FDM 13-1-1 Drainage Practice Background

February 18, 2020

1.1 Introduction

The Chief of the Design Standards and Oversight Section is the originator of this chapter.

1.2 General

Drainage has long been recognized as one of the primary considerations of highway construction. Its importance can be noted from the cost involved in providing drainage facilities for the highway, and for this reason alone a careful and scientific approach to drainage design should be taken. The purpose of this chapter is to provide a guide to existing standard procedures for drainage design throughout the state. The goal of design is to plan optimum drainage facilities considering function versus cost while meeting environmental requirements.

The methods of hydrologic and hydraulic analysis provided in this chapter will give the designer information necessary for drainage analysis. Experience and sound engineering judgment are not to be ignored and may at times differ from results obtained using methods in this chapter. Careful weighing of experience, judgment, and procedure are necessary for optimal drainage design. Terminology that is unique to this chapter and to "drainage" in general is defined in Attachment 1.1.

1.3 Basic Statewide Practice

In designing highway drainage systems, the three major considerations are:

1. The safety of the traveling public;
2. The use of sound engineering practices to economically protect and drain the highway;
3. In accordance with reasonable interpretation of the law, the protection of private property from flooding, water-soaking, or other damage.

In general, the hydraulic adequacy of pipe culverts shall be determined by the region based on sound hydrologic and hydraulic techniques and performance records at the same or similar locations. No improvement in the drainage of areas outside the right-of-way should be considered unless the state would benefit thereby, or the project is financed by others.

1.4 Design Responsibility

The Bureau of Structures (BOS) is responsible for the hydraulic and structural adequacy of all cast-in-place and precast box culverts and bridges. Preliminary hydrologic and hydraulic computations for such structures shall be performed by BOS or consultant staff. A hydraulic/sizing report shall be prepared by BOS or consultant designers (refer to FDM 13-1-10, and Chapter 8 (hydraulics) of the LRFD Bridge Manual).

In addition, a Structure Survey Report is required for all hydraulic structures designed or reviewed by BOS. Refer to Chapter 6 of the department's LRFD Bridge Manual for report procedures. The region is responsible for the hydraulic adequacy of all other types of drainage structures.

BOS should be notified whenever it is proposed to replace an existing bridge with a pipe culvert(s) so that records of existing bridges may be kept current. Refer to the bridge manual for bridge definition:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/strct/bridge-manual.aspx

The Statewide Drainage Engineer in the Bureau of Project Development Roadway Design Standards Unit shall be notified when plans include the box-shaped storm sewer. The Statewide Drainage Engineer will consult with the Bureau of Structures to determine the design requirements for the storm sewer and whether a structure number will be assigned.

1.5 Common Drainage Law

Drainage Common law is that body of principles found in court decisions based on customs, practices, and precedents that have evolved and are unwritten in statute or code.

According to Harold H. Ellis (1), Wisconsin's common law rules relating to diffused surface waters are as follows:

1. A lower owner may legally treat diffused surface waters as his enemy and prevent them from coming onto his/her land.
2. The upper owner has a right to alter the natural flow of diffused surface waters and may discharge them upon lower land, subject to the following limitations:
   - The water must be expelled onto the lower land without malice.
   - The actions of the upper owner may extend no further than reasonably necessary to protect himself or his/her land.
   - Such water may not be diverted into another watershed.
   - The upper owner may not unduly collect such waters in a pond or reservoir and thereafter discharge them on his/her neighbor's land or on his/her own land in such proximity to his/her neighbor that they will inevitably permeate and percolate so as to permanently injure the neighbor's soil.

Because the upper owner must not be negligent, and he/she must be reasonable in his/her use and improvement of his/her land, Wisconsin has moved to a middle ground, lying somewhere between the "common enemy rule (2)" and the "reasonable use rule (2)".

1.6 Statutory Drainage Law

When the Department of Transportation constructs a highway, the natural or pre-existing flow of surface water might be changed, and the effects of these changes might extend beyond the highway right-of-way to private property. The laws governing these matters are found in Chapter 88 of the Wisconsin Statutes, Drainage of Lands.

Section 88.87 of this chapter states that a highway "*...shall not impede the general flow of surface water or stream water in any unreasonable manner so as to cause either an unnecessary accumulation of waters flooding or water-soaking uplands or an unreasonable accumulation and discharge of surface waters flooding or water soaking lowlands.*" It further states that these highways "*...shall be constructed with adequate ditches, culverts, and other facilities as may be feasible, consonant with sound engineering practices, to the end of maintaining as far as practicable the original flow lines of drainage.*" The section also provides that drainage rights or easements may be purchased or condemned to aid in the prevention of damage to property owners, which might otherwise occur because of the highway construction. (WisDOT does not intend to acquire easements as a routine solution to drainage problems (refer to FDM 13-1-5, Drainage Rights and Easements).

It is the duty of every landowner to provide, and always to maintain, a sufficient drainage system to protect the highway from water damage or flooding, by directing the flow of surface waters into existing highway drainage systems or by permitting the flow of such water away from the highway. Chapter 86, Section 86.07 (2) states that *"no person shall make any excavation or fill or install any culvert or make any other alteration in any highway or in any manner disturb any highway or bridge without a permit therefore from the highway authority maintaining the highway."*

In addition to Chapter 88, Section 86.075 covers the responsibility of a highway authority to notify the county drainage board *"Whenever a highway crossing any draining ditch of a drainage district governed by Chapter 88 is being constructed or reconstructed or a culvert in any such ditch is being replaced, the highway authority in charge of such work shall consult with the drainage board having jurisdiction of such district for the purpose of determining the depth at which such drainage ditch was laid out."* If any culvert or similar opening in a highway is installed at a grade higher than the depth at which a drainage ditch was laid out, the expenses involved in any future lowering of the culvert pursuant to Section 88.68 (4) shall be borne by the unit of government in charge of maintenance of the highway.

The Wisconsin State Statutes, Chapter 146, Miscellaneous Health Provisions also state, in Section 146.13; *"Discharging noxious matter into highway and surface waters (1) If anyone constructs or permits any drain, pipe, sewer or other outlet to discharge into a public highway infectious or noxious matter, the board of health of the village, town or city shall, and the town sanitary district commission or the county board of health, acting alone or jointly with the local board of health may, order the person maintaining it to remove it within 10 days..."* This Section further states (2)*" No person shall discharge by any means whatsoever untreated domestic sewage into any surface water as defined by s. 144.01(5), or drainage ditch governed by ch. 88; nor shall any person discharge effluents or pumpage by any means whatsoever from any septic tank, dry well or cesspool into any surface water as defined by s. 144.01(5), or drainage ditch governed by ch. 88 ..."*

The Wisconsin State Statutes, Chapter 236, Platting Lands and Recording and Vacating Plats, state, in Section 236.13, that *"approval of the preliminary or final plat shall be conditioned upon compliance with: ...(e) The rules of the Department of Transportation relating to provisions for the preservation of the public interest and investment in such highways."* This department rule is TRANS 233 that states as one of its basic principles: one of its basic principles in 233.02 (5) *"A land division map shall include provisions for the handling of surface drainage in such a manner as specified in s TRANS 233.105 (3)."* Section 233.105 (3) states (3) Drainage - The owner of land that directly or indirectly discharges storm water upon a state trunk highway or connecting highway shall submit to the department a drainage analysis and drainage plan that assures to a reasonable degree, appropriate to the circumstances, that the anticipated discharge of storm water upon a state trunk highway or connecting highway following the development of the land is less than or equal to the discharge preceding the development and that the anticipated discharge will not endanger or harm the traveling public, downstream properties or transportation facilities. Various methods of hydrologic and hydraulic analysis consistent with sound engineering judgment and experience and suitably tailored to the extent of the possible drainage problem are acceptable. Land dividers are not required by this subsection to accept legal responsibility for unforeseen acts of nature or forces beyond their control. Nothing in this subsection relieves owners or users of land from their obligations under S.88.87 (3)(b), stats.

Note: In section 88.87 (1), Stats., the Legislature has recognized that development of private land adjacent to highways frequently changes the direction and volume of flow of surface waters. The Legislature found that it is necessary to control and regulate the construction and drainage of all highways in order to protect property owners from damage to lands caused by unreasonable diversion or retention of surface waters caused by a highway and to impose correlative duties upon owners and users of land for the purpose of protecting highways from flooding or water damage. Wisconsin law, section 88.87 (3), Stats., imposes duties on every owner or user of land to provide and maintain a sufficient drainage system to protect downstream and upstream highways. Wisconsin law, section 88.87 (3)(b), Stats., provides that whoever fails or neglects to comply with this duty is liable for all damages to the highway caused by such failure or neglect. The authority in charge of maintenance of the highway may bring an action to recover such damages but must commence the action within 90 days after the alleged damage occurred. Section 893.59, Stats.

The plats should be reviewed to ensure they conform to this principle.

For further details on drainage law, the designer is referred to:

- Wisconsin State Statutes, "Miscellaneous Highway Provisions," Chapter 86.
- Wisconsin State Statutes, "Floodplain Zoning," Chapter 87.
- Wisconsin State Statutes, "Drainage of Lands," Chapter 88.
- Wisconsin State Statutes, "Water, Sewage, Refuse, Mining and Air Pollution," Chapter 144.
- Wisconsin State Statutes, "Miscellaneous Health Provisions," Chapter 146.
- Wisconsin State Statutes, "Platting Lands and Recording and Vacating Plats," Chapter 236.
- Wisconsin Administrative Code, Chapter TRANS 233.

REFERENCES

(1) Ellis, Harold H.; Beuscher, J.H.; Howard, Cletus D.; De Braad, J. Peter; "Water-Use Law and Administration in Wisconsin," Department of Law, University Extension, The University of Wisconsin, First Edition, 1970, 694 pp.

(2) "Guidelines for the Legal Aspects of Highway Drainage," Volume V-Highway Drainage Guidelines, AASHTO, 2007, 24 pp.

LIST OF ATTACHMENTS

Attachment 1.1 Glossary of Terms

FDM 13-1-5 Major Drainage Guidelines and Criteria — *November 17, 2025*

5.1 Definition

This procedure defines the major drainage issues and sets guidelines and criteria for more detailed studies, when appropriate. More detailed studies, when required, are completed in the design phase of project development. Three basic questions are asked:

1. Are major drainage problems anticipated?
2. Are the available general drainage guidelines appropriate for solving the anticipated problems?
3. What are the surface drainage alternatives?

These questions should be asked and resolved at the region. The Bureau of Project Development function is to update and clarify the major drainage guidelines, as necessary.

5.2 General Guidelines

To clarify the study of major drainage, it is helpful to consider some typical guidelines. For the most part, these are statutory "guidelines" or traditional practices set up by the Department of Transportation. They are broad practices, the changing of which would have an immediate, statewide effect on adjacent properties. Therefore, they are not subject to random change by either the region or the central office.

The general guidelines are:

1. **Water Accumulation:** The highway shall not impede the general flow of surface water or stream water in any unreasonable manner so as to cause either an unnecessary accumulation of waters flooding or water-soaking uplands, or an unreasonable accumulation and discharge of surface waters flooding or water-soaking lowlands (from Section 88.87, Wisconsin Statutes). This objective should be accomplished by:
    - Anticipating the amount and frequency of storm runoff.
    - Determining natural points of concentration and discharge and other hydraulic controls.
    - Determining the necessity for protection from floating trash and debris.
    - Comparing and coordinating proposed design with existing drainage structures and systems handling the same flows.
    - Removing detrimental amounts of surface and subsurface water.
    - Providing the most efficient disposal system consistent with economy, the importance of the road, maintenance, and legal obligations.
    - Culverts designed with the intent to permanently impound water may be regulated by WDNR as dams. In general, this situation should be avoided because of the potential regulatory issues and the potential barrier to aquatic organism passage. The Statewide Drainage Engineer in Bureau of Project Development should be notified of any culvert designed to permanently impound water.
2. **Drainage Districts:** Any work that involves drainage districts must be coordinated with the county drainage board of such district. The legal procedures for these cases are set forth in Chapter 86 of the Wisconsin Statutes and ATCP 48 of Wisconsin Administrative Code (refer to FDM 5-15-1).
3. **WisDOT and Wisconsin Department of Natural Resources (WDNR) Cooperative Agreement:** The Department of Transportation shall design and construct drainage facilities in accordance with the spirit and intent of the WisDOT and WDNR Cooperative Agreement, a copy of which can be found at:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/environment/formsandtools.aspx

4. **401 and 404 Permits:** The necessity of 401 and 404 permits for a drainage facility should be determined by FDM 20-50.
5. **Local Sewerage Commissions:** Coordinate work with local sewerage commissions that are affected by the project.
6. **Aquatic Organism Passage:** The crossing of some streams by highways requires the construction of drainage facilities that will accommodate aquatic organism passage. In addition, other streams may require the construction of barriers at drainage structures to prevent the migration of rough fish or other invasive species. In the early stages of design, the WDNR shall be consulted when streams are involved that might require special drainage facilities. Moreover, if aquatic organism passage facilities are required at a drainage structure, a field review regarding questions on aquatic organism passage should be held with the WDNR. For culvert design including aquatic organism passage, the designer should consult with the Statewide Drainage Engineer responsible for AOP coordination.
7. **Drainage Patterns:** Highway reconstruction projects should match natural drainage patterns as closely as possible. New culverts should be located and designed to minimize change or disruption in the natural flow of water, commensurate with cost.

    When the highway is in fill, the amount of special ditching along the fill slope should be minimized except where required to protect the adjacent land.

    When a highway is constructed on relocation, changes in surface drainage are more significant. Culverts should be placed at natural draws or depressions. Culverts should be placed frequently enough to avoid excessive concentration of flow.
8. **Headwater:** Criteria for culvert headwater is generally set as 1.5 times the pipe diameter, or no overtopping of roadway for design storm event, provided there is no risk of damage to adjacent

upstream property. Headwater elevation shall have no rise in mapped zoned floodplains unless all requirements of the WisDOT/WDNR Cooperative Agreement are met.

9. **Drainage Rights and Easements:** Wisconsin Statutes provide WisDOT with the authority to acquire drainage rights and easements. However, WisDOT does not intend to acquire easements unless it is determined that significant damage would occur to private property or that the cost of a larger structure (designed to accommodate the regional flood) would not be justified.

10. **Overflow Section:** These sections are considered for special situations where on collectors and local roads, a specified flood (i.e. overtopping flood) may be conveyed by the structure and an overflow section, both acting together as a hydraulic system. This is not a preferred design so contact the Bureau of Structures or Bureau of Project Development Drainage Engineers when considering such a design.

11. **Maintenance Considerations:** For future maintenance considerations the designer should provide:
    - Sufficient erosion protection for channel banks, for the highway, and for culvert outlets to prevent scour or erosion on private land.
    - Large enough culverts for ease of maintenance.
    - Curbs or berms and downslope pipe or gutters along fills of erodible material.
    - Drainage easements wide enough for maintenance equipment.
    - Access at drainage facilities for power equipment.
    - Debris catches where needed.
    - Corrosion-resistant structures in areas with corrosive soils and waters.
    - Interceptor ditches along the top of cut slopes.
    - Necessary drainage structures should be located, if possible, beyond the clear zone (refer to FDM 11-15-1). Where this is not possible, suitable protective barriers should be provided.

5.3 Surface Data Collection

5.3.1 Probable Working Media for Major Drainage Studies

LiDAR elevation data and contours are available for many counties for use in drainage analysis and preparation of exhibits. Please contact the Region Survey Coordinator to request Aerial imagery and LiDAR elevation data. The Aerial imagery delivery will be the most recent available, leaf-off, with a 6” or better ground sample distance and in the Wisconsin County Coordinate System (WISCRS). The LiDAR data delivery will be provided as an SRV file from the most recent LiDAR data available, which will vary by county. The delivery will be in the Wisconsin County Coordinate System (WISCRS).

