td>Special Situations</td>
</tr>
<tr>
<td>15.4</td>
<td>Corrosion Concerns About Steel Culvert Pipe</td>
</tr>
<tr>
<td>15.5</td>
<td>Abrasion Concerns</td>
</tr>
<tr>
<td>15.6</td>
<td>Limited Clearance Installations</td>
</tr>
<tr>
<td>15.7</td>
<td>Culvert Selection Justification</td>
</tr>
<tr>
<td>15.8</td>
<td>Tied Joints</td>
</tr>
<tr>
<td>15.9</td>
<td>Height of Cover for Culvert Pipes</td>
</tr>
<tr>
<td>15.10</td>
<td>Roughness Coefficient for Culvert Pipe</td>
</tr>
</tbody>
</table>

**Attachment 15.1** | Potential for Bacterial Corrosion of Zinc Galvanized Steel Culvert Pipe (Map) |

<table>
<thead>
<tr>
<th>13-1-17</th>
<th>Storm Sewer Material Selection Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.1</td>
<td>Application</td>
</tr>
<tr>
<td>17.2</td>
<td>Selection Standard</td>
</tr>
<tr>
<td>17.3</td>
<td>Approved Materials</td>
</tr>
<tr>
<td>17.4</td>
<td>Special Situations</td>
</tr>
<tr>
<td>17.5</td>
<td>High Groundwater and Buoyancy of Thermoplastic Pipe</td>
</tr>
<tr>
<td>17.6</td>
<td>Storm Sewer Pipe Connections</td>
</tr>
<tr>
<td>17.7</td>
<td>Height of Cover for Storm Sewer</td>
</tr>
<tr>
<td>17.8</td>
<td>Roughness Coefficient for Storm Sewer</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>13-1-20</th>
<th>Large Drainage Conduit</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.1</td>
<td>Introduction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>13-1-21</th>
<th>Precast Box Culverts</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.1</td>
<td>Introduction</td>
</tr>
</tbody>
</table>

| 13-1-25 | Fill Height Tables |
FDM Chapter 13 Table of Contents

25.1 Design Criteria
25.2 Design Methods
25.3 Cut Ends
25.4 Multiple Structures
25.5 Abrasive or Corrosive Conditions

Attachment 25.1 Storm Sewer Fill Height Table for Concrete Pipe
Attachment 25.2 Fill Height Table-Corrugated Steel, Aluminum, Polyethylene, Polypropylene and Reinforced Concrete Pipe, HS20 Loading, 2- 2/3in x 1/2in Corrugations
Attachment 25.3 Fill Height Tables: Corrugated Steel Pipe, 3 in x 1in Corrugations; and Structural Plate Pipe, 6in x 2in Corrugations
Attachment 25.4 Fill Height Tables: Corrugated Steel Pipe Arch, 2- 2/3in x 1/2in Corrugations; and Corrugated Steel Pipe Arch, 3in x 1in Corrugations
Attachment 25.5 Fill Height Table, Structural Plate Pipe Arch, 6inx2in Corrugations
Attachment 25.6 Fill Height Tables: Corrugated Aluminum Pipe, 3in x 1in Corrugations; and Aluminum Alloy Structural Plate Pipe, 9in x 2 1/2in Corrugations
Attachment 25.7 Fill Height Table, Corrugated Aluminum Pipe Arch, 2 2/3in x 1/2in Corrugations
Attachment 25.8 Fill Height Table, Aluminum Alloy Structural Plate Pipe Arch, 9in x 2- 1/2in Corrugations
Attachment 25.9 Fill Height Table, Reinforced Concrete Arch and Elliptical Pipe (all sizes); and Dimensions for Reinforced Concrete Arch and Elliptical Pipe (English)

13-1-30 Culvert Replacement and Analysis for Perpetuation and Rehabilitation Projects
30.1 Background
30.2 Applicability
30.3 Guidelines for Culvert Replacement on Perpetuation and Rehabilitation Projects
30.4 Culvert Materials on Perpetuation and Rehabilitation Projects
30.5 Culvert Extensions, Endwalls and Traversable Grates on Perpetuation and Rehabilitation Projects
30.99 Resources
Attachment 30.1 Guidelines for Determining a Rural Area
Attachment 30.2 Culvert Sizing Quick Check

