River Restoration Toolbox
Practice Guide 9

Culvert Adjustment

Iowa Department of Natural Resources

April, 2018

Table of Contents

LIST OF PHOTOGRAPHS

Executive Summary

Culverts designed and constructed in an ecological manner provide floodwater conveyance while maintaining transport of sediment, ecological connectivity, and fish passage. A properly designed culvert can reduce maintenance, prevent erosion, which in turn results in cost savings over time. The following techniques are detailed in this report:

1. Bridge Spans / Bottomless Culverts
2. Buried Culverts
3. Floodplain Bypass Culverts
4. Stream Daylighting

The *River Restoration Toolbox Practice Guide 9: Culvert Adjustment* (Practice Guide) has been developed to assist with the presentation of design and construction information for stream restoration in Iowa. It is intended to provide guidance to:

- Those responsible for reviewing and implementing stream restoration,
- Engineers responsible for the design of stream restoration projects,
- Others involved in stream restoration at various levels who may find the information useful as a technical reference to define and illustrate culvert adjustment techniques.

The Practice Guide includes a written assessment of the culvert adjustment practice and describes a variety of culvert adjustment techniques. Each technique includes design guidelines, a specifications list, photographs, and, when applicable, drawings.

The information in the Practice Guide is intended to inform practitioners and others, and define typical information required by the State of Iowa to be included with the use of floodplain restoration techniques. The information and drawings are not meant to represent a standard design method for any type of technique and shall not be used as such. The Practice Guide neither replaces the need for site-specific engineering and/or landscape designs, nor precludes the use of information not included herein.

The Practice Guide may be updated and revised to reflect up-to-date engineering, science, and other information applicable to Iowa streams and rivers.

1.0 INTRODUCTION

Culverts have long been used as a means of passing stream flows under roads and other infrastructure. In the past, the engineering approach to crossing small streams considered only the hydraulic capacity of the culvert to handle flood events. Until recently there has been minimal consideration for the impact on the ecological function of the stream when designing stream crossings. The result has been culverts which impact stream functions upstream and downstream of the culvert.

Traditional culvert crossings interrupt healthy stream functions (carrying water and sediment) by affecting the channel shape, slope and bottom material. The evidence of these interruptions can be seen at culvert outlets and inlets. The culvert outlet often has erosion and scour due to high velocity flows exiting the culvert. The culvert inlets can accumulate sediment when culverts are over-wide and accumulate debris when multiple small openings are used. Standard culvert shapes (i.e. circle, rectangle, etc.) are effective for carrying floodwater but fail to transport sediment. Culverts can have negative impacts on a stream system when they are over-sized and when they are under-sized.

A proper width/depth ratio allows a stream system to sustainably carry floodwater and sediment. Multiple design concepts have been developed to provide a proper width/depth ratio through culvert crossings including bottomless culverts and buried culverts. Many designers have decided to remove existing culverts altogether by using bridge spans or providing alternative crossings. Stream systems with healthy water and sediment transport provide flood conveyance, water quality, and habitat for plants and wildlife. These streams will also resist erosion, manage debris, and provide recreation opportunities for a variety of users.

The guidelines and specifications provided in this document are general and not a comprehensive design manual. It is the responsibility of the designer to understand the design approach and the feasibility of using culvert adjustment techniques on a case-by-case basis. The following criteria in no way replaces design discretion, experience, and training, and cannot incorporate every scenario. They are intended to flag common errors, promote empirically stable design ranges, assist designers and reviewers in communication, and adapt tested designs to Iowa conditions.

2.0 CULVERT ADJUSTMENT TECHNIQUES

2.1 BRIDGE SPAN / BOTTOMLESS CULVERT

2.1.1 Narrative Description

Bridge spans or bottomless culverts provide ecological and floodwater conveyance benefits for streams at stream crossings. Often, existing culverts are oversized relative to the bankfull discharge, resulting in an over-wide section of stream at the location of the culvert. This is the case when double and triple-barrel culverts are used. In some cases, the stream may be constricted at the crossing resulting in higher velocities in the culvert and the adjacent portion of stream. The higher velocities create scour at the outlet of the culvert and make it difficult for fish species attempting to swim upstream inside the culvert.

Properly designed bridge spans or bottomless culverts allow for streams to maintain their natural bed material and bankfull channel shape through the crossing. They promote channel bed stability, allow for aquatic species passage, and maintain in-stream and floodplain habitats. The bankfull channel provides the appropriate width/depth ratio for the stream to carry water and sediment. The floodplain above the bankfull channel helps to pass debris and provide lower velocities during high flow events. The reduced velocities minimize scour and erosion forces at the outlet of the culvert and also allow fish to migrate upstream and downstream easily through the crossing.

A bridge span or bottomless culvert should be considered at new crossings and existing crossings where a culvert needs to be replaced and where site conditions allow the feasibility of the concept. The bridge span or bottomless culvert should be designed by a professional engineer or person meeting the qualifications required by the governing jurisdiction. The crossing should be designed to handle the peak flow required by the governing jurisdiction. Additional considerations for culvert replacements include buried culverts (See Section 2.2) and new culvert with floodplain culverts (See Section 2.3).

2.1.2 Technique Information

- **Use:** Bridge spans or bottomless culverts allow for long term dynamic channel stability, maintain stream integrity and natural channel characteristics, and preserve ecological connectivity. (Mendocino Co CA Chapter 4, pg 59)

- **Other uses:** Bridge spans or bottomless culverts allow streams to maintain a proper width/depth ratio, which is essential for healthy sediment transport through the culvert. They can prevent erosion by allowing for high flows to pass through the crossing without increasing flow velocities. Bridge spans or bottomless culverts also require less maintenance by allowing debris to pass through the crossing for more flood events.