Soils data can be found in NRCS Soil Survey Maps and digitally from the NRCS Geospatial Data Gateway.

5.3.2 Input Data Requirements

Desirable data will be of a general nature, as follows:

1. Watershed characteristics
2. Stream crossing locations
3. Climate information
4. Limiting design factors
5. Information on existing structures that would be readily available from logs, etc.
6. General information from local sources as to history of flooding and obvious problem areas.
7. Land use/cover
8. Soils data

5.3.3 Output Data

Desirable output data requirements are as follows:

1. Design discharge.
2. Proposed facilities.
3. Drainage easements.
4. Cost.

LIST OF ATTACHMENTS

Attachment 5.1	*intentionally left blank*
Attachment 5.2	Major Drainage Summary Sheet

FDM 13-1-10 Documentation of Hydrologic/Hydraulic Design — November 30, 2018

10.1 Introduction

Documentation of all hydrologic data and hydraulic design computations shall be assembled for each project and retained in the project files at the Region office. This documentation should contain all pertinent information used to design the drainage facilities and should be extensive enough to verify later the hydraulic design of any structure. It should also include any information about special commitments placed on the project for environmental or public involvement reasons.

The Stormwater-Drainage-Water Quality (WQ) Report Spreadsheets along with the Channel and Chute Design Spreadsheet Worksheets are required.

Hydrology and hydraulic design documentation is to be stored in the Region Central file system for25 years (Refer to RDA 00145-000, Roadway Drainage Hydrologic & Hydraulic Studies and Design Calculation). The documentation must be provided to the project manager, who will send it to the Region Central file system.

10.2 Bridge and Box Culvert Design

The hydraulic design documentation for a bridge, box culvert or other large drainage conduit requiring structural analysis shall contain a segment entitled "Discussion of Structure Sizing." This discussion should concisely summarize the engineering judgments that determined the structure size (waterway opening). Relevant factors to be highlighted include: relative construction cost considerations, environmental concerns, compatibility with local floodplain zoning ordinances, and risk considerations such as minimization of flooding, potential damages to abutting property, and protection of the motorist and/or highway.

A stream crossing Structure Survey Report (SSR) should be prepared by the Region and e-submitted to the Bureau of Structures (BOS) if the structure is to be designed by BOS. If the structure is to be designed by a consultant, the SSR should be e-submitted to BOS along with the preliminary structure plans and the hydraulic/sizing report referred to in the preceding paragraph. See Chapter 8, Appendix A, of the WisDOT Bridge Manual (https://wisconsindot.gov/dtsdManuals/strct/manuals/bridge/ch8.pdf) for a checklist of items that need to be included in the hydraulic/sizing report.

Typically, BOS will perform the hydraulic/hydrologic analysis for all bridges and box culverts that are designed by the Department. Consultants are responsible for the hydraulic/hydrologic analysis of the bridges and box culverts they design.

10.3 Stormwater Report Applicability

Each WisDOT project that has a stormwater component must have a completed Stormwater-Drainage-Water Quality (WQ) Report spreadsheet. A Stormwater-Drainage-WQ Report is not needed for projects that have no change to the culvert or storm sewer system that drains the project or for projects that do not trigger TRANS401 water quality requirements. Typically, traffic control, ITS (Intelligent Transportation Systems), signalization, or safety projects will not need a stormwater report. Overlay projects that do not include culvert replacements, extensions, or other modifications are also exempt from the stormwater reporting requirement.

The Drainage Summary Worksheet should be submitted at the 30% design stage to describe any significant flow changes and what may need to be done to address the changes in flow. The intent of this early submittal is to note potential drainage problems at an early stage. The updated Summary Worksheet and the initial Data Worksheet should be submitted at the 60% design stage.

This submittal should address the concerns brought up in the previous Drainage Summary Worksheet, any new issues, and include available information in the Data Worksheet. This submittal should also include any available drainage calculations or model analyses and drainage mapping. The final design submittal includes the completed Drainage Summary and Data Worksheets as well as all supporting documentation needed to review the worksheets.

The stormwater report spreadsheet is not applicable to bridges and box culverts designed or reviewed by Bureau of Structures nor is it applicable to storm sewer design.

10.4 Design Documentation

Each WisDOT project that has a stormwater component must develop a design for those components that includes the basin hydrology and the structure or system hydraulic design. The type and extent of the documentation for these components will vary, but the basic information includes the hydrology and hydraulic design information listed below. A summary of this information should be included in the Drainage-Stormwater Report spreadsheet described below. This spreadsheet provides a way for a designer to methodically describe the objectives and design of a project drainage system.

Hydrology

1. Design frequencies.
2. Methods used to compute the flow rates and the limitations of these methods.
3. The type and extent of future development and how it was considered in the design process.
4. List of all graphs that were used to determine rainfall depth, rainfall intensity, runoff, and time of concentration.
5. Any information that is used by the designer as general criteria for the determination of flow rates for ditches and culverts.
6. Location map indicating each drainage area. Show the drainage areas in the form of a mosaic on a 1 inch = 100-foot, (1:1200) scale, photogrammetric, contour map. Large drainage areas should be shown on USGS contour maps.
7. A statement of the characteristics of the drainage pattern about soil types, land usage and relief, special controls on the flow rates, possible future development effects, past flood of record, and any information that is needed to properly analyze the flow rate for the given drainage area and detailed computations of the flow rate.

Hydraulic Design

1. Detailed hydraulic design for each culvert location and each channel and ditch on the project.
2. A statement on any information gathered during the field review of the drainage area.
3. For culverts, provide the design work sheet or the computer design sheet for the culvert, which should contain information on the discharge, allowable headwater elevation, design headwater elevation, design tail-water depth, entrance conditions, grade of flow line, discharge velocity, freeboard (allowable headwater-roadway elevation), etc. This sheet should show designs for various types of inlet conditions and culvert materials, along with the final recommendation of the culvert used in the final design.
4. For storm sewer systems, include the urbanization factors, cost analysis, and any other factors that may affect the final design of the storm sewer. Provide a layout of the storm sewer system along with the contributing drainage areas, and a detailed design tabulation sheet showing the grate inlets, flow rates contributing to each inlet, and pipe sizes.

This documentation, initiated during the preliminary design stage, must be updated to reflect the final design. The stage of the design can be noted in the Drainage-Stormwater Report submittal described below on the Drainage-Summary worksheet.

As part of design documentation, the designer should determine whether a project is located within a regulatory floodplain. Unofficial floodplain maps can be viewed on WDNR's Surface Water Data Viewer:

https://dnr.wi.gov/topic/surfacewater/swdv/

Official Flood Insurance Rate Maps can be viewed and printed in "FIRMette" form at FEMA's Map Service Center under the Product Catalog at:

https://msc.fema.gov/

10.5 Stormwater-Drainage-WQ Report Spreadsheet Instructions for Drainage Design

There are two components to the spreadsheet: drainage and water quality. This section describes how to fill out the stormwater drainage worksheets of the report. Refer to FDM 10-30-1 for instructions on how to fill out the water quality worksheet sections of the Report.

The stormwater drainage section of the spreadsheet has two parts. The first part, which is on the 'Drainage-Summary' worksheet tab, is the Summary worksheet. This worksheet includes basic project information, (project name, limits, county, etc.) and a list of questions that will help the designer determine the drainage requirements for the project.

The second part of the stormwater drainage is a table of the stormwater flow and drainage issues that typically occur in a project. This list is in the 'Drainage-Data' worksheet tab and includes the following topic areas:

1. Outfall Information
2. Basic Subbasin Drainage Information
3. Urban/ and/or TRANS 401 Project Information (see FDM Chapter 10 for TRANS 401 requirements)
4. Culvert Design
    a. Existing Culvert Data
    b. Proposed Culvert Design
    c. Floodplain Management
    d. Drainage District Issues
    e. Aquatic Organism Passage
5. Culvert Liner Design
    a. Existing Culvert Data
    b. Liner Details
    c. Floodplain Management
    d. Drainage District Issues
    e. Aquatic Organism Passage

The spreadsheet includes an outline feature that allows the user to collapse topic groups that are not relevant for the project to make the worksheet easier to use.

There are ten worksheets in the Stormwater-Drainage-WQ Report spreadsheet. The Stormwater Water Quality Summary worksheet and the water quality control practice worksheets, which all begin with the letters 'WQ', are discussed in FDM 10-30-1. The Drainage-Summary worksheet and the Drainage-Data worksheet are described below.

10.5.1 Drainage Summary Worksheet

This worksheet includes basic project information and a Drainage Summary page that includes questions that address drainage issues (refer to Attachment 10.1 and 10.2). Water quality questions and issues are addressed in FDM 10-30-1. Be sure to enable the spreadsheet Macros by clicking on the security warning "options" box on the top of the spreadsheet and then highlight the "enable this content" button.

10.5.1.1 Basic Project Information

Basic project information includes information like the project number and name. When entering this information, only enter it in columns B and C of this worksheet; the appropriate information will be copied to other worksheets by the spreadsheet.

Please note that the planning stage generally includes only the water quality component of stormwater management unless drainage considerations are part of a planning study.

10.5.1.2 Drainage - Summary Narrative

The drainage summary narrative begins with line 15 on the "Drainage-Summary" tab of the stormwater report spreadsheets. This narrative is a series of questions that will, when completed, define the drainage goals, objectives, and issues for the project and how they were met. Enter your response in the cell below each question.

Line 15: IS THERE A SIGNIFICANT FLOW INCREASE OR DECREASE WITHIN ANY SUB BASIN? IF YES,

DESCRIBE THE REASON.

This question is intended to describe why any significant (greater than 5%) flow increases or decreases occur in the project. Examples of an explanation and justification could include “Outfall 3: New connection to municipal storm sewer system" or “Outfall 8: Outfall location shifted and combined with adjacent upstation drainage basin to avoid concentrated discharge to wetland.

Line 17: IS THERE A SIGNIFICANT IMPERVIOUS AREA CHANGE TO ANY SUB BASIN? IF YES, DESCRIBE THE REASON.

Increases in impervious surface area are often the result of added lanes, new alignment, or park and ride lots, etc. However, the impact on peak rate discharge may be insignificant if the impervious area is a small portion of the subbasin or if the impervious area is located near the outfall. Increased impervious surface will increase the runoff volume. The impact of the increased impervious area may be significant if the overall drainage basin is small or if the added discharge from the impervious area reaches the outfall at the same time as the peak flow from the balance of the drainage bas

Line 19: HAVE THE DRAINAGE SUB BASIN AREAS OR FLOW PATHS CHANGED SIGNIFICANTLY? IF YES, DESCRIBE THE REASON.

Altered flow paths may change the size of the drainage basin and affect the downstream drainage system. Existing ponds and wetlands may be affected if tributary drainage is relocated. Peak discharge rate increase may increase the potential for streambed erosion. Document the reason for the drainage area re-routing and describe erosion control plans to address increased peak discharge rates.

Line 21: DESCRIBE THE PROPOSED DRAINAGE CONVEYANCE AND CONTROL SYSTEMS.

The conveyance system may include any combination of drainage swales, culverts and/or storm sewers. Control systems may include detention ponds, diversion structures, etc.

Line 23: DESCRIBE ANY AQUATIC ORGANISM PASSAGE ISSUES.

If one or more culverts in the project require aquatic organism passage design, describe the water body classification, the requesting agency, and reason for request. Complete the AOP section of the Stormwater Report Drainage-Data section for the culvert(s).

Line 25: DESCRIBE ANY EXCEPTIONS TO WisDOT FDM CHAPTER 13 DRAINAGE REQUIREMENTS,

Document and explain any exceptions to the FDM Chapter 13 drainage design requirements. Examples may include the use of 12-inch diameter storm sewer pipes or wide-bottom special ditches.

Line 27: DESCRIBE WDNR COORDINATION.

Provide name of WDNR liaison, date of correspondence, and attach printed copy of correspondence.

Line 29: DESCRIBE ACCOMMODATIONS TO MEET LOCAL, MUNICIPAL, OR REGIONAL DRAINAGE OR STORMWATER MANAGEMENT THAT EXCEED FDM CHAPTER 13 REQUIREMENTS.

Sometimes accommodations are made to meet drainage design standards that exceed WisDOT FDM Chapter 13 design requirements. For example, a community may want a detention pond to decrease peak flows in the off-DOT ROW drainage area or may want all drainage structures in their jurisdiction to meet their higher design standards, so the entire drainage system meets a consistent set of standards. If this occurs, document the accommodation, why it was made, and the source of funding for the modifications.

Line 31: DOCUMENT SIGNIFICANT IMPACTS TO THE PROJECT CAUSED BY DRAINAGE, PROJECT MANAGER CONCURRENCE IS REQUIRED. (PM SIGN AND DATE).

The project manager must acknowledge any significant drainage impacts or non-standard design changes to the project by signing this report or providing documented concurrence using, for example, an email message stating he or she has reviewed and approved of the report.

10.5.1.3 Drainage - Data Worksheet

The number of columns in the worksheet can increase as needed by highlighting the last unfilled column and dragging the small box in the lower right-hand corner of the highlighted column to the right. The outfall numbers will increase consecutively.

As noted in FDM 13-1-10.4, there are several headings in the Drainage-Data spreadsheet. This section will review the contents of each heading.

If an explanation is required as part of the response to a line item in the report, provide the explanation on a separate attachment.

Section 1: Outfall Information:

Lines 8 – 28 should be completed for all outfalls, regardless of whether culverts or storm sewer system.

Documentation for storm sewer systems should be attached to the Stormwater Report, but no information past Line 28 is necessary in the Stormwater Report.

Line 8: Outfall number.

Consecutively numbered outfalls from the start to the end of the project. An outfall is any culvert, roadside ditch, or storm sewer drainage discharge point with runoff either originating from or passing through the project right-of-way.

Line 9: Outfall discharges to:

Use the pull-down menu to select the type of water body the outfall discharges to. The options are: 1) Overland, 2) Ditch, 3) Creek, 4) River, 5) Wetland, 6) Storm Sewer, 7) Combined Sewer, 8) Other.

Line 10: Waterway crossing type:

Use the pull-down menu to select the type of waterway crossing. The options are: 1) Culvert, 2) Box Culvert, 3) Storm Sewer, 4) Three-Sided Box Culvert, and 5) Bridge.

Line 11: If discharging to environmentally sensitive area, what kinds of buffers were used at outfall?

The options in the pull-down menu are: 1) Swales, 2) Filter Strips, 3) Vegetated Embankment.

Line 12: Previous flooding issues or flow restrictions?

Select yes or no from the pull-down menu. If yes, provide explanation.

Line 13: Is the drainageway in the DOT ROW a navigable waterway?

Select yes or no from the pull-down menu.

Line 14: Classify the drainageway in the DOT ROW.

The options are: 1) Wetland, 2) 303(d) Waters, 3) Exceptional Waters, 4) Outstanding Waters, 5) Waters of the U.S.

Section 2: Basic Sub Basin Drainage Information:

Line 16: Outfall number.

Consecutively numbered outfalls from the start to the end of the project. An outfall is any culvert, roadside ditch, or storm sewer drainage discharge point with runoff either originating from or passing through the project right-of-way.

Line 17: Outfall station.

The station along the reference line where the outfall is located.

Line 18: Design storm frequency.

