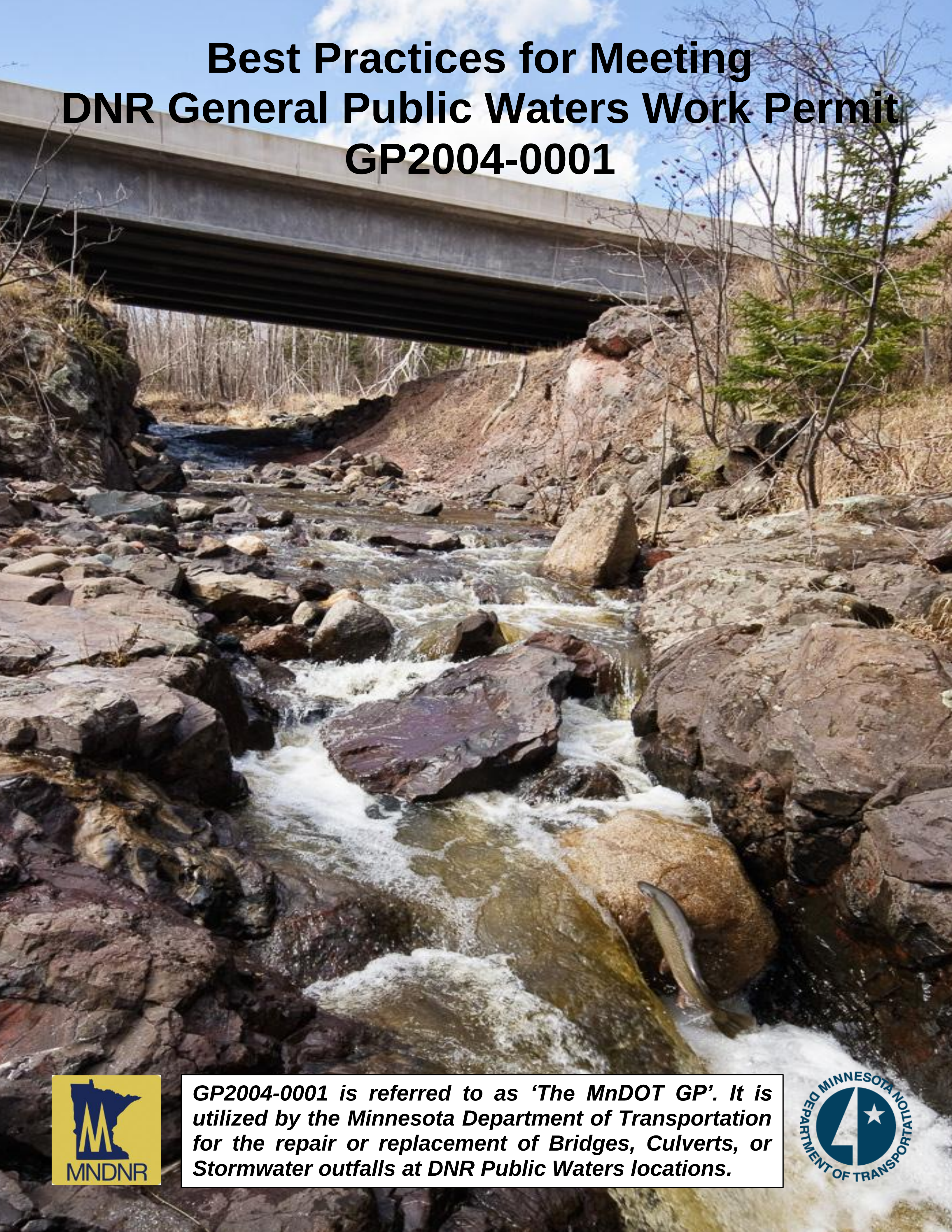
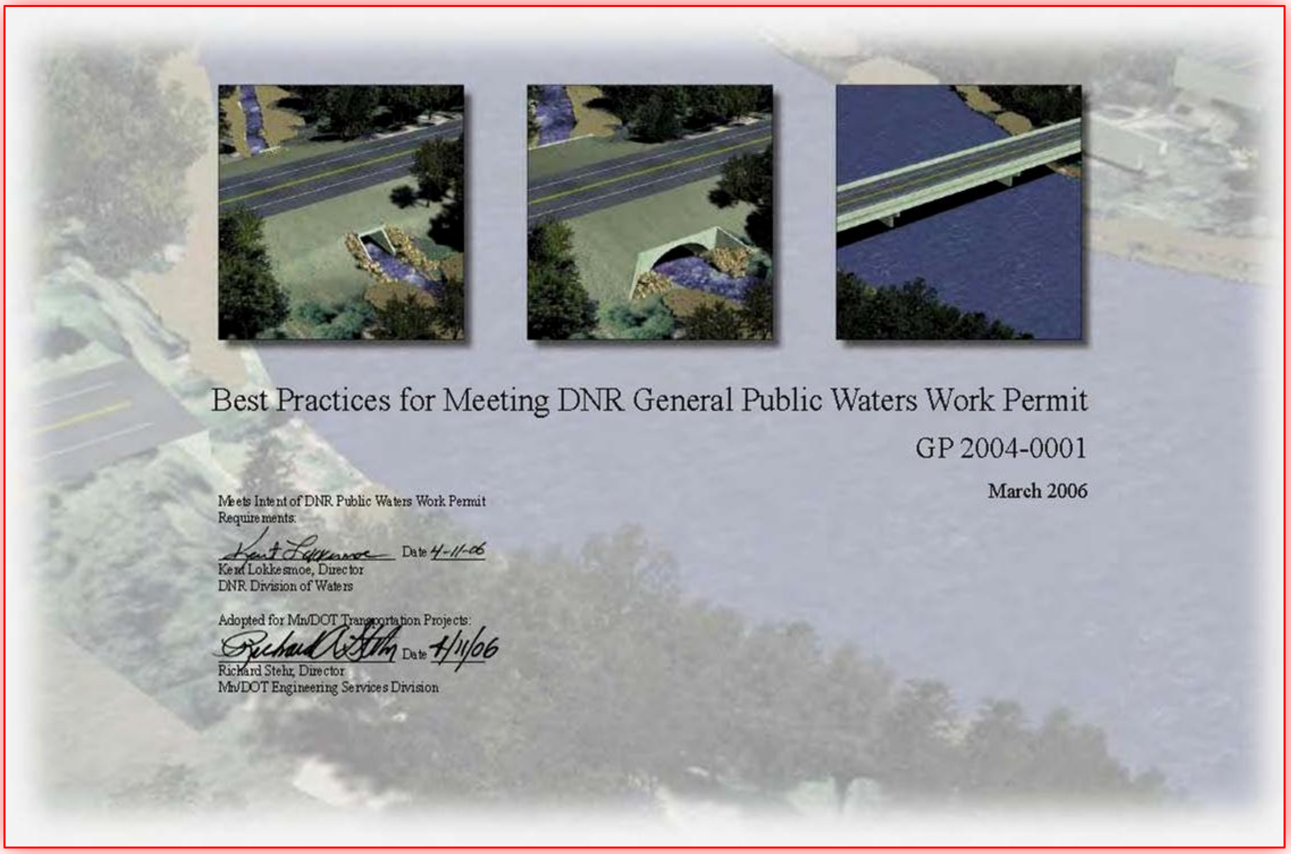
Best Practices for Meeting DNR General Public Waters Work Permit GP2004-0001



MNDNR

GP2004-0001 is referred to as 'The MnDOT GP'. It is utilized by the Minnesota Department of Transportation for the repair or replacement of Bridges, Culverts, or Stormwater outfalls at DNR Public Waters locations.

MINNESOTA DEPARTMENT OF TRANSPORTATION



October 2014

This 4th version replaces all previous versions.

1st Version: dated March 2006.
2nd Version: dated September 2010
3rd Version: dated May 2011

This collection of Best Practices includes revisions to previous versions, plus includes additional ecological protection measures associated within the regulatory framework of the DNR. Practices in this document are to be considered as recommendations for addressing GP2004-0001 permit conditions, as well as many DNR ecological protection regulations. These may be utilized as is or modified for a specific project. The practices in this collection are not the only way to meet DNR requirements, though are presented as 'Best Practices' for meeting the various conditions of GP2004-0001, thus reducing the time and cost of developing customized plans for every project.

All pages (unless noted as such) may be utilized for guidance in design and construction.

Changes to this document may occur at any time. Please check for the most recent version at:

www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_manual.html

This document is a collection of ‘Best Practices’ that provide guidance on meeting DNR regulations that are within the regulatory framework of GP2004-0001. These include best available methods for protecting or enhancing the ecological and water resources that our transportation system intersects. Our transportation infrastructure must be responsive to our population’s needs. However, as we do so, we must do it with a goal that we create a transportation network that does not undermine the essential ecological infrastructure that also exists here.

A road is a linear transportation system, connecting people with their places of residence, education, work, recreation, as well as being for supply of goods and services. Transportation agencies have multiple criteria for accommodating these needs in the design, construction, and operation of a road system. A river or stream is also a linear transportation system, and includes connecting an animal’s place of residence with areas to raise offspring, and supply of ‘goods and services’ for the animals that live there. Natural resource agencies have multiple criteria for accommodating the needs for protection, enhancement, and enjoyment of the users of a river system.

A bridge or culvert is an intersection of two differing linear transportation systems. One is a human system primarily based on needs for flow of goods and services, the other is an ecological system based on the flow of water. The ‘Best Practices’ provided in this document have guidance for road authorities on how best to take into account the ecological resources that move through such an intersection. Of the many ‘Best Practices’ in this document, use of just one may be enough to provide the needed element for an efficient intersection of two differing transportation systems.

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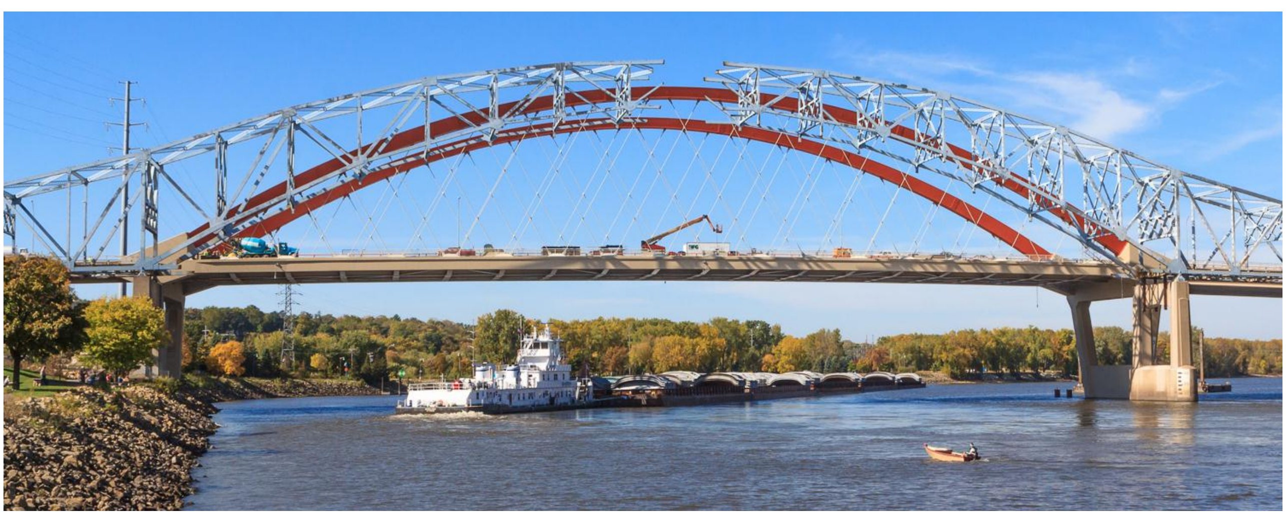

Peter Leete and Western Prairie Fringed Orchid
(selfie – 2007)

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Utilizing this Collection of Best Practices

The DNR anticipates that transportation projects will use practices in this document as a guide to address DNR Public Waters regulations associated with the protection of our water resources for fisheries, wildlife, rare features, invasive species, ecological connectivity, and recreational opportunity as identified in General Permit 2004-0001 (the 'MnDOT GP' for replacement or repair of Bridges, Culverts or stormwater outfalls). Though these practices are also applicable to other transportation projects the may require DNR approval or Public Waters permitting.   We recognize that other technical references, standards, and regulations may apply. However, use of these Best Practices provides consistency, reduces uncertainty, and increases the likelihood of environmental compliance for DNR Public Waters jurisdiction during all phases of a road project (scoping, design, construction, and maintenance).

The document is organized into three chapters. It is to be utilized as a comprehensive communication tool and implementation guide for the designer, construction manager, on-site contractor, or maintenance personnel. These pages show steps, procedures and examples of how to address various issues and meeting DNR regulations. Think of it as a sample plan for DNR constraints near a watercourse, lake, wetland or rare feature. During early coordination of a project, through MnDOTs Highway Project Development Process and Early Notification Memo (http://www.dot.state.mn.us/planning/hpdp/scoping.html), or other communications, the DNR will identify practices that should be incorporated into project documentation, design, or construction as guidance to meet DNR regulations. The entire document is not expected to be incorporated into every project. In fact, each Best Practice is written to be utilized as a stand-alone document. Within the framework of Preliminary Review and Early Coordination between MnDOT and DNR, appropriate sections will be identified as being applicable to a specific project.

Chapter 1 (Species Protection) provides information about protection of game fish, other aquatic or terrestrial species and sensitive native vegetation. There is also guidance to prevent the spread of invasive species. This chapter contains many options for ecological enhancements and/or protection to include in final design or construction methods. Much of this guidance is required under permit conditions, and if not, may qualify for mitigation measures for a projects impact to resources in the area.

Chapter 2 (Hydraulic and Hydrologic Recommendations) contains several detail illustrations, notes and guidance of Best Practice options for Hydraulic and Hydrologic design of structures impacting Public Waters. Each site will have to be evaluated to ensure that replacement of an existing structure does not result in an increase of flood potential to upstream or downstream properties. Additional information is also provided to improve or repair stream stability and local habitat.

Chapter 3 (Methods of In-Water Construction) offers illustrations, notes, and guidance on best practices for in-water construction work. These methods have been pre-approved by the DNR for use in the field (EG Site Management Plans); however, not all methods are appropriate for all work sites. Note that in most cases the applicable DNR Hydrologist will have to approve a method prior to construction. For this reason project designers, construction engineers, project managers, or contractors should work in consultation with the DNR for selection and approval of the appropriate method of in-water construction.

The Appendix is a collection of reports, publications, standard plans, or examples that have been utilized in actual projects to meet many of the best practices in this manual. They are included here, as they may prove useful during project development.

Acknowledgements

We thank all that have contributed directly or indirectly to the information provided in this manual. Please recognize there are numerous people (too many to list) from DNR, MPCA and MnDOT, that have contributed to this document.   There is also a need to recognize all the consultants and contractors out in the field that have contributed due to their work experience in the field. While regulators identify what to protect, contractors are often the ones to develop efficient methods to do so. Much of this manual is very much due to the interaction and sharing of information between DNR, MPCA, MnDOT, and MnDOTs consultants & contractors. This sharing of information has been essential to the development of new methods to meet the rules and regulations that make up the state's environmental protection policies and regulations.   We expect this practice to continue as all parties strive for 'better, cheaper, faster' methods to meet their needs.

About this Document

This collection of best practices was originally developed for meeting specifics of Minnesota Department of Natural Resources (DNR) General Public Waters Work Permit (GP) 2004-0001. This general permit has been issued to MnDOT for the repair or reconstruction of culverts, bridges, or stormwater outfalls impacting Minnesota's Public Waters. This latest version includes a growing number of best practices to protect the ecology of Public Waters, and many terrestrial ecological concerns that DNR oversees. When applicable, these practices are to be used in the same manner as MnDOT manual series for the design and construction of transportation projects. The DNR recommends information contained in these best practices be incorporated into the plans and specifications for a proposed project.

Some Best Practices are for guidance in design, others illustrate recommended construction practices. The information provided is not to be considered the only method for which a project may be designed and constructed. However, each illustration meets requirements set forth in GP 2004-0001, and may be utilized wholly or in part in order for a project to meet Public Waters Work Permit Regulations.

Many requirements of meeting the MPCA General Permit for Authorization to Discharge Stormwater Associated with Construction Activity (MN R100001) and the DNR Temporary Appropriations General Permit (GP 97-0005) are also integrated into Chapter 3. However, use of this document does not release the user from requirements of any rules, regulations, requirements, or standards of any applicable federal or state agencies; including, but not limited to the, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, MN Department of natural Resources, Board of Water and Soil Resources, Minnesota Wetland Conservation Act, MN Pollution Control Agency, or Watershed Districts.

Scope of this Document

This documents' focus is on DNR regulatory requirements that can be expected of transportation projects regarding Public Waters. Public Waters are designated as the lakes, wetlands, and watercourses over which DNR has regulatory jurisdiction. Public Waters are a subset of Waters of the State. The statutory definition of public waters includes Public Waters, Public Watercourses, and Public Waters Wetlands (Minnesota Statute 103G.005, Subdivision 15).

Public Waters defined:

Pubic Waters are bounded by the ordinary high water level (OHWL or OHW) on a basin or watercourse. The OHW reference defines the DNR's regulatory authority over projects that may alter the course, current or cross section of public waters and public waters wetlands. For lakes and wetlands, the OHW is the highest water level that has been maintained for a sufficient period of time to leave evidence on the landscape. The OHW is commonly that point where the natural vegetation changes from predominately aquatic to predominantly terrestrial. For watercourses, the OHW is the elevation of the top of the bank of the channel. For reservoirs and flowages, the OHW is the operating elevation of the normal summer pool.

> Note:
> The ordinary high water level (OHW) jurisdiction is waterward of a vertical line at the reference elevation point or the top of the bank of identified Public Waters basins and watercourses. Work waterward of this point is under DNR Public Waters regulatory authority, regardless of whether there is water present or not. Any construction activity that may alter the course, current or cross section within the boundaries of the OHW may require a Public Waters Work Permit, even if the activity does not directly affect the water at the time. Construction activities on bridges and culverts such as resurfacing, repair of lighting, installing or maintaining safety features such as guardrail, have no potential to change the course, current or cross section of a stream and do not require a permit from the DNR. However, activities that have the potential to temporarily or permanently change the course, current or cross section of a stream require the project be evaluated for a Public Waters Work Permit.

Contact Information

This is the fourth version of this document. Comments and recommendations for future versions are welcome, and should be sent to:

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Should questions arise whether a particular MnDOT project will impact a Public Water, contact Peter Leete or the appropriate DNR Area Hydrologist. For all other projects contact the DNR Area Hydrologist for the county in which the work is proposed. A complete list of Area Hydrologists is provided via the link provided below.

Links

DNR Area Hydrologists contact information:
http://files.dnr.state.mn.us/waters/dow_area_staff.pdf
or
http://files.dnr.state.mn.us/waters/area_hydros.pdf

A copy of GP 2004-0001 may be found at:
http://files.dnr.state.mn.us/waters/watermgmt_section/pwpermits/General_Permit_2004-0001.pdf

MPCA Stormwater Program for Construction Activity information may be found at:
http://www.pca.state.mn.us/water/stormwater/

The DNR Temporary Water Appropriations General Permit 97-0005 may be found at:
http://files.dnr.state.mn.us/waters/forms/tempprojectsgp.pdf

All Public Waters have been identified on county maps and are available via the web at:
http://www.dnr.state.mn.us/waters/watermgmt_section/pwi/maps.html

The Minnesota DNR Data Deli provides easy access to a wide variety of spatial data to the Minnesota GIS community at no cost:
http://deli.dnr.state.mn.us/

MnDNR Permtting and Reporting System (MPARS)
www.dnr.state.mn.us/**mpars**

All DNR Field Office locations may be found at:
http://www.dnr.state.mn.us/contact/locator.html

Preliminary Review & Early Coordination

We encourage in-office review of publically available information during early scoping and early design phases. Much can be learned about what may be in or near your project area by accessing publically available GIS information located on the DNR's Data Deli website at http://deli.dnr.state.mn.us/. If you have questions regarding proposed work near any of the data shown, please contact the local DNR offices or the DNR Transportation Hydrologist. The following files will be a good indicator of the level of DNR concerns that may be encountered within a project area.

MBS Railroad Rights-of-Way Prairies
MBS Native Plant Communities
MBS Sites of Biodiversity Significance
Public Waters Inventory (PWI) Watercourse Delineations
Public Waters Inventory (PWI) Basin Delineations
DNR managed lands such as Wildlife Management Areas, Scientific & Natural Areas, Public Access, State Parks, State Forests, etc
MN Prairie Conservation Plan
Trout streams, including PLS sections with trout streams
FEMA layers for flood impact potential
Minnesota Trails (water, state, and snowmobile)

Other Federal or State regulatory agencies may also have interests in preliminary review and early coordination. Additional information is also available for reviewing a project for other agencies requirements. These include, but are not limited to:

National Wetland Inventory (NWI) maps
Soil Survey
MPCA Special Waters
MPCA Impaired Waters
Historic properties

1. The Minnesota Natural Heritage Information System (NHIS) provides information on Minnesota's rare plants, animals, native plant communities, and other rare features. The NHIS is continually updated as new information becomes available, and is the most complete source of data on Minnesota's rare or otherwise significant species, native plant communities, and other natural features. Its purpose is to foster better understanding and conservation of these features. The NHIS is not provided through the Data Deli site. Though it will need to be queried to determine if there are rare species or biologically sensitive areas known to occur within or near a project area. Typically a search is conducted on all areas within a one-mile radius of the project area. For required survey information: http://www.dnr.state.mn.us/nhnrp/nhis.html

2. Preliminary review (either on your own or through direct contact with regulatory agencies) can help identify the likelihood of sites to have specific design parameters, mitigating options to include, and/or construction limitations set by the DNR. Examples are:

   Fish passage
   Navigational requirements
   Flood elevation constraints
   Invasive species protocols
   Rare species protection

3. Early coordination or pre-application meetings should take place to discuss general aspects of the project or specific site requirements. These meetings should be conducted regularly (annually) to discuss a road authority's projected work plan (often out a year or two or three). For MnDOT, the Early Notification Memo process is the typical avenue for the exchange of information on avoidance, minimization, and mitigation of a projects potential ecological impact.

Chapter 1. Species Protection

The following pages contain illustrations and notes on Best Practices for protection of gamefish, other aquatic or terrestrial species, and sensitive native vegetation. There are also protocols for preventing the spread of aquatic invasive species. This chapter contains options for ecological enhancement or protection measures. These may be incorporated into final design, special provisions, and construction plans. Much of this guidance is required under DNR permit conditions, and when not, can qualify for mitigation measures for a projects impact to resources in the area.

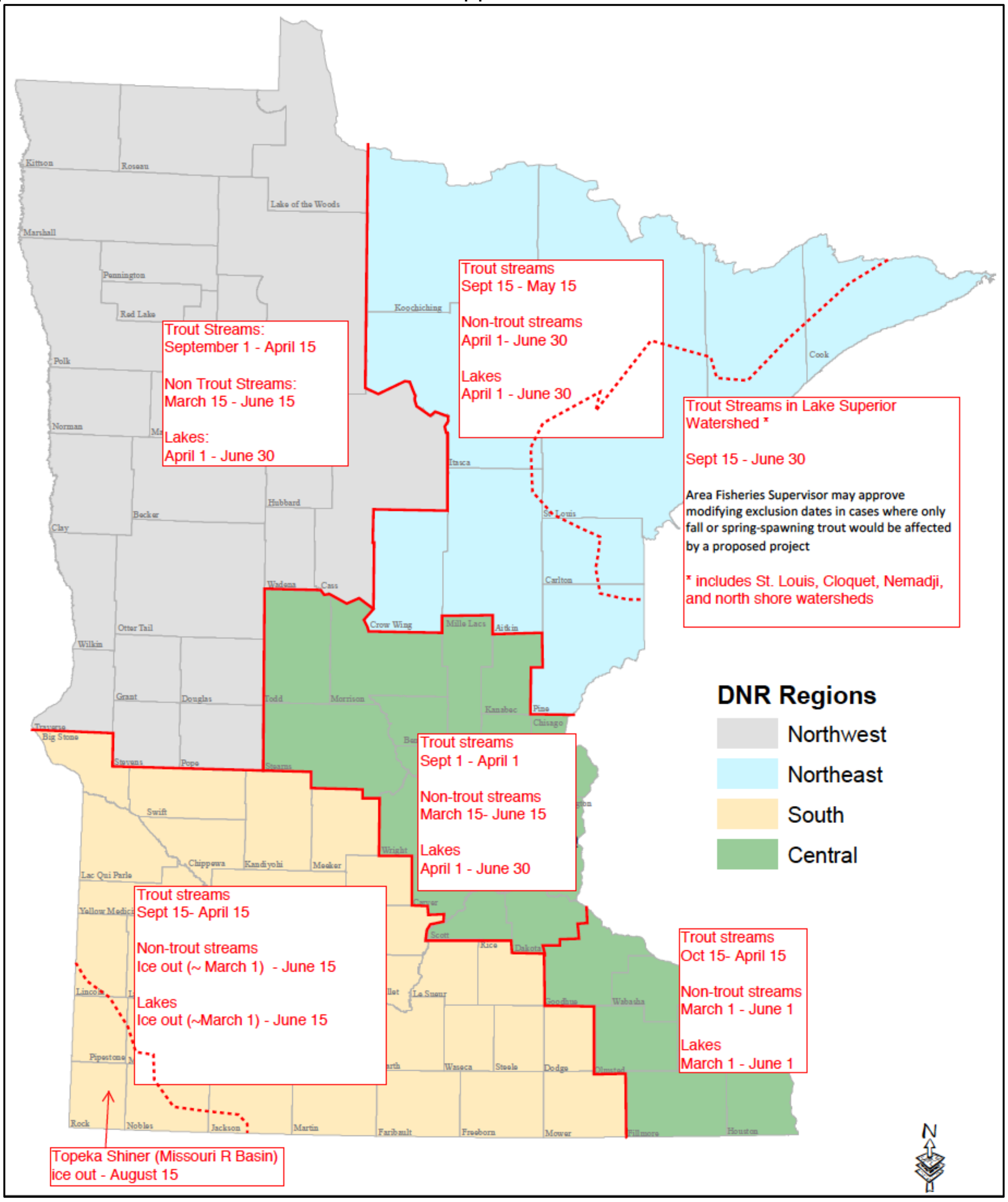
(Chapter cover and above photo: TH1 near Isabella, Lake County, MN)

(local road, southern MN)

WORK EXCLUSION DATES
TO ALLOW FOR FISH SPAWNING AND MIGRATION

To allow for fish migration or spawning, no in-water work is allowed in Public Waters during these dates*.

The Work Exclusion Dates below shall be incorporated into project scheduling and staging to protect fish spawning and migration. Work may be conducted elsewhere on a project during these dates; however no work shall occur within Public Waters during the specified exclusion dates without written approval from the DNR.



* Where the **permittee** demonstrates that a project will minimize impacts to fish habitat or if work during this time is essential, work during this period may occur only upon written approval of the DNR Area Fisheries Manager. Contact information for Area Fisheries Managers:
http://files.dnr.state.mn.us/fisheries/management/dnr_fisheries_managers.pdf

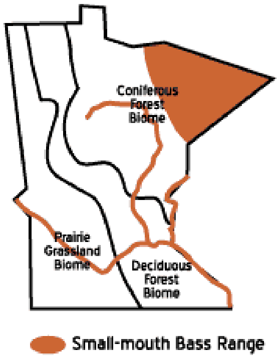
Please be aware that the MPCA NPDES general permit for authorization to discharge stormwater associated with construction activities (Permit MN R10001) recognizes the DNR "work in water restrictions" during specified fish migration and spawning time frames. During the restriction period, all exposed soil areas that are within 200 feet of the water's edge and drain to these waters, must have erosion prevention stabilization activities initiated immediately after construction activity has ceased (and be completed within 24 hours).

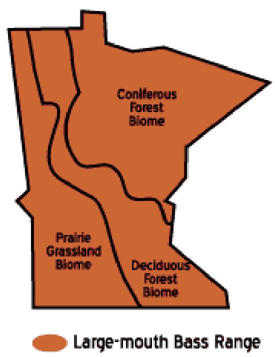
Spawning and Migration behavior of various fishes

The following pages have general information on reproductive habits of fish species that are commonly associated to the work exclusion dates set by DNR Area Fisheries Managers. Knowing which species are utilizing the waters where work is proposed is an important factor in determining work exclusion dates. Another important factor is water temperature, as all spawning correlates to water temperature as it warms up each year, or in the case of several trout species, the cooling of the water in the fall.

For more information on these and other species, see:
http://hatch.cehd.umn.edu/research/fish/fishes/natural_history.html
http://www.dnr.state.mn.us/fish/index.html

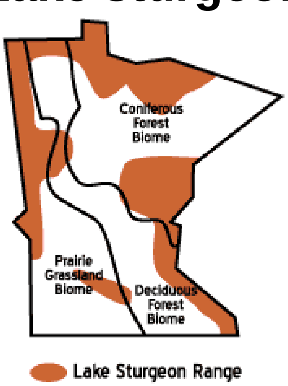
Bass





Bass spawn later than most species. They spawn mostly in May and June in Minnesota when water temperature reaches about 60° F. Largemouth and Smallmouth bass have similar spawning habits. As in other sunfish species, the male prepares the nest. Largemouth prefer a site in clear shallow water (1-4 ft deep) in areas of bulrushes, water lilies, coontail, or other submerged plants. The bottom may be gravel, sand, or even mud. Smallmouth bass prefer a gravel bed, often next to a log, boulder, or other obstruction in about 3-10 feet of water. The very assertive, territorial male uses his fins to clear an area until he exposes gravel, shells, or plant roots. Both males and females spawn with multiple partners. The male fans the eggs (embryos actually) and protects them from predation. The eggs (embryos) usually hatch in about a week. They spend another week in the nest while they develop their mouths, digestive tracts, and some fin rays. Finally, they swim up into the water column and begin feeding. At this time, most larvae of the sunfish family swim away. But largemouth larvae continue to swim together in a "brood swarm" for the next 3-4 weeks as they develop into juveniles. The male largemouth continues to protect this swarm until it breaks up.

Lake sturgeon

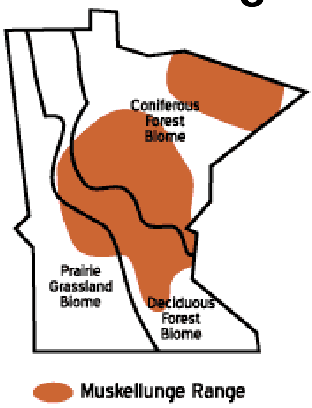


Lake sturgeon are listed as a species of special concern. They are present in limited numbers in the lower Mississippi, St. Croix, Minnesota, Red, and Rainy rivers. They also inhabit Lake Superior, Lake of the Woods, and some lakes in the Boundary Water Canoe area. Lake sturgeon have been reintroduced to the Red River system, and recovery of populations in the upper St. Croix and Rainy river systems has been reasonably good. Poor water quality and migration barriers such as locks and dams, continue to prevent recovery in the lower Mississippi River.