Section 13-5 Field Work
13-5-1 Introduction
1.1 Introduction
13-5-5 Survey Data
5.1 Drainage Cross Section for Small Culverts
5.2 Drainage Surveys for Large Culverts and Bridges
5.3 Preliminary Field Review
5.4 Changes in Existing Flow Conditions
5.5 Tail-Water Controls
5.6 Final Field Review

Section 13-10 Hydrology
13-10-1 Design Criteria
1.1 Introduction
1.2 Flood Frequency
1.3 Design Frequency
1.4 Freeboard Considerations
1.5 Use and Design of Overflow Sections
1.6 Probability of Flood Occurrence
1.7 Future Development Effects
1.8 Hydraulic Information on Plans
Attachment 1.1 Flood Design Frequency Selection Chart
Attachment 1.2 Probability of Flood Occurrence (Table)
Attachment 1.3 Probability of Flood Damage Before Payment of 25-Year Mortgage
13-10-5 Methods of Determining Peak Runoff
5.1 Design Discharge
5.2 Discharge Frequency Graph
5.3 Rational Method
5.4 Urban Hydrology for Small Watersheds (TR-55)
FDM Chapter 13 Table of Contents

5.5 USGS Flood Frequency Equations for Wisconsin
5.6 Gaging Station Data
5.7 Log Pearson Type III Distribution
5.8 Transferring Gaged Discharges
5.9 Comparison of Similar Drainage Basin at Gaged Sites
5.10 Published Watershed Studies
5.11 Field Review Notes, Interviews, and Historical Data
5.12 References

Attachment 5.1 Area Limits for Peak Discharge Methods
Attachment 5.2 Runoff Coefficients (C), Rational Formula, and Runoff Coefficients for Specific Land Uses
Attachment 5.3 Time of Concentration of Small Drainage Basins (Nomograph)
Attachment 5.4 Rainfall Intensity-Duration-Frequency Curves
Attachment 5.5 Contour Map for Example Problem
Attachment 5.6 Runoff Curve Numbers for NRCS TR-55 Method
Attachment 5.7 TR-55 Graphical Discharge Method (Example)
Attachment 5.8 Discharge Frequency Graph (Example)

13-10-10 Hydrograph Development and Routing
  10.1 Development
  10.2 Procedure
  10.3 NRCS Triangular and Curvilinear Dimensionless Unit Hydrograph Methods
  10.4 Routing
  10.5 Detention Pond Example
  10.6 References

Attachment 10.1 Basic Watershed Data Work Sheet
Attachment 10.2 Hydrograph Development Work Sheet
Attachment 10.3 Sample Hydrograph
Attachment 10.4 Headwater Depth Nomograph
Attachment 10.5 Depth-Outflow Graph (example)
Attachment 10.6 Storage Indicator Curve Work Sheet
Attachment 10.7 Storage-Indicator Curve (example)
Attachment 10.8 Stage-Storage Curve (example)
Attachment 10.9 Hydrograph Data Work Sheet
Attachment 10.10 Hydrograph (Example)
Attachment 10.11 Example Problem Illustration

Section 13-15 Hydraulic Design of Culverts

13-15-1 Economic Analysis
  1.1 Introduction

13-15-5 Design Criteria
  5.1 Introduction
  5.2 Culvert Location
  5.3 Structure Size Selection
  5.4 Allowable Headwater
  5.5 Design Freeboard and Headwater-to-Depth Ratio
  5.6 Inlet Treatments
  5.7 Improved Inlets
  5.8 End Protection
  5.9 Type, Shape, and Roughness of Culvert
  5.10 Design Tail Water
  5.11 Allowable Velocity
  5.12 Depth of Flow
  5.13 Check Discharges
  5.14 References

Attachment 5.1 Entrance Loss Coefficients (Ke) for Culverts

13-15-10 Culvert Hydraulics
  10.1 Introduction
  10.2 Available Design Aids
Section 13-30 Channels and Road Ditches