Enter the flood frequency used for the design of the culvert or storm sewer system. This value is typically found in FDM 13-10.

Line 19: Check storm frequency.

Enter the flood frequency used to check the design for unacceptable inundation of the highway facility or flooding. Refer to FDM 13-25-20 for additional information.

Line 20: Drainage area (ac).

Line 21: Hydrologic Method.

List the method used to compute the peak discharge rates for the design and check storms. Examples include, but are not limited to: The Rational Method, TR20/55, HEC-1/HMS, regional regression equations, and basin transfer methodology.

Line 22: Time of Concentration (min).

The time required from discharge to travel from the most hydrologically remote point in the drainage area to the outfall.

Line 23: C or CN.

Runoff coefficient, C, for use with the Rational Method can be found in FDM 13-10 Attachment 5.2, and Runoff Curve Numbers, CN, for use with TR20/55 can be found in FDM 13-10 Attachment 5.6.

Line 24: Rainfall Intensity (in/hr).

Rainfall intensity is used with the Rational Method for hydrologic computations and can be found using the Intensity-Duration-Frequency (IDF) curves in FDM 13-10 Attachment 5.3.

Line 25: Rainfall Depth (in)

For hydrologic methods using a design storm to determine the peak discharge rate, record the rainfall depth of the design storm. Unless a specific rainfall distribution is required by others (WDNR or SEWRPC), use NOAA Atlas 14 rainfall data with MSE-3 and MSE-4 24-hour rainfall distributions. These rainfall distributions are available from NRCS for use with the NOAA Atlas 14 rainfall data at:

https://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/technical/engineering/?cid=nrcs142p2_025417

Where the use of WDNR or SEWRPC distribution and a critical storm duration analysis is required, use NOAA Atlas 14 data as well. SCS Type II rainfall distribution should no longer be used.

Line 28: Hydraulics design software used.
Record the design software used for drainage analysis and design.

Section 3: Urban/TRANS 401 Project Information:

This section, including lines 29-43 of the stormwater/drainage report form, is required only for urban projects or projects with TRANS 401 water quality requirements.

Line 31: DOT right of way area (acres).
Enter the area draining to the outfall that is within the WisDOT right-of-way.

Line 32: DOT right-of-way compared to sub-basin drainage area (%) (calculated).
This value is self-populated based on data in Lines 20 and 31. The relative drainage area information may be used when negotiating storm sewer cost share agreements between WisDOT and a municipality.

Line 33: DOT impervious area – existing (acres).
Enter the existing (pre-project) impervious surface area within the WisDOT right-of-way to outfall.

Line 34: DOT impervious area – proposed (acres).
Enter the proposed impervious surface area within the WisDOT right-of-way to outfall.

Line 35: Change in impervious area (calculated).
This value is self-populated based on data in Lines 33 and 34. This information may be used to determine possible reason for change in discharge and potential downstream impacts.

Line 36: Percent change DOT in impervious area (calculated).
This value is self-populated based on data in Lines 33 and 34. This information may be used to determine possible reason for change in discharge and potential downstream impacts.

Line 37: Proposed peak discharge rate (cfs), before detention
Design peak flow for the proposed drainage system, not including impacts of detention.

Line 38: Peak discharge rate change (cfs).
This value is self-populated based on data in Lines 26 and 37.

Line 39: Percent change peak discharge rate (%).
This value is self-populated based on data in Lines 26 and 37.

Line 40: Design peak discharge rate (cfs) post-detention:
Enter the design peak discharge rate for the proposed drainage system post-detention. If there is no detention, then this value is the same as the value in Line 37.

Line 41: Existing 2-year peak discharge flow (cfs):
The pre-project 2-year peak discharge rate for the drainage system.

Line 42: Proposed 2-year peak discharge flow (cfs)
The post-project, pre-detention 2-year peak discharge rate for the proposed drainage system.

Line 43: Proposed 2-year peak flow (cfs), (after detention/in-line storage/other).
The design peak discharge rate for the proposed drainage system after any detention/ in line/other storage. If there is no detention, then this value is the same as the value in Line 42.

Section 4: Culvert Replacement/Extension Project Information

Culvert Design – Existing Culvert

Line 52: Manning's n:
Roughness values for common culvert materials can be found in Table B.1 of FHWA HDS-5.

Line 53: Inlet configuration:
Typical inlet configurations can be found in FHWA HDS-5, Chapter 1, Section 3.3. Choices in the drop-down menu include: apron endwalls, mitered to slope, headwall, projecting.

Line 54: Upstream invert (ft)
Elevation of bottom of culvert at upstream end.

Line 55: Downstream invert (ft).
Elevation of bottom of culvert at downstream end.

Line 56: Length (ft).
Culvert length, not including apron endwalls or headwalls.

Line 57: Slope (%)

Value automatically calculated by dividing invert elevation difference by pipe length.

Line 58: Computed upstream water surface elevation (ft).

Upstream water surface elevation computed for design peak discharge using hydraulic computation program in steady state analysis mode or FHWA HDS-5 nomograph methodology.

Line 59: Tailwater elevation (ft).

Water surface elevation at pipe outlet, based on normal depth of downstream channel or average of critical depth and culvert diameter. See FHWA HDS-5 for more detail.

Line 60: Outlet velocity (ft/s)

Water velocity at outlet end of pipe.

Culvert Design – Proposed Culvert

Line 62 to 82: Proposed culvert information.

Lines 63-72 contain similar inventory of physical properties as lines 48-57 for the existing culvert.

Line 76: Change in upstream water surface elevation.

Value automatically computed comparing Line 77 and Line 58. Note that increases in upstream water surface elevation are generally discouraged and may be prohibited without “appropriate legal arrangement” in mapped floodplains.

Line 77: Riprap outfall.

Size of riprap at culvert outfall, if necessary.

Line 78: Maximum allowable headwater (ft)

The maximum upstream water surface elevation.

Line 79: Maximum allowable headwater design criteria.

Drop down menu includes options of: existing conditions, shoulder subgrade point, or edge of pavement elevation, or headwater to culvert diameter ratio.

Line 80: Station of lowest subgrade shoulder point.

The sag point of the vertical curve over the proposed culvert.

Line 81: Elevation of lowest subgrade shoulder point (ft).

Top of subgrade at sag point of vertical curve.

Line 82: Headwater to pipe diameter ratio.

Value is automatically calculated based on depth at upstream end (highwater elevation minus invert elevation) divided by the culvert diameter or height.

Culvert Design - Floodplain Management

Line 84: Mapped floodplain.

To determine if the culvert is in a mapped floodplain, either check with the region stormwater engineer or view unofficial maps on the Wisconsin DNR Surface Water Data Viewer - FEMA Maps/DFIRMS at:

https://dnrmaps.wi.gov/H5/?Viewer=SWDV

Official Flood Insurance Rate Maps (FIRMs) can be found on FEMA’s website at:

https://msc.fema.gov/portal/home

Line 85: Increase in headwater.

If there is an increase in water surface elevation, attach an explanation for the change and how the increased water surface profile was approved.

Culvert Design – Drainage District Issues

Line 87: Is culvert in a drainage district?

To determine if the culvert is in a drainage district, check with the region stormwater engineer or go to the web site:

https://datcpgis.wi.gov/maps/?viewer=dd

Line 89: Increase in headwater

If there is an increase in water surface elevation, attach an explanation for the change and how the increased water surface profile was approved.

Line 90: Drainage board approval?

Drainage board approval is required for increases in water surface profiles in areas located within incorporated drainage districts.

Culvert Design – Aquatic Organism Passage

Line 92: Is aquatic organism passage (AOP) a concern?

If AOP is considered in project, please include a copy of the WDNR Initial Review Letter.

Line 93: Does WDNR concur with the AOP design?

Provide documentation of WDNR concurrence.

Line 94: Embedment Depth

The depth of the inverts below the natural stream channel.

Line 95: Embedment Material

Description of the gradation of material in culvert. The material should match the native streambed material to the extent possible.

<u>Section 5: Culvert Liner Design</u>

Lines 99 – 133 should be completed for any project that includes a culvert liner.

Culvert Liner Design - Existing Culvert

Line 99: Outfall number.

Consecutively numbered outfalls from the start to the end of the project. This value is auto-populated.

Line 105: Manning's roughness

Use standard values for "n" (i.e. 0.013 for concrete, 0.024 for corrugated metal)

Line 106: Pipe geometry

Cross sectional shape of pipe (i.e. circular, elliptical, arch, etc.)

Line 107: Upstream invert

Elevation of the upstream end of the pipe.

Line 108: Downstream invert

Elevation of the downstream end of the pipe.

Line 109: Length (ft)

Length of pipe, not including endwalls or aprons

Line 110: Slope (%)

Automatically populated based on invert elevations and pipe length.

Line 111: Depth of cover over pipe (ft)

Minimum depth at between roadway surface and top of pipe

Line 112: Is overtopping an issue?

Based on observed erosion or reports of local residents, document any past observed overtopping.

Line 113: Upstream flooding risk?

Note and buildings or infrastructure that may be at risk if upstream water surface elevations are increased as a result of lining the culvert.

Culvert Liner Design - Floodplain Management

Line 125: Is the culvert in a mapped floodplain?

Select the pull-down menu to answer either 'Yes' or 'No'. To determine if the culvert is in a mapped floodplain, either check with the region stormwater engineer or go to the Wisconsin DNR Surface Water Data Viewer – FEMA Maps/DFIRMS at:

https://dnrmaps.wi.gov/H5/?Viewer=SWDV

Official Flood Insurance Rate Maps (FIRMs) can be found on FEMA's website at:

https://msc.fema.gov/portal/home

Line 126: Will proposed liner increase water surface profile?

Select the pull-down menu to answer either 'Yes' or 'No'. If the answer is yes, attach an explanation of the reason for the change and how the increased water surface profile was approved.

Culvert Liner Design – Drainage District Issues

Line 128: Is culvert in a drainage district?

Select the pull-down menu to answer either 'Yes' or 'No'. To determine if the culvert is in a drainage district, either check with the region stormwater engineer or go to the web site:

https://datcpgis.wi.gov/maps/?viewer=dd

Line 129: Drainage District name.

Enter the name of the drainage district.

Line 130: Has the drainage board approved the use of a liner?

Select the pull-down menu to answer either 'Yes' or 'No'. If the answer is no, attach an explanation of the reason why the drainage board did not approve the change.

Culvert Liner Design - Aquatic Organism Passage

Line 132: Is aquatic organism passage a concern?

Select the pull-down menu to answer either 'Yes' or 'No'. If the answer is 'Yes', respond to the question on Line 135.

Line 143: Does WDNR agree with the AOP design?

Select the pull-down menu to answer either 'Yes' or 'No'. If the answer is no, attach an explanation of the reason for why the WDNR did not approve the design.

10.5.2 Example Stormwater-Drainage-WQ Worksheet

A completed Stormwater - Drainage Worksheet example is provided within the downloadable zip Stormwater-Drainage files (refer to link at top of Attachment 10.1 and 10.2). It includes both an urban and a rural component. The first sheet is the drainage basin overview figure, which illustrates basins for the entire project. If the corridor is long, additional sheets may be appropriate. For this example, not all drainage areas and outfalls for the project are shown. The map sheets provide additional detail, at a closer scale, of the drainage system along the highway for selected basins. The map sheets are followed by a completed stormwater report that illustrates both grass swale and storm sewer drainage.

LIST OF ATTACHMENTS

Attachment 10.1	Stormwater-Drainage-WQ Report Spreadsheet: Drainage - Summary Worksheet
Attachment 10.2	Stormwater-Drainage-WQ Report Spreadsheet: Drainage - Data Worksheet

FDM 13-1-12 Aquatic Connectivity

November 15, 2024

12.1 Introduction

The policies described in FDM subsection 13-1-12 provide guidelines for scoping and coordinating appropriate aquatic connectivity (ACONN) accommodations on WisDOT projects. The policies are largely based on the 2021 *Aquatic Connectivity at Road-Stream Crossings* attachment to the DNR-DOT Cooperative Agreement (2021 ACONN CoA Attachment). It is anticipated that these procedures will be routinely updated as WisDOT's ACONN related coordination and design policies continue to be refined. ACONN design guidance will be addressed separately in pending updates to FDM 13-15 *Hydraulic Design of Culverts.*

Aquatic connectivity (ACONN) is the transfer by water of matter, energy, and organisms within and between all natural resource components of a stream ecosystem and floodplain. When streams become fragmented, often by manmade features, it can impact the flow of water, establishment of vegetation, movement of fish and invertebrates, and the transport of sediments which impacts the stream's natural ability to modify its streambed and channel. Infrastructure such as roadways, multi-use trails, bridges, and culverts can impact ACONN. For example, some culverts can be barriers to ACONN due to perched outfalls, high water velocity, shallow water depth, turbulence within the culvert, and the accumulation of debris. This can cause unintentional physical, biological, and ecological impacts at road-stream crossings including: fragmented species populations, limited access to spawning areas and important habitat, loss of genetic diversity, decreased streambed and bank stability, and disruption of the natural mobility of sediment and biotic factors within the system. WisDOT, FHWA, State DOT's, and others often refer to these ACONN concepts as aquatic organism passage (AOP). For the purposes of WisDOT's FDM policies, aquatic connectivity is synonymous with aquatic organism passage.

***Figure 12.1* Examples of perched and high velocity conditions at culvert outfalls**
Photos by WDNR

The Wisconsin Department of Natural Resources (WDNR) estimates that there are 70,000 or more public road-stream crossings (locations where a state, county, or local roadway crosses a mapped stream) in Wisconsin (Diebel and Winston 2015). Roughly 85% of these crossings (60,000) are at culverts. While bridges can negatively affect ACONN and should be evaluated for ACONN impacts prior to replacement, more often impacts can occur at culverts. Even when stream crossings are not complete barriers to ACONN, many are only partially passable by some organisms depending on factors such as culvert flow conditions, species, or life stage.

The exact number of culverts impacting ACONN in Wisconsin is unknown. Studies have shown the estimated percent of culverts believed to be partially obstructing ACONN is between 40% to 80%. (Diebel, and Winston 2015), (Diebel, et al (2014). A study of the Pine River and Popple River watersheds in northeast Wisconsin found that up to 28% of culverts were believed to be complete barriers to ACONN (Diebel, et al 2014). While the percentage of road-stream crossings impacting aquatic connectivity can vary throughout the state based on terrain and other conditions, these studies suggest a fair number of culverts may be impacting ACONN. With responsibility for approximately 12,000 local and state-owned bridges, 2,200 state owned box culverts, and an estimated additional 9,000 state owned smaller culverts at waterway crossings, WisDOT plays an important role along with WDNR in identifying crossings where ACONN warrants consideration in the design and construction of culverts and bridges.

12.2 Applicability

This policy applies to all road-stream crossings (culverts, box culverts, or bridges) on projects subject to the WisDOT/WDNR Cooperative Agreement. It does not apply to culverts, storm sewer, or other drainage structures that the primary purpose is conveyance of runoff from roadway pavements and/or upland roadway ditches. Those drainage features generally do not provide adequate habitat for aquatic organisms so WDNR would not request ACONN accommodation. **This policy also does not apply to existing culverts or bridges that are not scheduled for replacement or rehabilitation as part of the scope of a current project**. Per the Department's asset management policies, bridges and culverts are only to be replaced if the life of the bridge or culvert will not outlast the pavement life of the current project. If ACONN concerns are identified by WDNR at a crossing that is not to be replaced with the current project, it shall be tracked by the WisDOT for ACONN consideration at the time of replacement (see FDM 13-1-12.3.3.5). Culverts or bridges shall not be added to the scope of projects, or scoped as stand-alone projects, solely for improvement of ACONN unless full funding has been secured from other sources. Past projects have included grant funding and funding from other agencies such as the US Forest Service and the US Fish and Wildlife Service. Often the culvert replacement is accomplished by coordinating the work as part of an adjacent WisDOT project or in some cases the sponsoring Agency carries out the work themselves having been issued a WisDOT work on highway right of way permit. As project schedules allow, partnering with WDNR or others if alternative sources of funding for culvert replacement is available is encouraged.