The spawning season for lake sturgeon in Minnesota spans the months of April, May, and sometimes June. Males do not reach sexual maturity until they are 20 years old, and females are usually 25 years old before they spawn for the first time.

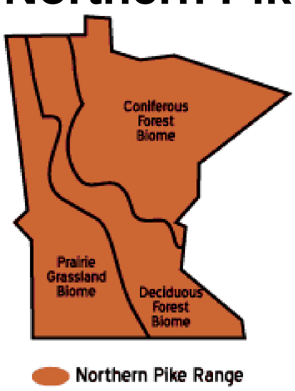
Females only spawn every 4 to 6 years, while the males usually spawn every other year. Lake sturgeon generally migrate long distances to reach suitable spawning habitat (gravel beds in moving water or lake shallows). Dams and other navigation devices can interfere with this migration and force sturgeon to spawn in unsuitable areas. Males arrive at the gravel spawning sites before females. When spawning begins, several male will swim along side a female, usually going against the current. The female deposits her eggs and the males fertilize them at the same time. Each spawning act is brief, but the entire process can last up to 8 hours and can be spread out over a couple of days. Eggs stick to the bottom of the lake or stream and hatch in 5-10 days depending on water temperature.

Muskellunge



The musky spawning season is in the spring (April or May) about 2 weeks or more later than the northern pike season. As do northerns, musky leave lakes and move up into small streams or into flooded shallows around lake margins to spawn. They choose heavily vegetated sites in water 15-20 inches deep. Pairs of musky swimming side by side spawn haphazardly over the vegetation, to which the fertilized eggs attach. Spawning normally goes on for about a week before the fish return to the deeper water leaving the eggs and soon-to-be young musky to fend for themselves. The eggs hatch in 8-14 days. As with the northerns, newly hatched muskies attach themselves to the vegetation using the adhesive organ on their heads. Here they develop their mouths and fins over another 1-2 weeks before they swim free and begin to feed.

Northern Pike



Northerns spawn in April or early May shortly after ice melts (when water temperatures approach 40 degrees). They move up into small streams during the night hours or select shallow, flooded marshlands or grassy lake margins as their spawning sites. Northerns spawn in groups of one female and one to three males. The fertilized eggs stick to the weeds. Females leave the spawning areas as soon as they have released all their eggs, but males may stay for a week or more. Though they do not protect the eggs. The eggs hatch in 12-14 days, but the newly-hatches embryos attach themselves to the vegetation using an "adhesive organ" on the tops of their heads. They continue to develop their mouth and fins for another 5-15 days before they swim free and begin to feed. The fry (newborns) stay in their spawning areas until they're about two to three inches long. Then they move to deeper water.

Salmon

Salmon are introduced species. Three species of Pacific salmon introduced to Lake Superior in the past few decades (Coho, Chinook, Pink) have been known to naturally reproduce. All feed in the big lake until they reach sexual maturity. Then, in the fall, they swim up rivers to spawn and then, inevitably, die. The largest, which has fared the best in its introduced environment, is the chinook salmon (also called king salmon).

The chinook pink, and coho salmon normally live in the Pacific Ocean and spawn in streams of eastern Asia (Russia) and western North America. In Minnesota, they inhabit Lake Superior and some of its tributaries. Most salmon return to spawning streams in their third year of life. They move shoreward in late September and October and wait for the fall rains before swimming up the streams. Spawning occurs in October and early November. Females use their tails and entire bodies to dig out nests in areas of gravel where they spawn, usually with a single male. The gravel and sand that she removes drifts down and covers adjacent downstream nests. These acts are repeated until the female has deposited all her eggs. Usually both the male and female die shortly after spawning is over. The alevins (free-swimming embryos) hatch in the mid to late winter and remain in the gravel for several weeks or months while their fins develop. They swim up into the current, begin to feed, and shortly afterward migrate to Lake Superior in April or May.

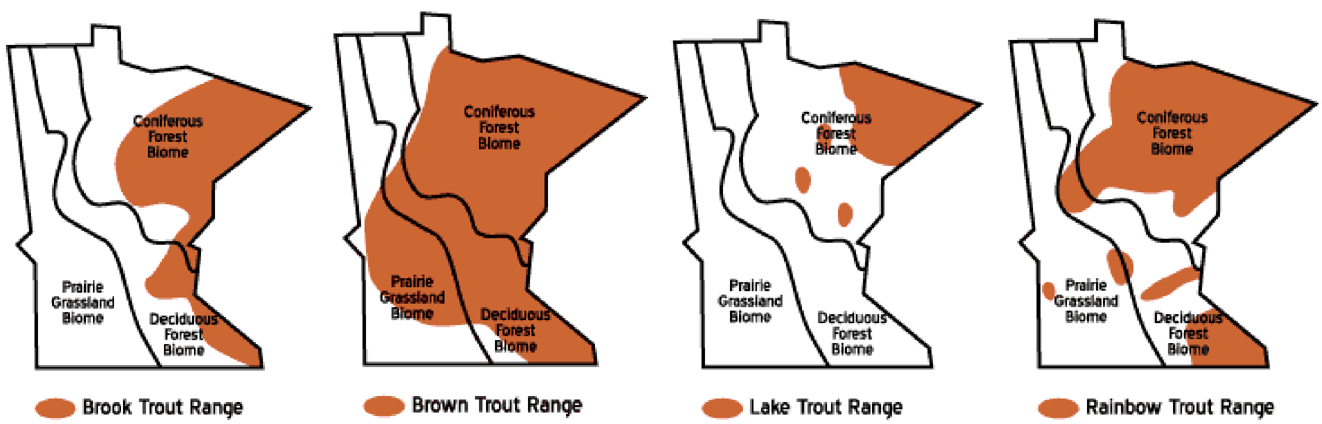
Topeka Shiner

Minnesota populations of Topeka shiners seem to be doing well and have a state designation of "special concern" in their limited distribution of the state (Missouri Watershed portions of Pipestone, Murray, Rock and Nobles Counties). In other states the species is doing very poorly. On January 14, 1999, the Topeka shiner was designated an endangered species by the Federal government. Thus, it became Minnesota's first and only Federally endangered fish species.

Their spawning season lasts for 8-10 weeks starting in mid-May to early June when water temperature reaches 70° F. They do not build their own nest, but share a nest with orange-spotted or green sunfish. Males establish small territories around the nest and aggressively defend it from all other Topeka shiners. Female may enter a territory only to be chased out repeatedly. If she is persistent she will finally he accepted by the male. The two spawn head to head above the nest. The female releases only a few eggs during each brief spawning episode. Topeka females produce clutches of eggs (groups of eggs that become ready for spawning at about the same time). A single clutch varies from 150-800 eggs depending on the size and condition of the female. We do not know how many clutches a female produces in a season, but we suspect it is several. At 70° F it takes about 5 days for the eggs to hatch and another 4 days before the larvae begin to feed.

Trout

Minnesota has two native trout species: the brook trout ("brookies") and the lake trout. The other trout in this state are brown trout and rainbow trout. Both were introduced to Minnesota in the late 1800s. The rainbow is native to western North America and the brown is native to Germany. A type of large rainbow trout that lives most of its life in Lake Superior and spawns in large North Shore rivers is called a steelhead. A cross between a lake trout and a brook trout, called a splake, is also found in some northern lakes.



Brook Trout

Brook trout spawn in October, November, and December. Depending on the year, sometimes spawning in streams flowing into Lake Superior begins in late September. During these spawning times the water temperatures are usually 40-49° F. The males and females gather in a shallow part of the stream that has fresh, well-oxygenated water and a clean gravel bed. The female digs a nest, called a redd, 4 to 12 inches deep in the bottom. The fish churn the water as they release eggs and milt. After the eggs are laid and fertilized, the female covers them with a bit of gravel. Streamflow across the gravel keeps the eggs oxygenated and clear of silt. The eggs hatch in late winter (50-150 days depending on water temperatures). The colder the water temperature is the longer the development period. Brook trout do not die after spawning. They spawn each year of their adult life.

Trout (cont.)

Brown Trout

Brown trout can live in warmer and more turbid (cloudier) water than brook trout can. This allows them to live in the downstream portions of coldwater streams, while brook trout tend to live in the headwater areas. Brown trout swim up into headwater areas to spawn. They usually choose gravel bottoms often where there are spring seeps and good moving water. Brown trout spawning season begins in October and goes into December. Spawning habits and seasons are similar to the brook trout. They also do not die after spawning. They spawn each year of their adult life.

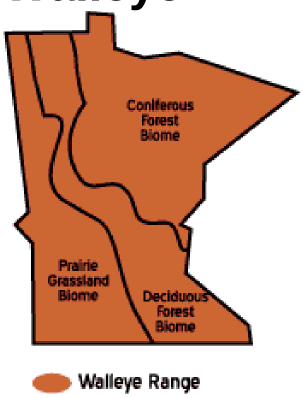
Lake Trout

Lake trout in Minnesota live primarily in Lake Superior and many of the deep, cold lakes of St. Louis, Lake, and Cook counties. They also occur in a few lakes of the upper Mississippi River drainage. They were introduced to Grindstone Lake near Sandstone many years ago. Lake trout only do well in lakes where the water temperature does not exceed 18° C (65° F). Lake trout spawn in the fall, mostly in October though early November, when water temperature falls below 10° C (50° F). They spawn over boulder beds where water currents keep the rocks clear of silt. The embryos develop for 4 to 5 months and hatch into alevins (free swimming embryos) in February and March. The alevins live in the rock crevices for another few weeks while they finish their fin development. Then they disperse into the lake.

Rainbow Trout (steelhead)

Stream-dwelling rainbows migrate upstream to spawn. Those in lakes migrate into tributary streams or spawn in shallow areas of rock or gravel if no streams are available. A few may spawn in the fall, but most spawn in the spring when water temperatures rise to the upper 30's or low 40's ° F. This rise in water temperature must correspond with a rise in stream elevations (from rain) or they will not spawn. The female scrapes out a nest in the gravel and is joined by one or two males. The female covers the eggs with the gravel she removed to build the nest. There is no parental care of the nest or the eggs, and adults return to their feeding areas. The embryos develop for 20-80 days depending on the water temperature. They hatch into what are called alevins (free-swimming embryos with huge yolk sacs) and stay down in the gravel for another 2-3 weeks while their fins develop. After that time, they swim up and begin feeding in the stream or lake. Migrating rainbows can live and grow in the stream for 2-3 years before they migrate downstream or out into a lake.

Walleye



The walleye is native to most of Minnesota, flourishing in large, shallow, windswept lakes with gravel shoals. It is also native to many smaller lakes and steams in all of Minnesota's major drainages. Walleye are a "cool-water" species, preferring warmer water than do trout and cooler water than do bass and panfish. Walleye spawn over rock, rubble, gravel and similar substrate in rivers or windswept shallows in water 1 to 6 feet deep, where current clears away fine sediment and will cleanse and aerate eggs. Male walleye move into spawning areas (usually the same location from year to year) in early spring when the water temperature may be only a few degrees above freezing. The larger females arrive later. Spawning reaches its peak when water temperature ranges from 42 to 50 degrees. Neither parent cares for the eggs in any way. After spawning, walleye move back to feeding areas. Eggs gestate for I - 3 weeks, depending on water temperature. Once hatched the fry float downstream.

Best Practices for Preventing the Spread of Aquatic Invasive Species

All equipment[1] being transported on roads or placed in Waters of the State shall be free of prohibited and regulated invasive species and unlisted non-native species (any other species not native to Minnesota)

1. **Project plans or documents should identify Designated Infested Waters[2]** located in or near the project area.

2. **Prior to transportation along roads into or out of any worksite, or between water bodies within a project area, all equipment** must be free of any aquatic plants, water, and prohibited invasive species.
   A. **Drain** all water from equipment where water may be trapped, such as tanks, pumps, hoses, silt curtains, and water-retaining components of boats/barges (see Figures 5 & 6) **AND**
   B. **Remove** all visible aquatic remnants (plants, seeds and animals). Removal of mud & soil is not required at all sites, though is encouraged as a Best Practice. Removal of mud and soil may be required on sites designated as infested (see #4).

3. **Prior to placing equipment <u>into any waters</u>,** all equipment must be free of aquatic plants and non-native animals.

4. **Additional measures are required on *Designated Infested Waters* to remove and kill prohibited species such as zebra mussels, quagga mussels, New Zealand mudsnails, faucet snails, or spiny waterfleas.**
   Note: The DNR is available to train site inspectors and/or assist in these inspections. Contact the appropriate Regional Invasive Species Specialist: www.mndnr.gov/invasives/ais/contacts.html
   A. For day use equipment (in contact with the water for 24 hours or less); Perform #2 above or,
   B. For in-water exposure greater than 24 hours: Perform #2 above, and inspect all equipment for the prohibited invasive species present (see Figure 1).

   Then choose one of the following three: **on-site treatment**, **off-site treatment**, or **customized alternative**.

Figure 1. Invasive species may not be readily visible on equipment. Some species are less than 1/4 inch in size.
Photo credit: Brent Wilber, Lunda Construction

On-Site Treatment

Remove by handscraping or powerwashing (minimum 3000 psi) all accessible areas (Figures 1 and 2) **AND**

Kill Prohibited Aquatic Invasive Species in non-accessible areas using one or more of the following four techniques:

- **Hot Water (minimum 140°F) for ten seconds** (Figure 2) for zebra mussels, quagga mussels, New Zealand mudsnails, faucet snails **OR**
- **Air Dry** (Figures 3 & 4)
  Spiny waterfleas – air dry for a minimum of 2 days
  New Zealand mudsnails – air dry for a minimum of 7 days
  zebra or quagga mussels, faucet snails – air dry for a minimum of 21 days **OR**
- **Freezing Temperatures**
  zebra mussels - expose to continuous temperature below 32°F for 2 days **OR**
- **Crush**
  Crush rock, concrete, or other debris by running it through a crushing plant to kill prohibited species

Figure 2. Removal of aquatic remnants is required before transporting.
Photo credit: Peter Leete, DNR

Off-Site Treatment

Under certain conditions, the DNR will allow transportation of equipment off-site after partial removal of prohibited species (for example, after "removal" has been done and equipment will be taken to a facility to complete final treatment [i.e., "kill"]) This is a 'one-way pass' to allow transport to a storage area or disposal facility. This option can only be utilized if the receiving site is at least 300 feet from riparian areas, wetlands, ditches, stormwater inlets or treatment facilities, seasonally-flooded areas, or other waters of the state. To be allowed to use the off-site treatment option you must do the following:

- Read, complete, and comply with the appropriate authorization form for transportation of Prohibited Invasive Species at www.mndnr.gov/invasives/ais_transport.html (Note that a completed form is required to be in every vehicle that is transporting equipment containing infested species) **AND**
- Complete on-site treatment described in 4B above prior to re-use in or adjacent to water.

Best Practices for Preventing the Spread of Aquatic Invasive Species

Contact a DNR Invasive Species Specialist for authorization of a customized alternative

There may be situations due to time of year, length of exposure, type of equipment, or site conditions that a DNR Invasive Species Specialist could approve alternative methods or requirements for treatment. Contact the appropriate Regional Invasive Species Specialist: www.mndnr.gov/invasives/contacts.html

5. **Temporary appropriations of water from Designated Invested Waters to utilize elsewhere (such as for dust control, landscaping, bridge washing, etc.) is not allowed except by permit, thus should be avoided.**

   If use of Designated Infested Waters is unavoidable, permit information is located at www.mndnr.gov/waters/watermgmt_section/appropriations/permits.html

Figure 3. Drying will also kill aquatic organisms. Lay out materials to dry in the proper time. Drying times vary by species. Inspect after drying period is over.
Photo credit: Dwayne Stenlund, MnDOT

Figure 4. Drying techniques must not trap water. This equipment will not dry adequately.
Photo credit: Peter Leete, DNR

Figure 5. Pumping from designated infested waters for use elsewhere on the project is prohibited without a permit.
Photo credit: Peter Leete, DNR

Figure 6. Drain all water from equipment where water may be trapped. Remove drain plugs and drain hoses prior to transport.
Photo Credit: Peter Leete, DNR

Document Information
www.mndnr.gov/waters/watermgmt_section/pwpermits/gp_2004_0001_manual.html
Best Practices for Meeting DNR GP 2004-0001 (published 5/11, updated 12/12) – Chapter 1/Page 8

More on the DNR Invasives Species Program can be found at: www.mndnr.gov/AIS

[1] **'Equipment'** is defined as any implement utilized in construction. This includes boats, barges, heavy machinery, light machinery, or other material that may be moved on-site or off-site, including but not limited to rock (riprap) or timber for temporary workpads, backhoes, pumps, hoses, worksite isolation materials (eg, sheet pile or jersey barriers), boats, barges, temporary staging materials, erosion prevention products, sediment control products (eg, silt curtain), water trucks that take water from open bodies of water (eg, dust control), or dewatering components.
[2] **List of Designated Infested Waters**: http://files.dnr.state.mn.us/eco/invasives/infested_waters.pdf

DNR Contact Information

DNR Ecological and Water Resources lists area office staff at www.mndnr.gov/waters

DNR Ecological and Water Resources
500 Lafayette Road, Box 32, St. Paul, MN 55155-4032, (651)259-5700 or 5100

DNR Ecological and Water Resources website provides information at www.mndnr.gov or by calling (651) 259-5700 or 5100.

DNR Information Center

This information is available in an alternative format on request

Twin Cities: (651) 296-6157
Minnesota toll free: 1-888-646-6367
Telecommunication device for the deaf (TDD): (651) 296-5484
TDD toll free: 1-800-657-3929

Protection Measures for Areas of Environmental Sensitivity (AES)

An Area of Environmental Sensitivity (AES) is a generic term to be utilized on plans to identify an area as containing unique characteristics that needs specific protection during construction. These areas may be any area that is identified for added protection due to habitat, wildlife, cultural resources/properties, ecological significance, geological features, visual quality, or its sensitivity to disturbance.

Areas identified on plans as an AES shall not be disturbed during construction. Commonly the actual area to be protected is adjacent to the right of way corridor and the AES identifier is utilized as a buffer. The concern is that soil disturbance, incidental herbicide exposure, hydrologic alterations, tree disturbance, competition from non-native, sod-forming grasses, introduction of weed seeds, or shading by encroaching shrubs can all lead to degradation of these sites.

MnDOT projects must adhere to processes and application of measures consistent with, but limited to, the MnDOT Highway Project Development Process Handbook (HPDP), 2014 Standard Specifications For Construction; Section 2572 (Protection and Restoration of Vegetation), and Section 2101 (Clearing and Grubbing), of which key aspects are listed below:

Examples of an Area of Environmental Sensitivity:
Not all Areas of Environmental Sensitivity (AES) are equal. Many may have stringent levels of regulatory protection on their own, such as Threatened and Endangered Species. However, identifying a site as an AES is to be considered as a generic "stay out of this area" for construction purposes and does not have to reveal the reason for the designation. Typical examples are:

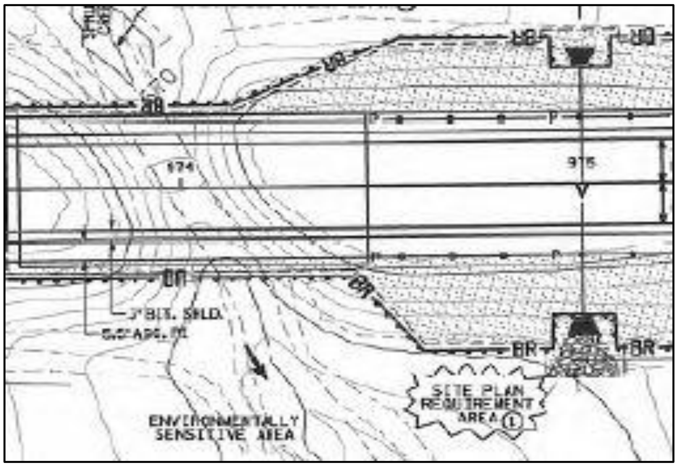
- Wetlands that are not permitted for construction activities.
- Open Water (such as DNR Public Waters, and other perennial streams and waterbodies)
- Trout Lakes and Streams along with their source springs.
- Calcareous Fens. These are identified in 'native plant communities' though due to their unique relationship with groundwater. Impacts to groundwater may also require separate analysis and protection.
- Impaired waters, Special Waters, and/or Outstanding Resource Value Waters (ORVW) as designated by the MPCA. http://pca-gis02.pca.state.mn.us/CSW/index.html.
- Wooded areas with Specimen Trees, or other permanent vegetation designated for preservation.
- Prairie remnants, including but not limited to areas adjacent to Railroad Rights-of-way Prairies.
- 'Sites of Biodiversity Significance' areas designated by the DNR Biological Survey. These sites contain varying levels of native biodiversity such as high quality 'Native Plant Communities', rare plants, rare animals, and/or animal aggregations. http://www.dnr.state.mn.us/eco/mcbs/biodiversity_guidelines.html.
- 'Native Plant Community' areas designated by the DNR Biological Survey. Native plant communities are classified and described by considering vegetation, hydrology, landforms, soils, and natural disturbance regimes. http://www.dnr.state.mn.us/npc/index.html.
- Federal or State listed species, and their habitat.
- Historical sites
- Any natural scenic elements, such as geological features not to be disturbed as designated by project planners, project managers, or project inspectors

Best Practices:
1. Design the project to avoid impacts to identified Area of Environmental Sensitivity.
2. Design and construction should incorporate protection and/or enhancement of adjacent AES features.
3. Label identified Areas of Environmental Sensitivity on all plans.
4. Drainage into Areas of Environmental Sensitivity may also have limitations on impacts.

In situations where work in or adjacent to an AES is authorized:
1. Prior to in-water work in an AES, check to see if a Mussel Survey is required.
2. Protect and preserve vegetation from damage in accordance with MnDOT Spec 2572.3
3. Prohibit vehicle and construction activities, including the location of field offices, storage of equipment and other supplies at least 25 feet outside the dripline of trees or other identified Area of Environmental Sensitivity to be preserved, also in accordance with MnDOT spec 2572.3
4. In areas where there are large or numerous separate of areas to protect, it may be preferred to identify those areas that are OK to be utilized, and have all other areas designated off limits for parking, staging, and/or stockpiling of materials.

5. Walk the perimeter of a sensitive area with the grading foreman so that all personnel understand and agree on the hard edge of the sensitive area.
6. Redundant sediment/erosion control Best Management Practices (BMP's) may be required for protection of areas of environmental sensitivity.
7. Revegetate disturbed soils with native species suitable to the local habitat. Revegetation plans may include woody vegetation (trees and shrubs) in addition to grasses and/or forbs.
8. Coordinate with MnDOT Office of Environmental Stewardship and/or the DNR if an Area of Environmental sensitivity is accidentally disturbed or damaged.
9. Relocate plants if harm is unavoidable (see Information on Transplanting Wildflowers and Other Plants).

For more information:
MnDOT Highway Project Development Process (HPDP): http://www.dot.state.mn.us/planning/hpdp/environment.html
MnDOT 2014 Standard specifications: http://www.dot.state.mn.us/pre-letting/spec/
DNR Sites of Biodiversity Significance: http://www.dnr.state.mn.us/eco/mcbs/biodiversity_guidelines.html
DNR Rare Species Guide: http://www.dnr.state.mn.us/rsg/index.html



Transplanting Wildflowers and Other Plants
(Plants Protected by Minnesota Statutes 2003, Chapter 18H.18)

(Prepared by Janet Boe, DNR NW Regional Plant Ecologist; Larry Puchalski and Bob Jacobson, DOT Botanists; and Mark Schreiber, MDA Nursery Inspection & Export Certification Unit Supervisor 5/30/2001. Updated 16 April 2004 by Mark Schreiber, Bob Jacobson, and Janet Boe)

Staff of the Minnesota Department of Agriculture, the Minnesota Department of Transportation, and the Minnesota Department of Natural Resources receive numerous calls each summer requesting information about transplanting orchids from locations threatened by construction or road-building. This information sheet was prepared to answer some of the frequently asked questions and direct inquiries to the appropriate agency.

Collection and sale of native orchids, trilliums, gentians, lilies, lotus (Nelumbo lutea), coneflowers, bloodroot, mayapple, and trailing arbutus are regulated by Minnesota Statutes 2003, Chapter 18H.18, Conservation of certain wildflowers. Although this section of Chapter 18H covers other species, most transplant requests and inquiries concern orchids, most commonly the showy lady's-slipper, Minnesota's state flower.

Minnesota Department of Agriculture

The Minnesota Department of Agriculture (MDA) has responsibility for administering the statutes and granting permits for the sale of wildflower species listed in Chapter 18H.18.

Wildflower collection by individuals for personal use (that is, transplanted to their own property and not offered for sale) is an issue between the property owner (whether public or private property) and the individual wishing to collect plants from that property. The collector needs the written permission of the landowner to enter the property and collect the plant species listed in the statute. The MDA requires a permit only if the plants are sold. Landowners may transplant species protected by Chapter 18H.18 within their own property without an MDA permit.

Wildflowers listed in 18H.18 cannot be collected or dug and immediately sold unless the plants are sold specifically for scientific or herbarium purposes. The individual selling the plants must own the land on which the plants are growing or have written permission of the landowner, and have a permit from the MDA. As part of the permit application, the MDA requires 1) written documentation that plants offered for sale grew naturally on the applicant's property or that the applicant had permission to collect them from property of another, and 2) the name and address of the organization receiving the plants.

If wildflowers are to be sold for purposes other than scientific and herbarium use, they must have been either A) growing naturally on the collectors property, then collected and cultivated by the collector on the collector's property, or B) collected with written permission from the property of another, then transplanted to the private property of the collector and cultivated on the collector's property. In either case, one or more permits and inspection by MDA are required prior to sale of the plants. Inspections must take place after the plant emerges from dormancy under cultivation and can be identified to species. As part of the permit application, MDA requires 1) written documentation that plants offered for sale grew naturally on the applicant's property or that the applicant had permission to collect them from the property of another, 2) a record of the dates they were collected and transplanted, 3) the cultivation techniques used by the applicant, and 4) the intended date of sale. Persons considering sale of these species collected from the wild should contact MDA staff listed below for further information.

Mark Schreiber (mark.schreiber@state.mn.us; 651-296-8388) and Steven Shimek (steven.shimek@state.mn.us; 651-296-8619), of the Agronomy and Plant Protection Division of the MDA, are the persons to contact for more information about MDA nursery certification requirements and to apply for permits. Their mailing address is Minnesota Department of Agriculture, Agronomy and Plant Protection Division, 90 West Plato Boulevard, St. Paul, MN 55107. They can also be reached by fax at 651-296-7386.

Minnesota Department of Transportation

The Minnesota Department of Transportation (MnDOT) is the landowner with jurisdiction over all state highways, interstates, and their rights-of-way. Collectors should contact the MnDOT District Permits Office serving their area to discuss collection of statute-listed plants from MnDOT-managed land. For plants adjacent to County State Aid Highways, the county engineer in the county in question is the contact person. Other roads may be under the jurisdiction of townships or cities, and township supervisors or city administrators would be the initial contacts for these ownerships.

MnDOT considers lady's-slippers a state asset and makes an effort to transplant those that are likely to be damaged by roadwork. They prefer to use their own crews, because of the dangerous nature of the activity, and to transplant them onto public land. Showy lady's-slippers are given first priority, followed by the two varieties of yellow lady's-slipper. If the road project allows, MnDOT prefers to mark the plants ahead of time, then dig them in the fall after they've faded and are dormant. Crews replant them the same day or the next day, keeping the plants wet in boxes or packed in the back of a pick-up truck until they can be placed in the ground.

Removal of orchids by private citizens from MnDOT rights-of-way in which they are threatened by roadwork may be possible but requires a permit from the local MnDOT District Office. MnDOT may require that the plants be transplanted to public land rather than to private property. Interested persons should contact either the MnDOT District Environmental Coordinator in their area directly (see the MnDOT website at www.dot.state.mn.us for contact information for the district offices), or they may contact the MnDOT Botanist in the MnDOT Office of Environmental Stewardship in St Paul. Transplanting orchids and then offering them for sale requires both permission of the landowner (in this case, MnDOT) and one or more permits from the Minnesota Department of Agriculture.

For more information about MnDOT's wildflower program and policies, see the MnDOT Office of Environmental Stewardship website at: www.dot.state.mn.us/environment

Minnesota Department of Natural Resources

If a citizen becomes aware that lady's-slipper orchids or other statute-listed plants are threatened by construction on public lands, the concerned citizen should contact the agency managing the land. In the case of the Minnesota Department of Natural Resources (DNR), lands are usually managed by either the Division of Forestry or the Division of Fish and Wildlife. Contact your local DNR forester or DNR wildlife manager with questions about orchids or other plants threatened by road construction on these lands. However, neither MnDOT nor DNR has a list of volunteer orchid rescuers.

Showy lady's-slippers and yellow lady's-slippers are not listed as rare species in Minnesota. However, some plants listed in Chapter 18H.18 are also covered by Minnesota's Endangered Species Act (Minnesota Statute 84.0895), including several species of lady's-slipper and other orchids. These plants are protected from collection or harvest by the state Endangered Species Act. Copies of Statute 84.0895 and associated rules can be found on the Minnesota legislature's web site at https://www.revisor.mn.gov/pubs/. The current state list of endangered, threatened, and special concern plants and animals is available from the DNR Natural Heritage and Nongame Research Program, 500 Lafayette Road, Box 25, St. Paul, MN 55155, or from the DNR's web site at http://www.dnr.state.mn.us/rsg/index.html

Most Minnesota orchids are also included in Appendix II of CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora). Species in Appendix II are not under immediate threat of extinction but require control of trade in order to avoid a level of use incompatible with their survival. An export permit from the U.S. Fish and Wildlife Service is required to export from the U.S. species that are listed under Appendix II. See the CITES website (http://www.cites.org/) for more information.

Persons interested in learning more about orchids should consult Orchids of Minnesota, a book written by Welby Smith, DNR Botanist, and published by the University of Minnesota Press. This book contains line drawings, color photographs, and descriptions of orchid species that are found in Minnesota.

Selecting a Seed Mix

MnDOT and the Board of Water & Soil Resources (BWSR) have revised their previously separate seed mix naming schemes into a single common five-digit nomenclature. This uniform system is now the standard numbering system for all users. New seed mixes have also been developed and are included for typical uses. The components of each mix are provided in the MnDOT Seeding Manual (2014 edition). Mixes considered 'native' all start with the numeral three (3x-xxx), and all mixes considered 'non-native' start with the numeral two (2x-xxx). For those familiar with the old naming systems, the table on the next page has a column showing the closest and often identical mix.

MnDOT Turf Establishment Recommendations Memo
MnDOT's 'Turf Establishment Recommendations' are regularly updated and the most recent update, dated April 14, 2014, include the new seed mix numbering system. The native vegetation options should be considered as the default (primary) option. Though we recognize that other contexts, such as mowing, compatibility with adjacent ownership or land use may rule out native vegetation. Separate letters for each District around the state are found here:
http://www.dot.state.mn.us/environment/erosion/seedmixes.html
Please follow the native recommendations where your project is located. In addition, for meeting DNR concerns, revegetation plans may include woody vegetation (trees and shrubs) in addition to or in place of grasses and/or forbs.

MnDOT Standard Specifications: Also refer to MnDOT Spec 3876 (Seed), 2014 edition, for additional information on standard seed mix requirements and characteristics.