- **Best applications:**

    - New stream crossings
    - Existing culverts with downstream erosion from constricted flow and high velocities
    - Existing culverts with perched outlets from unstable stream bed due to headcuts or improper culvert sizing
    - Existing culverts that are wider than the existing stream channel due to oversizing the culvert
    - Existing culverts with a need for frequent cleaning of debris at the culvert inlet
    - Existing culverts with condition or hydraulic capacity deficiencies

- **Variations:**

    - Replace culvert with bottomless culvert.
    - Add floodplain bypass culverts to convey flood events and reduce high flow velocities at the stream channel culvert. See Section 2.3.
    - Can be designed to allow for the passage of wildlife under roadways to reduce wildlife-related vehicle collisions and reduce the effect of habitat fragmentation due to roadways (Bissonette et al., 2008).

- **Computations:** The proposed bridge span or bottomless culvert should be sized to allow the bankfull channel to be formed within the span or culvert. The span or culvert must be deigned to meet appropriate design guidelines by governing bodies (i.e. Iowa DOT, etc.)

- **Key Features:**

- Bridge spans or bottomless culverts provide sufficient cross sectional area for the stream to convey high flow events through the culvert without significantly changing the velocity and sediment carrying capacity of the stream from the upstream and downstream stream sections.
- Natural channel bottom thru the crossing provides habitat for aquatic species.
- Bridge spans or bottomless culverts allow debris to pass through culvert during small and frequent flood events without requiring maintenance.

2.1.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for bridge spans or bottomless culverts. The data table includes design guidelines and sources, where applicable.

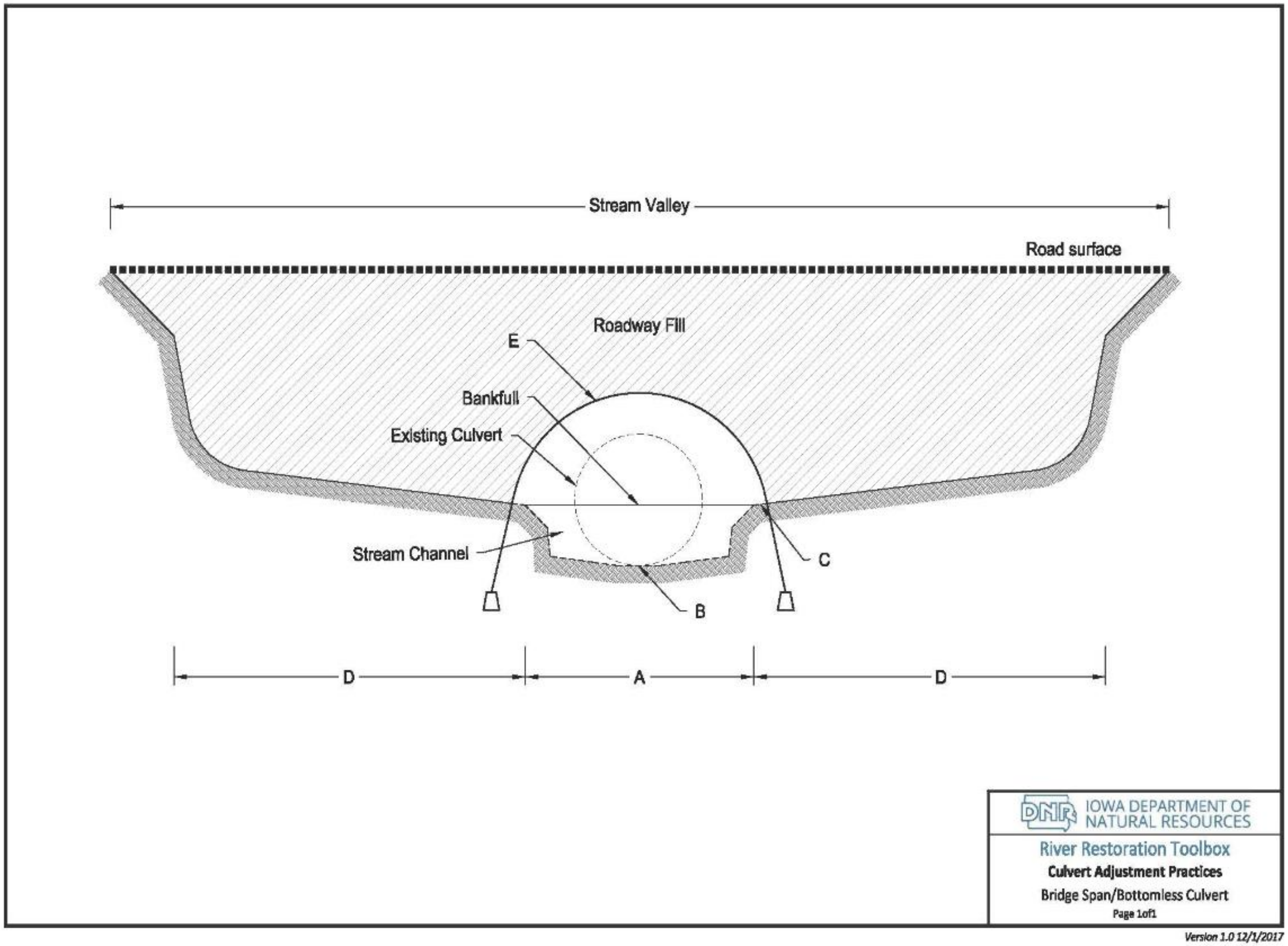
Table 1. Required Design Data for Bridge Spans / Bottomless Culverts

Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
A	Bankfull Width	Feet	Measured at site using surveying techniques or determined based on regional curves	The channel width at bankfull stage, where discharge has filled the channel to the top of its banks and water begins to overflow onto a floodplain
B	Channel Thalweg Elevation / Culvert Inlet Elevation	Feet (NAVD)	Existing thalweg elevation measured in the field or designed based on natural channel guidance	Lowest elevation within the cross section of the stream at a given station along the river
C	Bankfull / Floodplain Elevation	Feet (NAVD)	Measured at site using surveying techniques or determined based on regional curves	Maximum water level before floodwater rises above the bankfull channel and begins to overflow onto a floodplain
D	Bankfull Bench / Floodplain Width	Feet	Bench width should be greater than or equal to the bankfull width	Width of the bankfull bench/floodplain
E	Bridge Span / Bottomless Culvert	N/A	Sized based on guidelines specified in computations section	The culvert located at the stream channel

Notes:

1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.
3. NAVD-North American Vertical Datum or other, as appropriate.

Drawing 1. Bridge Span / Bottomless Culvert



2.1.4 Specifications

In addition to the information presented in Section 1.0 Introduction, the following information should be developed into specifications to accompany the use of bridge spans or bottomless culverts when replacing existing culverts:

- Materials:
  - Culvert material should comply with local requirements and meet design standards.
  - Embankment fill material should meet local standards.
- Equipment/Tools:
  - Machinery to excavate and install culverts
- Sequence:
  - Remove existing culvert and dispose of material according to project documents (if necessary)
  - Install bridge span or bottomless culvert.
  - Install scour protection, if necessary.
  - Construct stream crossing embankment (for road or other infrastructure).
  - Seed and/or plant appropriate vegetation.
  - Protect slopes with temporary erosion control measures.
- Workmanship:
  - The finished alignment and elevations of the bridge span or bottomless culvert should be within the tolerance specified by plan documents, including the lines, grades, cross sections and elevations of the design.
- Maintenance: During and immediately after construction, the project area will be vulnerable to erosion. Establishing vegetation or other cover material as soon as possible will help reduce erosion.

2.1.5 Photographs

Photo 1. Example 1 – Inga Creek, perched culvert, existing conditions. Source: Marty Rye, Superior National Forest.

Photo 2. Example 1 – Inga Creek, bottomless culvert, post construction. Source: Marty Rye, Superior National Forest.

Photo 3. Example 2 – Mark Creek, perched culvert, existing conditions. Source: Marty Rye, Superior National Forest.

Photo 4. Example 2 – Mark Creek, bottomless culvert, post construction. Source: Marty Rye, Superior National Forest.

Photo 5. Example 3 – Tait River, culvert, 12' span, existing conditions. Source: Marty Rye, Superior National Forest.

Photo 6. Example 3 – Tait River, bridge, 24' span, post construction. Source: Marty Rye, Superior National Forest.

2.2 BURIED CULVERTS

2.2.1 Narrative Description

Buried culverts mimic natural streams by incorporating a natural streambed within the culvert bottom. They promote channel bed stability, allow for aquatic species passage, and maintain in-stream and floodplain habitats. A buried culvert has a natural channel bed and is designed to accommodate bankfull flow without restriction.

Traditional culverts have been designed to convey a specific flood event. They have also been designed to have a minimum cleaning velocity for low flow periods of time. A cleaning velocity is the minimum velocity required in the culvert to wash away sediment and debris that could collect in the culvert bottom. The idea was that the entire culvert cross sectional area be available for floodwater conveyance. Culverts designed with a minimum cleaning velocity constrict the flow of the stream and increase velocities. Increased velocities create increased erosion potential downstream of the culvert and also impede passage of native aquatic organisms.

A buried culvert is an oversized culvert with a natural channel bottom constructed within the culvert. A buried culvert is set below the active channel elevation of the stream. The stream channel functions the same way within the culvert as it does upstream or downstream of the culvert up to the bankfull flow at minimum. This approach reduces erosion concerns at the culvert outlet because the flow velocities are similar to the flow velocities in the upstream and downstream portions of the stream.

Design considerations include bankfull elevations, ecological connectivity, safety, and economics. Design methods for buried culverts are described in Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings, USDA Forest Service, 2008.

Buried culverts should be considered at new crossings and existing crossings where a culvert needs to be replaced and where site conditions allow the feasibility of the concept. Buried culverts should be designed by a professional engineer or person meeting the qualifications required by the governing jurisdiction. The culvert should be designed to handle the peak flow required by the governing jurisdiction. Additional considerations for buried culverts include the use of floodplain bypass culverts (See Section 2.3).

2.2.2 Technique Information

- **Use:** Buried culverts provide a proper width/depth ratio for the bankfull channel resulting in channel bed stability.

- **Other uses:** Buried culverts provide aquatic species passage and maintain in-stream and floodplain habitats, while reducing scour at culvert entrances and outfalls. They typically require less maintenance by allowing debris to pass through the crossing for during flood events.

- **Best applications:**

    - Proposed stream crossings where a stable stream system exists.

    - Replacing existing culverts that have condition or hydraulic capacity deficiencies.

    - Replacing existing stream crossings that are barriers for fish passage.

- **Variations:**

    - Buried culverts can either be box culverts or round pipes with stream bed material placed within the culvert.

    - Bottomless culverts can be used in place of buried culverts. See Section 2.1.

    - Add floodplain bypass culverts to convey flood events and reduce high flow velocities at the stream channel culvert. See Section 2.3.

    - Can be designed to allow for the passage of wildlife under roadways to reduce wildlife-related vehicle collisions and reduce the effect of habitat fragmentation due to roadways (Bissonette et al., 2008).