ACONN accommodations on emergency projects will be considered by WisDOT only as timing and funding restrictions allow. Guidance for environmental coordination on emergency projects can be found here.

12.3 ACONN Evaluation Process

12.3.1 Scoping Structure Replacements for ACONN

12.3.1.1 Initial Screening

When a structure (culvert, box culvert, or bridge) is to be replaced or rehabilitated, such as a culvert lining or extension project, potential ACONN needs and/or impacts shall be evaluated prior to finalizing project scope and budget. Under the terms of the 2021 ACONN CoA Attachment, WisDOT shall perform an initial screening of the structures to be replaced or rehabilitated and identify potential ACONN needs prior to requesting an initial review letter (IRL) from WDNR. However, if ACONN may be a concern on a project it is recommended whenever possible to start coordinating with WDNR early in the environmental scoping process and prior to requesting an IRL. Early identification and communication are key to identifying potential ACONN needs when establishing project scope, schedule, and budget. The level of effort and cost for survey, design, construction will be higher for road-stream crossings with significant ACONN concerns. For example, often more field data will be required such as additional stream profile survey and streambed sediment characterization. Identifying ACONN needs is more critical for culverts and box culverts as ACONN associated costs can be significantly higher when compared to those for a bridge. Bridges still need to be evaluated for ACONN, especially in the case where a bridge may be significantly constricting (narrowing) a waterway, however the need for significant design changes for ACONN improvement is less common and should not have a substantial impact on project scope or budget. Conversely, upsizing a circular culvert to a box culvert or a box culvert to a bridge can be a significant impact to project scope, schedule, and budget that needs to be accounted for. FDM 13-1-12.4.1 describes the potential costs and benefits associated with improving ACONN.

12.3.1.2 ACONN Screening Resources and Site Assessment

One tool to investigate sites with the potential for increased ACONN needs prior to a field investigation is the WDNR's Surface Water Data Viewer (SWDV). Waterway resources at the project site can be screened using various layers on the SWDV. Of particular interest to ACONN are the *Priority Navigable Waterways, Fisheries Management, Clean Water Act Standards & Uses, and Monitoring Data* layers. However, it is also advised to check other layers for other potential environmental and water resource issues such as *Dams & Floodplains*, *Mapped Wetland*, *Wetland Indicators and Soils,* and *Assessments & Impairments*. DNR Transportation Liaisons are always available to help interpret these data sources.

The SWDV may also help to identify potential site characteristics that may require an increased level of effort and cost to address ACONN. For example, sites with special waterway designations may warrant more site modifications to address ACONN. Examples of these special designations include but are not limited to:

- Outstanding and exceptional water resources (ORW/ERW)[1]
- Areas of special natural resource interest (ASNRI)[2] including trout waterways
- Priority navigable waterways (PNW)[3]
- Wild rice waters

Another source of data is the Great Lakes Culvert Inventory. This site includes data collected in Wisconsin by WDNR, local and Federal government agencies, private partners, and volunteers. The inventory data is not limited to the Great Lakes region and is expanding statewide. The inventory is supported by WDNR as a helpful analysis tool. WisDOT agrees that it is a useful screening tool, but the data contained within shall only be used to further scope potential ACONN concerns at a crossing, not as a definitive source of the potential ACONN related needs at a crossing. The rating of a waterway crossing in the Stream Crossing Viewer can be influenced by factors such as the flow conditions during a site visit or differences between field examiners When examining the inventory, note the date that the data was collected (Wisconsin data gathering goes back to 2020 or earlier). It may not reflect the current conditions at waterway crossings or any recent improvements that may have been made.

Reviewing aerial imagery in the SWDV, Google Earth, or elsewhere is often helpful in screening for potential ACONN needs. This can help identify site indicators such as when the culvert is significantly modifying water

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1 Outstanding and exceptional water resources as defined in Wisconsin Administrative Code Chapter NR 102.10 and NR 102.11, respectively.

2 Areas of special natural resource interest as defined in Wisconsin Statutes Chapter 30.01.

3 Priority navigable waterways as defined in Wisconsin Statutes Chapter 30.19.

depths, flows, and channel dimensions. Conditions such as ponded water behind a culvert or a significant scour pool downstream of a culvert may indicate that the structure is undersized and impacting ACONN. Viewing

historic images over time can give the sense of the stability of the channel and may aid in determining how it may impact the roadway embankment or structure in the future.

Waushara County GIS 2015 County Aerial

Photo by WDNR

***Figure 12.2** Scour hole at the downstream end of undersized culvert in Waushara County*

***Figure 12.3** Twin culverts with poor horizontal alignment and potential velocity issues indicated by apparent turbulence as flow expands at the culvert outfall*

Source: Wisconsin Regional Orthophotography Consortium via Wisconsinview.org

***Figure 12.4** Downstream scour holes suggest high velocities at culvert outfalls.*

Source: Wisconsin Regional Orthophotography Consortium via Wisconsinview.org

Upon completion of a desktop screening of the site it is highly encouraged to conduct a field visit with WDNR to aid in verifying the results. Check the condition of the waterway crossings that are to be replaced or rehabilitated, to determine if there are significant ACONN needs or not. Confirm if there are field indicators of erosion or scour holes near the structure. As previously stated, this may indicate the structure is significantly undersized. Are there significant velocity differentials in the culvert? Is it perched? (See Figure 12.1) Was it anticipated from preliminary screening that a waterway was dry or mapped as an intermittent stream and is now found to have perennial flow? The designer should become familiar with the site and any unique features or constraints. FDM 13-1-12.98 includes ACONN related resources including FHWA's HEC 26, HEC 16 and the 2024 Aquatic Organism Passage at Highway Crossings Implementation Guide, the Minnesota Guide for Stream Connectivity and Aquatic Organism Passage through Culverts, and the US Forest Service Stream Simulation Manual that contain guidance on sites assessment.

Other site considerations impacting the need for ACONN may include the presence of aquatic threatened, endangered, or other listed species or other site-specific considerations identified through coordination with WDNR. Coordinating with WDNR prior to the request for initial review letter will help accurately identify these concerns during the scoping process.

If preliminary screening indicates potential ACONN concerns, or if there are uncertainties or questions, contact region environmental staff or WDNR Transportation Liaisons to help to identify potential concerns. It is also a good idea to check with the region's environmental staff to determine if past ACONN commitments have been made to WDNR regarding the structure.

12.3.2 Coordinating with WDNR on ACONN

A request for a WDNR initial review letter can be made upon completion of preliminary screening of waterway crossings for potential ACONN needs by WisDOT. The initial review letter is part of the Transportation Liaison review process described in FDM 20-55-40 and the DOT/DNR Cooperative Agreement. The review letter request shall include the list of all the crossings that are to be replaced or rehabilitated including the intended scope of work. Indicate those crossings that have been identified with potential ACONN needs through screening online resources and internal resources, site visits, and/or discussions with WDNR or region environmental staff. Include any pertinent data collected in the request to help WDNR develop timely recommendations. Work with the Regional Environmental Coordinator (REC) to determine who will initiate contact with WDNR. Each region may differ on whether the REC or designer is responsible for handling correspondence with WDNR. At a minimum the REC should be included in correspondence to and from WDNR.

WDNR will review the request per the Cooperative Agreement, including the results of the preliminary screening. They also will coordinate closely with WDNR stream biologists for impact analysis and ACONN recommendations. WDNR will then agree or disagree with the need for ACONN improvements or may request additional information. WDNR may also review the need for ACONN improvements at other waterway crossings within the project limits. WDNR will communicate the results and recommendations of their review in the initial review letter or other correspondence. Additionally, for any crossings not previously identified by WisDOT during initial screening of the project limits as potential ACONN sites, the Transportation Liaison should identify why ACONN improvements are needed and/or request additional information, when necessary.

Project coordination will otherwise continue as described in the Cooperative Agreement.

12.3.3 Evaluating Need and Feasibility of ACONN

12.3.3.1 Evaluating WDNR ACONN Requests

WisDOT is to evaluate the waterway crossings identified or confirmed by WDNR as needing ACONN accommodations. This includes both the sites identified during scoping and any additional road-stream crossings identified as requiring ACONN by WDNR. If WDNR requests ACONN at additional sites that were not identified during scoping by WisDOT, the design team shall first evaluate if the environmental and site conditions meet those described in FDM 13-1-12.3.1. If the need for ACONN improvements is not clear, contact the WDNR Transportation Liaison (TL) to provide justification and to document the ACONN need.

Some examples of issues or requests that may necessitate further discussion with DNR are as follows.

1. Floodplain concerns – If ACONN accommodations would significantly impact regulated floodplains additional consideration of the request and various alternatives should be evaluated and discussed. Negative impacts to regulated floodplains are more likely to be a concern in flood storage districts, dam failure floodplains (mapped hydraulic shadows), and some detailed studied areas (Zone AE).
2. Intermittent waterways – If the waterway at the crossing is dry and only has flowing water after a precipitation event, ACONN accommodations may not be warranted unless WDNR provides justification that the waterway serves a seasonal ACONN need or holds other significance.

3. Agricultural swales or ditches – These channels are generally low gradient, have little or no flow, and/or may not provide habitat for aquatic species.
4. Significant wetland impacts – If ACONN accommodations would significantly impact wetlands, the WDNR and WisDOT will need to consider the potential benefits of ACONN accommodations versus the potential wetland impacts to determine what level of ACONN accommodation is appropriate for the location or site conditions.

Other conditions that should be discussed when determining the extent of ACONN accommodation includes topography, extensive headcut potential, nearby dams or other natural or artificial barriers, and length of reconnected stream thread. Again, WisDOT should reach out to the Transportation Liaison if there are concerns with the scope of a request. Even in cases where there are concerns, constraints, or potentially limited benefit, it is still appropriate to evaluate and discuss slightly upsizing and embedding the new culvert to improve ACONN.

12.3.3.2 Evaluating Site Conditions and ACONN Feasibility

WisDOT will determine the appropriate structure type, geometry, and placement for sites requiring ACONN based designs. If WisDOT determines that it is not feasible to fully incorporate the requested ACONN accommodations, for example a structure spanning full bank width, WisDOT shall provide written justification to WDNR as early as possible during project development. The written justification shall describe the project and site constraints. A response of “ACONN cannot be incorporated at this site” is not acceptable justification. Furthermore, failure to properly scope and budget a structure for ACONN is also not a justifiable response, especially if it meets one of the screening criteria in FDM 13-1-12.3.1 or otherwise has demonstrated as having a need. Although site-specific physical, environmental, and financial constraints may make addressing ACONN challenging at some locations, designers shall coordinate with WDNR to investigate feasible design alternatives for improvements at road-stream crossings. Even if budget or site constraints are present, ACONN can often be improved in some manner. For example, if constructing a large bank full width culvert requires substantial profile adjustment and results in significant associated impacts, some ACONN improvement can be provided by placing and embedding the largest structure feasible for the site. In addition to the potential environmental or site issues described in FDM 13-1-12.3.3.1, there are site constraints related to engineering that can impact a site. Some examples of engineering constraints that should be evaluated when considering ACONN include:

- Increased impacts from adjustments to roadway alignment or roadway profile to accommodate larger structures.
- Maximum available size for structure type. For example, the maximum readily available reinforced concrete culverts in Wisconsin are 144-inch diameter for round pipe and 97-inch by 151-inch for horizontal elliptical reinforced concrete pipe. There are also limits on spans for single cell box culverts.
- Maximum ADT or Facility Type. Per FDM 13-1-15.2 there are ADT limits on certain material types. This can, for example, limit the use of a structure such as a steel plate arch to ADT’s of less than 20,000 vehicles per day and they are not allowed under some roadways such as interstates.
- Fill height limits may also impact structure selection. This is especially true in the case of large arch or elliptical culverts. In these cases, consider the constructability/feasibility of a larger round structure embedded deeper as an option.
- Change of structure type. Changing structure type has a significant impact on project costs. While it may be fully justifiable to upsize from a culvert to a box culvert or a box culvert to a bridge for conditions identified in FDM 13-1-12.3.1, more consideration should be given to other alternatives prior to changing structure type in some locations. For example, where the desired width of structure would require a bridge, consideration of multiple cells or an embedded culvert or box culvert of the largest feasible size may be an alternative. In these cases, analyzing the culvert’s hydraulic impacts on stream velocities may help demonstrate that ACONN can be significantly improved with a smaller structure. Similarly, design methods such as FHWA’s Aquatic Organism Passage Design Guidelines for Culverts, Hydraulic Engineering Circular, Number 26 (HEC 26) can be used to design a culvert that is smaller than one that spans the entire full bank width while still employing stream simulation based aquatic connectivity principles.

12.3.3.3 Other ACONN Considerations

If an ACONN request requires a specific design methodology or a methodology not referenced in the FDM, or a specific means of ACONN accommodation, it should be sent to the REC for review. The REC can involve the region’s Storm Water and Erosion Control Engineer (SWECE), Central Office Bureau of Technical Services Environmental Services Section (ESS), Bureau of Structures, or one of the statewide drainage engineers from the Roadway Design Standards Unit in the Bureau of Project Development for technical assistance as necessary.

Examples of ACONN features that should be discussed with the REC could include requests for; light wells or lighting systems, stream habitat features, unique accommodations for terrestrial animals or reptiles, a bridge where a culvert is proposed, a specific type of culvert (material, color, shape, size or limits on length), a wider than hydraulically necessary bridge, providing "openness ratio" for a culvert, or when ACONN improvement is seen as necessary for a site not otherwise meeting the conditions of FDM 13-1-12.3.1 without providing additional explanation and coordination. More specific examples are as follows:

1. Lighting - Artificial or natural lighting may be considered only if both WisDOT and WDNR agree on the efficacy and cost effectiveness of providing lighting specifically for ACONN, as supported by a justification of need. In most cases lighting or light wells will not be considered for fish or other aquatic organisms. Lighting may be considered under certain conditions such as high mortality turtle crossings or where endangered species crossings are involved where the ACONN structure is serving a dual purpose of improving wildlife passage as well.

2. Stream Habitat Features - Installation and maintenance of stream habitat features at roadway crossings such as root wads, lunker structures, in stream placement of boulders, and riffle rocks for maintaining culvert backwater, may be considered if both agencies agree these features are necessary to facilitate ACONN, prevent headcut, or to restore stream habitat impacts associated with modification or expansion of the roadway crossing. These features may be an option for locations where stream mitigation is required for Army Corps of Engineers waterway permitting. Consult with region environmental staff on the need for these additional features.

3. In Culvert ACONN Enhancements – Installation of ACONN enhancement features inside a culvert such as baffles, large boulders, tailwater control weirs, or enhanced roughness within the barrel of new, post-lining or retrofit culvert installations may be considered when both agencies agree these features are necessary to facilitate ACONN or restore stream habitat impacts associated with modification or expansion of the roadway crossing. This does not include prohibiting placement of streambed materials or a mix of bed material and large stone for stability within an embedded culvert as part of the design. Again, consult with region environmental staff on the need for these additional features.