New MPCA vegetative cover requirements for erosion control and sediment prevention
Be aware that the new MPCA NPDES Construction Stormwater General Permit (MN R 100001) has a change from previous versions in the percent vegetative cover required prior to the close out the permit. The previous permit conditions required 70% vegetative cover to be established, regardless of vegetation types. The new permit now requires 70% of the *expected* cover to be established prior to closeout. This small detail has a large impact on determining suitable permanent seed mix options. MPCA has recognized that some permanent vegetation types, such as grasses that will tolerate sandy soils aren't intended, nor were ever expected, to achieve 70% cover. This is also true of many of the native vegetation cover types in Minnesota. Rather than wait 3 or more years until maturity, (or bolster seed amounts as is commonly done now), the MPCA permit can now be closed out when we reach 70% of the eventual expected cover at maturity.

> Example: A project that utilizes of a permanent mix that is expected to reach 70% cover at maturity can be 'closed out' when that mix achieves 50% cover (70% of 70%, which is about 50%). This will reduce the focus on achieving 70% total cover for short term achievements, eliminate bolstering seed mixes to achieve 70%, and re-focus long-term benefits of other vegetation types, such as native vegetation options.

Beneficial use of native vegetation
Two primary objectives of roadside maintenance; weed prevention and erosion control, can be aided through the use of native grasses and forbs. The establishment of native plants in an area results in a diverse and strong plant community adapted to local conditions. The mixes have been developed to apply to a wide range of soil types, moisture levels, and climactic conditions. Most native mixes grow well during hot, dry summer months, and they provide excellent erosion control during the fall and spring. Deeper roots also may aid in preventing the invasion of noxious weeds and reduce the number of undesirable and competing shrubs and trees. Additionally, including native mixes creates a more stable and colorful environment throughout the growing season and adds color, texture, and beauty to the roadside.

Native Mixes may be required in certain situations
There are many types of areas that can be identified for inclusion of native species in a projects revegetation plan. These can be due to adjacent habitat, ecological significance, geological features in an area, or visual quality. Project design need not be all one type vs another. Projects may include some portions in native mixes, while others can be non-native. An example would be to have native mixes on the backslope and bottom, while the inslope and/or median may be a mow-able non-native mix. In addition, for meeting DNR concerns, revegetation may include woody vegetation (trees and shrubs) in addition to grasses and/or forbs.

The use of native seed mixes should also be utilized for mitigation due to impacts regulated by other agencies, such as within DNR Public Waters (IE when a project requires a Public Waters Work Permit). In fact, this is a standard condition of the DNR General Permit to MnDOT for repair or bridges and culverts (GP2004-0001). The DNR may also require that native vegetation be utilized when projects run through or adjacent to DNR managed lands such as Wildlife Management Areas, Scientific & Natural Areas, Public Access, State Parks, State Forests, etc. Native vegetation suitable to the local habitat is also recommended when projects run through or adjacent to areas that include rare species, in areas identified as a Site of Biodiversity Significance, or in an Area of Environmental Sensitivity (AES).

Table 3 from the MnDOT 2014 Seeding Manual, with 'expected final % cover' column added

TYPE	NUMBER	PLS Rate	NAME	REPLACES	Expected final % Cover of Target Plant Community*
CoverCrop					
	21-111	100	Oats Cover Crop	MNDOT 110, BWSR UT1	95%
	21-112	100	Winter Wheat Cover Crop	MNDOT 100	95%
	21-113	110	Soil Building Cover Crop	MNDOT 130	95%
Mid-Term Stabilization					
	22-111	30.5	Two-year Stabilization	MNDOT 150	95%
	22-112	40.0	Five-year Stabilization	MNDOT 190	95%
Non-Native Grassland					
	25-121	61.0	Sandy General Roadside	MNDOT 240	90%
	25-131	220	Low Maintenance Turf	MNDOT 260	95%
	25-141	59	Mesic General Roadside	MNDOT 250	95%
	25-142	45	Agricultural Roadside	MNDOT 280	95%
	25-151	120	High Maintenance Turf	MNDOT 270	100%
Mid-term Stabilization Native					
	32-241	38	Native Construction	BWSR U12, BWSR U11	85%
Stormwater Facilities					
	33-261	35	Stormwater South and West	MNDOT 310 & 328	90%
	33-262	44	Dry Swale / Pond	BWSR W4	85%
	33-361	35	Stormwater Northeast	BWSR W7, MNDOT 310 & 328	90%
Wetland					
	34-171	5.3	Wetland Rehabilitation	BWSR WT3	85%
	34-181	5	Emergent Wetland	BWSR W1	80%
	34-261	31.5	Riparian South & West	BWSR R1	85%
	34-262	14.5	Wet Prairie	BWSR W3, MNDOT 325	90%
	34-271	12	Wet Meadow South & West	BWSR W2	90%
	34-361	31.5	Riparian Northeast	BWSR R1	85%
	34-371	12.5	Wet Meadow Northeast	BWSR W2N	90%
Native Grassland					
	35-221	36.5	Dry Prairie General	MNDOT 330	75%
	35-241	36.5	Mesic Prairie General	MNDOT 350	85%
	35-421	11	Dry Prairie Northwest	BWSR U2	75%
	35-441	11	Mesic Prairie Northwest	BWSR U1	85%
	35-521	12.5	Dry Prairie Southwest	BWSR U4	75%
	35-541	12	Mesic Prairie Southwest	BWSR U3	85%
	35-621	11	Dry Prairie Southeast	BWSR U6	75%
	35-641	12	Mesic Prairie Southeast	BWSR U5	85%
Woodland					
	36-211	34.5	Woodland Edge South & West	BWSR U7	70%
	36-311	33.5	Woodland Edge Northeast	BWSR U13, BWSR U14	70%
	36-411	35.5	Woodland Edge Northwest		70%
	36-711	35.5	Woodland Edge Central		70%

(http://www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_manual.html)

More information to aid in planning, design, and maintenance of roadside vegetation:

Please contact your Districts representatives for the Erosion Control & Stormwater Management Unit, Roadside Vegetation Management Unit, and the Districts Maintenance staff to assist in determining appropriate permanent revegetation plans.

Information on designing and maintaining permanent roadside vegetation can be found here:
http://www.dot.state.mn.us/roadsides/vegetation/index.html

Information on planning your vegetation design, see the vegetation section of the Highway Project Development Process (HPDP) at:
http://www.dot.state.mn.us/planning/hpdp/environment.html

Also refer to the MnDOT Seeding Manual (2014 edition):
http://www.dot.state.mn.us/environment/erosion/pdf/seedingmanual.pdf

For selecting trees and shrubs, the MnDOT Plant Selector may be utilized:
http://dotapp7.dot.state.mn.us/plant/

For additional help selecting appropriate seed mixes for your project; contact the MnDOT Erosion Control & Stormwater Management Unit or Roadside Vegetation Management Unit.
http://www.dot.state.mn.us/environment/contactus.html

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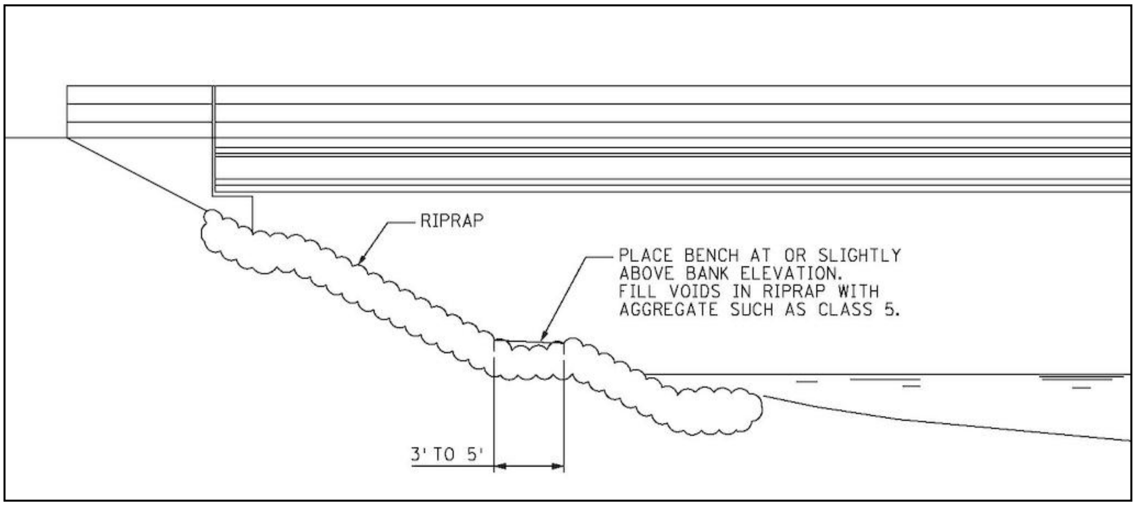
Passage Bench Design



NOTE: A PASSAGE BENCH MAY BE SIZED TO ACCOMMODATE ANY OR ALL OF THE FOLLOWING ISSUES COMMON TO WATERCOURSE CROSSINGS: SPECIES MOVEMENT, RECREATIONAL TRAILS, BRIDGE MAINTENANCE, AND HYDRAULICS.

IN SOME CASES THE DNR MAY REQUIRE CROSSINGS BE DESIGNED FOR SPECIES MOVEMENT. IF THE CROSSING IS LOCATED AT A SIGNIFICANT WILDLIFE TRAVEL CORRIDOR, AS DETERMINED BY DNR WILDLIFE OR ECOLOGICAL SERVICES STAFF, THE CROSSING SHALL BE DESIGNED TO MINIMIZE CONCERNS. THE DNR PREFERS BRIDGES OVER CULVERTS BECAUSE THEY ACCOMMODATE WILDLIFE MOVEMENT AS LONG AS THERE IS ADEQUATE CLEARANCE FOR PASSAGE BENEATH ROAD DECKS, AND/OR THE PRESENCE OF A STREAM BANK (DRY GROUND) AT NORMAL FLOW CONDITIONS.

The specifications above are from the original manual
'Best Practices for meeting DNR General Permit 2004-0001, March 2006'

Additional design considerations have been determined, they are:

1. Typical bridge riprap can be a barrier to animal movement along streambanks (see figure 3). Passage Benches allow for movement of animals under the bridge, thereby increasing road safety of bridge approaches.

2. The bench elevation should be at the approximate streambank elevation and be connected at either side of the road to allow for animal movement.

3. Use of Class 5 aggregate is a recommendation only. Any size aggregate will do as long as the surface is 'walk-able'. Note figures 1 & 6 show class 5 aggregate while figures 2 & 5 show larger aggregate (all meet design criteria).

4. The bench width need only be the width of a typical game trail. Wider benches may be desired for other criteria such as formal hiking trails. There is no minimum height clearance and widths of 2' to 3' have been successful for animal movement.

5. Bridge length is not necessarily increased. MnDOT has altered their typical cross-section design (lowering a flat area that was set next to the abutment) and has found that placing a 2' - 3' bench lower down, may add about 2' to the length of shorter bridges. This will vary depending on the hydrology of the stream and the overall length of the span.

6. It has gained support due to other benefits and is now included in the standard plans for riprap at bridge abutments (standard fig. 5-397.309 is included on page 19):
   - Increases road safety by getting animals off of bridge approaches.
   - Safe footing for bridge inspection and maintenance
   - Adds flexibility in design for normal channel and flood profile
   - Virtually no extra time/costs to install

(http://www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_manual.html)

Examples of Passage Benches

Figure 1.
Completed Passage Bench

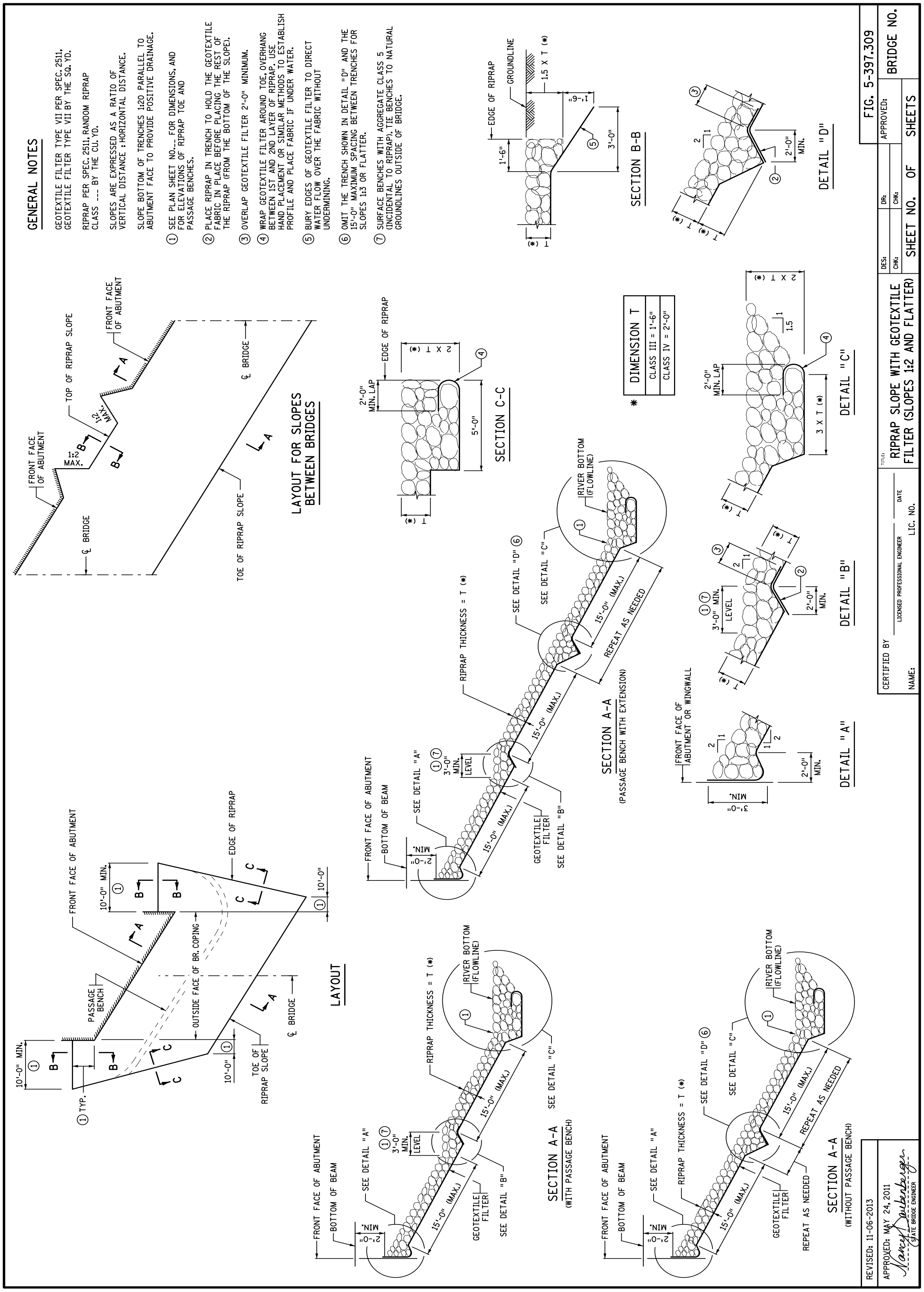
Figure 4.
Passage Bench is set to mimic shoreline game trail

Figure 2. Bench may be constructed of any size 'walkable' aggregate

Figure 5.
Bench must connect to surrounding topography

Figure 3.
Traditional Riprap is not passable by many animals

Figure 6.
Required in some areas, successful everywhere



The standard 11 x 17 plate is located in the appendix, or can be downloaded from:
DGN file: *http://www.dot.state.mn.us/bridge/pdf/cadd/files/bdetailspart2/dgn/fig7309e.dgn*
PDF file: *http://www.dot.state.mn.us/bridge/pdf/cadd/files/bdetailspart2/pdf/fig7309e.pdf*

General notes #1 (on plan sheet fig. 5-397.309). Passage bench elevation should be set near to the elevation of the adjacent top of the streambank. This is to simulate a natural streambank, providing continuity to any game movement along the waters edge.

(TH1 Flint Creek, St Louis County MN)

(TH60 Canon River, Rice County MN)

General notes #7 (on plan sheet fig. 5-397.309). Tie benches to the natural groundlines outside of bridge. It is essential that the adjacent area also have a bench included in plans. This is often a roadside ditch that outlets to the stream. Frequently the ditch design is in the grading plan and not addressed in the bridge plan. Be aware of this potential discrepancy, and be sure to have the bench mimic the natural streambank across the entire area.

(TH30 Bucksnort Bridge, Fillmore County MN)

Bench is to be carried through to adjacent streambank. These two examples show riprap blocking the bench.

In order to avoid passage bench washouts, roadside drainage and/or outfalls should be placed below the bench.

(TH8 in Lindstrom, Chisago County MN)

The bench elevation should be set at or just above the vegetation line. Generally, this is readily visible on site.

(I-94 Crow River, Hennepin County MN)

Note: Fencing may be required to encourage or 'train' animals to utilize the bench. Outside ROW fencing should be turned up installed tight to the abutment. On divided highway bridges with a median gap, the bridge gap should be fenced to prevent animals from making their way up onto the median.

Fencing on the right of way line should of been turned up at the abutment. With the standard practice of running the ROW fence to the waterline, there is no encouragement to go under the bridge (note the fence also caught flood debris).

Fencing of the medians is needed to prevent animals from coming up on to the roadway.

Examples of completed Passage Bench installations carried through to adjacent lands.

(I-35 Straight River, Steele County MN)

(County 16 Fillmore County MN)

(TH43 Choice Bridge, Fillmore County)

Curb Design and Small Animals

Traditional curb and gutter inadvertently directs small mammals and reptiles into the storm sewer. Animals trying to leave the road are blocked by the steepness and height of the curb and they will travel parallel to it until they find an exit. The storm sewer is the exit they literally fall into, often with fatal consequences.

A design without the side box inlet does give the animals a better chance of moving past the storm sewer to seek a safe way off the road. Coincidentally, this design is increasingly being utilized due to reduced installation and maintenance costs.

A sloped curb allows small animals to leave the road surface at any point. Yet it still provides for the collection and treatment of stormwater. If this modification to the entire curb system is not possible, a compromise is install sections of the curb on either side of the storm water drain for several feet will allow an area for animals to exit. Priority areas for mountable curbs are those with nearby wetlands.

(Specify **Type D** or **Type S** curb in plans)

In typical rural sections, trapping of animals on road surfaces is not an issue. Yet the movement onto the road surface from adjacent areas is a continuing concern. In areas of known concentrations, a wildlife barrier may be something to consider to reduce the likelihood of vehicle-animal collisions.

Preventing Entanglement by Erosion Control Blanket

Plastic mesh netting is a common component in erosion control blanket. It is utilized to hold loose fibrous materials in place (EG straw) until vegetation is established. Erosion control blanket is being utilized extensively and is effective for reducing soil erosion, benefitting both soil health and water quality. Unfortunately there is a negative aspect of the plastic mesh component: It is increasingly being documented that its interaction with reptiles and amphibians can be fatal (Barton and Kinkead, 2005; Kapfer and Paloski, 2011). Mowing machinery is also susceptible to damage due to the long lasting plastic mesh.

Potential Problems:

- Plastic netting remains a hazard long after other components have decomposed.
- Plastic mesh netting can result in entanglement and death of a variety of small animals. The most vulnerable group of animals are the reptiles and amphibians (snakes, frogs, toads, salamanders, turtles). Ducklings, small mammals, and fish have also been observed entangled in the netting.
- Road maintenance machinery can snag the plastic mesh and pull up long lengths into machinery, thus binding up machinery and causing damage and/or loss of time cleaning it out.

Suggested Alternatives:

- Do not use in known locations of reptiles or amphibians that are listed as Threatened or Endangered species.
- Limit use of blanket containing welded plastic mesh to areas away from where reptiles or amphibians are likely (near wetlands, lakes, watercourses, or rock outcrops) or habitat transition zones (prairie – woodland edges, rocky outcrop – woodland edges, steep rocky slopes, etc.)
- Select products with biodegradable netting (preferably made from natural fibers, though varieties of biodegradable polyesters also exist on the market). Biodegradable products will degrade under a variety of moisture and light conditions.
- DO NOT use products that require UV-light to degrade (also called "photodegradable") as they do not degrade properly when shaded by vegetation.

Solution: Most categories of erosion control blanket and sediment control logs are available in natural net options.

- Specify 'Natural Netting' for rolled erosion control products, per MnDOT Spec 3885. See Table 3885-1.
- Specify 'Natural Netting' for sediment control logs, per MnDOT Spec 3897

The plastic mesh component of erosion control blanket becomes a net for entrapment.

Literature Referenced

Barton, C. and K. Kinkead. 2005. Do erosion control and snakes mesh? Soil and Water Conservation Society 60:33A-35A.

Kapfer, J.M., and R.A. Paloski. 2011. On the threat to snakes of mesh deployed for erosion control and wildlife exclusion. Herpetological Conservation and Biology 6:1-9.

Birds and Bridges

The Federal Migratory Bird Treaty Act applies whenever protected bird species are involved. Most bird species that live in Minnesota are protected. The current exceptions are house sparrows, pigeons, and starlings. This means that a depredation permit is required to destroy active nests and/or harass nesting birds. Depending on the species involved, the nesting season is approximately from mid-March to August 15.

Under the regulations of the Federal Migratory Bird Treaty Act, depredation permits are required for the destruction of any active migratory bird nests. The U.S. Fish and Wildlife Service (USFWS) has formulated a policy that a permit for destruction of nests that are not active is not needed. All permits issued by the USFWS contain the requirement that any young swallows and eggs removed from the bridges must be turned over to a federally licensed rehabilitator for care and subsequent release (see section on depredation permits). The Minnesota DNR also has permit authority over the destruction or possession of protected wildlife. The DNR permits contain the same restrictions and requirements as the USFWS permits.

Swallow Protection

Cliff swallows and barn swallows are the most common migratory birds that build their nests on bridges or highway overpasses. Bank swallows tunnel into open sandy vertical surfaces near wetlands and streams and may try to take advantage of vertical surfaces in borrow sites or construction sites. The practices below apply to other migratory species as well.

Best Practice: Bank Swallows and Vertical Surfaces:

Avoidance is emphasized in cases where bank swallows have colonized vertical surfaces because the chances of rescuing birds from the tunnels are slim. The suggested measures to prevent swallows from nesting in bank are as follows:

1) Work may be performed outside of the nesting season, i.e., before May 15th or after September 1st. No permit is required for this activity.
2) Cover up the vertical surface prior to it being excavated for nesting, i.e., before May 15th.
3) Avoid having a vertical surface by leaving a slope at the excavation site.

Best Practice: Cliff and Barn Swallows, Avoidance and Minimization Measures:

The following options for dealing with swallows on bridges are acceptable to the USFWS and the DNR. The following measures should be identified in bridge removal and maintenance contracts, depending on how much responsibility is given to the contractor:

1) Bridge work may be performed outside of the nesting season, i.e., before May 15th or after September 1st. No permit is required for this activity.

2) Bridge work may be begun before May 15th and nest completion can be prevented by knocking down or hosing down the nests (at least three times a week) as they are being built. The success of this measure depends on the number of nests on a bridge. If the bridge contains only a few nests, the birds should be easily deterred from nesting. If the bridge contains a large number of nests, it is an indication that the site is very attractive to the birds and they will not be easily deterred from nesting. Preventing the birds from nesting by knocking down unfinished nests is acceptable to the USFWS, which considers this to be non-lethal harassment. No permits are required for this activity.

3) The portions of the bridge providing nesting sites (overhangs and ledges) may be covered with tarps, fabric or netting to prevent the birds from nesting. The entire underside of a bridge can be "diapered". For small bridges (over streams that do not carry canoe traffic) filter fabric reinforced with wire mesh can be suspended so that it hangs down from the side of the bridge to about a foot below the water line. When covering nesting sites it is crucial to seal off the entire area with a continuous barrier as the birds can enter through small openings in the netting. No permit is required for this activity.

4) Other preventative measures, such as sprays or chemicals, may be tried to discourage the birds from nesting, keeping in mind that water quality below the bridge should not be threatened. Such measures have not been officially proven to be effective, but they may work in specific cases.

5) Bridge work may be begun after September 1 in the hope that all or most of the birds will have completed nesting for the season. The risk with this approach is that some late nesters may still be present. If birds are still present, they must be turned over to a licensed rehabilitator. This activity requires a permit whenever there are active nests.

Netting Examples

Depredation Permits:

Applying for a depredation permit and complying with the requirements should be used as a last-resort option because the procedure is costly and can cause project delays. Depredation permits should be applied for under the following circumstances:

1) If the project is scheduled to begin before the end of the nesting season, e.g., August 15th, and birds are still actively nesting on a bridge (see above).

2) If the minimization measures listed above fail to prevent birds from nesting on a bridge (see above).

3) If the bridge contains a small number of nests, (i.e., a small enough number for the federally licensed rehabilitator to be willing to provide the service of caring for the three to five nestlings that each nest may contain), the timing of bird work need not be restricted.

The two major steps involved in working with depredation permits are A) obtaining the USFWS and DNR permits, and B) obtaining the services of a federally licensed rehabilitator.

1) Obtaining Permits: The permit applicant should be the party responsible for the bridge work, i.e., in most cases the contractor, in some cases the District (if the work is being done by Maintenance Personnel). The permit application (http://www.aphis.usda.gov/ws/ca/news/usfws_migratory_bird_depredation_permit.pdf) should be sent to USFWS and the DNR (the DNR does not have application forms, but will accept information in the USFWS format). The USFWS maintains its records on a calendar year basis and would prefer that the permit applications be submitted in the same year for which the permits are being requested. The turn-around time for receiving the approved permits is approximately 21 days.

2) Obtaining rehabilitator services: The USFWS and DNR permit issuers should be contacted to determine if there are any federally licensed rehabilitators in the project area. It is possible that the nearest rehabilitator may be hundreds of miles away. The network of rehabilitators was originally established to take care of limited numbers of orphaned or injured wildlife from the local area. The network, as it is presently set up, is neither able nor willing to commit to handling large numbers of young nestlings on a statewide basis. Most of the rehabilitators have full-time jobs from which they take time off to go and salvage the birds. Therefore the rehabilitators should be contacted at least several weeks in advance to make sure that their services will be available.

   The rehabilitators charge for their services. In 2002 the estimated rates were as follows (current rates may vary): $20.00/hour for the time spent salvaging and transporting the birds, $0.375/mile for door-to-door travel, and approximately $100.00/bird for subsequent care and release.

Eagle Protection

On 8 August 2007, the bald eagle was effectively de-listed from the Federal Endangered Species Act. Though it will continue to be protected under the Migratory Bird Treaty Act, and under the Bald and Golden Eagle Protection Act of 1940 and the Endangered Species Act of 1973, as amended, which prohibit the possession or taking of Bald Eagles, or their nests, eggs, or young. "Taking" is defined by the Endangered Species Act as to harass (i.e., create the likelihood of injury), harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. Prohibited activities include, for example, cutting down nest trees (at any time of the year), and intense human activity that is demonstrated to have caused adult eagles to abandon eggs or young in the nest. Possession permits may be issued by the U.S. Fish & Wildlife Service for Indian religious purposes, or for scientific or exhibition purposes of public museums, public scientific societies, or public zoological parks.

In addition, the National and Minnesota Environmental Protection Acts prevent certain actions which would cause significant adverse impacts to the environment (including destruction of habitat for listed species) if there is a reasonable alternative to the proposed action.

If you are uncertain whether a proposed action may take Eagles or their nests, or if you for any reason cannot follow the recommendations below, see the contact list below.

Best Practice for avoiding and minimizing impacts:

All federal actions (including federally funded road projects) that may affect eagles must also complete consultation with U.S. Fish and Wildlife Service under section 7 of the Endangered Species Act. A federal action is any action that a federal agency funds, authorizes, or carries out.

Contact information regarding the Migratory Bird Act or Eagle Protection Act:

For MnDOT projects that are federally funded contact: Jason Alcott, at MnDOT Office of Environmental Stewardship email: jason.alcott@state.mn.us , phone: 651-366-3605

For all other road projects contact:

U.S. Fish and Wildlife Service, One Federal Drive
Fort Snelling, MN 55111, phone: 612-713-5360
Website: http://www.fws.gov/midwest/

or

The nearest DNR Nongame Specialist:
NW Region - Bemidji (218-308-2641); NE Region - Grand Rapids (218-327-4518); Central Region - St. Paul (651-259-5764); South Region - New Ulm (507-359-6033) or Rochester (507-206-2820),
Website: http://www.dnr.state.mn.us/eco/nongame/index.html

Bridge Design and Potential for Bird Strikes

To date there are few and limited studies conducted on the subject (Peace Bridge on the Niagara River, a couple 'cable stay' bridges in Europe), though with talking to a few experts on the subject (USFWS migratory bird office, USFWS Mississippi River Wildlife Refuge Managers, Minnesota Audubon, and DNR non-game folks), and from personal research, we have the following observations:

- Bridge height is probably not a bird strike issue. Height limits can be looked at in context with the project area, however we have no definitive guidance or relationship of bridge height limits vs. bird strike potential. Here in the Mississippi River valley we've kicked around a height of 200' as being OK. The 200' is an arbitrary number based on observed flight levels of swans in Mississippi River wildlife refuges (considered a 'low flying' bird?). It's also coincidentally the approximate height of the river bluffs. It is not known how much leeway there is. 300' is a number that comes up too. Though it is also known that some species (such as warblers) travel close to the ground. Where bridge height has been limited in the past, it's been due to nearby airport requirements.

- Bridge lighting (on low bridges) may help prevent bird collisions. Deck lighting and architectural lighting may a benefit low flying birds. Though lighting should aim down and not up.

- Bridge lighting (on high bridges) has been found to be a factor in low visibility situations. If architectural lighting is considered, low intensity, shorter wavelength lights (violet, blue, green) should be used in preference to red and yellow. As stated previously, architectural lighting should aim down and not up. Up facing lights should focus on the structure and not have stray light. Turning off architectural lighting should be considered during spring and fall migration periods, particularly when conditions are overcast, cloudy, foggy or hazy. Aviation lighting should be blinking rather than steady lights.

- Bridge lighting can be a safety problem due to insect congregations at certain times of the year (such as the mayfly hatch). Deck lighting should be focused on the pavement and not surrounding areas (this should be done anyway to reduce energy use). Lighting color may also be a factor in mayfly congregations... Longer wavelengths such as yellow is better than white for reducing this problem. Methods to reduce lighting during the mayfly hatch should be considered (Some locations turn off all waterfront lighting during the hatch).

- Bridge railing design may be a design factor. Birds tend to fly up and over a bridge (not under it). If they see the deck/railing and just clear it, they are susceptible to be low enough to be swatted by vehicles. A higher railing or superstructure above the deck may alleviate this problem.

Note: We have been looking nationally and internationally for a consistent statement on major bridge design and birds, however it's apparent that such a conclusion does not exist. It's also likely that a single design might have negligible impact at one site, but be a significant risk at another. The above points are as definitive (and defendable) as we can find….