- **Computations:** The culvert should be sized so that the bankfull channel can be formed within the culvert. Scour potential calculations should be performed to determine the depth of material needed for the bed of the stream within the culvert. Check the culvert capacity at high flow events to ensure that the pipe will not become pressurized. Additional floodplain width (bankfull bench width) can be included within the culvert or floodplain culverts can be considered (See Section 2.3). The culvert must be deigned to meet appropriate design guidelines by governing bodies (i.e. Iowa DOT, etc.)

- **Key Features:**

    - Buried culverts provide a natural channel bottom within the culvert.

- Buried culverts provide ecological connectivity and maintain in-stream and floodplain habitats.
- Buried culverts provide channel bed stability.

2.2.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for buried culverts. The data table includes design guidelines and sources, where applicable.

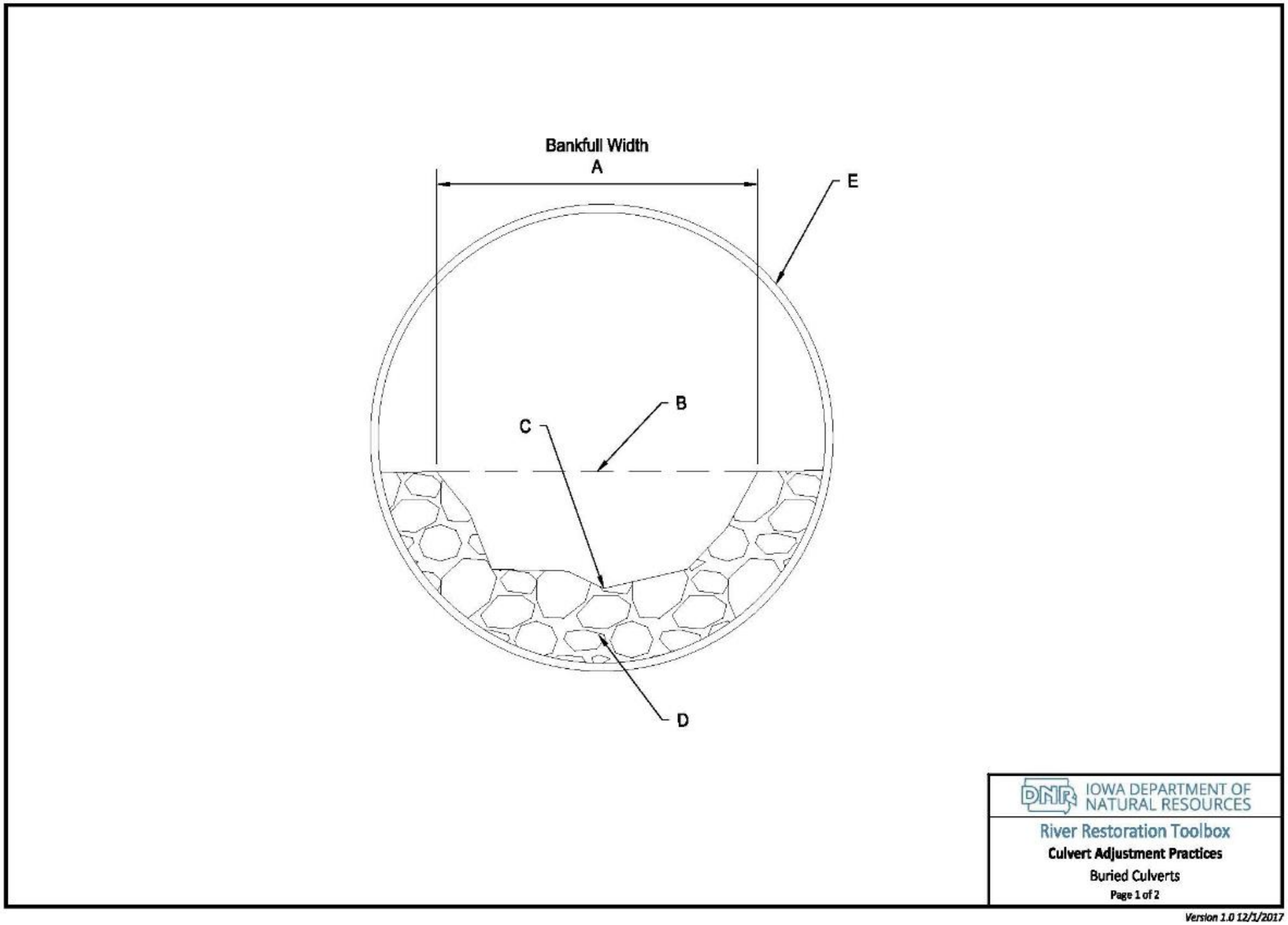
Table 2. Required Design Data for Buried Culverts

Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
A	Bankfull Width	Feet	Measured at site using surveying techniques or determined based on regional curves	The channel width at bankfull stage, where discharge has filled the channel to the top of its banks and water begins to overflow onto a floodplain.
B	Bankfull Elevation	Feet (NAVD)	Measured at site using surveying techniques or determined based on regional curves	Maximum water level before floodwater rises above the bankfull channel and begins to overflow onto a floodplain.
C	Channel Thalweg Elevation	Feet (NAVD)	Existing thalweg elevation measured in the field or designed based on natural channel guidance	Lowest elevation within the cross section of the stream at a given station along the river.
D	Channel Bed Material Sizing	Feet	Use scour analysis calculations to determine material sizing and thickness	Gradation of material to be used for channel bottom.
E	Culvert	N/A	Sized based on guidelines specified in computations section	Culvert located at crossing.