   When evaluating habitat features placed within a culvert, hydraulic impact must be considered. This is especially important when they are placed in existing culverts in regulated floodplains where even minor impacts to headwater are regulated. Impacts due to "in culvert" features could include lost culvert capacity or increased culvert roughness, both which impact hydraulics and may result in increased headwater.

In some cases, these additional accommodations or features may be low or no-cost options such as accommodating both terrestrial and aquatic connectivity at a bridge site. In those cases, the request should be given consideration by the region. More costly options that may require a substantial change in structure type will need to be supported by additional justification. In either case the communication and cooperation emphasized in the ACONN Cooperative Agreement attachment should be considered.

12.3.3.4 Communicating Evaluation of ACONN Accommodation Requests

Upon completion of evaluation of the ACONN needs for the project, the region shall reach out to the WDNR Transportation Liaison and describe if and how ACONN can be improved with the project. As described in FDM 13-1-12.3.3.2 if ACONN cannot be accommodated at a waterway crossing that needs to be justified and communicated to WDNR as soon as possible. That said most constrained sites can still accommodate some form of ACONN improvement such as slightly enlarging a culvert and embedding it to the appropriate stream profile. As stated previously, include the REC in these discussions.

If there is disagreement on the appropriateness of ACONN for a particular location, WDNR and WisDOT should work to communicate their differences and come to a mutual resolution. Thoughtful communication of the project scope, budget, and other constraints with the WDNR Transportation Liaison, even after receipt of an initial review letter, can help in reaching understanding and compromise and avoid project delays.

Agreed upon ACONN accommodations are to be included in the project's environmental document commitments. Associated impacts with upsized structures for ACONN accommodations (additional impacts to wetlands, right of way, etc.) will need to be addressed and included in the project's environmental documentation.

12.3.3.5 Tracking Requests for Future ACONN Consideration

As stated previously, it is not the intent of WisDOT's ACONN Cooperative Agreement to add bridge and culvert replacements to a project solely based on an identified ACONN concern. If WDNR identifies concerns at a particular crossing that is not to be replaced with the project, it shall be tracked within the WisDOT Aquatic Connectivity Project Tracking Tool by the WisDOT regional staff for future consideration at time of eventual replacement. At a minimum, the existing structure location and reason for the WDNR ACONN request should be tracked.

The WisDOT Aquatic Connectivity Project Tracking Tool is to be used in lieu of individual agreements with WDNR for replacement of culverts and bridges with a future project. Such agreements can lead to future disagreements if structure replacement is not within the asset management based scope of the "next project" which may only be a pavement preservation or similar improvement. With the ACONN Cooperative Agreement attachment in place there should be no need for additional individual ACONN agreements in the region.

12.4 ACONN Design

Coordination of the agreed upon ACONN accommodations will occur throughout the project development process and into final design.

In the instance where final design has commenced and the project team determines unforeseen circumstances that no longer allow for full ACONN accommodation, the design team needs to reach out to WDNR, with appropriate justification, as soon as practical to coordinate the change. This communication needs to occur well in advance of the time of final concurrence/401 water quality certification and PS&E or project delays are likely to occur. In these cases, the designer shall evaluate ways to accommodate aquatic connectivity to the extent practical while working within the unforeseen constraints.

Design of ACONN waterway crossing structures is to be further described pending updates to FDM 13-15 *Hydraulic Design of Culverts*, however the following gives a brief overview of design considerations.

12.4.1 ACONN at New or Replaced Culverts

Culverts for road-stream crossings have traditionally been designed using the Federal Highway Administration's (FHWA) Hydraulic Design Series 5 (HDS 5) – "Hydraulic Design of Highway Culverts." HDS 5 is primarily concerned with hydraulic efficiency by using the smallest culvert that protects the roadway while passing the design flow. This design approach provides little to no consideration for ACONN and can lead to the previously described potential barriers to passage such as high velocities or outfall scouring. Alternately, culverts designed using ACONN methodologies in almost all cases will be larger than those designed conventionally using HDS 5 or similar hydraulic design practices. WisDOT's Roadway Design Standards Unit (RDSU) evaluated the difference in size and cost (WisDOT 2023) of select ACONN culverts constructed between 2012 and 2017 and found culvert size increased 25% to over 500% and culvert associated project costs increased 57%-131% over HDS 5 design. This increase in cost is not only attributed to the structure size and type but there can be impacts to roadway geometry, backfill requirements, right of way, environmental impacts, erosion control, roadside hardware, and project duration. As described below there are many benefits to ACONN structures and their increased resilience, however these additional impacts need to be accounted for when scoping the cost and schedule for an ACONN project.

While there are potential costs associated with incorporating ACONN design features at a site, there are many direct benefits to upsizing and embedding culverts. Larger, embedded culverts may provide some additional flood resilience and can be less prone to clogging with woody debris. In addition, embedding metal culverts, may help reduce invert degradation in streams with abrasive mobile bedloads. There are also potential indirect benefits from healthier waterways due to improved ACONN such as increased recreational opportunities and the resulting economic and social benefits. For example, the tourism resulting from trout fishing in the west central Wisconsin portion of the Driftless Region brings significant economic benefit to the area. Applying ACONN principles can provide benefits to both infrastructure and the environment but the appropriateness of the selected structure size and type for the site should be considered.

While there are several methods for approaching ACONN design, WisDOT is still developing design policies related to these structures. Some key design guidance is pending in an update to FDM 13-15 and additional design guidance from other sources are listed in the resource section in FDM 13-1-12.98.

12.4.2 ACONN at Lined or Rehabilitated Culverts

Evaluation of ACONN shall be part of scoping whether rehabilitating or replacing culverts identified as deficient under the Department's asset management policies. If ACONN need is identified at these crossings it may suggest that the culvert should be replaced, or that the scope of the rehabilitation should be minimal, or non-intrusive as to maintain the structure until replaced with a future roadway reconstruction project. Culvert rehabilitation projects such as sliplining, spray liners, or even cured in place pipe (CIPP) liners can create or worsen existing ACONN problems. Spray liners, CIPP liners, and smooth slipliners can decrease the pipe roughness, especially for corrugated pipes and result in increased velocity. In addition, conventional solid slipliners, and some trenchless technologies such as pipe bursting, can raise the invert elevation of a culvert several inches. This can create a barrier to passage during low flow conditions, or otherwise result in flow obstruction. Solid culvert slipliners also significantly reduce the diameter of the pipe and can result in increased pipe velocity and headwater. Consequently, culvert slipliners are generally not the preferred alternative for structures that meet ACONN site considerations in FDM 13-1-12.3.1 without the concurrence of the WDNR. Slipliners may be appropriate when the culvert is significantly influenced by downstream backwater, is an equalizer pipe, or the flow characteristics of the culvert will not change significantly due to the liner. However, this may need to be demonstrated to WDNR to receive concurrence.

When trenchless methods are employed for culverts with potential ACONN concerns, consider technologies that can result in lower pipe inverts or result in increasing the culvert diameter such as pipe crushing or pipe swallowing technologies. In general, with pipe swallowing the existing invert can be maintained and a larger pipe installed. With pipe crushing the invert will be lowered. There are also low profile solid slipliners that are available that limit the raise of the culvert invert to 2 or 3 inches. Technologies such as CIPP liners have even less impact on culvert invert or diameter (often being only 0.5 to 0.75 inches or less in thickness) and are available with UV curing technologies with less environmental risk compared to traditional steam and hot water curing methods. Still, all these methods would be expected to have lifespans of 40 or more years which needs to be considered when discussing rehabilitation of a culvert with ACONN needs with WDNR. If the aim of rehabilitation is just to get the culvert to the next roadway reconstruction project perhaps the location needs to be tracked for future replacement per FDM 13-1-12.3.3.5 and a lesser repair considered. Less costly rehabilitation methods such as joint repair, grouting, or invert repair could be considered as an interim fix, especially if joint separation is the primary concern with the culvert. Ultimately it may make more sense to replace a culvert with ACONN needs when longevity and cost of the repair is considered versus replacement.

Regardless of the method employed, potential hydraulic changes from culvert lining shall be evaluated using an appropriate hydraulic model. See Chapter FDM 13-45 for additional guidance on culvert lining, culvert rehabilitation, and trenchless construction.

12.5 Plans and Specifications for ACONN Projects

Clearly identify ACONN commitments along with any other environmental commitments in the project plans and specifications to minimize the likelihood of unintended field adjustments during construction. For example, inverts given for an embedded culvert which are intentionally lower than the existing streambed may seem confusing in the field without context. Notes, profile drawings, or construction details showing the intended embedment or other ACONN features can help clearly communicate the intended accommodations to WisDOT construction leaders and contractors. A discussion of ACONN design elements should be a topic of discussion at project pre-construction and field meetings.

12.98 Resources

Aquatic Connectivity at Road-Stream Crossings attachment to the DNR-DOT Cooperative Agreement

Federal Highway Administration. Aquatic Organism Passage Design Guidelines for Culverts, Hydraulic Engineering Circular, Number 26 (HEC 26), FHWA-HIF-11-0008. October 2010.

Federal Highway Administration. Aquatic Organism Passage at Highway Crossings: An Implementation Guide, FHWA-HIF-24-054. July 2024.

Federal Highway Administration. Culvert hydraulic analysis program and supporting documentation, HY-8, Version 7.5. 2016.

Federal Highway Administration. Fish Passage in Large Culverts with Low Flows, FHWA-HRT-14-064. 2014.

Federal Highway Administration. Highways in the River Environment, Roads, Rivers and Floodplains (HEC 16) Second Edition, FHWA-HIF-23-004. 2023.

Federal Highway Administration. Hydraulic Design of Highway Culverts Hydraulic Design Series Number 5 (HDS 5) Third Edition, FHWA-HIF-12-026. 2012.

Forest Service Stream Simulation Working Group. Stream Simulation: An Ecological Approach to Providing Aquatic Organism Passage at Road-Stream Crossings, National Technology and Development Program, San Dimas, CA, United States Forest Service, May 2008.

Michigan/Wisconsin Stream Crossing Viewer

Minnesota Local Road Research Board and Minnesota Department of Transportation. Minnesota Guide for Stream Connectivity and Aquatic Organism Passage through Culverts, MN/RC 2019-02. 2019.

WDNR's Surface Water Data Viewer

12.99 References

Diebel, M and D. Winston (2015). “A Screening Method for Identifying Fish Passage Barriers at Road Crossings Using LiDAR-Derived Elevation Data”. Wisconsin Department of Natural Resources Bureau of Science Services, August 31.

Diebel, M.W., M. Fedora, S. Cogswell, and J.R. O'Hanley (2014). “Effects of Road Crossings on Habitat Connectivity for Stream-Resident Fish”. River Research and Applications, Volume 31 Issue 10, August 15.

Wisconsin Department of Transportation (WisDOT) (2022), Roadway Design Standards Unit ACONN Cost Evaluation, Updated January 11, 2022.

LIST OF ATTACHMENTS

Attachment 12.1 Aquatic Connectivity Coordination

FDM 13-1-15 Culvert Material Selection Standard

February 18, 2020

15.1 Application

This procedure establishes criteria for selecting the proper combination of culvert material and coating for different situations.

WisDOT has approved steel, aluminum, concrete and thermoplastic as suitable materials for culvert pipe. Coating systems for steel culvert pipe may be either zinc-coated (galvanized), aluminum or polymer. The standards in this procedure apply to all shapes of culvert pipe (circular, arch or elliptical) and to pipes in the range of 12 to 84 inches in diameter. The selection of larger drainage conduit is addressed in FDM13-1-20. Culvert replacement and analysis for perpetuation and rehabilitation projects is further discussed in FDM 13-1-30.

These standards are based on the expected service life of the material, the traffic volume to be supported, and the location of the pipe. Service life depends primarily on how durable the material is when subjected to corrosive or abrasive site conditions. Service life also depends on the proper structural design and installation of the pipe. These factors are considered in the Fill Height Tables of FDM13-1-25 as well as the standard specifications and the appropriate special provisions for individual projects.

The following table defines abbreviations commonly used throughout this chapter.

Table 15.1 WisDOT Standard Abbreviations for Pipe Materials

Material	Abbreviation
Corrugated Steel	CPCS
Corrugated Aluminum	CPCA
Corrugated Polyethylene	CPCPE
Corrugated Polypropylene	CPCPP
Reinforced Concrete	CPRC

FDM 15-1-35 contains examples of the correct notations for specifying culvert pipe on a plan and profile sheet. FDM 15-1-30 shows how to indicate culvert types on the Miscellaneous Quantities Sheet.

15.2 Selection Standard

Selection of pipe materials is to be based on Table 15.2 with consideration given to traffic volume and fill height in addition to the special situations and site conditions as described in FDM13-1-15.3 to FDM 13-1-15.6.

As conditions allow, and with the exceptions listed, Culvert Pipe Class III-A, Culvert Pipe Class III-A Non-metal, Culvert Pipe Class III-B, and Culvert Pipe Class III-B Non-metal under Standard Spec 520 shall be specified for culverts where ADT is less than or equal to 20,000 and where the diameter is 36-Inches or less.

These Class III-A and Class III-B bid items allow the contractor to choose from steel, concrete, and thermoplastic pipe (corrugated polyethylene and corrugated polypropylene) for sizes up to 36 inches in diameter. As described in FDM 13-1-17.3.1, the intent of these Class III-A and Class III-B items is to introduce potential project cost reductions into the competitive bid process by allowing the contractor to select from multiple material options for pipes sized up to 36 inches.

The four subclasses of Class III culverts are as follows:

- Class III-A
  - includes Class II and III reinforced concrete, corrugated steel, corrugated polyethylene, and corrugated polypropylene.
  - Class III-A has a maximum fill height of 11 ft.
- Class III-B
  - includes Class III reinforced concrete, corrugated steel and corrugated polypropylene
  - Class III-B has a maximum fill height of 15 ft.
- Classes III-A, Non-metal and Classes III–B, Non-metal
  - these non-metallic subclasses are for corrosive environments where it is not advisable to use metal pipe.
  - therefore, corrugated steel is removed.

The four subclasses of Class III-A and Class III-B culverts, steel culverts and thermoplastic culverts are not allowed under Interstate Highways or **divided** US Highways unless for temporary use or at maintenance crossovers in the median. When any of these materials is used on Interstate Highways or Divided US Highways for temporary use or at maintenance crossovers in the median, it is at the designer's discretion and there is no ADT restriction. There are three additional exceptions to the prohibition on thermoplastic and steel pipe on the Interstate and divided US Highways. The exceptions are the use of thermoplastic materials for inlets serving bridge deck drainage (SDD 8D3), PVC pipe used for slotted vane drains (SDD 8D14), and steel pipe used for slotted corrugated metal pipe surface drains (SDD 8D13). These types of installations take place outside of the travelled way limits or are encased in concrete.

For culverts greater than 36 inches in diameter and where ADT is less than or equal to 20,000, or where special situations, fill height or site conditions preclude the use of the Class III A and Class III B bid items, the designer may select another material type from Table 15.2 for the culvert. In situations where concrete or steel pipe is appropriate for a site, consider the use of the Culvert Pipe Class III items (520.3100-3199) under Standard Spec 520. These items also introduce potential project cost reductions into the competitive bid process by allowing the contractor to select from steel or concrete pipe.

Reinforced concrete pipe is required for culverts under high volume roadways (ADT >20,000) except as provided above for bridge deck drainage, slotted vain drains and slotted corrugated metal pipe surface drains, and special situations.

Table 15.2 on the next page lists the preferred materials permitted for culvert pipe by traffic volume. Material options for culvert replacement on perpetuation and rehabilitation projects is further discussed in FDM 13-1-30.4.