Reducing Wildlife Vehicle Collisions

The question of how to reduce the likelihood of Wildlife Vehicle Collisions (WVC) is regularly brought to our attention. However we do not have a definitive set of designs for reducing WVC along our roadways. Currently ‘typical’ or ‘standard’ designs in Minnesota are:

1. For small animals, use 5 foot chain-link fence installed tight to the ground. This is one of MnDOTs ‘standard’ or ‘typical’ right of way fence designs. For seasonal fencing to protect reptiles and amphibians, standard erosion control fence may be utilized to hinder movement into construction sites, onto roads, or for redirection to safer crossings (nearby culverts or bridges). Any proposed alternative designs will have to meet MnDOT criteria before they can become incorporated into MnDOT projects.

2. For deer, an 8’ woven wire or chain link fence is being utilized.

3. For crossings at streams and rivers, at bridges see guidance in Chapter 1, page 17 for the ‘passage bench’ design and fencing recomendations. For culverts use ‘off-set’ multiple inverts or ‘floodplain culverts’ to allow for a dry culvert during normal conditions.

4. Single culverts that are installed for topography with intermittent flow may also be incorporated into fencing design to funnel and ‘train’ wildlife to use them.

5. Curb design can trap small animals on the roadway. See the Curb Design and Small Animals (Chapter 1 page 24) in this chapter for added information on minimizing trapping animals on the road.

In all cases, methods to allow animals off the roadway also need to be incorporated into wildlife exclusion methods. There is also a growing trend to utilize vegetation as a deterrent instead of fence (EG for goose control). When a hazard situation is known, considerations for species specific issues should be incorporated into wildlife exclusion design, such as time of day, time of year, and typical habitat locations.

Developing typical methods for preventing wildlife-vehicle collisions will need to take into account the above issues, plus other measures due to site conditions or the occurrence of threatened, endangered or special concern species. Several states are developing standards, and new designs are regularly being proposed. However, there is no ‘one size fits all’ solution. Minnesota DNR will be review designs or situations as they are brought to our attention. Please contact us should you know of a situation that warrants wildlife protection and/or has safety issues due to vehicle-animal collisions.

There are numerous publications on this subject, though a comprehensive resource is the recently published FHWA publication ‘Best Practices Manual: The Wildlife Vehicle Collision Reduction Study’ (Report No. FHWA-HEP-09-022) [http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm]. This report covers a range of WVC characteristics and strategies to avoid wildlife vehicle collisions. They found that such collisions occur:

- Most often on rural two-lane, low-volume roadways.
- Most often in the early morning or evening and in the fall or spring,
- Where roadways cross drainages
- Are more likely on straight dry roads

The solutions presented in the FHWA manual primarily focus on Wildlife Vehicle Collisions involving species that pose a substantial safety risk (e. g., larger species such as deer and moose), though also provides discussion of measures for threatened and endangered species. The study was conducted to advance the understanding of the causes and impacts of WVCs and identify solutions to this growing safety problem. Design and implementation guidelines are provided for wildlife fencing, wildlife underpasses and overpasses, animal detection systems, vegetation management and wildlife culling. Additionally for a WVC reduction program, information is provided on regional planning, identification of priority areas, alignment and design considerations, guidelines for monitoring effectiveness of mitigations, and potential funding sources.


Large animals will require tall fence or large underpasses to minimize their crossing of roads


Medium to small sized animals may be redirected by topography, vegetation, or 4 to 5 foot fencing, though this is not enough height to prevent access by deer.


Providing passage at waterways or drainage ways reduces animal's need for going up over the road.

Typical roadway design may also trap animals within roadways, alternative designs that do not trap animals or allow escape routes should be considered.

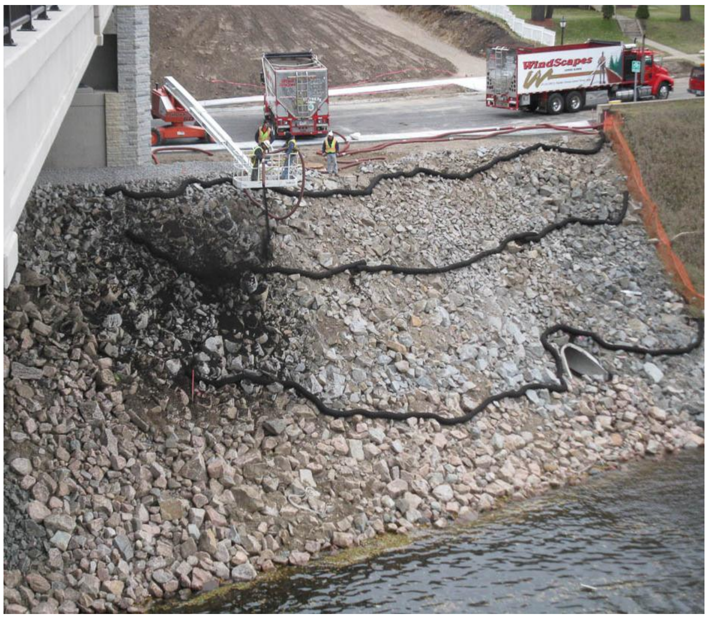
Vegetated Riprap
(Root-Rap, Compost Grouting)

This method is a bioengineering practice for establishment of plant material within the voids of typical riprap. The concept is to inject compost, or organic soils into the riprap voids, then seed the area. We expect to see this practice applied where vegetation is preferred for ecological or aesthetic seasons, yet traditional riprap is required for slope stability or scour prevention. This method has been considered a success along the rocky north shore TH61 roadsides, and is now being applied throughout the state. MnDOT Specification 2577 (Soil Bioengineering Systems) have two applicable specifications for placement of riprap, soil, and overseeding of the riprap voids (2577.3 H Root-Rap & 2577.4 D Granular Channel liner). Costs are similar to sod installation (though this does not include the riprap itself). Where there is suitable light and water, we surmise that this method is better at shoreline protection than either riprap or vegetation alone. The following photos are of this method being applied at the site of the TH23 DeSoto Bridge replacement in St. Cloud. Final grading and site restoration of the temporary access road called for riprap to the top of the bank. In order to vegetate the area, MnDOT worked with DNR and the City of St Cloud to develop a solution to meet all parties interests. MnDOT desired riprap for protection of the slope adjacent to bridge abutments, while the DNR and city desired natural vegetation. The agreed to plan called on Composted Riprap as a solution. For more information on the development of this method see: http://www.glc.org/basin/pubs/projects/mn_AppNatRes_pub02.pdf

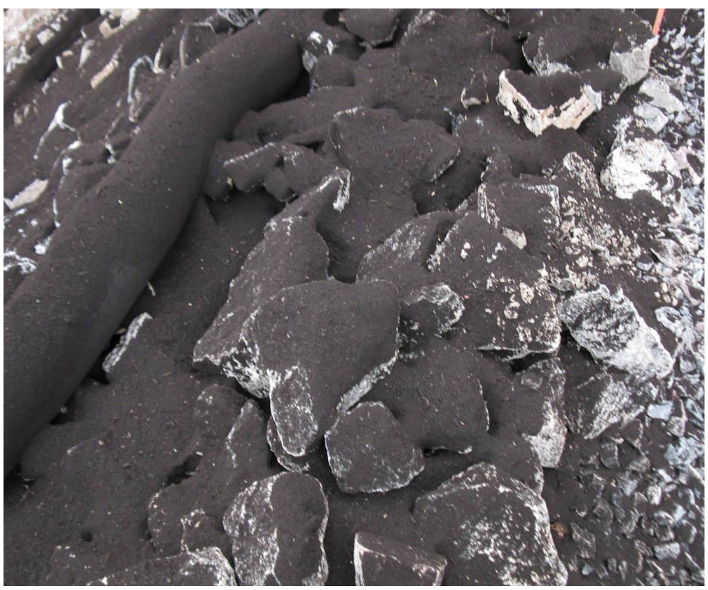
This method has proven successful on open slopes, though has only recently been applied adjacent to bridges or open water. Application should be limited to areas above the expected flow line of the river and more than 10 feet away from abutments or the 'drip line' of a bridge.

In the photos on the next page, a Grade 2 leaf and grass feedstock compost, at a rate of 270 cubic yards per acre was applied. This typically filled the riprap voids. Typically voids are filled approximately ¾ full. Compost is not always required, though soils suitable for plant growth is required. Downslope perimeter controls may also be required to limit movement of the compost or soil due to rain and wind events until plant establishment. Unless controlled, over time natural succession from grasses and forbs to shrubs and trees will occur due to seed dispersal from adjacent vegetation.

In this example sediment control logs were placed horizontally to break the slope for erosion control purposes. Also, the steep slope was not favorable for safely walking on, so a boom truck was called upon for broadcast application. Ideally the compost should be truly injected into the voids, though in this case was broadcast over the entire area with hopes of it settling into the voids prior to the winter setting in. Seeding followed compost placement. In this example project, applied seed did not germinate as expected. This was determined to be a combination of the south facing slope along and drought conditions. Subsequent years growth was noted to include species from natural dispersal of adjacent vegetation.



The TH 23 Mississippi River Crossing project was installed during in the fall of 2009.



First spring (2010)

One year later (2011)

Third year (2013)

Chapter 2. Hydraulic and Hydrologic Recommendations

The following pages contain several detailed illustrations, notes and guidance of Best Practice options for Hydraulic and Hydrologic design of structures impacting Public Waters. Each site will have to be evaluated to ensure that replacement of an existing structure does not result in an increase of flood potential to upstream or downstream properties. Additional information is also provided to improve or repair stream stability and local habitat.

Natural stream geomorphological processes are required to be incorporated into hydraulic and hydrologic design process. (Devil Track River, TH61 Cook County MN)

(TH171 Floodway bridge near St. Vincent, Kittson County MN)

Chapter cover photo, TH61 at Palisade Creek, Lake County, MN)

Things to Consider for Improved Culvert Design

Casual observations of stream characteristics at a crossing can provide definitive information on how an existing culvert has matched (or not matched) the surrounding stream characteristics. This section lists characteristics that road maintenance crews and bridge inspectors should be trained to identify during regular maintenance and inspections. Historical knowledge of how a culvert is interacting with the surroundings will be valuable if the crossing is proposed for replacement.

A redesign should include knowledge of how the existing crossing is functioning, and noted if there are contributing factors as to why an existing crossing is no longer adequate. It is entirely possible that a crossing was sized appropriately at the time of installation, though became insufficient as changes in the watershed occurred. Natural bedload composition can also be expected to have been altered due to land use changes in the watershed, or changes in storm frequency/intensity since the crossing was installed. Regardless of the structural reasons for the need for crossing replacement, there are several observations that can be utilized for determining if an existing crossing size or alignment is inadequate.

Traditional hydraulic design has been the standard requirement for crossing designs since the 1950s. These programs calculate stage increase (water elevations) based on storm event and watershed area/characteristics. Road authorities set thresholds to be met regarding road overtopping (maximum depth of water on the road for a chosen storm event). DNR regulations require that the headwater elevation for the 100yr frequency not exceed 0.5' over the calculated stage when compared to calculations without any crossing. DNR allows exceptions to this rule for replacement of existing crossings that previously had a higher stage increase (A new crossing can be replaced with the up to the pre-existing stage increase as long as there are no structures impacted). These processes typically lead to the smallest opening being chosen for installation. Thus traditional hydraulic design models, by suggesting a smallest opening size, may inadvertently lead to an increased potential for destabilizing natural stream integrity. This can lead to situations that are not good for either the interests of road stability or ecological connectivity.

There are many design objectives, which result in different designs for different settings. Flood elevations, wetland control elevation, ecological connectivity, safety and economics are all pieces being considered when a crossing is to be replaced. Recognizing flaws in the existing crossing will help to prevent duplicating defects in the new design. Currently, DNR regulations allow for replacement of existing crossings 'in-kind' (same size opening and invert elevations) with minimal scrutiny. However this may not be in the best interest of either the road authority or stream ecology.

The DNR and road authorities may have differing missions, though the DNR's responsibility to require ecological connectivity need not be in conflict with a road authorities responsibility to provide for safe travel on the road. A crossing designed with aspects of ecological connectivity can also:

- Minimize the consequences of plugging and overtopping.
- Prevent stream diversion (unstable banks and road slopes).
- Have sufficient hydraulic capacity:
  - Headwater depth does not cause pressurized flow during flood events
  - Culvert hydraulics do not cause scour at the outlet or inlet
- Maximize the life cycle of crossing.

Thus, a properly designed culvert does compliment the interest of both the road authority and the DNR.

Problem indicators on existing crossings:

1. **Plunge pools, stream bank scour, & sediment deposits)**
2. **Debris accumulation.**
3. **Perched outlet**
4. **Change in road overtopping frequency or depth.**
5. **Shallow culverts (but not perched)**

Other issues:

6. **Liners**
7. **Basin Outlets and its control elevation:**
8. **Non Public Waters**
9. **Deficient flood capacity and nearness to critical cultural operations**

1. Plunge pools, stream bank scour, & sediment deposits:
And undersized culvert produces an 'hourglass effect' with the upstream segment widening due to sediment deposition, while at the same time a downstream plunge pool scours a wide area. The formation of a scour hole or streambank erosion on the downstream side of the crossing provides evidence that an existing crossing is undersized and/or not properly aligned (slope or skew). The primary cause of this phenomenon on the downstream is the 'fire-hose' effect of high velocities through the crossing. Scour can also destabilize the end sections and roadbed. If a culvert is not to be replaced, scour hole protections such as riprap and/or grade control should be considered.

The photo above shows upstream aggradation (deposits). This area may look good, but the braided wide shallow channels through sediments is indicative of sediment deposition. Below is the downstream side of the same crossing which show the presence of a large scour hole. Having both features on the same crossing is sometimes called the 'hourglass' effect. (TH56 Freeborn County MN)

Scour holes can often seen in air photo review. They are typical of undersized culverts and found throughout the state in a variety of topography (top left, Mississippi River, Itasca State Park, TH73, TH56, TH23)

The accumulation of sediment on the upstream side of the crossing provides evidence that an existing crossing is undersized. When there is a stage increase of the headwater elevation (ponding) it causes a change in water surface slope. The slower water drops a portion of its load of suspended solids (gravel and silt). Vegetation can also become established on these deposits, thus compounding the adverse impact to the crossing's hydraulics. There are no long term solutions other than replacement with a properly designed culvert. Without replacement, maintenance crews can expect to regularly remove these deposits in order to maintain hydraulic capacity. Failure to do so may increase potential for road overtopping.

Note on location: Crossings on alluvial areas or very low gradient streams should be noted. Alluvial areas may be aggrading naturally, thus sediment deposits may not be the result of an improperly designed crossing. Determining the cause of aggradation can be difficult, and sources could be numerous. Running a Hec Ras model may also provide validation if the sedimentation is natural or not. A survey of the longitudinal profile upstream, and check changes to the stream cross sections may provide the limits of the aggradation. Though where it occurs, a comparison of culvert opening width and stream bankfull width should be noted. On very low gradient streams the deposits may be primarily composed of organic materials (decaying plant matter), not mineral in composition (sand or gravel). A properly designed culvert should take these situations into account.

2. Debris accumulation

A crossing that does not pass debris is vulnerable to plugging and failure during a flood event. A properly sized crossing will pass debris (including ice). If there is a history of debris maintenance at a location, it indicates the opening is too small. The replacement crossing should be designed with a properly sized crossing.




Woody debris is a problem in many parts of the state, and ice jams occur throughout the state. 'Debris catchers' are proving to be a short term fix at best.

3. Perched outlet

Perched crossings are those that have a drop of water level at the downstream end of a culvert. These are commonly blocks to all upstream movement of aquatic species. This situation can be due to several reasons, including improper invert elevation at installation. If a culvert has both an upstream aggradation deposit and a perched situation, it is due to an undersized culvert. A streams interrupted bedload capacity due to an undersized opening causes both upstream aggradation (sediment deposits) and causes the stream to perch the outlet when water picks up downstream material as it reestablishes bedload carrying capacity. If a perched culvert has no upstream aggradation, there are velocity issues (downstream scour hole) that have continued unchecked. In flood conditions perched culverts are vulnerable to apron undercutting, and in worse case scenarios can weaken the associated road grade.

Options to reestablish fish passage are either complete replacement with a properly sized culvert, or retro-fitting the outlet pool with grade control such as a rock rapids (series of weirs). Grade control is required to raise the pool elevation up and back through the culvert at normal flow conditions. Retrofitting existing culverts (floor or wall overlays) generally reduce hydraulic capacity or increase velocity of the structure, thus also increase the importance of including grade control structures to aid aquatic organism passage.

Four examples above are all along the North Shore of Lake Superior. Higher gradient streams are more prone to perched conditions, though it can happen throughout the state.

4. Road Overtopping:
Increased frequency or higher than predicted water depths during road overtopping is an obvious indicator that the crossing is no longer functioning within the desired parameters. There are no long term solutions other than replacement with a properly designed culvert.

Extreme example, though valid for pointing out what can happen with overtopping. (TH210, City of Thompson, Carlton County MN)

5. Depth and Velocity barriers
A situation where water depths are much shallower in the culvert than in the downstream channel is indicative of either improper elevation installation, or high velocities. Unchecked, these can lead to a perched culvert. Repairs to the flow line at the outlet should be considered.

This type of flow effect is more common on low gradient streams than on high gradient streams where fully perched conditions are more likely. If the water levels drop this will create too low a depth for fish passage (TH61 Split Rock River and Lake Superior, Lake County MN).

6. Culvert liners

Lining a culvert a common alternative to complete replacement of the structure. Such structures should be noted since it indicates that culvert performance may have changed since the original crossing was installed. Liners reduce culvert diameter and raise the invert. They may of maintained hydraulics by increased velocity with their smoothness, though fish passage may be an issue due to the increased velocities and/or change of invert elevation. See the section on Culvert Liners for more detailed information on concerns with this practice as it relates to ecological issues (Chapter 2 page 38)


The above left is a hard plastic pipe inserted into a failing corrugated metal pipe, diameter is reduced several inches, volume remains about the same though velocities are increased by the loss of roughness (TH210 Aitkin County MN), The example on the upper right, I have no idea why (TH 11 Koochiching County MN).

The above photo represents four iterations. The original timber bridge was replaced with a large culvert, which in turn was lined with a smaller culvert. A third culvert liner proposal was rejected, and a bridge was required to restore navigation (TH8, Lindstrom, Chisago County MN).

7. Basin Outlet and its control elevation:
It should be noted that crossings can act as an elevation control for a upstream wetland or lake. Many roads loop along wetlands and lakes, often crossing the outlet stream. State law prohibits alteration of outlet elevations of Public Waters without DNR authorization. The Minnesota Wetland Conservation Act has oversight of all other wetlands. Any alteration of altering existing invert elevations should include an evaluation of impact to water levels of the upstream basin. Design for sediment transport is generally not an issue on outlets of large waterbodies since it would be expected that the lake/wetland would have acted as a settling basin and removed sediment from stream flow prior to the discharge point. However long shore wave action can result in shoreline deposition, and on smaller waterbodies and wetlands these areas may be depositional zones for sediment and vegetation accumulation. Thus culvert at outlets should be designed to take into account potential for long term aggradation at the inlet.

> **Note on locations:** Crossings on very low gradient streams should be noted. Sediment and/or bedload can be very low, thus sediment movement may not be noticeable. A new design that accommodates bedload may not be necessary (IE recessed inverts). Though an evaluation or risk analysis should be included in the design process.

At outlets and in wetlands, flows may not carry mineral bedload. If desired, it may have to be added during construction, or forgo recessing inverts in order to maintain basin control elevation.

8. Non Public Waters

Crossings of Public Waters are a small portion of the crossings over Waters of the State. The DNR only has jurisdiction over the crossings that are over Public Waters. Public Waters are specifically identified on maps. Public Waters Watercourse (rivers and streams) are generally those perennially flowing streams that have at least 5 square miles of watershed at their mouth, or perennial flowing tributaries to designated trout streams. Crossings of Waters of the State may have design requirements of other entities such as the US corps of Engineers, Watershed districts, the County Ditch Authority, or other local authority.

Not all culverts are Public Waters. DNR Public Waters regulations and/or requirements of Attachment A do not apply to waters that are not Public Waters.

9. Deficient flood capacity and nearness to critical cultural operations

If not done already, identifying crossings for replacement should take into account how essential a road is for connecting critical operations, such a hospitals, schools, commercial districts, factories, power generating facilities, neighborhoods, cities, and such. It is not in the realm of the DNR to determine which road serves these critical functions, nor which roads would have the most detrimental impact if a culvert were to be washed out and lost for even a short period of time. However, any road that has critical functions should have all crossings evaluated to be sure that they can carry emergency services and/or maintain local safety and economies during flood flows. Such roads should be looked at to be certain that all crossings along such roads either meet or exceed current flood design standards or are identified as deficient. Deficient crossings should be replaced with structures that meet the latest design standards to be sure they can pass floodwater without failure. Replacement of deficient structures should be done regardless of their current condition.

Fish Passage

Culverts have a variety of factors associated with the ability for fish to pass through them, including perched outlets, high in-pipe velocity and/or turbulence, inadequate water depth, and excessive pipe length without fish resting space. Any of these can cause difficulties for fish movement and thus adversely affect their habitat, natural range, and ability to spawn. On Minnesota's Public Waters, culverts shall provide for fish movement unless the structure is intended to impede rough fish movement or the stream has negligible fisheries value. The current GP2004-0001 has the following requirement for fish passage:

> Bridges, culverts and other crossings shall provide for fish movement unless the structure is intended to impede rough fish movement or the stream has negligible fisheries value as determined by the Transportation Hydrologist or Area Hydrologist in consultation with the Area Fisheries Manager. The accepted practices for achieving these conditions include:
>
> A. Where possible a single culvert or bridge shall span the natural bankfull width adequate to allow for debris and sediment transport rates to closely resemble those of upstream and downstream conditions. A single culvert shall be recessed in order to pass bedload and sediment load. Additional culvert inverts should be set at a higher elevation. All culverts should match the alignment and slope of the natural stream channel, and extend through the toe of the road side slope. "Where possible" means that other conditions may exist and could take precedence, such as unsuitable substrate, natural slope and background velocities, bedrock, flood control, 100yr flood elevations, wetland/lake level control elevations, local ditch elevations, and other adjacent features.
>
> B. Rock Rapids or other structures may be used to retrofit crossings to mimic natural conditions.

Traditionally, culvert design was based on hydrologic and hydraulic models that predict peak runoff from a watershed, with the culvert sized accordingly to pass a specified design storm. Fish passage was not always addressed with these designs. Several alternative design methods have been developed that focus on matching the natural characteristics, and consider sediment transport and fish passage requirements. These recent improvements to hydraulic design practices may also reduce the frequency of scour at pipe outlets in many areas. Other potential benefits include lower maintenance costs, longer life span, and better sediment and erosion control. Alternative designs or simulation techniques inherently take fish passage into account by addressing issues of low flow, hydraulic variability and sediment transport. A variety of design techniques are being implemented in Minnesota where fish passage is a concern.

Culvert Design Approaches

Open bottom span: Open bottom structures are not considered as restricting flow or impinging upon the channel cross sectional area. These structures are generally not considered an impediment to fish movement in Minnesota.

Conventional Hydraulic Design: Culverts sized to pass a specified design storm event (e.g., 10 years peak flow) with no consideration given to fish passage needs.

Hydraulic Design for Fish Passage: Techniques that create water depths and velocities to meet the swimming abilities of target fish populations. This approach considers the flow requirements (eg: maximum velocity, sustained velocity, flow depth, etc) needed by specific species. The goal is to keep the velocity below a set of thresholds corresponding to a fish's maximum swim speed, sustained swim speed, and related measures. This is the method for meeting the frequent DNR requirement of: 'Velocities of the 2-year 24-hour event shall not exceed 2 feet per second".

FHWA has the publication 'HEC-26' that utilizes the hydraulic design approach to select culvert size and bedload material. HEC-26 presents a mathematical design procedure, methods, and best practices for designing roadway culverts to facilitate aquatic organism passage (AOP). http://www.fhwa.dot.gov/engineering/hydraulics/pubs/11008/hif11008.pdf.

Hydraulic Simulation: Hydraulic design approaches that simulate natural hydraulics of streams by adding rock or roughness elements to simulate natural hydraulic variation within or adjacent to the culvert. Typically these include placement of rock on the floor of the culvert or placement of rock rapids below the outlet to create pools and riffles, etc.

Stream Simulation (Geomorphic Design): Design approaches that recreate or allow natural channel morphology and sediment transport. In Minnesota, two differing methods are being utilized.

1. ‘**MESBOAC**’ was developed in the northern forested region of Minnesota and is based on principles of fluvial geomorphology rather than individual fish swimming ability. **MESBOAC** aims to match the culvert width with natural stream dimensions, while maintaining sediment balance (sediment in = sediment out). In addition to burying the culvert bottom below the streambed to provide for a natural substrate in the culvert, it also provides a low-flow channel that is important for late season migrations which occur from August to November. MESBOAC assumes that since the natural flow characteristics are maintained, fish passage will occur. See Appendix A for more information on MESBOAC methods.

MESBOAC stands for:

Match culvert width to bankfull stream width.
Extend culvert length through the side slope toe of the road.
Set culvert slope the same as stream slope
Bury the culvert
Offset multiple culverts.
Align the culvert with the stream channel.
Consider headcuts and cutoffs.

2. The Aquatic Organism Passage (AOP) program is a broader ecosystem-based design approach developed by the USDA Forest Service for designing and constructing a channel through the road-stream crossing structure based on physical and ecological continuity along the stream corridor. The premise of stream simulation (AOP) is that the culvert be large enough for a channel to be constructed within the crossing that simulates the dimensions and characteristics of the adjacent natural channel. Therefor, fish and other aquatic organisms should experience no greater difficulty moving through the structure than if there were no road crossing. Identifying a ‘reference reach’ is a key concept and component of stream simulation as it provides the natural template for designing a channel through the crossing and determining the size and embedment depth of the replacement structure. The manual ‘**Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings’** is located here: http://www.stream.fs.fed.us/fishxing/aop_pdfs.html.
A copy of the published report on a summary of this program is in Appendix A (Stream Simulation for Aquatic Organism Passage at Road-Stream Crossings, by Cenderelli, Clarken, Gubernick and Weinhold).

Note: The link to the FishXing program that is embedded in the AOP website is a culvert assessment tool for aquatic organism passage. The program models various organisms capabilities against culvert hydraulics across a range of expected stream discharges. AOP methodology does not require a check on velocities since it uses reference conditions in the stream to emulate a crossing that has the proper context with its surrounding profiles.

MESBOAC and AOP are similar in the use of bankfull width determination, though differ in determination of slope and invert elevations for a culvert.

MESBOAC utilizes a line connecting the thalweg riffle elevations from upstream and downstream of the crossing to set culvert slope and elevation.

In addition to utilizing riffle elevations, the AOP program methodology incorporates pool depths, stable control points, and other vertical control points in the steam (bedrock, pool-tailcrests, and large woody debris) to determine a streambeds potential upper and lower vertical adjustment profile (VAP) to which the culvert invert and slope are determined.

Summaries of both methods are located in Appendix A

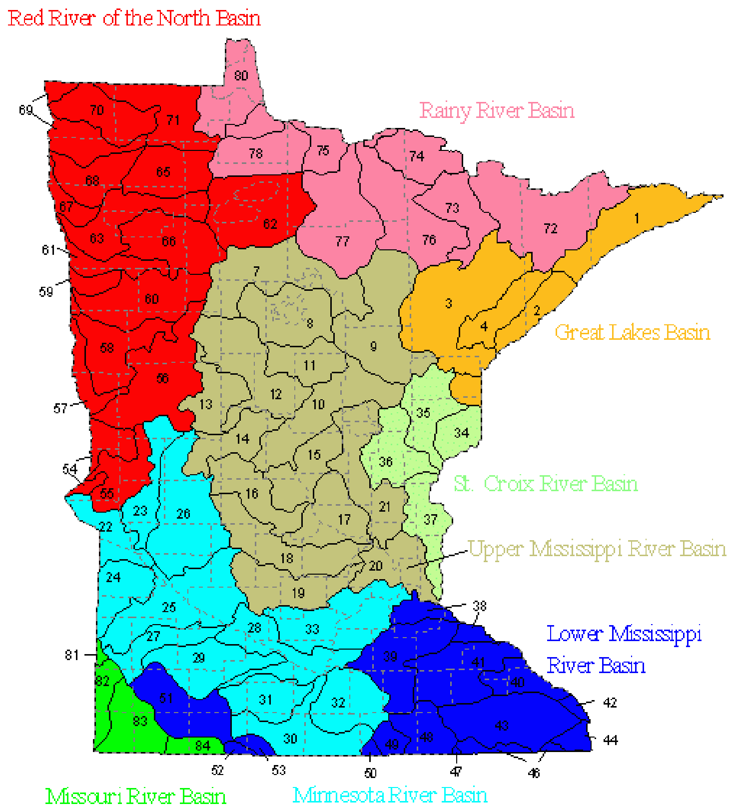
Floodplain Connectivity: In addition to the above, there is growing attention in the concept of ‘floodplain culverts’. These culverts are set in the floodplain, away from the main channel and are dry, except in flood conditions. It is gaining interest for use within floodplains, and in areas with woody debris or ice issues. An initial study by the DNR is located here: http://files.dnr.state.mn.us/eco/streamhab/geomorphology/reducing-rior.pdf

Please contact the DNR Area Hydrologist for design information at the earliest stages of project development. Determining the appropriate design method is influenced by project objectives. Consideration for fish passage, other aquatic organisms, rare species, invasive species, habitat protection/restoration, wildlife passage, traffic (road safety), funding limits, adjacent property and right-of-way limits, floodplain ordinances and other regulatory requirements (e.g., wetland protection) are to be considered.

Key Fish Populations by Major Watershed*

The figure and chart below show key fish populations that may impact crossing design. * From the 'Final Report - Cost Analysis of Alternative Culvert Installation Practices in Minnesota, June 2009', by B. Hansen, J. Nieber, and C. Lenhart. For the full report see the U of Minnesota, Center for Transportation Studies, report #2009-20, http://www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=1796

MAJOR BASINS AND WATERSHEDS OF MINNESOTA



Major river basins in Minnesota and fish passage issues

Name	Key fish	Geomorphology	Other issues
Great Lakes	Chinook salmon, Lake trout,	High gradient, cobble beds	Fall spawning
Upper Mississippi	Walleye, bass, pike	Mod gradient, sand-gravel bed	
Minnesota River	Catfish, smallmouth bass,..	Low gradient, sand/fines bed	
St. Croix River	Smallmouth bass, sturgeon…	Moderate gradient	
Lower Mississippi	Brook & brown trout, smallmouth bass	High gradient tribs, low gradient in Mississippi	Brook & brown Trout spawn in fall; highest fish diversity of all basins
Red River	Sturgeon, pike	Low gradient	agriculture
Rainey River	Lake trout, smallmouth bass, walleye	Moderate gradient, gravel bed	BWCA wilderness, forestry
Missouri River	Topeka Shiner	Prairie streams	Endangered species

Grade Control

Miller Creek at TH53 crossing, Duluth

Grade control structures may be beneficial to add to a stream crossing design. They can be used to protect: a) single span bridge pilings from scour, b) provide grade control to prevent head-cutting where past undersized and/or perched culverts have caused upstream aggradation and downstream degradation, c) create slower velocity backwater type habitat for fish passage, or d) direct flow away from a bank. There are several sources of information for design of grade control structures.