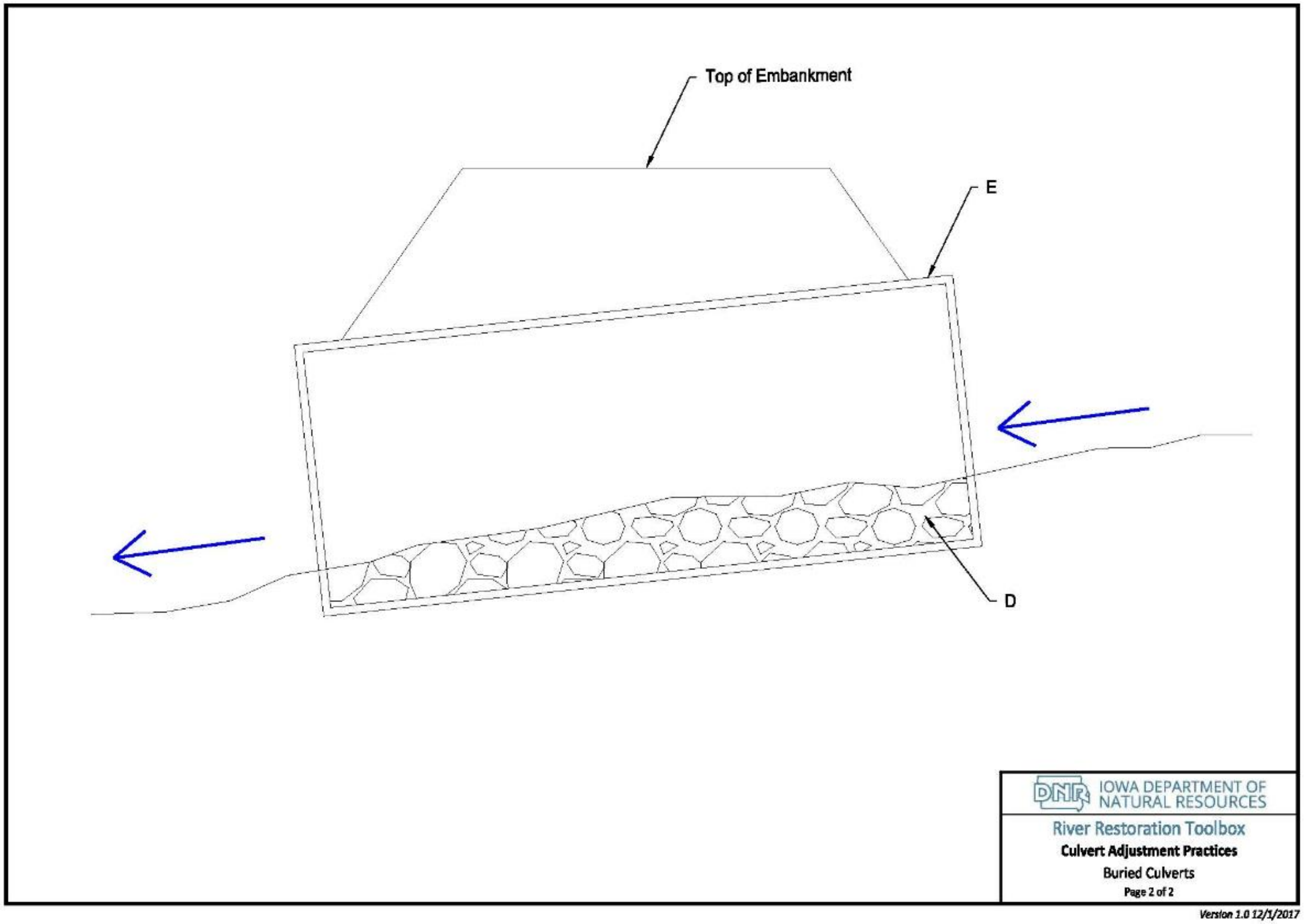
Notes:

1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.
3. NAVD-North American Vertical Datum or other, as appropriate.

Drawing 2. Buried Culvert – Cross Section



Drawing 3. Buried Culvert – Profile View



2.2.4 Specifications

In addition to the information presented in Section 1.0 Introduction, the following information should be developed into specifications to accompany the use of buried culverts:

- Materials:
  - Culvert material should comply with local requirements and meet design standards.
  - Embankment fill material should meet local standards.
  - Stream bedding material. Bed should be well compacted (vibratory compaction recommended).
- Equipment/Tools:
  - Machinery to excavate and install culverts
- Sequence:
  - Place culvert per design elevations.
  - Place stream bed material and compact.
  - Install scour protection, if necessary.
  - Seed and/or plant appropriate vegetation in vicinity of culvert.
  - Protect slopes with temporary erosion control measures.
- Workmanship:
  - The culvert and stream bed material should be within the tolerance specified by plan documents, including the lines, grades, cross sections and elevations of the design.
- Maintenance: During and immediately after construction, road banks are vulnerable to erosion. Establishing vegetation or other cover material as soon as possible will help reduce erosion.

2.2.5 Photographs

Photo 7. Buried culvert. Source: Doug Peterson/USFWS

Photo 8. Buried culvert. Source: Maine Watch, PBS

Photo 9. Buried aluminum box culvert. Source: Ozaukee Co, WI

Photo 10. Buried aluminum circular culvert. Source: Ozaukee Co, WI

Photo 11. Buried concrete box culvert. Source: Ozaukee Co, WI

2.3 FLOODPLAIN BYPASS CULVERTS

2.3.1 Narrative Description

Floodplain culverts provide floodwater conveyance within the floodplain. Allowing floodwater to stay in the floodplain helps streams remain self-sufficient and maintain their width/depth ratio at bankfull stage. A floodplain culvert is a culvert located in the floodplain of a stream crossing designed with the intent to pass floodwater from the floodplain during high flow events.