***Table 15.2** Culvert Material Selection Criteria*

All Roadways with Design Year ADT < 20,000 Excluding Interstate Highways and Divided US Highways			
BID ITEM (Culvert Pipe)	**DESIGN ADT**	**ALLOWABLE SIZES (Inches)**	**NOTES**
Class III-A, Class III-A Non-metal	Up to 20,000	12 – 36	- Max fill height of 11 ft. - Min. fill height 2 ft. from top of subgrade. - For Culvert Pipe Class III-A indicate required thickness for steel culverts in Misc. Qualities. - Use non-metal bid items in corrosive environments.
Class III-B, Class III-B Non-metal	Up to 20,000	12 – 36	- Max fill height of 15 ft. - Min. fill height 2 ft. from top of subgrade. - For Culvert Pipe Class III-B indicate required thickness for steel culverts in Misc. Quantities. - Use non-metal bid items in corrosive environments.
Corrugated Steel	Up to 20,000	42 – 84	- Not to be used in corrosive environments unless polymer or aluminum coated. See FDM 13-1-15.4. - 12- 36-inch sizes can only be used in special situations. See FDM 13-1-15.3. - Refer to FDM 13-1 Attachment 25.2 and 25.3, for appropriate fill heights. - Indicate required thickness in Misc. Quantities.
Reinforced Concrete	Up to 20,000	12 – 36(1) 42 – 84	- Consider for use in corrosive environments. - (1) 12- 36-inch sizes can be considered in special situations. See FDM 13-1-15.3. - Refer to FDM 13-1 Attachment 25.1 and 25.2 for appropriate fill heights.
Polyethylene	Up to 20,000	12 – 36	- Max fill height of 11 ft. - Min. fill height 2 ft. from top of subgrade. - Consider for use in special situations. See FDM 13-1-15.3 and FDM 13-1-15.4.1
Polypropylene	Up to 20,000	12 – 36	- Max fill height of 15 ft. - Min. fill height 2 ft. from top of subgrade. - Consider for use in special situations. See FDM 13-1-15.3 and FDM 13-1-15.4.1
Corrugated Aluminum	Under 1,500	42 – 84	- Consider for use in corrosive environments. - 12- 36-inch sizes can only be used in special situations. See FDM 13-1-15.3. - Refer to FDM 13-1 Attachment 25.2 and 25.6 for appropriate fill heights. - Indicate required thickness in Misc. Quantities.
Interstate Highways, Divided US Highways or Any Class of Roadway with Design Year ADT > 20,000			
BID ITEM (Culvert Pipe)	**DESIGN ADT**	**ALLOWABLE SIZES (Inches)**	**NOTES**
Reinforced Concrete	> 20,000	12 – 84	- Refer to FDM 13-1 Attachment 25.1 and 25.2 for appropriate fill heights.

Note: Steel and thermoplastic culverts are allowed under any roadway type at any ADT when used for temporary use, or at maintenance crossovers in the median. In addition, thermoplastic pipe is allowed when used for bridge deck drainage and slotted vain drains, and steel pipe is allowed for slotted corrugated metal pipe surface drains.

15.2.1 Local Approval of Culvert Pipe Materials

Local approval of culvert pipe materials is required for projects such as those in the local road program, STP program, or in the case where the local government is paying more than 50% of the cost of the pipe. Local approval is not required for roadways classified as State Trunk Highways, Connecting Highways or other roadways on the NHS system, unless the 50% pipe cost participation threshold is exceeded. The local approval is intended to come from the local unit of government or agency participating in the cost of the project, which may not necessarily be the entity responsible for maintenance. In addition, a participating local unit of government or agency may specifically request the installation of concrete, metal, thermoplastic, or the four subclasses of Class III pipe listed in Standard Spec 520 for projects meeting the criteria described in this part.

15.3 Special Situations

Special conditions at the proposed culvert site may require that a specific type of pipe be used. Such special conditions include acidity of soils/water or other corrosive conditions, local preference when meeting the conditions described in FDM 13-1-15.2.1, limited cover (see FDM 13-1-15.6), extending existing culvert pipes, unusual loading from high embankments, steep gradients, or other pertinent reasons.

15.4 Corrosion Concerns About Steel Culvert Pipe

Corrosion of zinc-coated (galvanized) steel pipe results from different mechanisms in different regions of the state. A Wisconsin map outlining the potential areas for bacterial corrosion of zinc galvanized steel culvert pipes is shown on Attachment 15.1. In the north and central part of Wisconsin (Area 1, Figure 15.1), corrosion of steel pipe is due mainly to the activity of anaerobic sulfate reducing bacteria (ASR) in the surface water. This region is characterized by low alkalinity of the surface water. These ASR bacteria do not attack the steel directly but create an environment favorable to corrosion. Corrosion resistant pipe should be specified for use in Area 1 except for commonly dry sites where existing zinc-coated (galvanized) steel pipe have not had a history of corrosion.

In Area 2, zinc-coated (galvanized) steel pipe should be used only at sites where surface water has a minimum alkalinity of 120 milligrams per liter or where existing zinc-coated (galvanized) steel pipe at the site have had an acceptable service history. Metal culvert pipe of any type should provide a minimum service life of 20 years before perforation occurs.

In the remainder of the state (Area 3), corrosion is more commonly related to local conditions such as high electrical conductivity of water and fine-grained soil. Other contributing factors would include high or low pH of soil or water and the presence of ASR bacteria in organic, poorly drained soil.

Corrosion resistant pipe may be necessary where drainage originates in bogs, swamps, barnyards or low-lying lands drained by ditches or tile. An acceptable corrosion resistant pipe should be specified in Area 3 when the pH is outside the range of five to nine and the resistivity is below 2000-ohm centimeters, or when the resistivity is below 1000-ohm centimeters regardless of the Ph. Acceptable corrosion resistant pipe materials are concrete, aluminum, aluminized steel, polymer coated steel, polyethylene and polypropylene.

* Note: Inspection of several aluminum drainage structures in 1993 revealed localized corrosion of the top and sides of the center sections of the structures. The corrosion appears to be related to the use of chlorides for snow and ice removal. The use of aluminum pipe should therefore be limited to side drains and highways with traffic volumes under 1500 Design AADT unless some provision is made to insulate the upper surface of the structure from infiltrating road salt.

Information about the corrosive characteristics of the soil or water at a site may already be available from region soils or maintenance records. In some cases, it may be necessary to conduct field and laboratory tests to determine whether corrosive conditions exist. The region Soils Engineer can normally advise the designer about the need for such tests and conduct them if needed.

As conditions allow, and with the exceptions listed, Culvert Pipe Class III-A Non-metal, and Culvert Pipe Class III-B Non-metal under Standard Spec 520 are to be specified for culverts in corrosive conditions where ADT is less than or equal to 20,000. Reinforced concrete pipe is required for culverts under high volume roadways (ADT>20,000).

15.4.1 Corrosion Concerns for Concrete Pipe

Where existing reinforced concrete pipe has corroded consider specifying thermoplastic pipe under Standard Spec 530 for roadways with ADT's up to 20,000. Where corrosion has occurred in concrete pipes under high volume roadways (ADT>20,000), contact one of the statewide drainage engineers in the Roadway Design Standards Unit for assistance.

15.4.2 Corrosion Concerns for Steel Endwalls

Where corrosion resistant pipe materials or coatings are specified for a project similar treatment of the endwalls may be necessary. In the case of Culvert Pipe Class III-A and Class III-B items consider the need for a special provision article requiring aluminum apron endwalls meeting the requirements of Standard Spec 525 for corrugated polyethylene and corrugated polypropylene pipe culvert installations.

15.5 Abrasion Concerns

The thickness of metal pipe should be increased, or the pipe invert paved where water velocity combined with a bed load of sand, gravel or stone is likely to cause significant erosion or abrasion of the pipe invert. The existence of abrasive conditions at a proposed culvert site can be determined from inspection of the existing metal pipe at the site or inspection of other pipes in the same general area or on the same watercourse.

15.6 Limited Clearance Installations

When a low clearance pipe is required, the designer may call for any of the following.

- Reinforced concrete elliptical pipe
- Corrugated steel or aluminum pipe arch
- Structural plate pipe arch
- Aluminum structural plate pipe arch.

Due to limited availability, use of concrete arch pipe is discouraged. However, it may be warranted based on special hydraulic or aquatic organism passage (AOP) design requirements. When specifying concrete arch pipe however, or when it is requested by a regulatory agency for AOP, be aware availability is very limited in Wisconsin and horizontal elliptical pipe may be the only viable option for a limited clearance concrete pipe.

Table 15.3 Culvert Material for Arch or Elliptical Culverts

BID ITEM(S)	DESIGN ADT	ALLOWABLE SIZES (Inches)	NOTES
Pipe-Arch Corrugated Steel	Up to 20,000	17 x 13 to 83 x 57 (Pipe Arch)	- Not to be used in corrosive environments unless polymer or aluminum coated. See FDM 13-1-15.4. - Indicate required thickness in Misc. Quantities. - Refer to FDM 13-1 Attachment 25.4 for appropriate fill heights - Not allowed on Interstate Highways, or Divided US Highways unless for temporary use or maintenance crossovers in the median.
Reinforced Concrete Horizontal Elliptical Pipe Culverts	All Volumes	14 x 23 to 68 x 106 (Horz. Elliptical)	- Refer to FDM 13-1 Attachment 25.9 for appropriate fill heights. - Arch sizes can be specified by SPV item but availability may be limited.
Pipe-Arch Corrugated Aluminum	Up to 1,500	17 x 13 to 71 x 47 (Pipe Arch)	- Indicate required thickness in Misc. Quantities. - Refer to FDM 13-1 Attachment 25.7 for appropriate fill heights. - Can only be specified as SPV item

15.7 Culvert Selection Justification

When special situations require the use of a non-standard type, shape or coating of pipe; relevant information to that determination should be included on the Stormwater-Drainage-WQ Report Spreadsheet (See FDM 13-1-10.4.

15.8 Tied Joints

Reinforced concrete pipe culverts are required to be tied at the joints with joint ties to prevent separation of adjacent pipe sections. This is required at the last three joints on the upstream and downstream ends of concrete culvert and concrete cattle pass installations. If using apron endwalls, the joint is tied at the endwalls and the next two pipe to pipe joints. No ties are required on culverts with masonry endwalls unless the plans show otherwise. Refer to Standard Spec 520 - pipe culverts. Include the standard detail drawing "Joint Ties for Concrete Pipe" when using concrete culvert and concrete cattle pass pipe.

Restraining all the joints in a pipe installation with ties is very costly and should rarely be necessary. Where soil conditions or past experience with separation of RCCP sections at joints seems to justify an extensive use of pipe ties, a metal or thermoplastic pipe may be a more cost-effective pipe material.

Joint ties are not required for thermoplastic pipe where a full (+/- 20 foot) pipe section is utilized from the infall and outfall to the first joint. Where a partial pipe section must be used at the infall or outfall end, it should be restrained with a manufacturer supplied external mechanical coupling, a mastic impregnated geotextile wrap with mechanical fastening bands, or concrete collar. Apron endwalls shall be secured to the pipe. No ties are required on pipes with masonry endwalls unless the plans show otherwise.

15.9 Height of Cover for Culvert Pipes

Height of cover for the pipe materials in Table 15.2 and Table 15.3 shall be in accordance with the fill height tables referenced in the table notes and as described in FDM 13-1-25.

Required minimum cover for Culvert Pipe Class III-A, Culvert Pipe Class III-A Non-metal, Culvert Pipe Class III-B, and Culvert Pipe Class III-B Non-metal shall be 2 feet measured from top of pipe to top of subgrade.

For steel and concrete pipe, the desired minimum cover shall be 2 feet measured from top of pipe to top of subgrade. Exception to this requirement can be made, and minimum cover reduced, based on pipe class and the minimum cover values listed in the fill height tables.

When breaker run or a similar material is placed for subgrade stabilization, and it is not a part of the pavement structure, it can be counted towards required subgrade cover for the purposes of compliance with this part.

Where less than two feet of subgrade cover is provided special measures may be required during construction to minimize equipment loading impacts on the pipe. At a minimum, locations with reduced subgrade cover should be identified on the plans so that the contractor can take precautionary measures.

15.10 Roughness Coefficient for Culvert Pipe

If a specific pipe material is specified by the designer, a Manning's roughness values appropriate to the material shall be selected. For example, when a reinforced concrete culvert is specified for a project with ADT>20,000 a Manning's roughness value of 0.013 should be used for the design.

Where the contractor is allowed to select from two or more pipe materials, the more restrictive Manning's roughness value should be used for design. For example, a Culvert Pipe Class III-A culvert allows steel, reinforced concrete, high density polyethylene or high density polypropylene pipe. In this case a Manning's roughness of 0.024 for corrugated steel should be used for design. For Culvert Pipe Class III-A Non-metal culverts only reinforced concrete, high density polyethylene or high density polypropylene pipe are allowed and the designer should use a Manning's roughness value of 0.013 accordingly.

LIST OF ATTACHMENTS

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

FDM 13-1-17 Storm Sewer Material Selection Standard — *February 18, 2020*

17.1 Application

This procedure provides guidelines for the selection of storm sewer materials.

WisDOT has approved concrete and thermoplastic pipe as suitable materials for storm sewers. The standards in this procedure apply to both round and elliptical storm sewers.

These standards are based on the expected service life of the material, the highway facility type, and the location of the pipe. Service life depends on the proper structural design and installation of the pipe. These factors are considered in the Fill Height Tables of FDM 13-1-25 as well as the standard specifications and the appropriate special provisions for individual projects.

17.2 Selection Standard

Selection of pipe materials is to be based on Table 17.1 with consideration to size, facility type and fill height in addition to the special situations and site conditions as described in FDM 13-1-17.3 to FDM 13-1-17.5. Storm sewer material selection does not have an ADT restriction.

As conditions allow, and with the exceptions listed, Storm Sewer Pipe Class III-A, and Storm Sewer Pipe Class III-B under Standard Spec 608 shall be specified for storm sewers where the diameter is 36-Inches or less.

These Class III-A and Class III-B bid items allow the contractor to choose between concrete pipe and thermoplastic pipe (corrugated polyethylene and corrugated polypropylene) for sizes up to 36 inches in diameter. As described in FDM 13-1-17.3.1, the intent of these Class III-A and Class III-B items is to introduce potential project cost reductions into the competitive bid process by allowing the contractor to select from multiple material options for pipes sized up to 36 inches.

Class III-A and Class III-B storm sewer differ as follows:

- Class III-A
  - includes Class II and Class III reinforced concrete, corrugated polyethylene, and corrugated

polypropylene.

  - Class III-A has a maximum fill height of 11 ft.
- Class III-B
  - includes Class III reinforced concrete and corrugated polypropylene
  - Class III-B has a maximum fill height of 15 ft.

Reinforced concrete pipe is required for storm sewers greater than 36-Inches in diameter although some exceptions are allowed as described in FDM 13-1-17.3.1.

Once it has been determined which storm sewer materials are suitable for a specific project or site, it may be required to get the approval of affected local government officials prior to developing final plans and specifications. FDM 13-1-17.3.2 describes when local approval is required for projects.

17.3 Approved Materials

The materials shown in Table 17.1 below may be used with the following restrictions.