The development of Rock Rapids (Rock Ramps) in Minnesota has been primarily due to the removal of dams. However, this practice is increasingly being utilized for grade control to retrofit culverts that are perched at the outlet. The DNR publication **'Reconnecting Rivers: Natural Channel Design in Dam Removal and Fish Passage'** provides information on the concept of this practice and has case examples to illustrate technical problems that may be encountered in such design. http://www.dnr.state.mn.us/eco/streamhab/reconnecting_rivers.html.

Other reports:
"Stream Restoration in the Vicinity of Bridges", by P. Johnson, R. Hey, E. Brown, and D. Rosgen.", Journal of the American Water Resources Association Vol 38, No1 February 2002
http://www.wildlandhydrology.com/assets/SRITVOB.pdf

"The Cross-Vane, W-weir and J-Hook Vane Structures, by D. Rosgen."
http://www.wildlandhydrology.com/assets/cross-vane.pdf

The report "**DESIGN METHODS FOR IN-STREAM FLOW CONTROL STRUCTURES"** on the results and recommendations from a study on the performance of in-stream flow control structures, conducted by the St. Anthony Falls Laboratory (SAFL) at the University of Minnesota (UMN) is in the final stages of publication. National Cooperative Highway Research Program (NCHRP) NCHRP Project 24-33 will be published at any time. See:
http://apps.trb.org/cmsfeed/trbnetprojectdisplay.asp?projectid=1641

Hydrologic/Hydraulic Data Reporting

A Hydrologic/Hydraulic report will be required for the construction or replacement of Public Waters crossings. If an approved Flood Insurance Study (FIS) exists, the FIS shall be used as a basis for the calculations for the crossing. Any variance shall be approved by the applicable DNR Hydrologist. The Hydrologic/Hydraulic Data should be provided in the format as shown. If a Flood Insurance Study is used as a basis for the report, information including Title and Date of the FIS shall be included.

		When reporting, replace text in this column with project data	
	Vertical Datum	Datum of survey information	ft
*	Stream Name	Name of stream	
	Drainage Area	Area of watershed contributing to the site	mi^2
	Flood of Record	Maximum observed discharge, date of occurrence, and any other notes	ft^3/s
(a)	Maximum observed highwater elevation	Highest recorded water elevation, date of occurrence, and any other notes	ft
*	Design flood ([example:50] year frequency)	Design discharge and design frequency	ft^3/s
(b)	Road sag point elevation	Roadway low point elevation used to determine overtopping flood frequency, note location	ft
	Stage	Water surface elevation (without crossing) taken at location where stage increase is calculated with design discharge	ft
	Total stage increase	Calculated stage increase for proposed structure with design flood	ft
*	Headwater elevation	Calculated headwater elevation for proposed structure with design flood	ft
	Stage increase of the inplace condition	Calculated stage increase for existing structure with design flood	ft
	Minimum Waterway opening		ft^2
	Below elevation		ft
(c)	Low member at or above elevation		ft
	Mean velocity through structure	Calculated mean velocity through proposed structure with design flood	ft/s
	Main channel velocity	Calculated main channel velocity for design flood	ft/s
*	Greatest flood (500-year frequency or overtopping)	500-yr flood discharge or roadway overtopping discharge (if less than 500-year)	ft^3/s
(b)	Road sag point elevation	Roadway low point elevation used to determine overtopping flood frequency	ft
	Stage	Water surface elevation (without crossing) taken at location where stage increase is calculated with overtopping or 500-year flood	ft
	Total stage increase	Calculated stage increase for proposed structure with overtopping or 500-year flood	ft
*	Headwater elevation	Calculated headwater elevation for proposed structure with overtopping or 500-year flood	ft
	Stage increase of the inplace condition	Calculated stage increase for existing structure with overtopping or 500-year flood	ft
	Mean velocity through structure	Calculated mean velocity through proposed structure with overtopping or 500-year flood	ft/s
	Main channel velocity	Calculated main channel velocity for overtopping or 500-year flood	ft/s

*	Basic flood (100-year frequency)	100-year flood discharge (1% annual chance flood)	ft^3/s
	Stage	Water surface elevation (without crossing) taken at location where stage increase is calculated with 100-year flood	ft
	Total stage increase	Calculated stage increase for proposed structure with 100-year flood	ft
*	Headwater elevation	Calculated headwater elevation for proposed structure with 100-year flood	ft
	Stage increase of the inplace condition	Calculated stage increase for existing structure with 100-year flood	ft
	Minimum overflow area above sag point elevation	Overflow area over roadway sag point elevation	ft
	Mean Overflow velocity	Calculated mean velocity over roadway	ft/s
	Mean velocity through structure	Calculated mean velocity through proposed structure with 100-year flood	ft/s
	Main channel velocity	Calculated main channel velocity for 100-year flood	ft/s
**	2-year flood frequency	Flow for the 2-year flood	ft^3/s
**	Average velocity through structure	Calculated velocity at mid-length of structure	ft/s
**	Main channel velocity	Calculated main channel velocity of 2-year flood	ft/s
	Approximate flowline elevation	Elevation of flowline at inlet of structure	ft
	Skew	Angle of structure to roadway	^{o}
	Riprap size	Required class of riprap at outlet of structure	

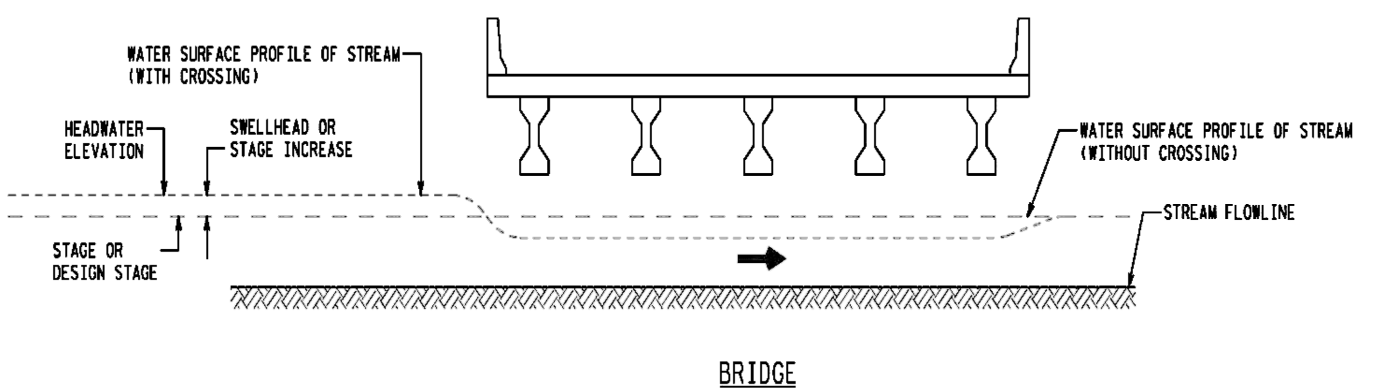
* Items to be shown on grading plan

** Calculations showing velocities through the structure at 2-year peak flow may be required for fish passage considerations (typically only required on culverts).

(a) Any notes on event or location of highest known water elevation

(b) Any notes on location of low point in the road (sag location)

(c) Any notes on low member elevation, required on DNR canoe routes (typically 3' minimum clearance above 50yr for DNR requirements). Also note high-low and low-low elevation points if sloped bridge.



Reporting Impacts to Flood Elevations

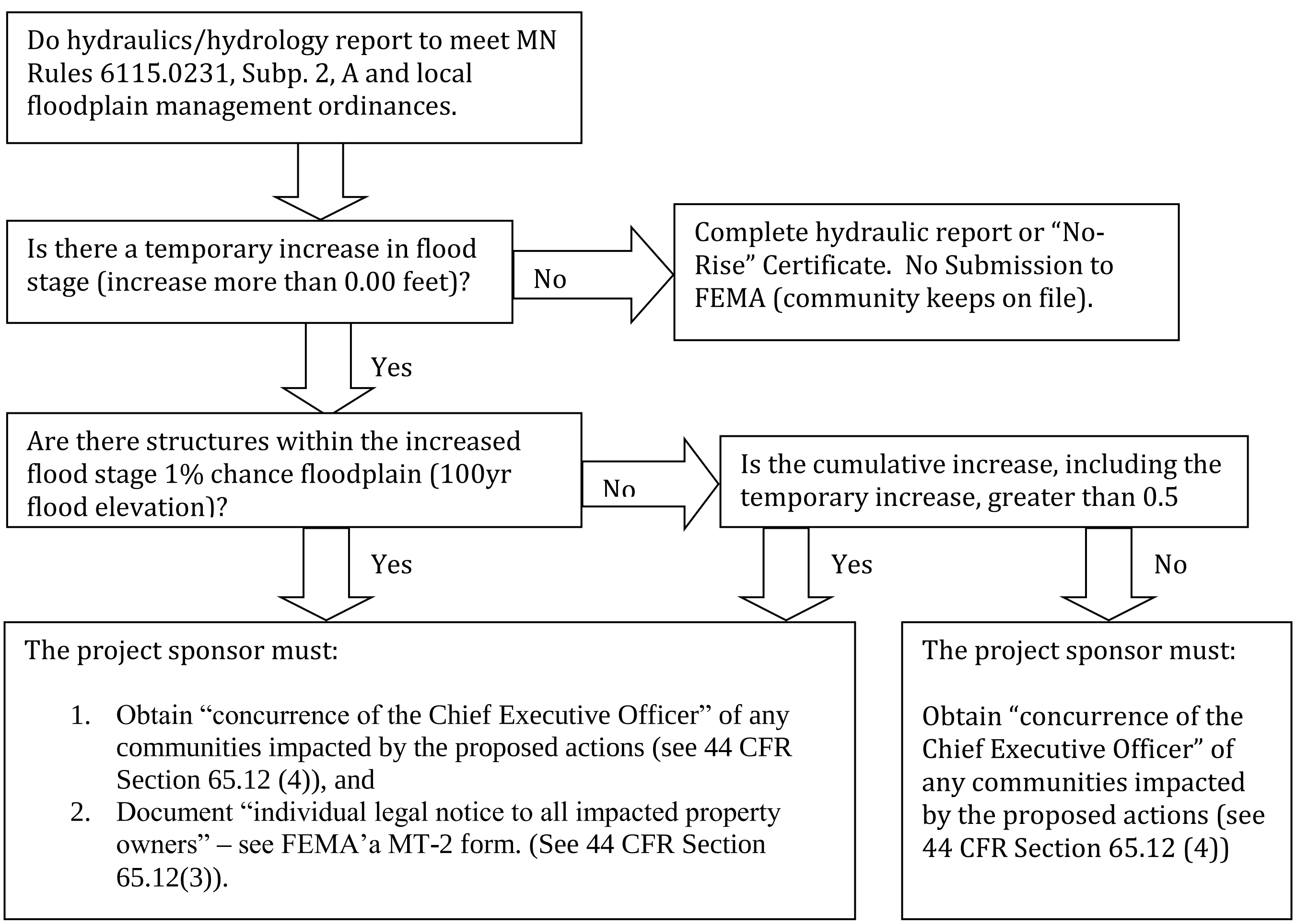
The following flow charts are for use in determining correct forms for reporting impacts within areas designated as 100-year (1% annual chance) floodplain by the Federal Emergency Management Agency (FEMA). These flow charts focus on road crossing hydraulics and not overall floodplain ordinance compliance. Zones A and AE are identified on official FEMA maps as areas subject to inundation by the 1% annual chance flood (100yr flood event). Zone X identifies areas subject to inundation by the 0.2% annual chance flood (500-year flood event) and is not regulated under DNR Public Waters Rules and are not mandated for protection by FEMA. However, some Local Units of Government (LUG's) have chosen to be more restrictive than the federal/state regulations. The LUG zoning administrator should be contacted whenever proposing projects within designated floodplain areas.

The following flow charts, plus more information is located at:
http://www.dnr.state.mn.us/waters/watermgmt_section/floodplain/fp_resource_material.html

Bridges & Culverts
Temporary** stage increase (construction related) in AE Zones

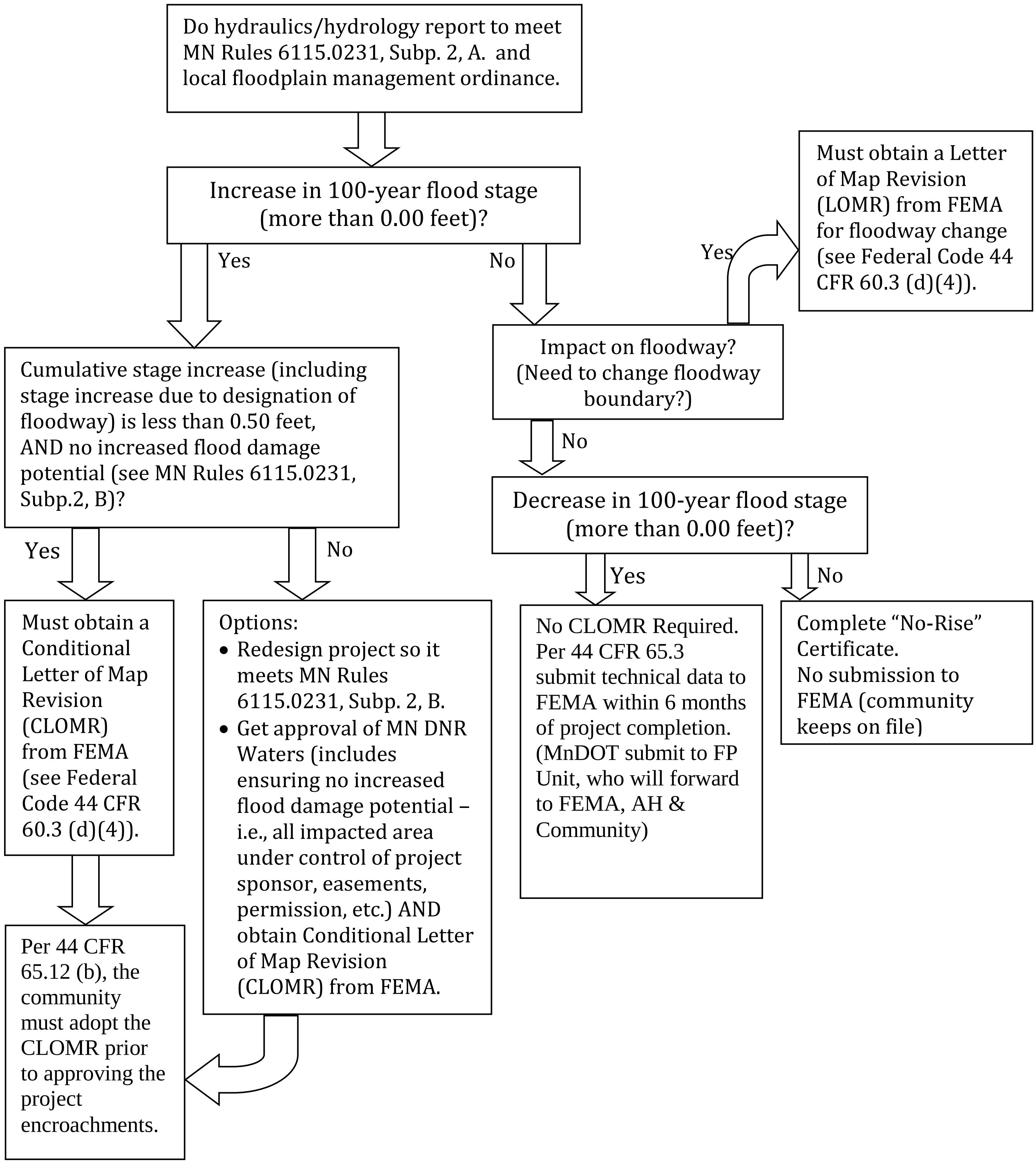
'AE Zones' are designated 100 year (1% annual chance) floodplain areas where an approved detailed flood study has generated flood profiles for various events along with a mapped floodway.

**'Temporary' is typically defined as less than one year.



NEW Bridges & Culverts
Floodplain Reporting Requirements in FEMA's AE Zones

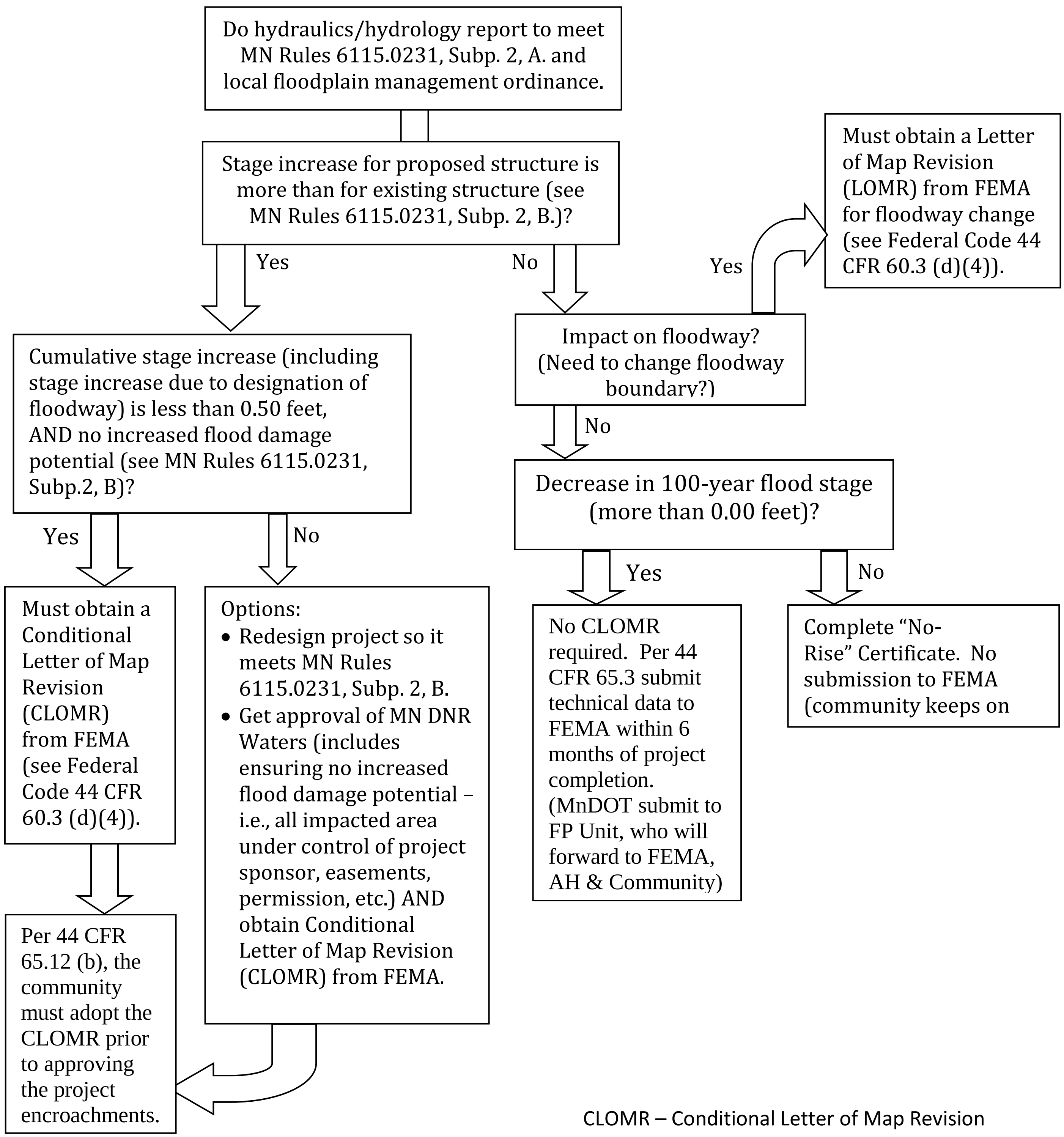
'AE Zones' are designated 100 year (1% annual chance) floodplain areas where an approved detailed flood study has generated flood profiles for various events along with a mapped floodway.



CLOMR – Conditional Letter of Map Revision
LOMR – Letter of Map Revision

REPLACEMENT Bridges & Culverts
Floodplain Reporting Requirements in FEMA's AE Zones

'AE Zones' are designated 100 year (1% annual chance) floodplain areas where an approved detailed flood study has generated flood profiles for various events along with a mapped floodway.



CLOMR – Conditional Letter of Map Revision
LOMR – Letter of Map Revision

Bridges & Culverts – Floodplain Requirements in FEMA's A Zones

'A zones' are designated 100 year (1% annual chance) floodplain areas where a detailed flood study has not been done.

Do hydraulics/hydrology report to meet MN Rules 6115.0231, Subp. 2, A. and local floodplain management ordinance.

Note: If associated with development of > 5 acres and/or 50 lots, detailed study is required (44 CFR 60.3, (b), 3.)

↓

Change in 100-year flood stage (increase or decrease of more than 0.00

No → Complete hydraulic report or "No-Rise" Certificate. No submission to FEMA (community keeps on file)

Yes ↓

Construction conditions*	Permanent conditions
• Stage increase for proposed structure is equal to or less than for existing structure, OR • Cumulative stage increase is less than 1.0 feet AND no increased damage potential (see MN Rules 6115.0231, Subp. 2, B.)?	• Stage increase for proposed structure is equal to or less than for existing structure, OR • Cumulative stage increase is less than 0.50 feet AND no increased damage potential (see MN Rules 6115.0231, Subp. 2, B.)?

Construction conditions – Yes → No submission to FEMA. Construction conditions removed prior to predicted flood conditions.

Permanent conditions – Yes → No submission to FEMA. Community keeps data on file and tracks portion of 0.5 foot surcharge used.

No ↓

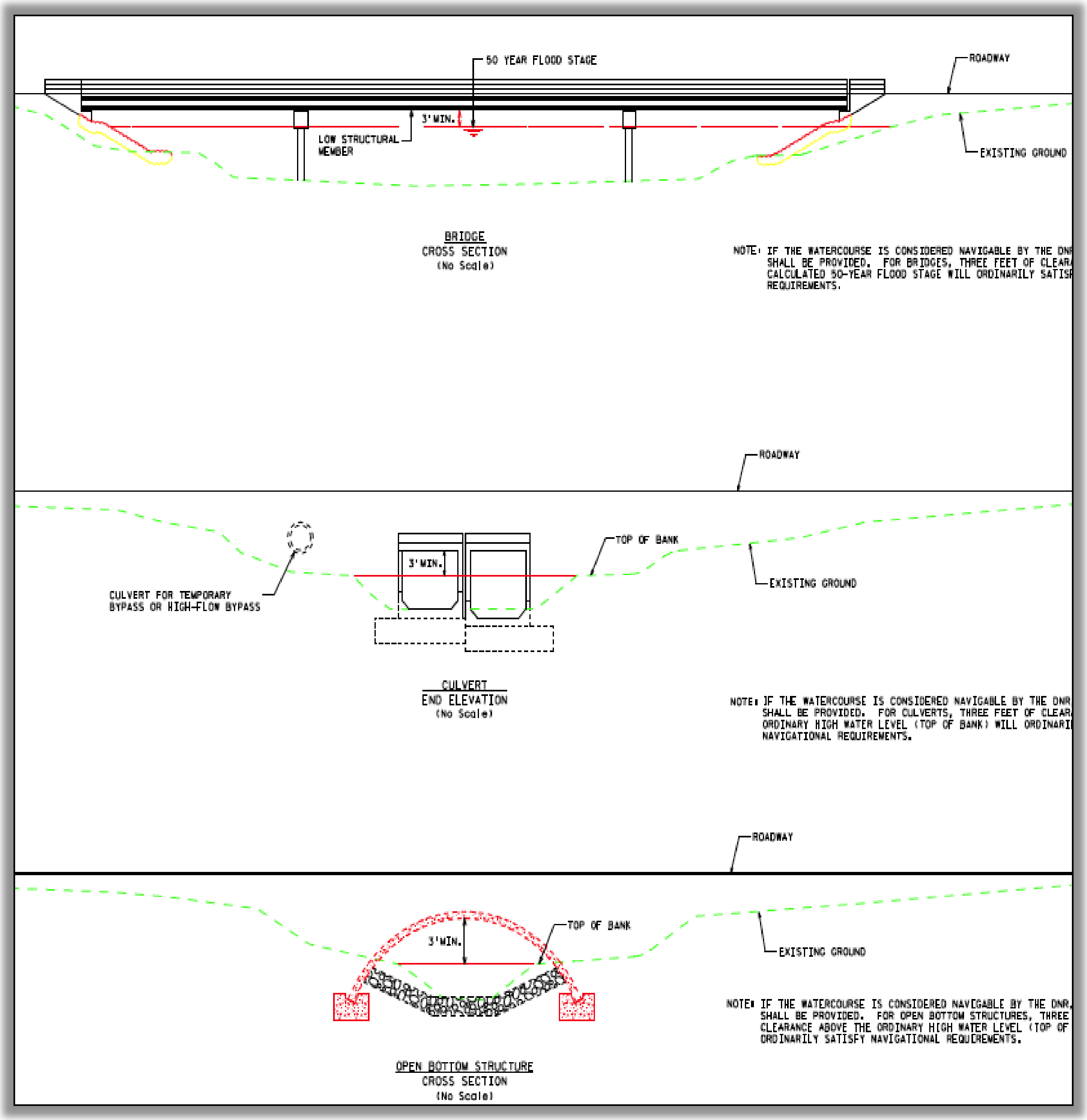
Options:

- Redesign project so it meets MN Rules 6115.0231, Subp. 2, B.
- Get approval of MN DNR Waters (includes ensuring no increased flood damage potential – i.e., all impacted area under control of project sponsor, easements, permission, etc.)

* Construction conditions are those that are very short in duration, such as where stream blocks, diversions, or temporary crossings, are in place during construction of permanent structures. Construction conditions are removed when the permanent structure is completed, or should a flood be predicted.

Navigation Requirements

For waters with commercial navigation, the DNR defers to the US Corps of Engineers and the US Coast Guard for navigational requirements. For other rivers and lakes and streams, to meet DNR navigation requirements, clearance of three feet above the; 1) Ordinary High Water Elevation (OHW), or 2) top of the adjacent bank, or 3) 50-yr flood stage elevation, will ordinarily satisfy DNR requirements. In no case should waters with navigation be re-designed with reduced clearance



State Water Trails

For an interactive trail map with links to individual canoe route information, go to: http://www.dnr.state.mn.us/watertrails/location_map.html

Crossings of canoe routes must be evaluated for navigation clearance. Generally 3 ft above the 50 yr event, OHW, or top of the bank is sufficient for recreational navigation (see previous page).

Best Practice: Road Projects near State Parks, State Trails or Public Access's should be considered as opportunities for joint MnDOT-DNR projects, such as improved access and parking facilities.

State Trails

Interactive trail maps are located here: http://www.dnr.state.mn.us/state_trails/map.html

For Public Access locations by county: http://www.dnr.state.mn.us/water_access/counties.html

For snowmobile trail maps, go here: http://www.dnr.state.mn.us/snowmobiling/maps.html

Bridge Scuppers

Scupper definition: A vertical hole through a bridge deck for the purpose of deck drainage. Sometimes, a horizontal opening in the curb is called a scupper.

MnDOT Road Design Manual, Chapter 8 (Drainage Design & Erosion Control) section 8.5.6, provides the following Design information regarding drainage of bridge decks:

> *Drainage of bridge decks is similar to other curbed roadway sections. Deck drainage is often less efficient, because cross slopes are flatter, and small drainage inlets or scuppers have a higher potential for clogging by debris. Because of the difficulties in providing and maintaining adequate deck drainage systems, gutter flow from roadways should be intercepted before it reaches a bridge. In many cases, deck drainage must be carried several spans to the bridge end for disposal.*
>
> *Zero gradients and sag vertical curves should be avoided on bridges. The minimum desirable longitudinal slope for bridge deck drainage should be 0.5 percent. If a sag curve cannot be avoided, the sag should not occur directly over a water body unless it is a treatment pond. Deck drainage can generally not be discharged directly to a water body without providing a pond or other means of intercepting a hazardous spill. Runoff should be handled in compliance with applicable stormwater quality regulations.*
>
> *The use of scuppers should be evaluated for site-specific concerns. Scuppers should not be located over embankments, slope pavement, slope protection, navigation channels, driving lanes, or railroad tracks. For bridges that require deck drains, it may be necessary to provide a drainage system on the bridge to convey water off the bridge.*

Chapter 8 of the MnDOT Road Design manual can be downloaded from:
http://www.dot.state.mn.us/design/rdm/metric/8m.pdf

The above guidance is generally adequate for DNR concerns. However there may be site specific concerns (EG Areas of Environmental Sensitivity) that will require drainage treatment systems. When water is directed off the bridge and back past the abutments, there may be retrofit options in the road ditch prior to discharge to the stream.

Culvert Liners

County 43, Mayhew Creek, Benton County

Lining a failing culvert is a common alternative to complete replacement of the structure. The DNR evaluates culvert projects on Public Waters to ensure there are no adverse impacts associated with this practice. Potential adverse impacts on stream hydrology or ecology are:

a. Permanent changes to velocity, water elevations, or invert elevation may occur due to the reduced culvert size, or
b. Temporary impacts due to discharge of construction precipitate created by the installation process. This could have adverse impacts to fish populations (e.g. fishkill).

Culvert lining projects typically occur on smaller culverts. These tend not to be on Public Waters and are not in DNR Public Waters jurisdiction. However they are occurring on Public Waters with increased regularity. In general, DNR will request a culvert to be assessed for complete replacement (under current design recommendations) prior to authorizing a culvert lining project.

1. There are three general types of culvert lining projects.

    a. Cured in place plastic (CIPP) liners. These are essentially a flexible plastic tube that is inflated inside the pipe (like a balloon). Cured in place liners are thin (about an inch) and are intended to bond with the existing culvert wall.
    b. Hard pipe liners. Smaller diameter pipes are slid through the existing opening and the outside void is filled with expansion foam or other suitable material (e.g. cement slurry). The new pipe material may be plastic, metal or concrete.
    c. Spray on liners or overlays. Either concrete or resin based materials may be applied to existing walls or floors for spot repairs or a complete lining. Thicknesses vary by material and the pre-existing culvert condition.

2. Potential implications of center-line culvert lining projects:

a. Hydraulics (water elevations and velocities) of the stream through a road is altered due to a liners smaller opening. Culvert lining projects should not adversely impact flood elevations or control elevations of upstream water basins. On corrugated metal pipes, a CIPP liner is generally self-mitigating as the slightly smaller diameter is compensated by the liners smoothness (change in Manning's 'n' value). However, an increase of velocity may compromise fish passage on currently marginally passable culverts.
b. Liners will raise the culvert inverts slightly. On culverts with inverts above the stream profile (perched), this will make the perched situation worse and may compromise fish passage,
c. Scour may be an issue. Increased velocity may increase the scour potential at the outfall.

The DNR may ask for hydraulics information to evaluate the concerns above. There are situations where we have not allowed liners because of the increased velocities or changes to invert elevations can turn marginally fish passable culverts into impassable barriers. Total replacement may be required in these situations.

