



TABLE OF CONTENTS

Chapter 13: Drainage

Section 13-1 Drainage Practice

- 13-1-1 Drainage Practice Background
 - 1.1 Introduction
 - 1.2 General
 - 1.3 Basic Statewide Practice
 - 1.4 Design Responsibility
 - 1.5 Common Drainage Law
 - 1.6 Statutory Drainage Law
 - Attachment 1.1 Glossary of Terms
- 13-1-5 Major Drainage Guidelines and Criteria
 - 5.1 Definition
 - 5.2 General Guidelines
 - 5.3 Surface Data Collection
 - Attachment 5.1 Drainage Data Requirements, Design Aids and Computer Software
 - Attachment 5.2 Major Drainage Summary Sheet
- 13-1-10 Documentation of Hydrologic/Hydraulic Design
 - 10.1 Introduction
 - 10.2 Bridge and Box Culvert Design
 - 10.3 Stormwater Report Applicability
 - 10.4 Design Documentation
 - 10.5 Stormwater-Drainage-WQ Report Spreadsheet Instructions for Drainage Design
 - Attachment 10.1 Stormwater-Drainage-WQ Report Spreadsheet: Drainage - Summary Worksheet
 - Attachment 10.2 Stormwater-Drainage-WQ Report Spreadsheet: Drainage - Data Worksheet
- 13-1-15 Culvert Material Selection Standard
 - 15.1 Application
 - 15.2 Selection Standard
 - 15.3 Special Situations
 - 15.4 Corrosion Concerns About Steel Culvert Pipe
 - 15.5 Abrasion Concerns
 - 15.6 Limited Clearance Installations
 - 15.7 Culvert Selection Justification
 - 15.8 Tied Joints
 - 15.9 Height of Cover for Culvert Pipes
 - 15.10 Roughness Coefficient for Culvert Pipe
 - Attachment 15.1 Potential for Bacterial Corrosion of Zinc Galvanized Steel Culvert Pipe (Map)
- 13-1-17 Storm Sewer Material Selection Standard
 - 17.1 Application
 - 17.2 Selection Standard
 - 17.3 Approved Materials
 - 17.4 Special Situations
 - 17.5 High Groundwater and Buoyancy of Thermoplastic Pipe
 - 17.6 Storm Sewer Pipe Connections
 - 17.7 Height of Cover for Storm Sewer
 - 17.8 Roughness Coefficient for Storm Sewer
- 13-1-20 Large Drainage Conduit
 - 20.1 Introduction
- 13-1-21 Precast Box Culverts
 - 21.1 Introduction
- 13-1-25 Fill Height Tables

- 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)

- 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)
- 13-10-10Hydrograph 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

- 13-15-1Economic Analysis
 - 1.1.....Introduction
- 13-15-5Design 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
- 13-15-10Culvert Hydraulics
 - 10.1.....Introduction
 - 10.2.....Available Design Aids

- 10.3.....Inlet-Outlet Control
- 10.4.....Discharge Velocity
- 10.5.....Improved Inlets
- 10.6.....Culvert Performance Curve
- 10.7.....References
- Attachment 10.1....Energy Losses Through a Conduit (schematic)
- Attachment 10.2....Inlet and Outlet Control Problem Sample Work Sheets
- Attachment 10.3....Culvert Hydraulic Performance Curves (examples)
- 13-15-15Special Hydraulics
 - 15.1.....Introduction
 - 15.2.....Drainage Disposal by Pumping
 - 15.3.....Siphons and Sag Culverts
 - 15.4.....Type of Conduit

Section 13-20 Hydraulic Design of Bridges

- 13-20-1Design Methods
 - 1.1.....Definition
 - 1.2.....Type of Flow
 - 1.3.....Methods
 - 1.4.....Additional Literature
- Attachment 1.1.....Types of Flow Encountered at Bridges

Section 13-25 Storm Sewer Design

- 13-25-1Introduction
 - 1.1.....Introduction
 - Attachment 1.1.....Storm Sewer Design Flow Chart
- 13-25-5Basic Drainage Area Information
 - 5.1.....Basic Information Needs
- 13-25-10Field Drainage Information
 - 10.1.....Field Information Needs
- 13-25-15Preliminary Layout of System
 - 15.1.....Background Information
 - 15.2.....Inlet Locations
 - 15.3.....Conduit Location
 - 15.4.....Standards for Storm Drain Pipe
 - 15.5.....Manholes
 - 15.6.....Outfalls
- 13-25-20Design Discharge
 - 20.1.....Design Discharge Information
- 13-25-25Gutter Design
 - 25.1.....Capacity
 - 25.2.....Gutter Types
 - 25.3.....Longitudinal Slopes
 - Attachment 25.1....Gutter Design Nomograph
 - Attachment 25.2....Gutter Design Example
- 13-25-30Hydraulic Design of Inlets
 - 30.1.....Inlet Types
 - 30.2.....Allowable Inlet Capacities
 - 30.3.....Capacities of Gate Inlets and Combination Inlets on a Continuous Grade
 - 30.4.....Capacity of Gate Inlets in a Sag
 - 30.5.....Capacity of Curb Openings in a Sag
 - 30.6.....Spacing of Inlets on a Continuous Grade
 - 30.7.....Literature on Inlet Design
 - 30.8.....References
 - Attachment 30.1....Reduction Factors for Inlets
 - Attachment 30.2....Performance Curves for Slotted CMP Surface Drains
- 13-25-35Hydraulic Design of Storm Sewers
 - 35.1.....Background Information