TABLE 17.1 Storm Sewer Materials Selection Criteria

Diameter ≤ 36-Inches on all Roadways Excluding Interstate Highways or Divided US Highways			
BID ITEM (Storm Sewer Pipe)	**DESIGN ADT**	**ALLOWABLE SIZES (Inches)**	**NOTES**
Class III-A	All Volumes	12 - 36	- Max fill height of 11 ft. - Min. fill height 2 ft. from top of subgrade.
Class III-B	All Volumes	12 - 36	- Max fill height of 15 ft. - Min. fill height 2 ft. from top of subgrade.
Reinforced Concrete	All Volumes	12 - 36 (Round) (1) 42 - 108 (Round) (2)	- (1) 12-36-inch sizes can only be used in special situations. See FDM 13-1-17.4. - (2) Maximum size for concrete pipe varies by pipe class. - Refer to FDM 13-1 Attachment 25.1 and 25.2 for appropriate fill heights for round pipe.
Composite	All Volumes	6 - 15	- Min. fill height 2 ft. from top of subgrade. - Consider for use in special situations. See FDM 13-1-17.4.
Diameter > 36-Inches, Interstate Highways or Divided US Highways, or Horizontal Elliptical Pipe			
BID ITEM (Storm Sewer Pipe)	**DESIGN ADT**	**ALLOWABLE SIZES (Inches)**	**NOTES**
Reinforced Concrete	All Volumes	12 – 108 (Round) (2) 14 x 23 to 68 x 106 (Horz. Elliptical) (2)	- Refer to FDM 13-1 Attachment 25.1 and 25.2 for appropriate fill heights for round pipe. - Refer to FDM 13-1 Attachment 25.9 for appropriate fill heights for horizontal elliptical. - (2) Maximum size for concrete pipe varies by pipe class.

Note: Thermoplastic pipe is allowed under any roadway type at any ADT when used for bridge deck drainage, slotted vain drains, temporary use, or at maintenance crossovers in the median.

17.3.1 Criteria for Use of Storm Sewer Pipe Class III-A and Class III-B Bid Items

The objective of Class III-A and Class III-B bid items is to take advantage of advances in materials technology. When new materials are approved for use on WisDOT projects, the competitive bidding process is enhanced. The Storm Sewer Pipe Class III-A and Class III-B bid items allow contractors to bid based on total installed cost for multiple materials options which should result in the lowest total cost for the project. Therefore, the Storm Sewer Pipe Class III-A and Class III-B bid items shall be utilized on all WisDOT projects, regardless of ADT, where conditions allow and subject to the following:

1. Local approval is granted when required for projects meeting the criteria in FDM 13-1-17.3.2.
2. The diameter of the pipe may not exceed 36 inches.
3. Unless a special situation as defined in FDM 13-1-17.4 applies.
4. Storm Sewer Pipe Class III-A and Class III-B is not allowed on Interstate Highways or Divided US Highway unless for temporary use or at maintenance crossovers in the median. When any of these materials is used on Interstate Highways or Divided US Highway for temporary use or at maintenance crossovers in the median, it is at the designer's discretion and there is no ADT restriction. There are two additional exceptions to the prohibition on thermoplastic storm sewer on Interstate and divided US Highways. The exceptions are the use of thermoplastic materials for inlets serving bridge deck drainage (SDD 8D3) and PVC pipe used for slotted vane drains (SDD 8D14). The reason being is that these types of installations take place outside of the travelled way limits or are encased in concrete.

Exceptions to these conditions may be granted at locations determined in cooperation with the Bureau of Technical Services and Roadway Design Standards Unit for gaining additional experience with the materials in a variety of conditions.

While Class III-A and Class III-B bid items shall be used whenever possible, some discretion is left to the designer on roadways with fill height, high groundwater, or other material limitations. Designers are not expected, for example, to change materials back and forth between manholes as fill heights change or call out a few individual short runs of Class III-A or B pipe on a site where it otherwise doesn't fit the conditions. In addition, there may be situations where the selection of a specific material is justified such as specifying concrete pipe or thermoplastic pipe to match an existing pipe material.

WisDOT has traditionally taken a conservative approach to the implementation of the use of new materials such as thermoplastic pipe. However, thermoplastic pipe is not a new material to the Department as it has been utilized throughout the state for many years without significant issues in advance of the development current standards. Continued monitoring of the performance of these materials in the field will take place, and standards will be adjusted as necessary.

17.3.2 Local Approval of Storm Sewer Materials

Local approval of storm sewer materials is required for projects such as those in the local road program, STP program, or in the case where the local government is paying more than 50% of the cost of the pipe. Local approval is not required for roadways classified as State Trunk Highways, Connecting Highways or roadways otherwise on the NHS system, unless the 50% pipe cost participation threshold is exceeded. The local approval is intended to come from the local unit of government or agency participating in the cost of the project, which may not necessarily be the entity responsible for maintenance. In addition, a participating local unit of government or agency may specifically request the installation of concrete, thermoplastic, Storm Sewer Pipe Class III-A or Storm Sewer Pipe Class III-B for projects meeting the criteria described in this part.

17.4 Special Situations

Special conditions at the proposed storm sewer site may require that a specific type of pipe be used. Such special conditions include; local preference when meeting the conditions described in FDM 13-1-17.3.2, limited cover, extending existing storm sewer, unusual loading from high embankments, steep gradients, or other pertinent reasons. Additional special situations where a particular pipe material, such as composite pipe, may be desirable include storm water control BMP's outside of traffic areas, very short pipe runs between adjacent inlets or where a pipe less than 12 inches in diameter is required.

17.5 High Groundwater and Buoyancy of Thermoplastic Pipe

All pipe materials, including concrete, are subject to buoyant forces and floatation in saturated conditions. Buoyancy is of concern for thermoplastic pipe due to its light weight. When covered even with minimal roadway pavement, floatation of thermoplastic pipe is not a significant concern. For installations outside the pavement structure, however, high groundwater can be a concern. Examples of this condition are storm sewer running in a median, ditchline, terrace, or other "soil only" areas of cover.

Where high groundwater and fully saturated soil conditions are anticipated, the minimum cover for storm sewer outside the roadway shall be 48 inches for thermoplastic pipe, otherwise reinforced concrete pipe should be specified. For locations where storm sewer is under the roadway pavements, the required minimum 2-foot subgrade cover specified in the FDM is sufficient. Additional depth of cover may be necessary if backfill materials other than the standard foundation and trench backfill materials described in Standard Spec 608 are employed.

The risk of high groundwater conditions can be found from soil boring data such as depth to groundwater or soil morphology. Other resources include; soil mapping (presence of hydric soils), standing water, historic aerial photography, presence of dry weather infiltration in existing storm sewer systems, local well drilling records, USGS data, wetland mapping, field review, and local knowledge.

17.6 Storm Sewer Pipe Connections

17.6.1 Storm Sewer Joints

Standard Spec 608 lists several acceptable joint types for the range of allowable storm sewer materials. In general, these joints are intended to be soil tight. Standard Spec 608 does not specifically require joints to be watertight currently.

Watertight joints are required however in areas of contaminated groundwater and/or soil and may be necessary in areas of high groundwater. In these cases, a special provision article will be necessary to specify watertight joints. Often the AASHTO or ASTM material designations referenced in standard spec 608 contain standards for watertight joints and should be reviewed for applicability to the project conditions. Applicable sections of the Bridge Construction Specifications also reference requirements for watertight joints and can be referenced.

17.6.2 Tied Joints

In certain circumstances, concrete pipe storm sewers are required to be tied at the joints with joint ties to prevent separation of adjacent pipe sections. This is required at the last three joints of the system infalls and outfalls. If using apron endwalls, the joints are tied at the endwall and the next two pipe to pipe joints. No ties are required on storm sewers with masonry endwalls unless the plans show otherwise (refer to Standard Spec 608 - Storm Sewers). Include the standard detail drawings "Joint Ties of Concrete Pipes" when using concrete pipe storm sewers with infalls or outfalls.

Restraining all the joints in a pipe installation with ties is very costly and should rarely be necessary. Where soil conditions or past experience with separation of RCP sections at joints seems to justify an extensive use of pipe ties, the use of thermoplastic pipe materials may be more cost effective.

Joint ties are not required for thermoplastic pipe where a full (+/- 20 foot) pipe section is utilized from the infall and outfall to the first joint. Where a partial pipe section must be used at the infall or outfall end, it should be restrained with a manufacturer supplied external mechanical coupling, a mastic impregnated geotextile wrap with mechanical fastening bands, or a concrete collar. Apron endwalls shall be secured to the pipe. No ties are required on pipes with masonry endwalls unless the plans show otherwise.

17.6.3 Connections at Structures

Currently, WisDOT Standard Specifications and standard detail drawings do not require watertight connections for storm sewer at catch basins, manholes and inlets. Mortared connections between the structure and sewer pipe are required. In areas of groundwater and/or soil contamination or areas otherwise designated as requiring watertight joints, a special provision will be necessary. In preparing a special provision article to address groundwater infiltration into a structure, consider the need for additional waterproofing at joints between structure sections and for joints at risers and castings. A cautious approach should be used when specifying the manner of waterproof connection between the sewer pipe and structure. On projects where multiple material types can be allowed (i.e. Storm Sewer Pipe Class III-A and Class III-B) constructability issues could arise if a specific, or proprietary manner of connection is specified.

17.7 Height of Cover for Storm Sewer

Height of cover for the pipe materials in Table 17.1 shall be in accordance with the fill height tables referenced in the table notes and as described in FDM 13-1-25.

Minimum cover for Storm Sewer Pipe Class III-A, Storm Sewer Class III-B and composite pipe shall be 2 feet measured from top of pipe to top of subgrade where the pipe is under pavement. Additional cover is required when high groundwater may be encountered per FDM 13-1-17.5.

For concrete pipe, the desired minimum cover shall be 2 feet measured from top of pipe to top of subgrade. Exception to this requirement can be made based on pipe class and the minimum cover values listed in the fill height tables and whether the pipe is located outside the limits of current or potential future roadway pavements.

When breaker run or a similar material is placed for subgrade stabilization, and it is not a part of the pavement structure, it can be counted towards required subgrade cover for the purposes of compliance with this part.

Where less than two feet of subgrade cover is provided special measures may be required during construction to minimize equipment loading impacts on the pipe. At a minimum, locations with reduced subgrade cover should be identified on the plans so that the contractor can take precautionary measures.

17.8 Roughness Coefficient for Storm Sewer

A constant coefficient of roughness value of 0.013 should be used in the Manning Formula for all the storm sewer materials described in this procedure.

FDM 13-1-20 Large Drainage Conduit *December 18, 2015*

20.1 Introduction

Large drainage conduit is defined in general as conduit larger than 84 inches in equivalent diameter, which equates in cross-sectional area to 38.5 square feet. This size was selected because it is near the top of the range of sizes at which pipe can be factory assembled while still being a practical size for transporting.

The types of large conduit available include structural plate pipe and structural plate pipe arch (AASHTO m167), aluminum alloy structural plate pipe and pipe arch (AASHTO m219), steel pipe with 3" x 1" corrugations (AASHTO m36), reinforced concrete pipe (AASHTO m170), reinforced concrete arch pipe (AASHTO m206), reinforced concrete elliptical pipe (AASHTO m207), and cast-in-place or precast box culverts (AASHTO m259).

The selection of a specific type of large conduit should be made based on economics unless other considerations dictate the need for a particular type of large conduit. Other factors that should be considered include the availability of the conduit in the area of the project; foundation conditions at the project site; time available for construction, including consideration of how traffic will be handled; and the existence of corrosive or abrasive conditions at the site. Special hydraulic requirements, aquatic organism passage, or limited clearance conditions may require the use of a corrugated steel pipe arch, structural plate pipe arch, or wide box culvert.

Two or more conduit types may be specified as equal alternates when either type will satisfy design requirements. For example, aluminum structural plate pipe arch and (steel) structural plate pipe arch could be specified as equal alternates.

Multiple lines of pipe culverts or pipe arches may also be a feasible alternative to large drainage conduit.

FDM 13-1-21 Precast Box Culverts *December 18, 2015*

21.1 Introduction

Precast box culverts are one of the large drainage conduit alternatives the designer may choose to resolve a given drainage problem. The choice of this option should be based on the criteria given in FDM 13-1-20 as well as sound engineering judgment. One factor that must be considered is earth cover. Fill height criteria for similarly sized cast-in-place culverts may be used, except precast box culverts may be used only in those situations which provide for at least two feet of earth cover under the traffic areas.

The broad range of sizes offers the designer many choices when studies indicate large drainage conduit is suitable. Multiple cell installations are permitted.

When determining whether a box culvert should be precast or cast-in-place, an analysis should be conducted to compare the options. This analysis should attempt to identify all the factors involved, including costs, many of which are not readily apparent.

Generally, initial cost of a cast in place box is less expensive than a precast box culvert. However, precast box culvert installation can be completed in a much shorter time than a cast-in-place option. This is especially of value where a detour is not feasible, and a short-term closure can be allowed. Precast box culverts may be used in emergency situations. In situations where complete closure is impossible, precast units can be used in a bypass, and then left in place or reset to a new position. Some local roads can carry detour traffic for short durations but cannot sustain long-term use without costly maintenance and repair. Road user costs, such as delays due to indirection, may be a factor. Grading projects may realize a cost advantage by providing early access to an entire project, expediting movement of embankment materials and other construction operations. The minimum time and amount of disruption to streams is an easily identified positive environmental aspect.

Quality control of materials and curing conditions is an advantage to casting the units in a plant environment. The dry mix used in the units yields a denser, less permeable concrete than the cast-in-place option.

End treatments may be precast, cast-in-place, or a combination of both.

If a precast box culvert is selected for a particular design project, the designer shall notify the Bureau of Structures (BOS) early in scoping or design phase. If project is designed by a consultant, preliminary plans and complete final structure plans are required to be sent to BOS for approval. Please refer to 36.12 of the Bridge Manual

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/strct/bridge-manual.aspx

FDM 13-1-25 Fill Height Tables

November 30, 2018

25.1 Design Criteria

The fill height tables included in this procedure are based on the following design criteria:

1. Weight of Embankment: 120 lbs/ft^3
2. Backfill: Good side fill material compacted to 90 percent of standard density based on AASHTO T 99. Modulus of passive soil resistance, E' = 1050 psi. Soil stiffness coefficient, K = 0.33.
3. Installation Type: Class C bedding, in accordance with AASHTO standards at the time of adoption [4]. The only exception to this bedding requirement is shown in Fill Height Table (Attachment 25.3), where a Class B bedding is required for reinforced concrete pipe placed under fill heights in excess of 35 ft. (see Attachment 25.2). Load factors for the zero-projecting embankment condition were used in the fill height determinations.

   For pipe arch structures, the confining backfill must be capable of supporting a corner pressure of two tons per square foot.
4. Safety factors: 4 for longitudinal seams; 2 for buckling.
5. Materials and fabrication: In accordance with the appropriate AASHTO specification as required by the Standard Specifications or special provisions.

25.2 Design Methods

The fill height tables for flexible conduit were developed using the service load design method described in the AASHTO LRFD Bridge Design Specifications. The fill height table for reinforced concrete pipe was developed using the design procedure included in the Concrete Pipe Design Manual prepared by the American Concrete Pipe Association.

25.3 Cut Ends

The ends of metal pipe cut as skews or mitered to slope (or both) are not as strong as square ends. Cut ends should be reinforced with concrete headwalls or collars when the bevel is flatter than 2:1 and the skew is greater than 20 degrees.

25.4 Multiple Structures

Where multiple lines of pipes or pipe arches greater than 48 inches in diameter or span are used, they shall be spaced so that the adjacent sides of the pipe are at least one-half diameter or three feet apart, whichever is less, to permit adequate compaction of backfill material. For diameters up to 48 inches the minimum spacing shall be 24 inches.