3. Lining projects on culverts that outfall into Public Waters:

    a. If a culvert outfall is not within the stream during normal water levels, fish passage is less of an issue, though #2 above still applies.

4. Liner methods may temporarily alter the chemical or thermal properties in the receiving water during the installation process, curing process, or initial flush. These by-products of installation have potential for adverse impacts to receiving waters. In extreme cases, impacts may result in a localized fish kill. To help assure that suitable containment or treatment prior to discharge to Public Waters is conducted, the following is recommended:

    a. Special Conditions to construction specifications should be written to prevent hot water precipitate or chemical containing precipitate (e.g. styrene or cement waste) from discharging into receiving waters.

    b. The following provision should be included on Public Waters permits for culvert lining projects: CULVERT LINER CONSTRUCTION METHODS: Liquid or other by-product waste resulting from the construction or curing processes of liner installation shall not be discharged into Public Waters.

TH61 Indian Camp Creek (Cook County)

TH61 Carlson Creek at normal flow after floor overlay and grade control installation downstream (Cook County)

(comment: Project was marginally successful, as velocities through the culvert were still very high post project)

Chapter 3. Methods of In-Water Construction

The following pages contain illustrations, notes, and guidance on Best Practices for in-water construction work. These methods have been pre-approved by the DNR for use in the field; however, not all methods are appropriate for all work sites. Note that in most cases the applicable DNR Hydrologist will have to approve a method prior to construction. For this reason project designers, construction engineers, project managers, or contractors should work in consultation with the DNR for selection and approval of the appropriate method of in-water construction.

(Public Water Access installation, Mississippi River at Hastings, Dakota County MN)

(Lowry Ave Bridge, Minneapolis, Hennepin County.   photo Peter Leete)

Demolition or Repair of Bridges over Water

The following is an overall checklist of items that may be required prior to (and during) bridge demolition or redecking repair:

Potential permits or notifications required:

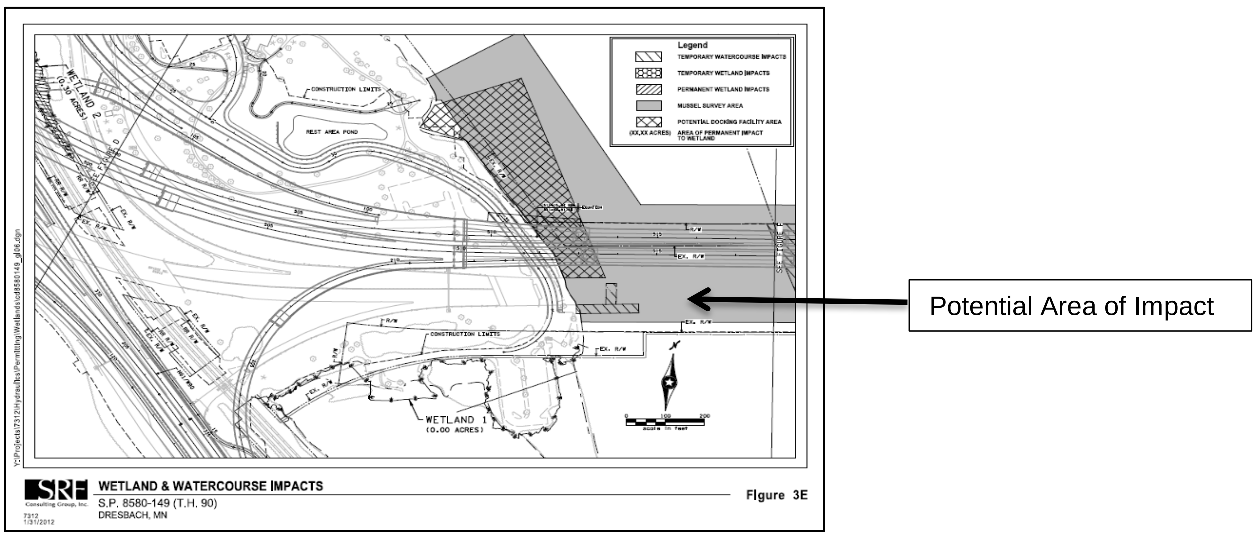
DNR Public Waters Work Permit
MPCA Asbestos Abatement Notification (14 day)
MPCA Demolition Notification (14 day lead time)
US Corps of Engineers
Watershed District Permits
DNR Temporary Appropriations Permit
MPCA Construction Site NPDES
MPCA 401 Water Quality Certification
US Coast Guard
Wetland Conservation Act (wetland impacts)

Check Work Exclusion dates for Staging/scheduling:

Work exclusion dates that protect fish migration and spawning limit the time allowed for work in the water. See Chapter 1, Page 3. These dates may affect work schedules. Also see Chapter 3, Page 11 for guidance on in-stream work methods, as some methods of construction will not be allowed if fish movement is a concern.

Identify Work Area Limits (Potential Area of Impact)

DNR permitting authorizations can be more efficient if both permanent impacts and temporary impacts are reviewed simultaneously. Often, temporary work areas are not known by regulatory authorities until after contract letting, as these areas may be determined by contractor after project letting. However, the project proposer should make attempts to define the potential area of impact for regulatory review at the onset of project development. Special provisions can be added to bid documents to constrain contractors to these areas. Thus avoiding a second round of review (and possible delays) should the contractor propose work outside the identified ‘Potential Area of Impact’. The potential area of impact should include areas of permanent disturbance plus those areas that may be disturbed temporarily during demolition or construction activities. This includes staging areas and in-water areas such as cofferdams, temporary fill for access, barge loading/unloading facilities, areas of spud pole use, or any other activity that could limit public use of the water or cause permanent or temporary impacts to the cross section of the lake or riverbed.



The early identification of the in-water ‘Potential Area of Impact’ is utilized by the DNR to review for all potential resources in or near the project area. This example shows the area identified by MnDOT for potential impacts. All resources were identified (including a native Mussel Survey) within this ‘box’ prior to permit review or amendment request, thus there is no need to re-survey resource concerns as the project moved from design to construction to in-water work proposals by contractor for demolition/construction. Thus project delay from redundant regulatory review of adjacent areas is avoided. Conversely the ‘potential area of impact’ is not expected to be completely impacted, though has a high enough possibility for some impact during construction that it should be included in the early review process.

Check for Protected Species and Ecologically Sensitive Areas.

Bird nests and mussel species are commonly encountered at bridges. The most common bird nests on bridges over water are Barn & Cliff Swallow nests. If swallow nests are present, the structure must be netted (figure 5) or use other suitable methods to prevent nesting should work be proposed during that time (Spring to early summer). Mussel Surveys may also be required prior to demolition. For questions regarding Threatened and Endangered Species, contact:

- DNR Natural Heritage Information System
  http://www.dnr.state.mn.us/eco/nhnrp/nhis.html
- or refer to MnDOT's Highway Project Development Process (HPDP)
  http://www.dot.state.mn.us/planning/hpdp/environment.html

Check for Regulated Materials.

An assessment/inspection must be done to identify regulated materials a minimum of 9 months before letting to set up assessment of bridge to be demolished, renovated, or moved. Additional information can be found on Chapter 3, page 6 or the MnDOT Office of Environmental Stewardship Regulated Material Management website: http://www.dot.state.mn.us/environment/buildingbridge/index.html

Check with MPCA Stormwater Program for Construction Activity.

MPCA administers the requirements of the National Pollutant Discharge Elimination System and the State Disposal System (NPDES/SDS) requirements. To ensure state water quality standards during construction are not violated, check with the MPCA Stormwater Program http://www.pca.state.mn.us/stormwater for permit application requirements, pollution prevention guidance documents, and additional measures required for work in Special or Impaired Waters.

The MPCA requires increased water quality protection measures on projects located within one mile of waters designated Special Waters and/or Impaired Waters. Check the interactive map called "Special Waters and Impaired Waters Search" located at

http://pca-gis02.pca.state.mn.us/csw/index.html

NPDES/SDS permits from MPCA for construction sites near specially-protected and impaired waters require additional controls, conditions or an individual permit:

a. Sites that discharge near waters with qualities that warrant extra protection (special waters) must use additional best management practices and enhanced runoff controls.
b. Sites that discharge near an "impaired water," impaired for phosphorous, turbidity, dissolved oxygen, and biotic impairment, must meet special conditions during project design and/or when preparing a Stormwater Pollution Prevention Plan (SWPPP), or a Construction Stormwater permit application.

Failure to incorporate increased protection measures on Special and/or Impaired Waters could be a violation of MPCA Water Quality regulations.

Demolition Notification.

MPCA Notification of Demolition is required at least 10 working days prior to demolition or re-decking repair (http://www.dot.state.mn.us/environment/buildingbridge/pdf/mpca-bridge-form.doc). Debris shall not be allowed to drop into the water without prior written approval of the appropriate DNR Hydrologist. Methods to contain materials and dust must be undertaken, such as:

- Demolition onto temporary access road or utilize barges. (ex: figure 1 &2).
- Cutting and lifting bridge pieces/sections when dropping into water is not allowed (ex: figure 3).
- Temporary work pads in the water for placing of equipment must meet guidance on Chapter 3 Page 13 (figure 6).
- Use of demolition debris may be offered for use by other federal, state, or local government for beneficial use.
- All regulated materials need to be managed appropriately.

Check for appropriate in-stream work methods.

The DNR or MPCA may limit types of construction methods based on natural resources or water quality concerns. Limitations should be written into project bid documents. See Chapter 3, Page 11 for guidance on in-Water construction methods.

Spill Containment.

Spill containment kits or supplies must be located on the site, near where potential spills could occur (figure7)

figure 1. Temporary causeway built for demolition and construction

figure 2. Barge use for capturing debris

figure 3. Cut and lifting sections instead of dropping debris

figure 4. Redundant BMPs for added protection of the waterway

figure 5. Net bridges prior to nesting season.

figure 6. Access pad with filter fabric pad and silt curtain for waterway protection.

figure 7. Spill Containment kit must be on site

MnDOT Assessment/Inspection for Regulated Materials

Prior to bridge demolition or repair, the bridge must be assessed for asbestos containing material, loose or peeling lead based paint, and other regulated materials such as treated wood, florescent bulbs, light ballasts, transformers and other electronic components. If the bridge contains asbestos, lead based paint or other regulated materials such as mercury or PCBs, the materials must be properly managed and disposed/recycled by MnDOT certified contractors and at MnDOT approved end sites. The inspector conducting the assessment must be licensed by the Minnesota Department of Health (MDH). The assessment will determine if the bridge contains regulated amounts of asbestos and other regulated materials. More information is located on the MnDOT's Office of Environmental Stewardship Regulated Materials and Waste website: http://www.dot.state.mn.us/environment/regulatedmaterials/index.html

Contact: MnDOT Districts 1,2,3,4 and Metro N or E:
Mark Vogel, MnDOT, Office of Environmental Stewardship.
Mark.Vogel@state.mn.us or 651-366-3630

Or

MnDOT Districts 7,8, and Metro S or W:
Jackie Klein, MnDOT, Office of Environmental Stewardship.
Jackie.Klein@state.mn.us 651-366-3637

Description: There are numerous regulations that apply to management and disposal of regulated materials/waste. The environmental management of asbestos and other wastes are regulated by the following agencies: US Environmental Protection Agency, US Department of Transportation, Minnesota Pollution Control Agency, and Minnesota Department of Health. These regulations place both short and long term liability on the owner or generator of the material/waste.

MnDOT Office of Environmental Stewardship coordinates with MnDOT approved contractors and regulatory agencies for proper notification and management of asbestos containing materials and other regulated waste. All assessments, sampling, testing, removal, transportation, and disposal will be done under oversight of MnDOT Office of Environmental Stewardship and performed by personnel certified by the Minnesota Department of Health and on MnDOT's certified contractor list.

Best Practice: **An assessment/inspection must be done to identify regulated materials. Contact Mark Vogel, MnDOT Office of Environmental Stewardship, a minimum of 9 months before letting to set up assessment of bridge to be demolished or redecked.** Information includes: SP#, TH#, bridge#, district contact, and bridge as-built plans. The Office of Environmental Stewardship will prepare contracts for structure assessment and oversight of asbestos removal procedure.

Note: For local projects, the same process is required, though local coordination with the MPCA is required (provide MPCA links for local folks here). The following materials shall be separated from general construction debris and treated accordingly:

- **Asbestos:** Asbestos Containing Material (ACM) will be removed prior to or during demolition
- **PCBs:** Polychlorinated Biphenyls (PCBs) will be removed from the bridge prior to demolition.
- **Mercury:** Material containing mercury will removed from the bridge prior to demolition.
- **Treated Wood:** Treated wood will be removed from the bridge prior to demolition.
- **Lead:** Lead plates will be removed and peeling or loose lead paint will be encapsulated or be removed prior to demolition

Typical regulated material and locations:

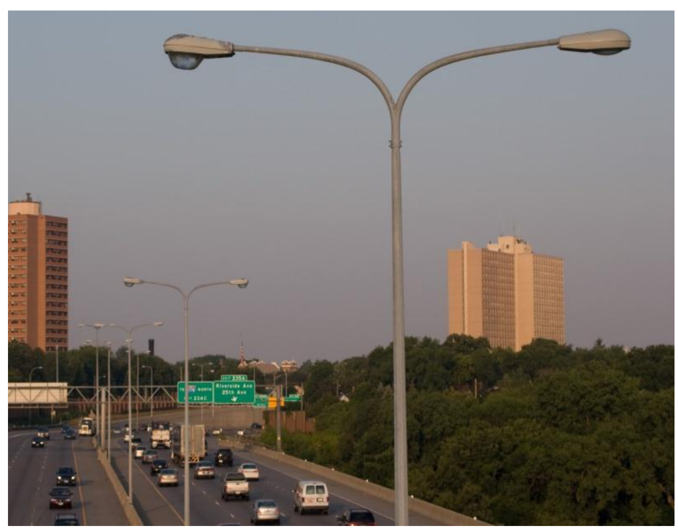
Wood preservatives

lead plates

deck materials & joint compounds

asbestos

lead paint



lighting ballasts

Erosion Prevention and Sediment Control

The following erosion prevention and sediment control requirements are taken from Part IV (Construction Activity Requirements) and Appendix A (Special Waters and Impaired Waters) of MPCA Permit #MN R100001 (General Permit Authorization to Discharge Stormwater Associated with Construction Activity under the National Pollutant Discharge Elimination System). The text has been reworded as a stand-alone document for meeting DNR GP 2004-0001 Erosion Prevention and Sediment Control requirements for in-water projects regardless if a MPCA permit is required or not.

1. A MPCA NPDES stormwater permit for construction activity (Permit #MN R100001) is required for any construction activity disturbing:

   a. One acre or more of soil.
   b. Less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre.
   c. Less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources.

   The requirements in this section are a subset of requirements of MPCA's Permit #MN R100001. As a standalone guidance document, parts A through G below may not meet all MPCA Construction Activity NPDES permit requirements. To ensure state water quality standards during construction are not violated, check with the MPCA Stormwater Program http://www.pca.state.mn.us/stormwater for permit application requirements, pollution prevention guidance documents, and additional measures required for work in Special or Impaired Waters.

2. Temporary work below the Ordinary High Water (OHW) elevation, such as channel diversions, placement of temporary fill, structures for work pads/dock walls, bypass roads, coffer dams, or staging areas to aid in the demolition or construction of any authorized structure shall be submitted for review and approval in writing by the DNR Transportation Hydrologist or Area Hydrologist prior to beginning work

3. The DNR may prohibit in-water construction if the project will be detrimental to water quality or significant fish and wildlife habitat. Erosion Prevention and Sediment Control practices that have been determined to be the most effective and practical means of preventing or reducing sediment from leaving the worksite are required. These practices shall be installed in areas that slope to the water and on worksite areas that have the potential for direct discharge due to pumping or draining of areas from within the worksite (EG coffer dams, temporary ponds, stormwater inlets). These methods, such as mulches, erosion control blankets, temporary coverings, silt fence, silt curtains or barriers, vegetation preservation, redundant methods, isolation of flow, or other engineering practices, shall be installed concurrently or within 24 hours after the start of the project, and will be maintained for the duration of the project in order to prevent sediment from leaving the worksite.

   a. Any cofferdams, turbidity barriers, or berms placed within Public Waters must be installed and maintained in a manner that does not allow soil erosion or deposition of soil or debris into the water. If they are constructed using earthen material, then sheet piling, armoring with riprap, or a synthetic cover such as silt curtain or filter fabric must be included to prevent their erosion. Upon removal of a cofferdam or turbidity barrier, the affected area must be restored to pre-project conditions.

   b. In-water sediment control measures must be properly installed prior to the authorized activities and must be maintained for the duration of the in-water disturbances. The chosen measures must be monitored to ensure turbidity or sedimentation are not occurring outside of the expected area of impact (work area). If the measures fail to contain sediment or turbidity the Permittee must immediately repair, replace or use an alternative measure, which will adequately control turbidity and sedimentation.

To aid in determining appropriate methods to be identified in a Storm Water Pollution Prevention Plan or Site Plan, see:

- The MPCA Stormwater Best Management Practices Manual 'Protecting Water Quality in Urban Areas' (www.pca.state.us/index.php/water/water-types-and-programs/stormwater/stormwater-management/stormwater-best-practices-manual.html), and
- The following section on 'Typical In-Water Construction Methods' of construction (Chapter 3, page 11).

A. SITE MANAGEMENT PLAN

A Storm Water Pollution Prevention Plan (SWPPP) is a document required by the MPCA for compliance to the Construction Stormwater Permitting requirements. A SWPPP is not required by the DNR, however it may be utilized as part of the site management plan for review and authorization for work authorized by DNR Public Waters Work Permitting. See GP2004-0001 condition 'TEMPORARY IMPACTS DURING CONSTRUCTION' and items 'A' though 'L' for subjected conditions.

The Permittee (or its contractor) must submit for approval a site management plan detailing proposed measures and schedules indicating construction operations. These must meet the requirements listed here in Parts A through G (also refer to Site Management Plan requirements in MnDOT Construction Specification 1717.2.D). The Best Practices selected to meet these requirements are to be identified in the plan. Following DNR approval, these practices must be installed and maintained in an appropriate and functional manner that is in accordance with relevant manufacturer specifications and accepted engineering practices.

1. The plan shall implement appropriate demolition and construction phasing, and other construction practices to prevent adverse impacts from debris, minimize erosion, and prevent sediment from leaving the worksite.
2. The location of areas not to be disturbed must be delineated (e.g. with flags, stakes, signs, fence, etc.) on site before work begins.
3. Other provisions of GP 2004-0001 may have requirements more stringent than those listed here. In such cases, the more stringent provision takes precedence (Example: selected practices shall not adversely affect endangered or threatened species, Areas of Environmental Sensitivity (see Chapter 1 page 10), or MPCA Special or Impaired Waters water quality requirements).

B. EROSION PREVENTION PRACTICES

1. In all cases, erosion prevention and sediment control methods that have been determined to be the most effective and practical means of preventing or reducing sediment from leaving the worksite shall be installed in areas that are within 200 feet of the water's edge and drain to these waters, and on worksite areas that have the potential for direct discharge due to pumping or draining of areas from within the worksite (EG coffer dams, temporary ponds, stormwater inlets). These methods, such as mulches, erosion control blankets, temporary coverings, silt fence, silt curtains or barriers, vegetation preservation, redundant methods, isolation of flow, or other engineering practices, shall be installed concurrently or within 24 hours after the start of the project, and shall be maintained for the duration of the project in order to prevent sediment from leaving the worksite. DNR requirements may be waived in writing by the authorized DNR staff based on site conditions, expected weather conditions, or project completion timelines.
2. For Designated Trout Waters, including all perennially flowing tributaries to the designated trout streams within the Public Land Survey (PLS) Section where the designated trout stream is located, the following also apply:
   a. Stabilization of all exposed soil areas must be initiated immediately to limit soil erosion but in no case completed later than seven (7) days after the construction activity in that portion of the site has temporarily or permanently ceased.
   b. Where possible, a 100 foot undisturbed vegetated buffer zone from the designated Trout Waters shall be preserved as part of the construction phasing, unless encroachment is necessary to complete the project.
   c. The permanent stormwater management system must be designed such that the discharge from the project will minimize any increase in the temperature of trout stream receiving waters resulting from the 1-and 2-year 24-hour precipitation events.
3. For areas not in Public Land Survey System (PLSS) sections with Designated Trout Waters, stabilization of all exposed soil areas must be initiated immediately to limit soil erosion whenever any construction activity has permanently or temporarily ceased and will not resume for a period of 14 calendar days.
4. Work exclusion dates (no work in the water during fish migration and/or spawning): Areas landward of the OHW may be worked during the DNR work exclusion dates (See Chapter 1 page 3). However, in areas that are within 200 feet of the Public Water OHW, and drain to these waters, must complete stabilization activities within 24 hours during this restricted work period.
5. Pipe outlets must be provided with temporary or permanent energy dissipation within 24 hours.

C. SEDIMENT CONTROL PRACTICES

1. Sediment control practices must be established before any shoreline or in-water disturbing activities begin.
2. Sediment control practices must minimize sediment from leaving the worksite. If the selected practices become overloaded, additional sediment control practices or redundant Best Practices must be installed to eliminate the overloading.
3. The timing of the installation of sediment control practices may be adjusted to accommodate short-term in-water activities.
4. Contributing curb or storm drain inlets must be protected by appropriate Best Practices during construction until all sources with potential for discharging sediment to Public Waters have been stabilized.
5. Temporary stockpiles must have silt fence or other effective sediment controls, and shall not be placed in

wetlands or surface waters.

6. Vehicle tracking of sediment off the construction site must be minimized.

D. WORKSITE DEWATERING

1. Worksite Dewatering (e.g., pumped discharges of coffer dams and other work areas,) related to the construction activity must be discharged to a temporary or permanent sedimentation basin on the project site. If the water cannot be discharged to a sedimentation basin prior to entering the surface water, it must be treated with the appropriate Best Practices, such that the discharge does not adversely affect the receiving water or downstream landowners. Sediment control devices can be bypassed when the discharge water appears clear.
2. Stream Diversion Water, such as a pumped bypass, shall be immediately returned to the original channel downstream. This water does not require treatment prior to discharge.
3. In either case (worksite dewatering or stream diversion water), practices must be in place to ensure that discharge points are adequately protected from erosion and scour.
4. All drain plugs on pumps shall be removed and all dewatering equipment, including hoses, shall be drained prior to transport off site (see Best Practices for Prevention of Spread of Aquatic Invasive Species, Chapter 1 page 8).
5. For construction dewatering amounts that exceed 10,000 gallons/day or 1 million gallons/yr, the permittee or their Contractors must submit a GP 1997-0005 Notification Form to the DNR at least 5 days prior to the start of pumping operations. Prior authorization to use General Permit 1997-0005 must be obtained by submitting an application using the **MNDNR Permitting and Reporting System**.
   a. **Note:** GP 1997-0005 is not valid for appropriations from surface water sources that are designated as infested waters unless accompanied by an Infested Waters permit or written notification from the Department that an Infested Waters permit is not required. For a current list of designated infested waters, see: http://files.dnr.state.mn.us/eco/invasives/infested_waters.pdf
   b. Application forms for an Infested Waters permit application are available at: http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/permits.html

E. INSPECTIONS AND MAINTENANCE

1. Either the Permittee, or whoever is identified in the SWPPP or Site Management Plan must routinely inspect the in-water work areas and determine the adequacy of existing measures. The MPCA requires this be conducted at least once every seven (7) days during active construction and within 24 hours after a rainfall event greater than 0.5 inches in 24 hours to ensure integrity and effectiveness of the selected practices.
2. All nonfunctional Best Practices must be repaired, replaced, or supplemented with functional Best Practices within 24 hours after discovery, or as soon as field conditions allow.
3. Should Best Practices fail, resulting in sediment deposition in Public Waters, the DNR shall be notified immediately. The Permittee and/or its contractor(s) must plan for corrective actions to remove all deltas and sediment deposited in Public Waters. Such a plan shall include DNR input, and removal and stabilization must take place within seven (7) calendar days of obtaining access. The Permittee and/or its contractor(s) is responsible for contacting all local, regional, state and federal authorities and receiving any applicable permits, prior to conducting any additional in-water work associated with delta removal.

F. POLLUTION PREVENTION MANAGEMENT MEASURES

1. Storage and disposal of hazardous waste must be in compliance with MPCA regulations.
2. Liquid and solid wastes must be disposed of properly and in compliance with MPCA regulations.

G. FINAL STABILIZATION

1. All soil disturbing activities must be stabilized by a uniform perennial vegetative cover, or other equivalent means necessary to prevent soil failure under erosive conditions. The DNR prefers that native vegetation (grasses, forbs, shrubs and/or trees) that is suitable to the local habitat to be utilized where appropriate. In some case it may be required as part of the mitigation package for the permitted project.
2. Note that the current MPCA Construction Stormwater General Permit (R1000001) language has a subtle change from previous permits regarding permanent vegetative cover (final stabilization). The requirement is now that uniform perennial vegetative must provide cover with a density of 70 percent of its ***expected*** final growth density over the entire pervious surface area. This should remove disincentive for using native vegetation in permanent cover plans because even though a native mix might take longer to reach full coverage, it could potentially reach 70% of its mature density in an amount of time comparable to what it takes a non-native mix to reach 70% of its mature density. See Chapter 1 page 14 for native vegetation best practices.
3. All temporary synthetic and structural erosion prevention and sediment control practices (such as silt fence) must be removed. Best Practices designed to decompose on site (such as some compost logs) may be left in place.

Typical In-Water Construction Methods

To facilitate construction in Public Waters, it is usually necessary that portions of the worksite be separate from open water and be relatively dry. There are several options available for providing a stable, dry work area during construction. The following options shall be considered for project construction. Several options may be suitable for any specific site. However not all options are suitable for all projects. Suitable options are to be determined based on the project size, required resource protection levels, and available materials.

In-water work methods will require prior written approval from the applicable DNR Hydrologist (Area Hydrologist). Below is a list of options for in-water work or stream diversions during construction.

For All Options:

1. Potential permits or notifications required: The following is an overall checklist of items that may be required prior to authorization of temporary in-water impacts for construction:
   - DNR Public Waters Work Permit
   - MPCA Construction Site NPDES Permit
   - MPCA 401 Water Quality Certification
   - US Corps of Engineers
   - US Coast Guard
   - Watershed District Permits
   - Wetland Conservation Act (wetland impacts)
   - Local Floodplain Zoning administrator

2. Check DNR work exclusion dates that protect fish migration and spawning (see Chapter 1 page 3). These dates may affect work schedules.

3. All equipment intended for use at a project site must be free of prohibited invasive species and aquatic plants prior to being transported into or within the state and placed into state waters. All equipment used in designated infested waters shall be inspected by the Permittee or their authorized agent and adequately decontaminated prior to being transported from the worksite. See Best Practices for Prevention of Spread of Aquatic Invasive Species, Chapter 1 page 8).

4. Check navigation requirements for the effected waterway (see chapter 2, page 22).

5. MPCA may have designated a Public Water as a Special Water and/or an Impaired Water. The MPCA requires increased water quality protection measures on projects located within one mile of waters designated Special Waters and/or Impaired Waters. To determine if Special or Impaired waters are near the project area, check the interactive map "Special Waters and Impaired Waters Search" located at:

   http://pca-gis02.pca.state.mn.us/csw/index.html

   To determine MPCA design requirements for work in Special Waters and/or Impaired Waters, go to the MPCA Stormwater Program for Construction Activity website:

   http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/construction-stormwater/construction-stormwater.html

6. A mussel survey may be required prior to authorization of work in the water. Generally streams with native mussel populations are the larger streams or rivers.

7. Dewatering. A separate water use permit is required for withdrawal of more than 10,000 gallons of water per day or 1 million gallons per year from surface water or ground water. GP1997-0005 (temporary water appropriations) covers a variety of activities associated with road construction and should be applied if applicable. An individual appropriations permit may be required for projects lasting longer than one year or exceeding 50 million gallons. Information is located at: http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/permits.html However, in all cases:
   a. In-stream pump intakes shall be fitted with screens, filter geotextiles, rock berms, or similar to prevent fish from being drawn into the system.
   b. Keep stream diversion water separate from worksite water (diverted stream water does not require treatment prior to discharge).
   c. Stream diversion water must be returned to the original channel downstream.

d. All worksite water requires treatment prior to discharge.
e. All discharge points shall be adequately protected from erosion and scour by use of riprap, plastic sheeting, geotextiles, plywood, existing vegetation, or suitable alternatives.
f. Sediment control devices can be by-passed when discharge water appears clear.
g. Pumps are to be sized for a typical storm event for the time period when work is proposed, commonly a 2 year – 24 hour event.
h. A second pump of the same size should be on site for contingency purposes.
i. All drain plugs shall be removed and hoses drained prior to transport off site.

8. Any temporary in-water construction methods, such as cofferdams, turbidity barriers, berms, or access facilities (EG temp access roads, workpads, temporary barge facilities) placed within Public Waters must be installed and maintained in a manner that they do not lead to streambank erosion or allow sediment to leave the worksite. If they are constructed using earthen material, then sheet piling, armoring with riprap, or a synthetic cover such as silt curtain or filter fabric must be included to prevent their erosion and creation of sediment. Erosive slopes must be stabilized with aggregate, slash mulch, or comparable non-erosive material. In-water materials may consist of any number of alternative measures:
    a. Rock burrito [washed rock wrapped in geotextile].
    b. Earthen berm – only allowed when there is no sediment issue to surrounding areas such as fish habitat or Areas of Environmental Sensitivity (see Chapter 1, page 10). The MCPA has regulations prohibiting earthen berm use on waters designated as Special Waters or Impaired Waters
    c. Silt curtain
    d. Heavy duty silt fence (jersey barriers)
    e. Sand bags (large or small)
    f. Water dams (such as the Aqua Barrier)
    g. Sheet piling
    h. Cookie cutter barrier (large sheets of metal or plywood pressed into the ground)

   If approved, temporary fill shall be free of organic material or any material that may cause siltation or pollute the waterbody. All such material shall be removed and the area restored to pre-existing profiles prior to project completion.

9. Hydrologic modeling of temporary fill or temporary structures may be required by DNR Transportation Hydrologist or Area Hydrologist in order to evaluate impacts to the 100-yr (1% chance) flood elevation. Contingency plans may also be required to ensure all construction equipment and unsecured construction materials are moved out of the floodplain to prevent impacts to the 100-yr (1% chance) flood elevation or from being swept away by flood waters.

10. Diversion structures or cofferdam construction placed in the water should be constructed and maintained so not to cause scouring conditions.

11. Project materials must be deposited or stored in an upland area, in a manner where the materials will not be deposited into the public water by reasonably expected high water or runoff.

12. Spill containment kits or supplies must be located on the site, near where potential spills could occur.

13. Site Restoration. All in-stream materials shall be removed upon project completion. The impacted area must be restored to the original cross-sections and existing shoreline restored. Revegetation plans must be reviewed in consultation with the landowner and the DNR. It is common that the DNR require revegetation of disturbed soil with native plant species suitable to the local habitat (grasses, forbs, shrubs, and/or tress) see Selecting a Seed Mix in Chapter 1, page 14).