- 35.2.....Design Aids
- 35.3.....Conduit Design - Full Flow
- 35.4.....Pressure Flow
- 35.5.....Energy and Hydraulic Grade Lines (EGL and HGL)
- 35.6.....Hydraulic Standards for Storm Drain Pipe
- 35.7.....References
- Attachment 35.1....Manning Roughness Coefficients
- Attachment 35.2....Graphic Solution of the Manning Equation
- Attachment 35.3....Hydraulic Elements of a Circular Section
- Attachment 35.4....Capacity and Velocity Diagram for Circular Corrugated Pipe Flowing Full ($n = 0.024$)
- Attachment 35.5....Capacity and Velocity Diagram for Circular Concrete Pipe Flowing Full ($n = 0.013$)
- Attachment 35.6....Sewer Bend Loss Coefficients
- Attachment 35.7....Loss Coefficients for Miter Bends
- 13-25-40Design Procedure: Full and Partially Full Flow
 - 40.1.....Background Information
 - 40.2.....Procedure
 - Attachment 40.1....Work Sheet for Storm Sewer Design
 - Attachment 40.2....Full and Partially Full Sewer Design Problem
- 13-25-45Design Procedure: Surcharged Full Flow
 - 45.1.....Background Information
 - 45.2.....Procedure
 - Attachment 45.1....Energy and Hydraulic Grade Lines for a Properly and Improperly Designed Storm Sewer
 - Attachment 45.2....Work Sheet for Storm Sewer Design
 - Attachment 45.3....Example Work Sheet for Sewer Design Problem

Section 13-30 Channels and Road Ditches

- 13-30-1Channel Types and Characteristics
 - 1.1.....Channel Types
 - 1.2.....Roadside Ditches
 - 1.3.....Median Ditches
 - 1.4.....Toe of Slope and Intercepting Embankments
- 13-30-5Channel Characteristics
 - 5.1.....Introduction
 - 5.2.....Vertical Alignment
 - 5.3.....Horizontal Alignment
 - 5.4.....Roughness Factors
 - 5.5.....Channel Geometry
 - 5.6.....Natural Channels
- 13-30-10Hydraulic 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
- 13-30-15Grass 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)

- [Attachment 15.2](#).....Grass Lined Channel Design WisDOT Spreadsheet Worksheet
- [Attachment 15.3](#).....Grass Lined Channel Design Example (Using WisDOT Spreadsheet)
- [13-30-25](#)Rock Riprap Lined Channels
 - [25.1](#).....Introduction
 - [25.2](#).....Analysis of Slopes Less than or Equal to 20 Percent
 - [25.3](#).....Manning's Roughness (for Rock Riprap Lined Channels)
 - [25.4](#).....Permissible Shear Stress
 - [25.5](#).....Rock Riprap Design Procedure
 - [25.6](#).....Design Example (Using Equations): Riprap Channel (Mild Slope)
 - [25.7](#).....Example Riprap Lined Design for Channel Slopes $\leq 20\%$ Using the WisDOT Spreadsheet
 - [25.8](#).....Additional Design Considerations
 - [25.9](#).....References
- [Attachment 25.1](#).....Design Example (Using Equations): Riprap Channel (Mild Slope)
- [Attachment 25.2](#).....Riprap Channel (Mild Slope) WisDOT Spreadsheet Worksheet
- [Attachment 25.3](#)... Instructions and Example for Riprap Lined Design for Channel Slopes $\leq 20\%$ Using the WisDOT Spreadsheet
- [Attachment 25.4](#).....Angle of Repose of Riprap in Terms of Mean Size and Shape of Stone
- [Attachment 25.5](#).....Map of Areas in Wisconsin where Rounded Riprap is Predominantly Available
- [13-30-30](#)Rock Riprap Lined Chutes
 - [30.1](#).....Introduction
 - [30.2](#).....Steep Slope Analysis
 - [30.3](#).....Rock Chute Design Spreadsheet
 - [30.4](#).....References
- [Attachment 30.1](#).....Rock Chute Design Data Spreadsheet and Design Example
- [Attachment 30.2](#).....Rock Chute Design - Plan Sheet
- [Attachment 30.3](#).....Rock Chute Design- Construction Detail

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

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

13-45-1Background

1.1.....Introduction

1.2.....Design Responsibility and Coordination

1.3.....Definitions

13-45-5Design 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

13-45-10Culvert 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

13-45-15Other Culvert Repair and Rehabilitation Practices

15.1.....Introduction

15.2.....Invert Paving

15.3.....Cured in Place Pipe 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

13-45-20Trenchless 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

13-45-99Resources and References

99.1.....Resources

99.2.....References