When streams are constricted or over-wide at culverts, the sediment transport function of the stream is altered. Higher velocities within the stream channel culvert create scour, especially near the culvert outlet. Floodplain bypass culverts reduce constriction at one location and connect the upstream and downstream floodplains with multiple culvert openings. The result is a stream channel and floodplain that both function efficiently and sustainably in terms of carrying floodwater and sediment. The floodplain culvert concept still provides flood conveyance via the combination of the stream culvert and the floodplain culverts.

The appropriately sized stream channel culvert (See Sections 2.1 and 2.2) should be designed to convey the bankfull flow. The stream channel culvert should be located within the bankfull dimensions of the stream. The floodplain culverts should be designed to convey flood flows that overtop the stream banks and run out onto the floodplain. Floodplain culverts should be located within the floodplain and constructed with the inlet set at the floodplain elevation.

Floodplain culverts should be considered at new crossings and existing crossings where a culvert needs to be replaced and where site conditions allow the feasibility of the concept. Floodplain culverts should be designed by a professional engineer or person meeting the qualifications required by the governing jurisdiction. The floodplain culvert(s), combined with the stream channel culvert, should be designed to handle the peak flow required by the governing jurisdiction. Additional considerations for culvert replacements include bridge spans or bottomless culverts (See Section 2.1)

2.3.2 Technique Information

- **Use:** Floodplain culverts provide floodwater conveyance within the floodplain.

- **Other uses:** Floodplain culverts allow streams to more effectively access the floodplain near road crossings and other common restrictions. They help streams to maintain the proper width/depth ratio and effectively transport sediment.

- **Best applications:**

    - Stream crossings with a wide and accessible floodplain

    - Shallow crossings where cover over the channel culvert is minimal

    - Replacing existing culverts with condition or hydraulic capacity deficiencies

- **Variations:**

    - Stream channel culvert should be sized to handle the bankfull flow at a minimum. See Section 2.1 and 2.2.

    - Provide outlet protection at the floodplain culverts.

    - Floodplain culvert inlet elevations should be set above the bankfull elevation and located within the floodplain.

    - Can be designed to allow for the passage of wildlife under roadways to reduce wildlife-related vehicle collisions and reduce the effect of habitat fragmentation due to roadways (Bissonette et al., 2008).

- **Computations:** The steps below assume that the stream channel is functioning in a healthy manner. The designer should know how to identify the characteristics of the bankfull channel. Hydraulic modeling tools, such as HEC-RAS, should be used to confirm that the combination of floodplain culverts and stream channel culvert will meet governing flood conveyance requirements.

    - Determine required cross sectional area based on standards of governing jurisdiction.

    - Stream channel culvert should be sized to handle the bankfull flow at a minimum. Remaining required cross sectional area should be achieved by floodplain culverts spaced evenly across the floodplain.

- o Stream channel culvert flowline elevation should be designed based on the stream channel thalweg elevation (See Section 2.2). Floodplain culvert flowline elevations should be set at the bankfull elevation.

- o Hydraulics modeling may be necessary to justify that combination of culverts can convey the required design flood event.

Key Features:

- o Floodplain culverts provide floodwater conveyance within the floodplain.

- o Outlet protection at all culverts prevents scour.

2.3.3 Detail Drawings and Data Table

The following drawing depicts information that should be included in construction plans for floodplain bypass culverts. The data table includes design guidelines and sources, where applicable.

Table 3. Required Design Data for Floodplain Bypass Culverts

Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
A	Bankfull Width	Feet	Measured at site using surveying techniques or determined based on regional curves	The channel width at bankfull stage, where discharge has filled the channel to the top of its banks and water begins to overflow onto a floodplain
B	Channel Thalweg Elevation / Culvert Inlet Elevation	Feet (NAVD)	Existing thalweg elevation measured in the field or designed based on natural channel guidance	Lowest elevation within the cross section of the stream at a given station along the river
C	Bankfull / Floodplain Elevation	Feet (NAVD)	Measured at site using surveying techniques or determined based on regional curves	Maximum water level before floodwater rises above the bankfull channel and begins to overflow onto a floodplain
D	Bankfull Bench / Floodplain Width	Feet	Bench width should be greater than or equal to the bankfull width	Width of the bankfull bench/floodplain
E	Stream Channel Culvert	N/A	Sized based on guidelines specified in computations section	The culvert located at the stream channel