13-30-1 Channel Types and Characteristics
   1.1 Channel Types
   1.2 Roadside Ditches
   1.3 Median Ditches
   1.4 Toe of Slope and Intercepting Embankments

13-30-5 Channel Characteristics
   5.1 Introduction
   5.2 Vertical Alignment
   5.3 Horizontal Alignment
   5.4 Roughness Factors
   5.5 Channel Geometry
   5.6 Natural Channels

13-30-10 Hydraulic Design of Open Channels
   10.1 Introduction
   10.2 Types of Flow
   10.3 Uniform Flow
   10.4 Manning's Roughness Coefficient
   10.5 Shear Stress
   10.6 Design Parameters
   10.7 General Design Procedures
   10.8 References

13-30-15 Grass Lined Channels
   15.1 Introduction
   15.2 Grass Lining Properties
   15.3 Manning's Roughness
   15.4 Permissible Shear Stress
   15.5 Grass Cover Factor
   15.6 Permissible Soil Shear Stress
   15.7 Grass Lined Channel Design Example
   15.8 References

Attachment 15.1 Grass Lined Channel Design Example (Using HEC-15)
### Section 13-35 Erosion and Water Pollution Control

**13-35-1 Special Hydraulic Structures**

1.1 Introduction
1.2 Flow Control Gates
1.3 Debris Control Structures
1.4 Detention Basin
1.5 Temporary Sediment Structures

**13-35-5 Energy Dissipaters**

5.1 Introduction
5.2 Riprap Blanket
5.3 Lined Channel Expansions
5.4 Outlet Expansion
5.5 Literature on Energy Dissipaters

**Attachment 5.1** Dissipater Limitations

**Attachment 5.2** Recommended Configuration of Riprap Blanket Subject to Maximum and Minimum Tail Waters

**Attachment 5.3** Culver Outlet Erosion Protection, Lined Channel Expansions

**Attachment 5.4** Example Problem, Lined Channel Expansion Design

**Attachment 5.5** Typical Outlet Expansion Diagram

**Attachment 5.6** Length Requirements for Expanded Pipes

### Section 13-40 Subgrade Drainage

**13-40-1 Underdrains**

1.1 Introduction
1.2 Descriptions
1.3 Design Criteria
1.4 Underdrain Conduit Installations
1.5 Material Considerations
1.6 Geotextile Fabric
1.7 Selection of Type
1.8 Construction
FDM Chapter 13 Table of Contents

Attachment 1.1......Subdrains
Attachment 1.2......Suggested Depth and Spacing of Underdrains for Various Soil Types

Section 13-45 Culvert and Storm Sewer Rehabilitation and Replacement

13-45-1......Background
   1.1......Introduction
   1.2......Design Responsibility and Coordination
   1.3......Definitions

13-45-5......Design Considerations
   5.1......Introduction
   5.2......Evaluation
   5.3......Hydraulics
   5.4......Structural Condition
   5.5......Cleaning and Verification of Clearance
   5.6......Environmental
   5.7......Safety
   5.8......Access
   5.9......Traffic

13-45-10......Culvert Rehabilitation by Sliplining
   10.1......Introduction
   10.2......Types of Sliplining
   10.3......Sliplining Materials
   10.4......Slipliner Design Considerations

Attachment 10.1......Culvert Liner Hydraulic Check

13-45-15......Other Culvert Repair and Rehabilitation Practices
   15.1......Introduction
   15.2......Invert Paving
   15.3......Cured in Place Liner (CIPP)
   15.4......Centrifugally Cast and Spray-on Liners
   15.5......Pre and Post Installation Inspection of Cured in Place Pipe Liners (CIPP), Cast, and
            Spray-on Liners
   15.6......Design Requirements for Cured in Place Pipe Liners (CIPP), Cast, and Spray-on Liners
   15.7......Cost Considerations for Cured in Place Pipe Liners (CIPP), Cast, and Spray-on Liners

13-45-20......Trenchless Installation of New or Replacement Culvert Pipe and Storm Sewer
   20.1......Introduction
   20.2......Environmental Considerations
   20.3......Geotechnical Considerations
   20.4......Trenchless Construction Methods

13-45-99......Resources and References
   99.1......Resources
   99.2......References