14. Use MnDOT Spec 1717 Site Management Plan requirements and Erosion Control Schedule

Option 1. Temporary Stream Block

This method is applicable to low flow stream characteristics with no fish passage concerns during the time of construction. With large bypass pumps it has been utilized on larger streams as well. It is also common for stormwater outfall repairs. With little or no flow, a bypass pump may not be needed at all. It is also a common choice for very short term projects.

Construct temporary berms upstream and downstream of the proposed structure in order to block off water from the construction area. To install structures in this manner, approval may require up to three pumps; A stream diversion pump, a worksite dewatering pump, and a standby pump. When flowing water is present, install pumps to direct water around the construction site to provide downstream flow. See Chapter 3, page 15 for an illustration of this setup.

Option 2: Culvert By-Pass

This method is applicable to higher flow characteristics, though may not be allowed by the DNR during periods of fish migration unless velocity criteria to facilitate fish passage is met. They are generally utilized for larger culvert installations that have larger flow regimes, access requirements, or on projects that will take a considerable amount of time.

Construct temporary dikes upstream and downstream of the proposed structure in order to block off water from the construction area. Install a temporary culvert, tube, or hose to carry the water through or around the work area.

See Chapter 3, page 16 for an illustration of this setup

Option 3: By-Pass Channel

This method provides for better accommodation for fish passage during construction. They are generally utilized for larger or longer culvert installations that have larger flow regimes, fish passage requirements during construction, or on projects that will take a considerable amount of time.

Construct a by-pass channel around the culvert/bridge installation site. The channel must be designed to withstand erosion and bed shear potential. Commonly they are lined with plastic or other non-erosive materials, sometimes jersey barriers are incorporated into the side berms to protect the channel as well. With the channel diverted, the work area is isolated for the duration of the project. Any water pumped from the worksite area must be treated prior to discharge to the stream

See Chapter 3, page 16 for an illustration of this setup

Option 4: Partial Stream Diversion

This method is often utilized on wide streams, multiple culvert installations, or bridge construction. The natural channel is partially spilt by a berm, thus allowing water to continue on its same alignment, though in a constricted state. The berm may split the channel in half, working on one side, and then shifting to the other at a later date. Only the upper and lower ends need moving from one phase to the other. Alternately, where conditions allow, a berm may be placed along both stream banks to provide simultaneous work areas to both banks, while water flows through the middle.

See Chapter 3, page 17 for an illustration of this setup

Option 5: Speed BMP

This method is appropriate when there is little to no flow, no need to pump the worksite, and it can be done within 24 hrs. These are usually on culverts that are smaller than those found on Public Waters, though can include stormwater outfall work during relatively dry conditions. Temporary berms may be placed for worksite protection from water seepage.

All materials, including final stabilization materials, must be on-site before any in-water work begins. Once works begins, continue until the installation is 100% complete in 24 hours or less. This includes final grading and seeding. Often temporary erosion control is not needed with this method.

Option 6: Winter Work

This method is becoming more common, especially on projects that would normally require work in the water during the Work Exclusion Dates (see Chapter 1 page 3). It is also well suited for in-water pier work or demolition. This method has no specific construction methods, other than scheduling portions of the project that are adjacent to or in-water when conditions are frozen, and before the Work Exclusion Dates for Fish Migration and Spawning.

Option 7: Temporary Fill for Workpads, Isolating Worksites, Cofferdams, and Staging Areas.

This method is a regular requirement for bridge construction. It utilizes any combination of the above options (options 1 through 6), plus requires temporary fill for workpads, causeways, and/or cofferdams. Large areas may be required to be impacted. Habitat protection items and floodplain protection items often require added precautions and detailed workplans for the site prior to approval. Several options for in-water berms are available. Typically they are constructed with sheetpile, rock, or jersey barrier, and may be backfilled. Often the work area is not backfilled, and berms only function as containment barriers for debris and materials during construction.

1. When rock is utilized for berm or workpad construction, typically it is the same rock that will ultimately be used for

final riprap for abutment and streambank protection.

2. Silt curtain (turbidity barrier) shall be placed as close to the area of impact as possible prior to workpad installation. In moving water it is essential that the silt curtain not cause scour to undisturbed streambed. After installation of workpads or berms in moving water, silt curtain should be pulled tight against the outer edge. Silt curtain is not required on sheetpile walls.

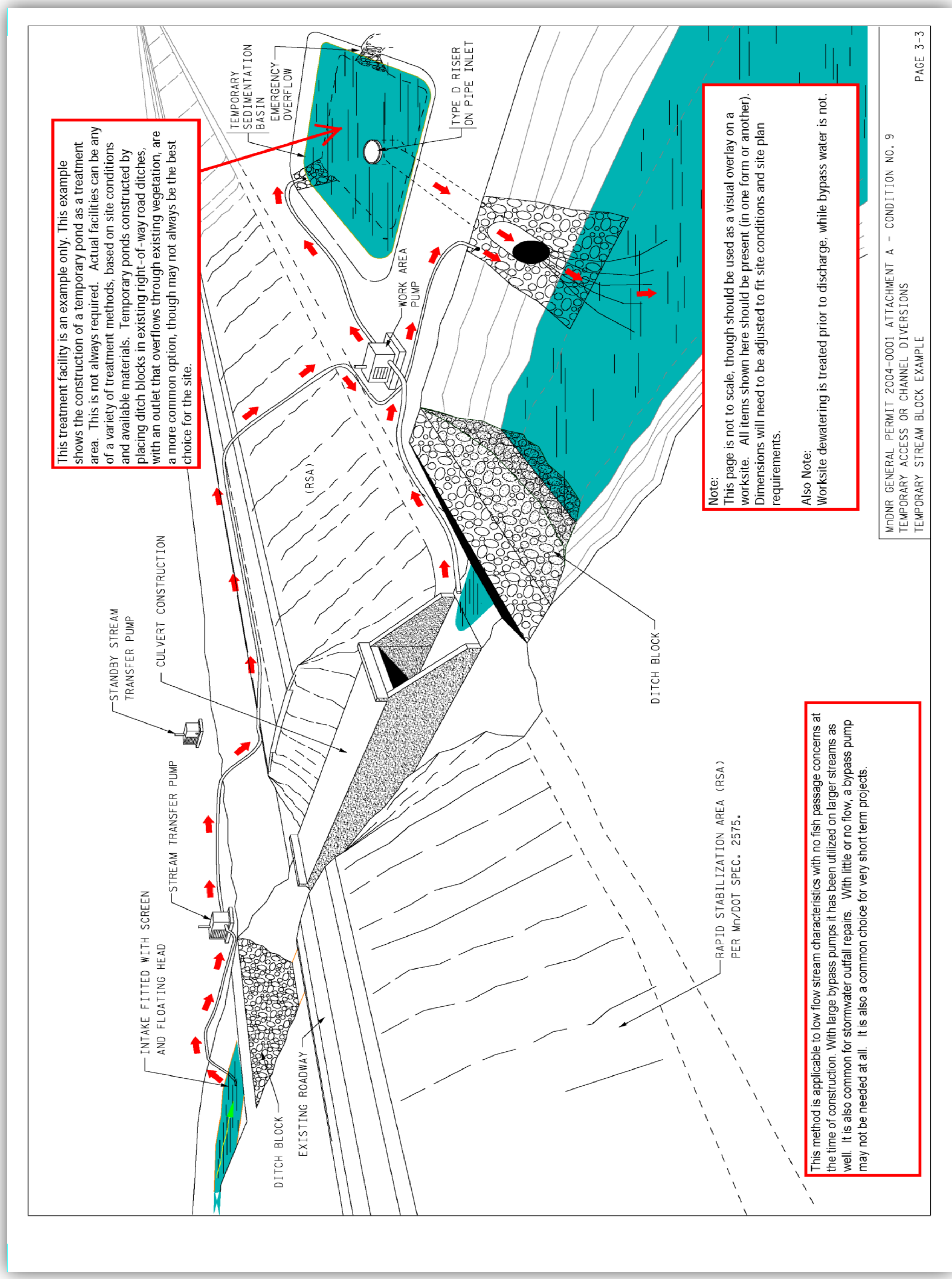
3. The area separated from the water may be back filled or left with shallow water. Should dewatering be required the items listed above will apply.

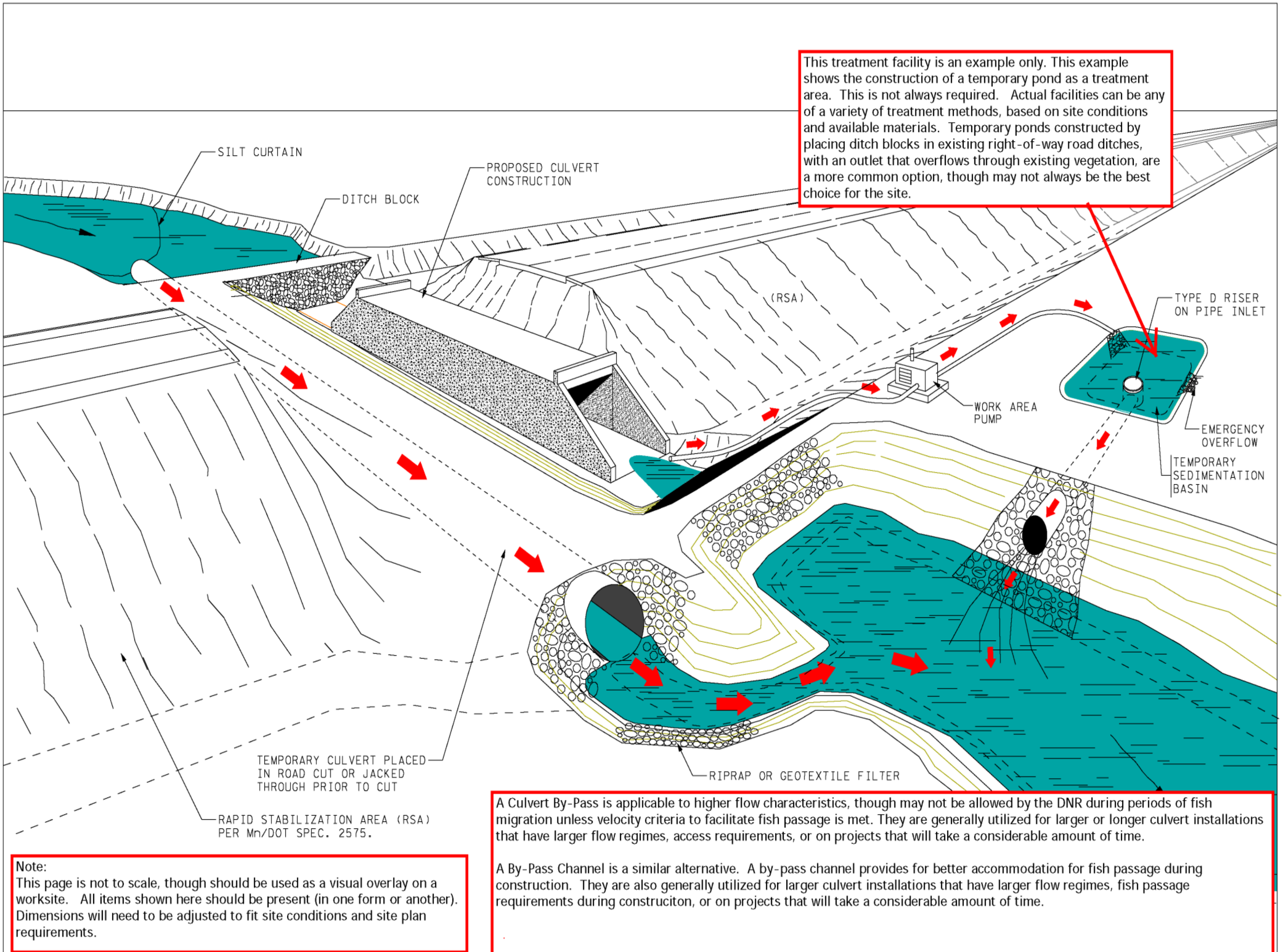
4. Flood Protection:
   a. An unobstructed opening shall be provided for normal river flow and navigation.
   b. The temporary fill must be built to withstand the flows of the 'design flood event' chosen by the permittee/contractor.
   c. The choice of the 'design flood event' is up the permittee/contractor.
   d. Modeling may be required to show the fill material used in construction will withstand the shear stresses of the design flood event.
   e. Additional modeling may be required to show flood elevation impacts. A rise in 100yr elevations may require reporting and concurrence from the impacted communities, plus legal notification to any impacted property owners. See 'Reporting Impacts to Flood Elevation' Flow Charts in Page 2 page 18 or bridge/culvert floodplain requirements at: http://www.dnr.state.mn.us/waters/watermgmt_section/floodplain/fp_resource_material.html
   f. Floodplain Modeling requirements may be waived by the DNR should a Removal Contingency Plan be adequate for the site (item 'g' below).
   g. The Contractor may be required to provide a Removal Contingency Plan to the DNR and/or erosion control inspector for approval. This plan must detail how the Contractor plans to remove or protect the temporary fill before flooding would occur and how the Contractor will ensure all construction equipment and materials are removed from flood prone areas to prevent being swept away by the river.

Option 8: Specific site management plan

This method occurs for those unique situations that come up due to unique combinations of concerns relating to topography, natural resources, cultural or historical resources, or contaminated property. An approved plan is developed in consultation with the DNR Hydrologist, US Army Corps of Engineers, MPCA, MnDOT Office of Environmental Stewardship, and other effected parties.

I-90 Mississippi River Bridge Replacement, Dresbach, MN


This treatment facility is an example only. This example shows the construction of a temporary pond as a treatment area. This is not always required. Actual facilities can be any of a variety of treatment methods, based on site conditions and available materials. Temporary ponds constructed by placing ditch blocks in existing right-of-way road ditches, with an outlet that overflows through existing vegetation, are a more common option, though may not always be the best choice for the site.
TEMPORARY SEDIMENTATION BASIN
EMERGENCY OVERFLOW
TYPE D RISER ON PIPE INLET
WORK AREA PUMP
(RSA)
STANDBY STREAM TRANSFER PUMP
CULVERT CONSTRUCTION
STREAM TRANSFER PUMP
INTAKE FITTED WITH SCREEN AND FLOATING HEAD
DITCH BLOCK
EXISTING ROADWAY
DITCH BLOCK
RAPID STABILIZATION AREA (RSA) PER Mn/DOT SPEC. 2575.
Note:
This page is not to scale, though should be used as a visual overlay on a worksite. All items shown here should be present (in one form or another). Dimensions will need to be adjusted to fit site conditions and site plan requirements.
Also Note:
Worksite dewatering is treated prior to discharge, while bypass water is not.
This method is applicable to low flow stream characteristics with no fish passage concerns at the time of construction. With large bypass pumps it has been utilized on larger streams as well. It is also common for stormwater outfall repairs. With little or no flow, a bypass pump may not be needed at all. It is also a common choice for very short term projects.
MnDNR GENERAL PERMIT 2004-0001 ATTACHMENT A - CONDITION NO. 9
TEMPORARY ACCESS OR CHANNEL DIVERSIONS
TEMPORARY STREAM BLOCK EXAMPLE
PAGE 3-3

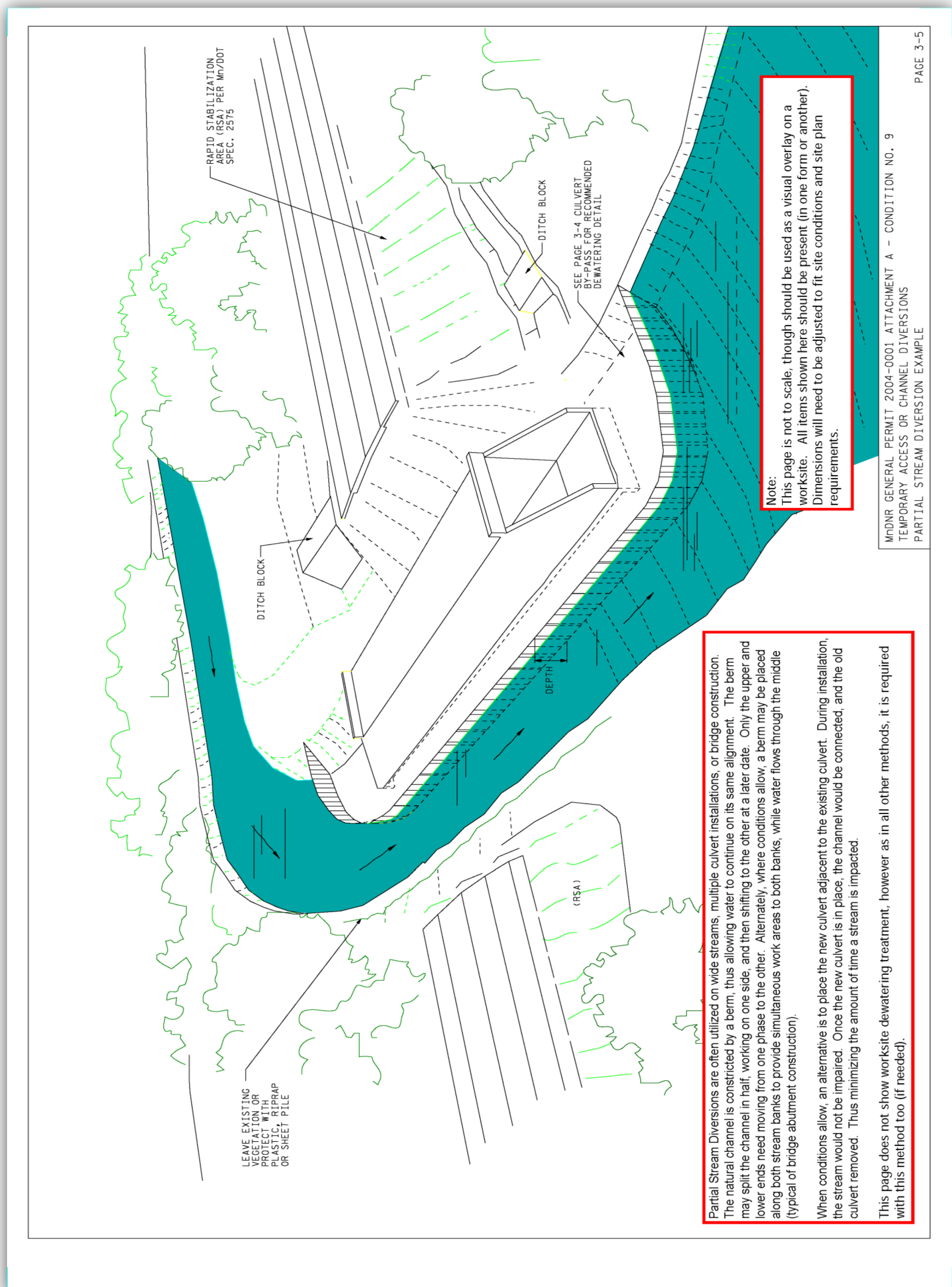


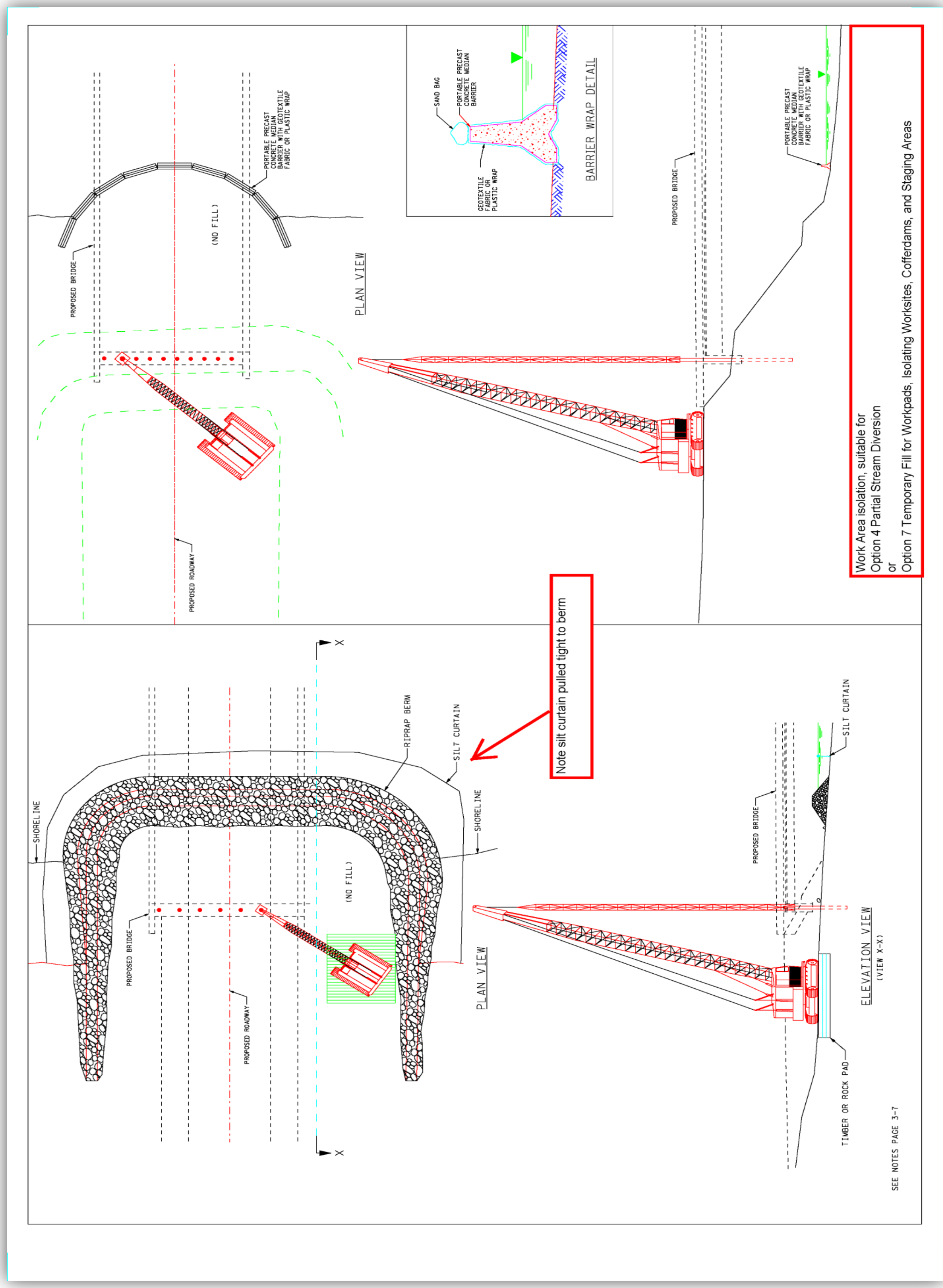
This treatment facility is an example only. This example shows the construction of a temporary pond as a treatment area. This is not always required. Actual facilities can be any of a variety of treatment methods, based on site conditions and available materials. Temporary ponds constructed by placing ditch blocks in existing right-of-way road ditches, with an outlet that overflows through existing vegetation, are a more common option, though may not always be the best choice for the site.

A Culvert By-Pass is applicable to higher flow characteristics, though may not be allowed by the DNR during periods of fish migration unless velocity criteria to facilitate fish passage is met. They are generally utilized for larger or longer culvert installations that have larger flow regimes, access requirements, or on projects that will take a considerable amount of time.

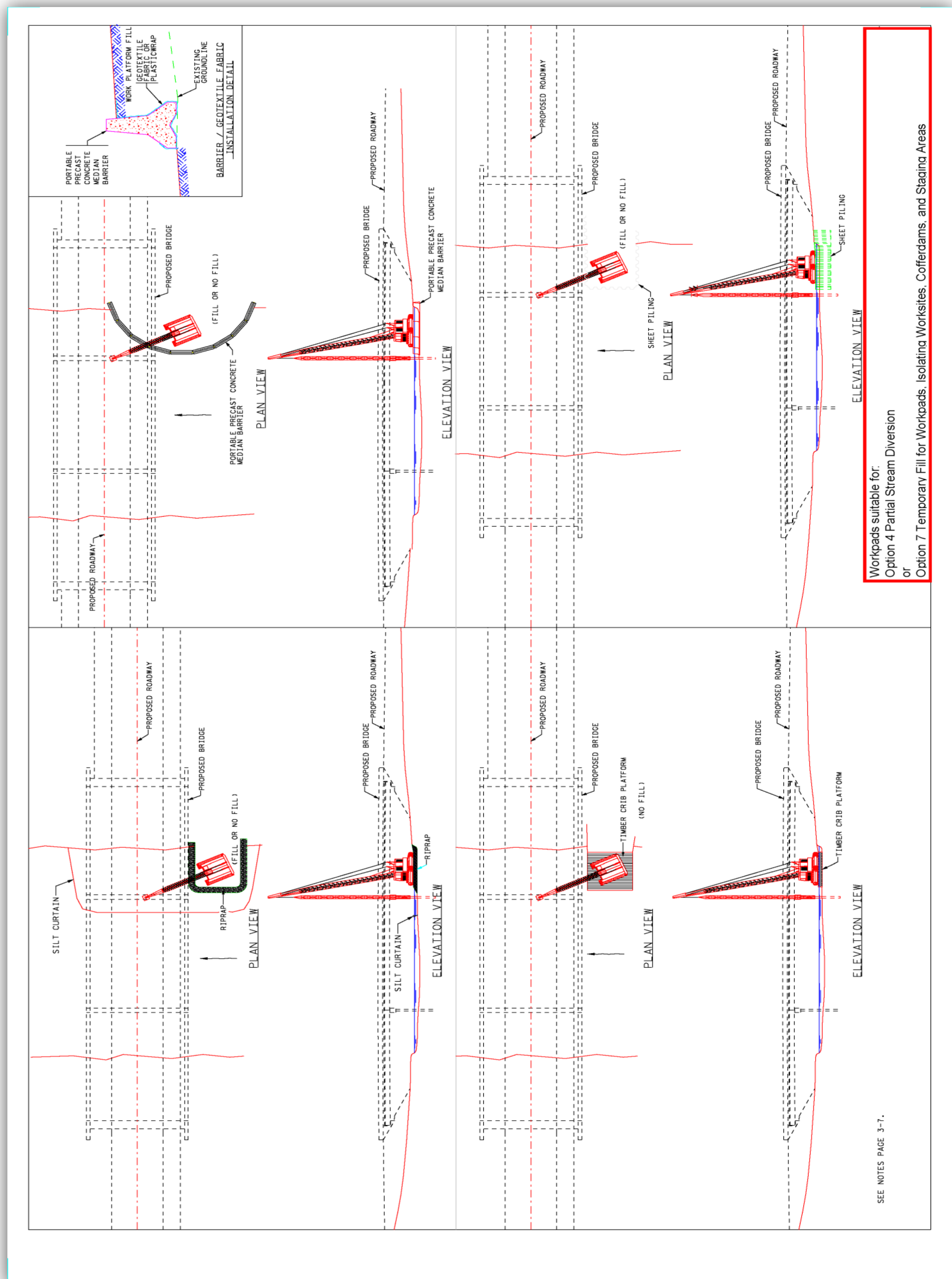
A By-Pass Channel is a similar alternative. A by-pass channel provides for better accommodation for fish passage during construction. They are also generally utilized for larger culvert installations that have larger flow regimes, fish passage requirements during construciton, or on projects that will take a considerable amount of time.

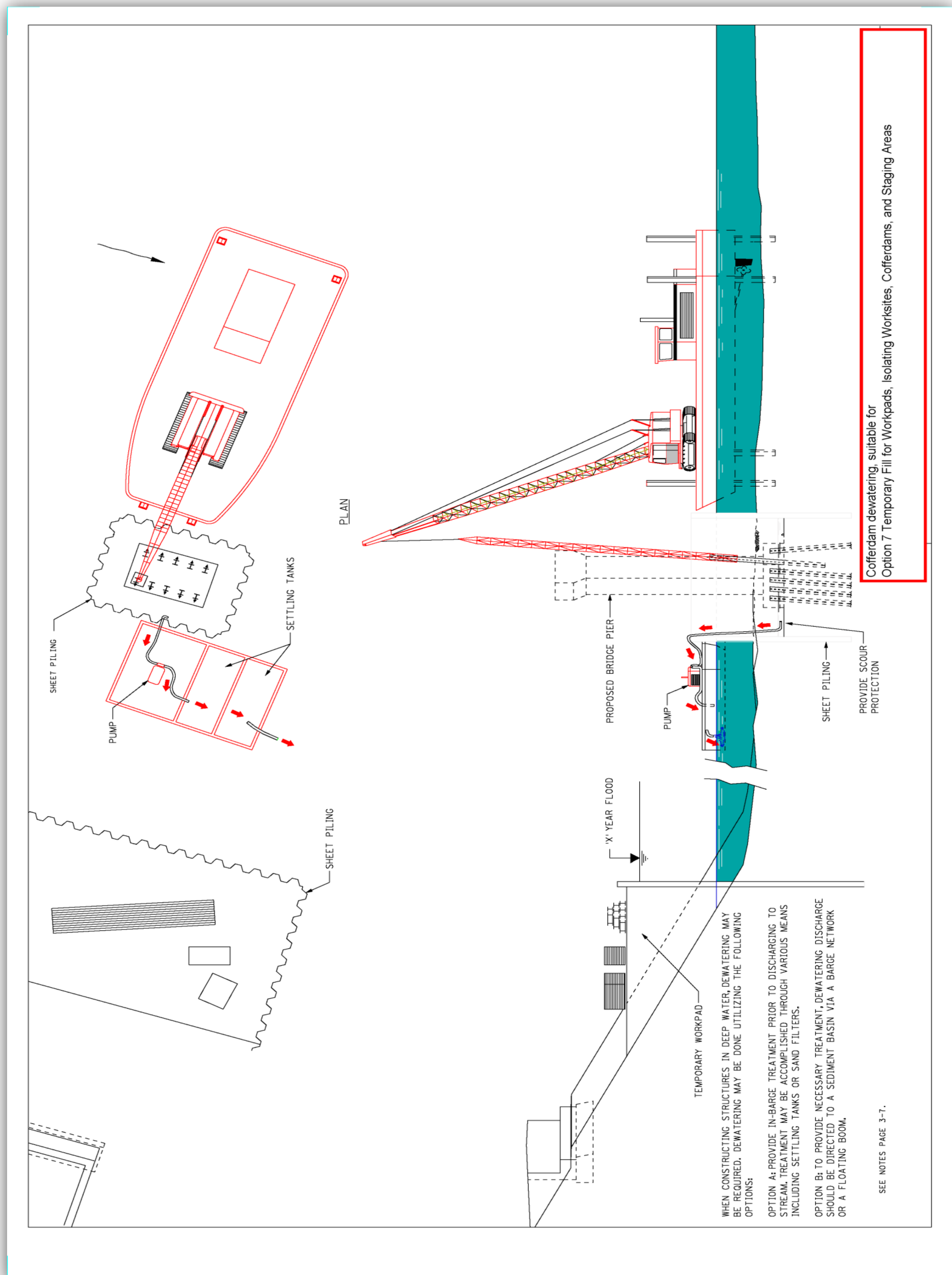
Note:
This page is not to scale, though should be used as a visual overlay on a worksite. All items shown here should be present (in one form or another). Dimensions will need to be adjusted to fit site conditions and site plan requirements.