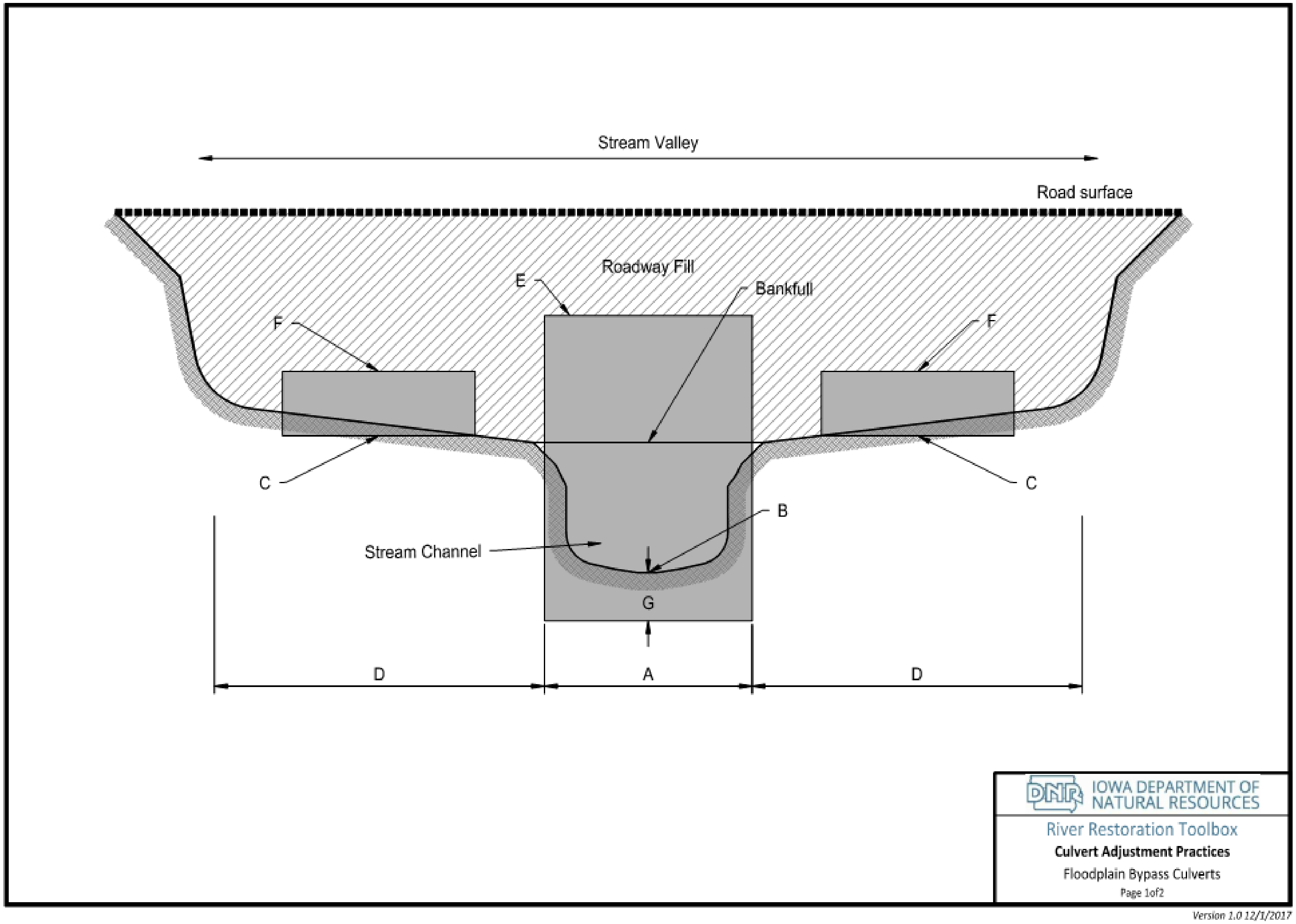
Table 3. Required Design Data for Floodplain Bypass Culverts

Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
F	Floodplain Culvert	N/A	Sized based on guidelines specified in computations section	The culvert(s) located within the floodplain
G	Bed Material Depth	Feet	Determined based on velocity, sediment transport, and conveyance calculations	Depth Main Culvert is Buried in the Stream Bed

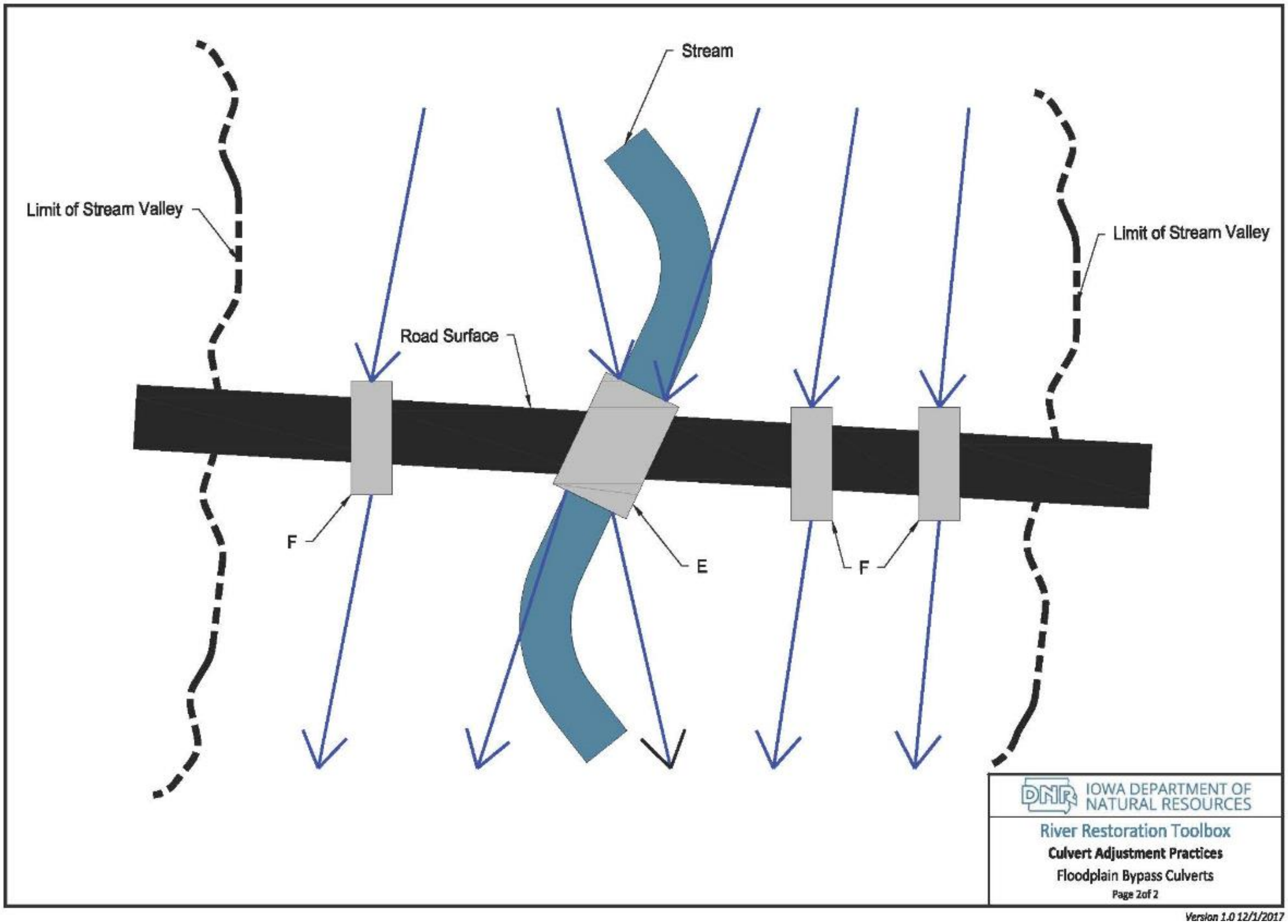
Notes:

1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.
3. NAVD-North American Vertical Datum or other, as appropriate.

Drawing 4. Floodplain Bypass Culverts – Cross Section



Drawing 5. Floodplain Bypass Culverts – Plan View



2.3.4 Specifications

In addition to the information presented in Section 1.0 Introduction, the following information should be developed into specifications to accompany the use of floodplain culverts:

- Materials:
  - Culvert material should comply with local requirements and meet design standards.
  - Embankment fill material should meet local standards.
- Equipment/Tools:
  - Machinery to excavate and install culverts
- Sequence:
  - Install stream channel culvert.
  - Construct stream crossing berm (for road or other infrastructure)
  - Install floodplain culverts.
  - Install scour protection.
  - Seed and/or plant appropriate vegetation in vicinity of culverts.
  - Protect slopes with temporary erosion control measures.
- Workmanship:
  - Culvert flow lines should be within the tolerance specified by plan documents, including the lines, grades, cross sections and elevations of the design.
- Maintenance: During and immediately after construction, the project area will be vulnerable to erosion. Establishing vegetation or other cover material as soon as possible will help reduce erosion. Maintenance will be needed to clear debris at the entrances of the culverts.

2.3.5 Photographs

Photo 12. Fishpot Creek Tributary, St. Louis Co, MO. Source: Steve Gough

Photo 13. 3-culvert design with varying elevations. Maryland. Source: Delaware River Basin Commission.

Photo 14. Floodplain culvert on Lamothe Hollow Creek in Spruce, WV. Source: Canaan Valley Institute

2.4 STREAM DAYLIGHTING

2.4.1 Narrative Description

Stream daylighting provides streams with a restored channel and floodplain. Stream daylighting includes removing buried culverts or storm sewers and exposing the streams that run through them to a natural stream channel and floodplain. This technique has been used primarily in urban areas and requires removing pavement, removing the culvert, and constructing a new stream channel. In many urban areas the answer to rainfall runoff has been to increase storm sewer sizing and quantity. The short term advantage to storm sewer is more area available for development. However, as flooding and flood damage costs have accumulated over the years, many municipalities and agencies have begun to rethink their approach to flooding. They have started to look at the idea of giving up some land available for development and daylighting the storm sewer system into a natural stream. The approach has resulted in less frequent flooding of surrounding properties, a natural corridor of green space within the city, water quality benefits, and less maintenance of the stormwater system.

The investment in stream daylighting can be cost effective when compared to repairing or replacing damaged or failing culverts. Long term cost savings includes reduced flood damage and maintenance costs associated with the culverts. Water quality improvements are achieved by reconnecting the daylighted stream to a natural stream bed, vegetated stream banks, and floodplain. The ecological benefits of stream daylighting are numerous, including restoring habitat for fish, birds, and other wildlife.

Stream restoration practices described (See Practice Guide 5 – Geomorphic Channel Design) should be utilized to develop the restoration design following stream daylighting. Stream daylighting should be considered in areas where existing culverts and storm sewers experience frequent flooding, are in disrepair, and where site conditions allow the feasibility of the concept (i.e. property can be acquired to construct a stream channel, etc.). Stream daylighting should be designed by a professional engineer or person meeting the qualifications required by the governing jurisdiction. Design of the stream daylighting should meet all permitting requirements required by the governing jurisdiction. Flood modelling software may be required to demonstrate feasibility and likelihood of success for the project.

2.4.2 Technique Information

- **Use:** Stream daylighting provides a natural stream channel and floodplain to existing streams conveyed by a culvert.

- **Other uses:** Stream daylighting reduces flooding impacts and maintenance costs and often provides water quality and recreational benefits.

- **Best applications:**

    - Existing culverts that are undersized and flood frequently

    - Existing culverts that require frequent maintenance and are in disrepair

    - Existing culverts that are located in areas where property can be acquired to construct a natural stream channel

- **Variations:**

    - Stream daylighting can be done in combination with the culvert adjustment techniques described in this guide for street crossings along the existing culvert. See Section 2.1 – 2.3.

- **Computations:** The restored stream following stream daylightin stream should be designed based on Practice Guide 5 – Geomorphic Channel Design. The key features of the stream are the bankfull channel, floodplain, channel slope, and channel bed material.

- **Key Features:**

    - Daylighted stream provides natural channel with floodplain.

2.4.3 Photographs

Photo 15. Lower Bee Branch pre-construction. Source: City of Dubuque

Photo 16. Lower Bee Branch post construction. Source: City of Dubuque

Photo 17. Saw Mill River daylighting project during construction. Source: Younkers, NY

Photo 18. Saw Mill River daylighting project post construction. Source: Nathan Kensinger, Curbed New York

Photo 19. Fairmeadows Park pre-construction. Source: LT Leon Associates

Photo 20. Fairmeadows Park post construction. Source: LT Leon Associates

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