When multiple lines of pipe have less than half the diameter of the smallest pipe between them and the out-to-out length along the roadway reference line is greater than 20 feet, the pipe installation shall be assigned a B-number by the Region. Coordination with the Bureau of Structures is required in these situations.

25.5 Abrasive or Corrosive Conditions

Metal thicknesses shown in the fill height tables are adequate for structural requirements only. Where corrosive and/or abrasive conditions exist, either greater thicknesses or protective coatings should be provided. For structural plate pipe, greater thicknesses may be specified for the plates in the invert.

LIST OF ATTACHMENTS

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" x 2/3" Corrugations
Attachment 25.3	Fill Height Tables: Corrugated Steel Pipe, 3in 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

[4] Class A, B, C and D Bedding Type has been superseded by Installation Types 1-4. At 90% compaction WisDOT's foundation and trench backfill specifications meets or exceeds a Type 2 installation and subsequently the past B or C bedding class. Future fill height tables will refer to the new installation type nomenclature.

	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)

FDM 13-1-30 Culvert Replacement and Analysis for Perpetuation & Rehabilitation Projects *August 16, 2022*

30.1 Background

As described in FDM 3-5-1, the Department's preservation focus in the asset management roadway delivery program is a practical design approach to system management that maintains acceptable serviceability using improvement strategies that optimizes to the best possible system-wide service at the lowest practicable cost. Central to the Department's practical design approach is to not degrade safety and operations when applying practical design standards to the roadway. While the practical design approach may seemingly only apply to the geometric elements of the roadway, drainage does have an impact on safety and operations and should be evaluated as well. This section describes practices to evaluate and replace or upgrade existing drainage systems on perpetuation and rehabilitation type projects. Similar to geometric elements of the project, under certain conditions the Department allows the application of practical design approaches to drainage systems. While it is best practice to perform hydrology and hydraulic (H&H) analysis for all drainage structures, this section describes criteria for when engineering judgement can be used in lower risk installations utilizing simplified procedures for the analysis of roadway culverts.

30.2 Applicability

The culvert selection practices of this section apply only to perpetuation and rehabilitation roadway segments. This section does not apply to:

- Modernization projects or sections of a project utilizing modernization standards.
- Spot improvements reconstructed for safety or otherwise [5]
- The analysis and sizing of storm sewer systems regardless of project type.
- Any improvements on Interstates, Expressways and Freeways (Non-Interstate Highways), Connecting Highways or the NHS system.

Standard H&H analysis and materials selection requirements, as described elsewhere in this Chapter, is required for all other culverts not meeting the conditions of this section.

30.3 Guidelines for Culvert Replacement on Perpetuation and Rehabilitation Projects

30.3.1 Evaluation and Identification

Drainage structures will typically remain intact with perpetuation and rehabilitation improvement projects. For these projects evaluate the existing drainage structures along the corridor to identify signs of failure, excessive erosion, or indications of undersizing or recurring flooding. Where local testimony or other evidence indicates a recurring flooding issue, a hydrology and hydraulics (H & H) analysis is required to determine if the structure is appropriately sized. Replacement of drainage structures may be included within a perpetuation or rehabilitation project if the existing drainage structure is determined to be nearing a failure threshold or demonstrated to cause recurring flooding.

Identifying the size, type, and condition of the culverts within the project limits should be performed early in the scoping process. Evaluating the condition of the culvert not only includes the physical condition of the structure itself but also looking for signs that the structure is not adequately sized. It is also recommended to engage WDNR during scoping if Aquatic Organism Passage could be a concern. AOP culvert sizing almost always will significantly increase the size of a culvert when compared to the existing. (see FDM 13-1-30.3.2.2 for additional

[5] Where spot improvements are made on a perpetuation or rehabilitation project due to safety or otherwise, the upgraded portion of the roadway shall include culverts and drainage features designed using WisDOT's standard hydrology and hydraulic (H&H) analysis and materials selection practices.

discussion on AOP coordination).

In most cases, Regional maintenance staff will identify the size, type and physical condition of the culverts within the project limits and identify culverts in need of replacement or repair. This assessment may be performed in cooperation with Bureau of Structures for large culverts (25 sf or >60 inches). When recommending culverts in need of replacement, consideration shall be given to if the remaining service life of the culvert meets or exceeds the pavement treatment surface life for the planned improvement. For example, if the culverts on an individual project appear to have 15 or more years of service life remaining it would be ill advised to replace functioning culverts if the proposed improvement type has a 10-year pavement treatment service life.

Once all the culverts in need of replacement due to physical condition are identified, the regional Stormwater and Erosion Control Engineer, or an engineering working under their direction, shall inspect and further evaluate the culverts, especially those under consideration for 'in-kind' replacement per FDM 13-1-30.3.2 to determine if there are concerns with the size of the existing culverts. Signs of an undersized culvert can include:

- Erosion/scour at the inlet and/or outlet
- Excessive sediment on the upstream side of the crossing
- Frequent accumulation of debris
- Increased depth of flow upstream and downstream of the culvert
- A significant increase in development (impervious area) within the culvert's drainage area
- Evidence of roadway overtopping such as downstream shoulder erosion or washouts
- Plunge pools, scour, culvert perching on the downstream side of the culvert.

Regional maintenance staff or local officials may also be aware of past issues related to flooding or erosion at a culvert site.

***Figure 3.1* Erosion Damage to Downstream Embankment Slopes from Previous Overtopping - Sources FHWA and Utah DOT**

***Figure 3.2* Scour Holes and Perched Culverts – Sources FHWA and WisDOT**

Figure 3.3 ***Stable and Unstable Channels Downstream of Culvert – Source FHWA and UDOT***

30.3.2 Simplified Culvert Sizing Evaluation

30.3.2.1 Background

As stated previously, while it is best practice to perform hydrology and hydraulic (H&H) analysis for all drainage structures, this section describes criteria for when engineering judgement can be used in lower risk installations utilizing simplified procedures for the analysis of roadway culverts. For perpetuation and rehabilitation roadway segments this involves "in kind" replacement of drainage structures under limited conditions.

30.3.2.2 Criteria for "In-Kind" Replacement

For a culvert to be eligible for "in kind" replacement on perpetuation and rehabilitation roadway segments, the following additional criteria apply:

- Pavement treatment service life < 18 years.
- No clear signs or evidence of undersizing have been observed or reported.
- The culvert is located in rural or undeveloped areas or otherwise outside municipal boundaries and outside populated areas (when in doubt see Attachment 30.1 for guidance).
- Not located in a TS4 Permitted Area. (TS4 areas are transportation facilities with MS4 areas defined by Wisconsin DNR https://dnr.wi.gov/topic/stormwater/data/Municipal/. Contact WisDOT's stormwater coordinator in the Bureau of Technical Services, Environmental Services Section when in doubt).
- ADT < 7,000.
- The fill height for the culvert does not exceed 15 feet.
- The proposed culvert slope meets or exceeds the slope of the existing culvert.
- The culvert is not extended more than 10% of its existing length.
- Culvert diameter ≤ 48 inches.
- The total open area of the culverts does not exceed 15 sf for multiple culverts in place at a single crossing.
- The project is not located in rolling terrain (primarily areas of southwest and central Wisconsin - see FDM Chapter 11 and Highway Capacity Manual, 7th Edition (Chapter 12, Section 3).
- No structures (buildings) are located immediately upstream and are at least 2 feet higher than the point of roadway overtopping.
- No valuable properties or unique resources are located immediately upstream.
- The culvert is not located in a floodplain, drainage district (FDM 5-15-1) or mapped perennial or intermittent stream. WDNR's surface water data viewer can assist in locating these resources (https://dnr.wi.gov/topic/surfacewater/swdv/).
- The Wisconsin Department of Natural Resources has not identified Aquatic Organism Passage Concerns (AOP) for the culvert in question. [Note: The Regional Environmental Coordinator and/or Storm Water and Erosion Control Engineer must agree with WDNR with the need for AOP consideration. A WDNR request for AOP consideration alone does not warrant upsizing structures without regional concurrence.]

Please note that a single culvert with the project limits not meeting these additional criteria does not exclude the remaining culverts from "in-kind" replacement.

30.3.2.3 Confirmation of "In-Kind" Replacement

To confirm field observations, or where evaluation of a culvert is otherwise inconclusive, the tables in Attachment 30.2 offer a check of culvert size for "replace in kind" structures. The tables trend towards being conservative and are intended for small watersheds typical to the maximum "replace in kind" culvert size described in this part. These tables shall not be used to size culverts requiring complete hydrology and hydraulic (H&H) analysis such as those on modernization projects or segments of a project using modernization standards (see FDM 13-1-30.2). In those cases, however, the tables can still be used as part of the QA/QC of the H&H drainage design.

The tables require the user to have a general idea of land cover, soil type, and watershed area. This does not have to be an extensive delineation and characterization of the watershed. Only the basic characteristics of the watershed are required. The tables assume a time of concentration based on the size of the watershed.

This check should also be only part of the evaluation of "in kind" replacement. The tables are not meant to dictate the need to increase or reduce the size of an existing culvert, they are intended as a check. Still, in the event the in-place culvert size and the tabulated size are substantially different, a full H&H analysis may be appropriate.

30.3.2.4 Determining Watershed Area

There are numerous methods and tools available to size and characterize a watershed. GIS tools (ArcGIS online), surface models in design software, digital topographic maps, and many other resources can be used to delineate a watershed. There are also online and software-based tools that can approximate a watershed boundary in a manner of minutes. The user should keep in mind the digital terrain employed by these tools may not be high resolution and/or up to date and results need to be scrutinized. This is especially the case in flat areas where low resolution terrain models may not depict breaks in drainage from roadways, small embankments or depressions, or other localized formations. Some available resources for delineating watersheds include:

- Civil 3D – WisDOT's standard design software, Civil 3D, includes tools for delineating the boundary of a watershed. Results will depend on the quality of the surface model created for the project. WisDOT maintains training videos for various design tasks including inserting aerial images, creating surface models and defining culvert 'catchments'. When in doubt it is good to compare results to USGS maps or similar contour maps to affirm the accuracy of the results.
- General Civil 3D Training:

  https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/civil3d/civil-train.aspx
- H&H in Civil 3D Training:

  https://c3dkb.dot.wi.gov/Content/c3d/hydro-dsn.htm
- USGS Streamstats - Some larger watersheds can be delineated using USGS's streamstats online tools. The user zooms in to the area of interest and the available stream data shows up as pixilated threads. https://streamstats.usgs.gov/ss/

In addition to these tools many counties have LIDAR generated contours available on their GIS sites. This may be the most accurate of the readily accessible public data. In most cases the user will have to delineate the boundary using online measurement tools and characterize the watershed using the aerial photography available on these sites.

30.4 Culvert Materials on Perpetuation and Rehabilitation Projects

Replacement of culverts "in-kind", as described in this chapter, does not require that the new culvert be the same material as the existing culvert. More cost effective or site appropriate materials may be available. For example, it would not make sense to replace a metal culvert that has corroded due to soil conditions with the same type of metal culvert. In this case a coated metal culvert, class III-A or III-B non-metal culvert, or concrete culvert of the same diameter may be more appropriate. In selection of a culvert material for "in-kind" culvert replacement projects the criteria of FDM 13-1-15 apply with exceptions shown in Table 30.1.

***Table 30.1** Culvert Materials for "In-Kind" Replacement on Perpetuation and Rehabilitation Projects*

Existing Material	Replacement Requirements
Corrugated Metal	- Metal, Concrete, Class III-A or III-B, or Class III-A or III-B Non-Metal in conformance with FDM 13-1-15 - Refer to FDM 13-1 Attachment 25.1 - 25.9 for allowable fill heights
Reinforced Concrete (1)	- Concrete or Class III-A or III-B Non-Metal in conformance with FDM 13-1-15 - Refer to FDM 13-1 Attachment 25.1 - 25.9 for allowable fill heights
Thermoplastic (1)	- Concrete or Class III-A or III-B Non-Metal in conformance with FDM 13-1-15 - Refer to FDM 13-1 Attachment 25.1 - 25.9 for allowable fill heights

Note:

1. Reinforced concrete and thermoplastic culvert pipes shall not be replaced 'in-kind' with corrugated metal pipe due to significant differences in manning's roughness.

30.5 Culvert Extensions, Endwalls and Traversable Grates on Perpetuation and Rehabilitation Projects

30.5.1 Culvert Extensions, and Traversable Grates on Perpetuation and Rehabilitation Projects

Lengthening proposed culvert replacements, extending existing culverts beyond the clear zone, or adding traversable grates to replacement or existing culverts (Apron Endwalls for Culvert Pipe Sloped Cross Drains or Apron Endwalls for Culvert Pipe Sloped Side Drains) are not required for Perpetuation and Rehabilitation projects where S-1 standards are applied.

For Rehabilitation projects subject to S-2 standards, or areas of a project employing S-2 standards, consider lengthening replacement culverts or extending existing culverts beyond the clear zone. Remove/remedy adjacent hazardous drainage features identified in the roadside hazard evaluation or analysis process (RHA). Consideration shall be given to areas with identified crash history or areas subject to high "run off the road" crashes such as the outside of sharp horizontal curves. Examples of additional locations with high "run off the road" crashes can be found in FDM 11-45-20.4.2. Note that culvert replacements with improvement projects may be predicated on existing structural, hydraulic capacity or maintenance issues and not on exclusively on existing roadside hazardous conditions.

Some limiting factors for lengthening culverts within S-2 areas could include need for right of way acquisition, environmental concerns (wetlands, floodplains, endangered or threatened species) or cost justifications that consider maintenance and crash cost. In evaluating factors limiting extensions also consider future plans for upgrading the facility. There may be a benefit to lengthening structures to more easily accommodate future improvements.

Where culverts within S-2 areas cannot be extended due to limiting factors consider installing traversable grates. Some limiting factors for traversable grates may include where increased headwater or potential for debris accumulation threaten adjacent properties, environmental concerns (wetlands, floodplains, endangered or threatened species) or cost justifications that consider maintenance and crash cost.

Refer to FDM 11-38 for details on the Safety Certification Process (SCP) and to FDM 11-45-20 for further guidance on the RHA process. For all improvement projects, document final decisions and outcomes with roadside hazard evaluations and treatments Design Study Report (DSR) especially those not identified in the initial Safety and Operations Certification Document (SOCD).

30.5.2 Endwalls on Perpetuation and Rehabilitation Projects

Culverts replaced on Perpetuation and Rehabilitation projects shall have standard endwalls installed even when endwalls are not in place on the existing culvert. Where an existing culvert does not have an end wall and is not scoped for replacement, there is no requirement to install endwalls on the existing pipe.

30.99 Resources

The following is a brief list of useful resources for learning more about evaluating culverts.

Assessment:

FHWA. (2010). Culvert Assessment and Decision-Making Procedures Manual. Lakewood, CO.

FHWA (2014). Hydraulic Toolbox Version 4.2. [Offers hydraulic tools including a culvert assessment tool based on the 2010 Culvert Assessment and Decision-Making Procedures Manual.]

Design:

Federal Highway Administration. Culvert hydraulic analysis program and supporting documentation, HY-8, Version 7.5. 2016.

Federal Highway Administration. Hydraulic Design of Highway Culverts Hydraulic Design Series Number 5 (HDS 5) Third Edition, FHWA-HIF-12-026. 2012.

FHWA (2014). Hydraulic Toolbox Version 4.2. [Offers hydraulic tools including a culvert assessment tool based on the 2010 Culvert Assessment and Decision-Making Procedures Manual.]

LIST OF ATTACHMENTS

Attachment 30.1 Guidelines for Defining a Rural Area

Attachment 30.2 Culvert Sizing Quick Check