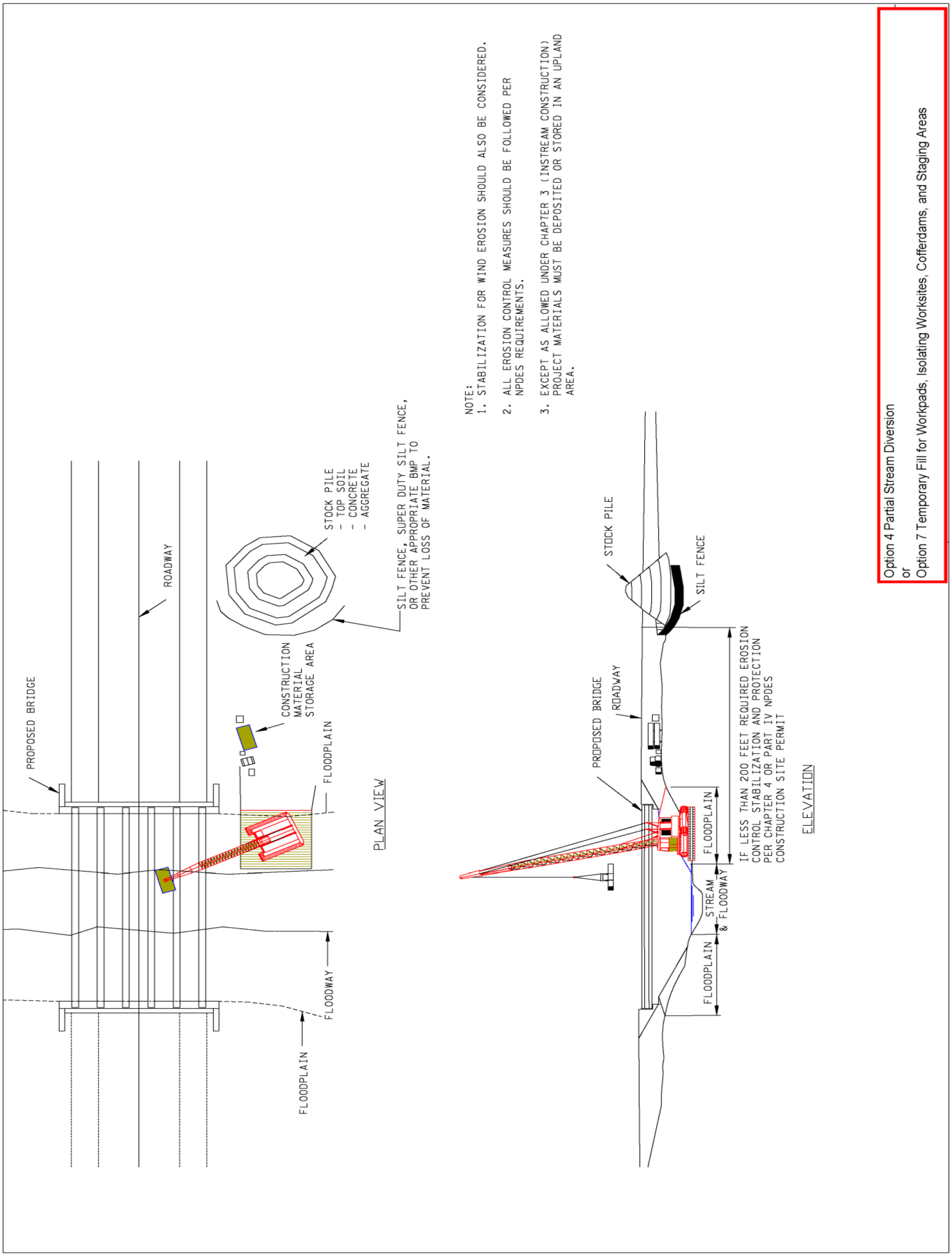

RAPID STABILIZATION AREA (RSA) PER Mn/DOT SPEC. 2575
DITCH BLOCK
SEE PAGE 3-4 CULVERT BY-PASS FOR RECOMMENDED DEWATERING DETAIL
DITCH BLOCK
DEPTH
(RSA)
LEAVE EXISTING VEGETATION OR PROTECT WITH PLASTIC, RIPRAP OR SHEET PILE
Note:
This page is not to scale, though should be used as a visual overlay on a worksite. All items shown here should be present (in one form or another). Dimensions will need to be adjusted to fit site conditions and site plan requirements.
Partial Stream Diversions are often utilized on wide streams, multiple culvert installations, or bridge construction. The natural channel is constricted by a berm, thus allowing water to continue on its same alignment. The berm may split the channel in half, working on one side, and then shifting to the other at a later date. Only the upper and lower ends need moving from one phase to the other. Alternately, where conditions allow, a berm may be placed along both stream banks to provide simultaneous work areas to both banks, while water flows through the middle (typical of bridge abutment construction).
When conditions allow, an alternative is to place the new culvert adjacent to the existing culvert. During installation, the stream would not be impaired. Once the new culvert is in place, the channel would be connected, and the old culvert removed. Thus minimizing the amount of time a stream is impacted.
This page does not show worksite dewatering treatment, however as in all other methods, it is required with this method too (if needed).
MnDNR GENERAL PERMIT 2004-0001 ATTACHMENT A - CONDITION NO. 9
TEMPORARY ACCESS OR CHANNEL DIVERSIONS
PARTIAL STREAM DIVERSION EXAMPLE
PAGE 3-5



PROPOSED BRIDGE
PORTABLE PRECAST CONCRETE MEDIAN BARRIER WITH GEOTEXTILE FABRIC OR PLASTIC WRAP
(NO FILL)
PLAN VIEW
PROPOSED ROADWAY
SAND BAG
PORTABLE PRECAST CONCRETE MEDIAN BARRIER
GEOTEXTILE FABRIC OR PLASTIC WRAP
BARRIER WRAP DETAIL
Work Area isolation, suitable for
Option 4 Partial Stream Diversion
or
Option 7 Temporary Fill for Workpads, Isolating Worksites, Cofferdams, and Staging Areas
Note silt curtain pulled tight to berm
SHORELINE
RIPRAP BERM
SILT CURTAIN
ELEVATION VIEW
(VIEW X-X)
TIMBER OR ROCK PAD
SEE NOTES PAGE 3-7


Workpads suitable for:
Option 4 Partial Stream Diversion
or
Option 7 Temporary Fill for Workpads, Isolating Worksites, Cofferdams, and Staging Areas
BARRIER / GEOTEXTILE FABRIC INSTALLATION DETAIL
PORTABLE PRECAST CONCRETE MEDIAN BARRIER
WORK PLATFORM FILL
GEOTEXTILE FABRIC OR PLASTICWRAP
EXISTING GROUNDLINE
PROPOSED ROADWAY
PROPOSED BRIDGE
(FILL OR NO FILL)
SILT CURTAIN
RIPRAP
TIMBER CRIB PLATFORM
(NO FILL)
SHEET PILING
PLAN VIEW
ELEVATION VIEW
SEE NOTES PAGE 3-7.


SHEET PILING
PUMP
SETTLING TANKS
SHEET PILING
PLAN
'X' YEAR FLOOD
PROPOSED BRIDGE PIER
TEMPORARY WORKPAD
PUMP
WHEN CONSTRUCTING STRUCTURES IN DEEP WATER, DEWATERING MAY BE REQUIRED. DEWATERING MAY BE DONE UTILIZING THE FOLLOWING OPTIONS:
OPTION A: PROVIDE IN-BARGE TREATMENT PRIOR TO DISCHARGING TO STREAM. TREATMENT MAY BE ACCOMPLISHED THROUGH VARIOUS MEANS INCLUDING SETTLING TANKS OR SAND FILTERS.
OPTION B: TO PROVIDE NECESSARY TREATMENT, DEWATERING DISCHARGE SHOULD BE DIRECTED TO A SEDIMENT BASIN VIA A BARGE NETWORK OR A FLOATING BOOM.
SEE NOTES PAGE 3-7.
SHEET PILING
PROVIDE SCOUR PROTECTION
Cofferdam dewatering, suitable for
Option 7 Temporary Fill for Workpads, Isolating Worksites, Cofferdams, and Staging Areas


PROPOSED BRIDGE
ROADWAY
FLOODPLAIN
FLOODWAY
FLOODPLAIN
CONSTRUCTION MATERIAL STORAGE AREA
STOCK PILE
- TOP SOIL
- CONCRETE
- AGGREGATE
SILT FENCE, SUPER DUTY SILT FENCE, OR OTHER APPROPRIATE BMP TO PREVENT LOSS OF MATERIAL.
PLAN VIEW
NOTE:
1. STABILIZATION FOR WIND EROSION SHOULD ALSO BE CONSIDERED.
2. ALL EROSION CONTROL MEASURES SHOULD BE FOLLOWED PER NPDES REQUIREMENTS.
3. EXCEPT AS ALLOWED UNDER CHAPTER 3 (INSTREAM CONSTRUCTION) PROJECT MATERIALS MUST BE DEPOSITED OR STORED IN AN UPLAND AREA.
PROPOSED BRIDGE
ROADWAY
STOCK PILE
SILT FENCE
FLOODPLAIN
STREAM & FLOODWAY
FLOODPLAIN
IF LESS THAN 200 FEET REQUIRED EROSION CONTROL STABILIZATION AND PROTECTION PER CHAPTER 4 OR PART IV NPDES CONSTRUCTION SITE PERMIT
ELEVATION
Option 4 Partial Stream Diversion
or
Option 7 Temporary Fill for Workpads, Isolating Worksites, Cofferdams, and Staging Areas

Appendix

Miscellaneous reports or publications

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

Limited/Amended

Public Waters Work General Permit

Expiration Date: 11/27/2018

General Permit Number
2004-0001

Pursuant to Minnesota Statutes, Chapter 103G, and on the basis of statements and information contained in the permit application, letters, maps, and plans submitted by the applicant and other supporting data, all of which are made part hereof by reference, **PERMISSION IS HEREBY GRANTED** to the applicant to perform actions as authorized below. This permit supersedes the original permit and all previous amendments.

Project Name:	**County:**	**Watershed:**	**Resource:**
MNDOT Statewide General Permit	All counties in Minnesota	All watersheds in Minnesota	All waters shown on the Public Waters Inventory

Purpose of Permit:	**Authorized Action:**
Bridge, culvert, or stormwater outfall repair or replacement.	Upon notification of approval by the DNR Transportation Hydrologist or Area Hydrologist, replace or repair of bridges, culverts, riprap, or stormwater outfalls on Public Waters, where all conditions and provisions specified herein are met.

Permittee:	**Authorized Agent:**
MN DEPARTMENT OF TRANSPORTATION CONTACT: CLARKOWSKI, LYNN, (651) 366-3602 OFFICE OF ENVIRONMENTAL STEWARDSHIP 395 JOHN IRELAND BLVD, MS 620 ST. PAUL, MN 55155 (651) 366-3600	N/A

Property Description (*land owned or leased or where work will be conducted*):

The Permittee or its authorized agent must own, control, or have permission to access and use all lands affected by the project.

Authorized Issuer:	**Title:**	**Issued Date:**	**Effective Date:**	**Expiration Date:**
Tom Hovey	Water Regulations Unit Supervisor	11/27/2013	11/27/2013	11/27/2018

This permit is granted **subject to** the following **CONDITIONS**:

APPLICABLE FEDERAL, STATE, OR LOCAL REGULATIONS: The permittee is not released from any rules, regulations, requirements, or standards of any applicable federal, state, or local agencies; including, but not limited to, the U.S. Army Corps of Engineers, Board of Water and Soil Resources, MN Pollution Control Agency, watershed districts, water management organizations, county, city and township zoning.

NOT ASSIGNABLE: This permit is not assignable by the permittee except with the written consent of the Commissioner of Natural Resources.

NO CHANGES: The permittee shall make no changes, without written permission or amendment previously obtained from the Commissioner of Natural Resources, in the dimensions, capacity or location of any items of work authorized hereunder.

SITE ACCESS: The permittee shall grant access to the site at all reasonable times during and after construction to authorized representatives of the Commissioner of Natural Resources for inspection of the work authorized hereunder.

TERMINATION: This permit may be terminated by the Commissioner of Natural Resources at any time deemed necessary for the conservation of water resources of the state, or in the interest of public health and welfare, or for violation of any of the conditions or applicable laws, unless otherwise provided in the permit.

(MPARS revision 10/07/2013, Permit Issuance ID 10959, printed 11/27/2013)

CONDITIONS continued on next page...

GENERAL PERMIT CONDITIONS (*Continued from previous page*)

COMPLETION DATE: Construction work authorized under this permit shall be completed on or before the date specified above. The permittee may request an extension of the time to complete the project by submitting a written request, stating the reason thereof, to the Commissioner of Natural Resources.

WRITTEN CONSENT: In all cases where the permittee by performing the work authorized by this permit shall involve the taking, using, or damaging of any property rights or interests of any other person or persons, or of any publicly owned lands or improvements thereon or interests therein, the permittee, before proceeding, shall obtain the written consent of all persons, agencies, or authorities concerned, and shall acquire all property, rights, and interests needed for the work.

PERMISSIVE ONLY / NO LIABILITY: This permit is permissive only. No liability shall be imposed by the State of Minnesota or any of its officers, agents or employees, officially or personally, on account of the granting hereof or on account of any damage to any person or property resulting from any act or omission of the permittee or any of its agents, employees, or contractors. This permit shall not be construed as estopping or limiting any legal claims or right of action of any person other than the state against the permittee, its agents, employees, or contractors, for any damage or injury resulting from any such act or omission, or as estopping or limiting any legal claim or right of action of the state against the permittee, its agents, employees, or contractors for violation of or failure to comply with the permit or applicable conditions.

EXTENSION OF PUBLIC WATERS: Any extension of the surface of public waters from work authorized by this permit shall become public waters and left open and unobstructed for use by the public.

INVASIVE SPECIES - EQUIPMENT DECONTAMINATION: All equipment intended for use at a project site must be free of prohibited invasive species and aquatic plants prior to being transported into or within the state and placed into state waters. All equipment used in designated infested waters, shall be inspected by the Permittee or their authorized agent and adequately decontaminated prior to being transported from the worksite. The DNR is available to train inspectors and/or assist in these inspections. For more information refer to the "Best Practices for Preventing the Spread of Aquatic Invasive Species" at http://files.dnr.state.mn.us/publications/ewr/invasives/ais/best_practices_for_prevention_ais.pdf. Contact your regional Invasive Species Specialist for assistance at www.mndnr.gov/invasives/contacts.html. A list of designated infested waters is available at http://files.dnr.state.mn.us/eco/invasives/infested_waters.pdf. A list of prohibited invasive species is available at www.mndnr.gov/eco/invasives/laws.html#prohibited.

APPLICABLE PROJECTS: This permit applies only to the replacement, reconstruction, or repair (including associated minor channel or shoreline work) of existing bridges, culverts, stormwater outfalls, or riprap in Public Waters that are designed under the supervision of a registered professional engineer. A project not meeting applicable conditions of this permit or a project the DNR identifies as having the potential for significant resource impacts, is not authorized herein. Rather, such projects will require an individual permit application.

PROJECT AUTHORIZATION: This permit provides conditions to aid project planning and facilitate initial design to streamline DNR regulatory approval. A project must be reviewed by the DNR Transportation Hydrologist through the MnDOT Early Notification Memo (ENM) process in order for it to qualify for authorization under this permit. The existing framework of MnDOT environmental review by the applicable DNR personnel will be utilized to review projects at the earliest possible stage for permit needs and additional conditions. Additional design information may be required of MnDOT during this process. If a project can not meet the conditions of this permit, a separate individual permit will be required. If emergency or unforeseen projects arise that can not include the framework of the ENM process, the permittee shall contact the DNR Transportation Hydrologist or Area Hydrologist immediately to provide details and discuss project design and applicable standards for authorization under this permit. Work shall not commence until written approval that the project will meet these (and any additional written) permit conditions is received from the applicable DNR Hydrologist.

RESPONSIBILITY: The permittee is responsible for satisfying all terms and conditions of this permit. When a project is awarded to a said third party (contractor) for work to be completed, the permittee may notify the DNR in order to administratively amend the project authorization form to include the said third party as a co-permittee for joint responsibility in compliance with this permit.

ENVIRONMENTAL REVIEW: If the bridge/culvert construction is part of a road project that requires mandatory environmental review pursuant to MN Environmental Quality Board rules, then this permit is not valid until environmental review is completed.

DNR NOTIFICATION: The permittee shall notify the DNR Transportation Hydrologist or Area Hydrologist at least five days in advance of the commencement of the work. An email notification of the pre-construction meeting will suffice for this notification.

CONDITIONS continued on next page...

GENERAL PERMIT CONDITIONS (*Continued from previous page*)

PHOTOS AND AS-BUILTS: Upon completion of the authorized work, the permittee may be required to submit a copy of established benchmarks, representative photographs, and may be required to provide as-built surveys of Public Watercourse crossing changes.

STATE & FEDERAL LISTED SPECIES PROHIBITION: If there are unresolved concerns regarding impacts to federally or state listed species (endangered, threatened, or special concern), this general permit is not applicable, and the project must be submitted as a separate permit application. Compliance with DNR and federal guidelines established for a listed species (e.g. Topeka Shiner conditions) would constitute a resolved concern.

PRELIMINARY ENGINEERING: This permit authorizes preliminary engineering studies in the water associated with bridge planning (e.g., core sampling). All core holes must be sealed in accordance with Department of Health well sealing requirements. On designated infested waters, all equipment in contact with the water must be decontaminated per the Invasive Species condition.

HYDROLOGIC/HYDRAULIC DATA REPORTING: Unless waived by the DNR Transportation Hydrologist or Area Hydrologist, hydrologic modeling to show the impacts of the structure(s) on the 100-yr (1% chance) flood elevation is required. Calculations showing calculated velocities through the structures at 2-year peak flows may also be required.

NAVIGATION MAINTAINED OR IMPROVED: The structure's final design will not obstruct reasonable public navigation, as determined by the DNR. For bridges, three feet above the calculated 50-year flood stage ordinarily satisfies navigational clearance requirements. For culverts, three feet of clearance above the ordinary high water level (top of the bank) ordinarily satisfies navigational requirements.

STATE TRAILS: Projects proposed near an existing or proposed state trail system should be consistent therewith.

FLOWLINE/GRADIENT NOT CHANGED: Replacement of culverts or crossings are to follow (or be restored to) the natural alignment and profile of the stream. Changes from the existing flowline, gradient or alignment must be consistent with the Water Level Control and Fish Passage conditions and authorized by the DNR Transportation Hydrologist or Area Hydrologist.

FLOOD STAGES/DAMAGES NOT INCREASED: A. No approach fill for a crossing shall encroach upon a DNR approved community designated floodway. When a floodway has not been designated or when a floodplain management ordinance has not been adopted and approved, increases in flood stage in the regional flood of up to one-half of one foot shall be approved if they will not materially increase flood damage potential. Additional increases may be permitted if: a field investigation and other available data indicate that no significant increase in flood damage potential would occur upstream or downstream, and any increases in flood stage are reflected in the floodplain boundaries and flood protection elevation adopted in the local floodplain management ordinance as determined by the applicable DNR Hydrologist; B. If the existing crossing has a swellhead of one-half of one foot or less for the regional flood, the replacement crossing shall comply with the provisions for new crossings in (A). If the existing crossing has a swellhead of more than one-half of one foot for the regional flood, stage increases up to the existing swellhead may be allowed if field investigation and other available data indicate that no significant flood damage potential exists upstream from the crossing based on analysis of data submitted by the applicant. The swellhead for the replacement crossing may exceed the existing swellhead if it complies with the provisions found in (A) above.

WATER LEVEL CONTROL: Permittee is responsible for maintaining existing water level control elevations.

FISH PASSAGE: Bridges, culverts and other crossings shall provide for fish movement unless the structure is intended to impede rough fish movement, aquatic invasive species movement, or the stream has negligible fisheries value as determined by the Transportation Hydrologist or Area Hydrologist in consultation with the Area Fisheries Manager. The accepted practices for achieving these conditions include: A. Where possible a single culvert or bridge shall span the natural bankfull width adequate to allow for debris and sediment transport rates to closely resemble those of upstream and downstream conditions. A single culvert shall be recessed in order to pass bedload and sediment load. Additional culvert inverts should be set at a higher elevation. All culverts should match the alignment and slope of the natural stream channel, and extend through the toe of the road side slope. "Where possible" means that other conditions may exist and could take precedence, such as unsuitable substrate, natural slope and background velocities, bedrock, flood control, 100-yr (1% chance) flood elevations, wetland/lake level control elevations, local ditch elevations, and other adjacent features. B. Rock Rapids or other structures may be used to retrofit crossings to mimic natural conditions.

TERRESTRIAL SPECIES MOVEMENT: Structures shall not be detrimental to significant wildlife habitat. If the crossing is located at a significant wildlife travel corridor as determined by DNR Wildlife or Ecological & Water Resources staff, the

CONDITIONS continued on next page...

GENERAL PERMIT CONDITIONS (*Continued from previous page*)

crossing shall be designed to minimize concerns. Typically this is accomplished with the presence of a walkable surface (dry ground) at normal flow conditions. For bridges this is known as a 'Passage Bench', which is incorporated into bridge abutment riprap. On multiple culvert installations, outer culvert inverts can be set at an elevation higher than normal flow to allow terrestrial species use during non-flood conditions. A Passage Bench design is incorporated into MnDOT Standard sheet (Figure 5-397.309) and available at http://www.dot.state.mn.us/bridge/cadd/files/bdetailspart2/pdf/fig7309e.pdf. Also see 'Passage Bench Design' as well as other species protection measures in Chapter 1 of the collection of "Best Practices for Meeting DNR General Public Waters Work Permit GP 2004-0001" http://www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_manual.html.

RESTORATION OF VEGETATION: On areas of disturbed soil adjacent to Public Waters, final vegetation plans should include native species suitable to the local habitat. This may include trees, shrubs, grasses, and/or forbs. Also see MnDOTs "Native Seed Mix Design for Roadsides" http://www.dot.state.mn.us/environment/erosion/pdf/native-seed-mix-dm.pdf.

TEMPORARY IMPACTS DURING CONSTRUCTION: Construction methods not finalized at the time of project review shall be submitted for review and approval at a later date. Temporary work below the Ordinary High Water (OHW) elevation, such as channel diversions, placement of temporary fill, structures for work pads/dock walls, bypass roads, coffer dams, or staging areas to aid in the demolition or construction of any authorized structure shall be submitted for review and approval in writing by the DNR Transportation Hydrologist or Area Hydrologist prior to beginning work. This is normal procedure for bridge or culvert projects as we recognize that final project designs are often posted for bid without final construction/ demolition plans. The following conditions must be met:

A. AQUATIC INVASIVE SPECIES - EQUIPMENT DECONTAMINATION: All equipment intended for use at a project site must be free of prohibited invasive species and aquatic plants prior to being transported into or within the state and placed into state waters. All equipment used in designated infested waters, shall be inspected by the Permittee or their authorized agent and adequately decontaminated prior to being transported from the worksite. The DNR is available to train inspectors and/or assist in these inspections. For more information refer to the "Best Practices for Preventing the Spread of Aquatic Invasive Species" at http://files.dnr.state.mn.us/publications/ewr/invasives/ais/best_practices_for_prevention_ais.pdf. Contact your regional Invasive Species Specialist for assistance at www.mndnr.gov/invasives/contacts.html. A list of designated infested waters is available at http://files.dnr.state.mn.us/eco/invasives/infested_waters.pdf. A list of prohibited invasive species is available at www.mndnr.gov/eco/invasives/laws.html#prohibited.

B. WORK EXCLUSION DATES FOR FISH SPAWNING AND MOVEMENT: Work within Public Waters may be restricted due to fish spawning and migration concerns. Dates of fish spawning and migration vary by species and location throughout the state. Specific dates for each DNR Region may be found on page 3 of Chapter 1 of the manual: Best Practices for Meeting DNR General Waters Work Permit GP2004-0001. http://www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_manual.html. Work in the water is not allowed within these dates. The DNR Transportation Hydrologist, Area Hydrologist, or Area Fisheries Supervisor shall be contacted about waiving work exclusion dates where work is essential or where MnDOT demonstrates that a project will minimize impacts to fish habitat, spawning, and migration.

C. HYDROLOGIC MODELING: Hydrologic modeling of temporary fill or temporary structures may be required by DNR Transportation Hydrologist or Area Hydrologist in order to evaluate impacts to the 100-yr (1% chance) flood elevation. Contingency plans may also be required to ensure all construction equipment and unsecured construction materials are moved out of the floodplain to prevent impacts to the 100-yr (1% chance) flood elevation or from being swept away by flood waters.

D. TEMPORARY FILL: If approved, temporary fill shall be free of organic material or any material that may cause siltation or pollute the waterbody. All such material shall be removed and the area restored to pre-existing profiles prior to project completion.

E. WETLAND PROTECTION: Should MnDOT or its contractors chose to do work in association with this project that is outside MnDOT project area right-of-way (EG excavation, grading, fill, vegetation alterations, utility installations, etc), they must obtain a signed statement from the property owner stating that permits required for work have been obtained or that a permit is not required, and mail a copy of the statement to the regional DNR Enforcement office where the proposed work is located. The Landowner Statement and Contractor Responsibility Form can be found at: http://www.bwsr.state.mn.us/wetlands/wca/index.html#general

F. STORAGE/STOCKPILES: Project materials must be deposited or stored in an upland area, in a manner where the

CONDITIONS continued on next page...

GENERAL PERMIT CONDITIONS (*Continued from previous page*)

materials will not be deposited into the public water by reasonably expected high water or runoff.

G. NAVIGATION: All work on navigable waters shall be so conducted that free navigation of waterways will not be interfered with, except as allowed by permits issued by the proper public authority. See MnDOT Standard Specifications for Navigable Waters (spec #1709) of MnDOT Standard Specifications for Construction, 2005 edition, or its successor: http://www.dot.state.mn.us/pre-letting/spec/2014/2014-Std-Spec-for-Construction.pdf.

H. EROSION PREVENTION AND SEDIMENT CONTROL: In all cases, erosion prevention and sediment control methods that have been determined to be the most effective and practical means of preventing or reducing sediment from leaving the worksite shall be installed in areas that are within 200 feet of the water's edge and drain to these waters, and on worksite areas that have the potential for direct discharge due to pumping or draining of areas from within the worksite (EG coffer dams, temporary ponds, stormwater inlets). These methods, such as mulches, erosion control blankets, temporary coverings, silt fence, silt curtains or barriers, vegetation preservation, redundant methods, isolation of flow, or other engineering practices, shall be installed concurrently or within 24 hours after the start of the project, and shall be maintained for the duration of the project in order to prevent sediment from leaving the worksite. DNR requirements may be waived in writing by the authorized DNR staff based on site conditions, expected weather conditions, or project completion timelines.

I. MPCA WATER QUALITY REQUIREMENTS: MPCA administers the requirements of the National Pollutant Discharge Elimination System and the State Disposal System (NPDES/SDS) requirements. To ensure state water quality standards during construction are not violated, check with the MPCA Stormwater Program www.pca.state.mn.us/stormwater for permit application requirements, pollution prevention guidance documents, and additional measures required for work in Special or Impaired Waters. For questions on MPCA requirements, contact the MPCA-MnDOT Liaison (Dan Sullivan at Dan.Sullivan@state.mn.us or 651-366-4294).

J. TEMPORARY DEWATERING: A separate water use permit is required for withdrawal of more than 10,000 gallons of water per day or 1 million gallons per year from surface water or ground water. GP1997-0005 (temporary water appropriations) covers a variety of activities associated with road construction and should be applied if applicable. An individual appropriations permit may be required for projects lasting longer than one year or exceeding 50 million gallons. Information is located at: http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/permits.html .

K. PROTECTION OF VEGETATION: If DNR Ecological & Water Resources staff determine that Native Plant Communities, Sites of Biodiversity Significance, other Areas of Environmental Sensitivity are present in or adjacent to Public Waters, precautions must be implemented to ensure protection and restoration of vegetation. MnDOT Standard Specifications for Protection and Restoration of Vegetation (spec #2572) of MnDOT Standard Specifications for Construction, 2005 edition, or its successor must be followed to minimize disturbance to such areas, see http://www.dot.state.mn.us/pre-letting/spec/2014/2014-Std-Spec-for-Construction.pdf. This may include, but is not limited to, the following: (1) During the project, parking, placement of temporary structures or material shall not be allowed outside the existing road right-of-way; (2) Place temporary fence at the construction limits and at other locations adjacent to vegetation designated to be preserved; (3) Minimize vehicular disturbance in the area (no unnecessary construction activities); (4) Leave a buffer of undisturbed vegetation between the critical resource and construction limits; (5) Precautions should be taken to ensure that borrow and disposal areas are not located within native plant communities; and (6) Revegetate disturbed soil with native species suitable to the local habitat.

L. NESTING BIRDS: MnDOT adherence to existing federal migratory bird protection programs will suffice for DNR concerns. Should active nests be encountered on the project (including swallow nests attached to bridges or culverts), contact MnDOT Office of Environmental Stewardship (Jason.Alcott@state.mn.us, ph; 651-366-3605), for specific guidance relating to Federal Threatened and Endangered Species and U.S. Fish and Wildlife Service coordination.

BEST PRACTICES - MNDOT: Please refer to the collection of "Best Practices for Meeting DNR General Public Waters Work Permit GP 2004-0001" for guidance to meeting the conditions of this General Permit. A PDF version is available at: http://www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_manual.html.

'MESBOAC' CRITERIA FOR DESIGNING A CULVERT TO ALLOW FISH PASSAGE AND MAINTAIN STREAM STABILITY

Undersized culvert.

Properly sized and placed culverts.

1. **M**atch culvert width to bankfull width (minimum). Minimum height should be at least 1/3 the bankfull width. Where multiple culverts are used, non-thalweg culverts may be 1 foot shorter than thalweg culverts so top elevations can match.
2. **S**et culvert at same slope as riffle slope as measured in the thalweg.
3. **B**ury culvert(s) to 1/6th the bankfull width of the stream (up to 2 feet), 1/5th for steeper streams with larger cobble substrate.
4. **O**ffset elevation of multiple culverts, with thalweg culvert buried according to permit requirements and centered on the thalweg; other culvert(s) set one foot higher.
5. **A**lign culvert with stream alignment.
6. **C**heck for potential headcuts. Provide grade control above and/or below where there is potential for head-cuts that could degrade the channel.

Note:

A. If the existing culvert has a lateral erosion or is perched, it is likely that the culvert is undersized. Care should be taken in re-design, as it is also possible that the stream has aggraded on the upstream side. An improperly re-designed culvert can lead to head cutting and destabilizing stream conditions, potentially adversely effecting upstream or downstream property.

B. Culvert sizing for matching bankfull width can be adjusted to utilize the nearest standard culvert sizes.

C. Be aware that culvert widths that add up to 10feet or more are considered a 'bridge' by MnDOT and such crossings are subject to MnDOT's bridge inspection and maintenance requirements.

(Much of the information contained within this section was developed and provided by Sandy Verry, retired U.S. Forest Service Hydrologist and currently geomorphology consultant with Ellen River Partners.) Photo source: Karl Koller

MESBOAC Guidance as often referred to by DNR in NE Minnesota

Bankfull Width Determination

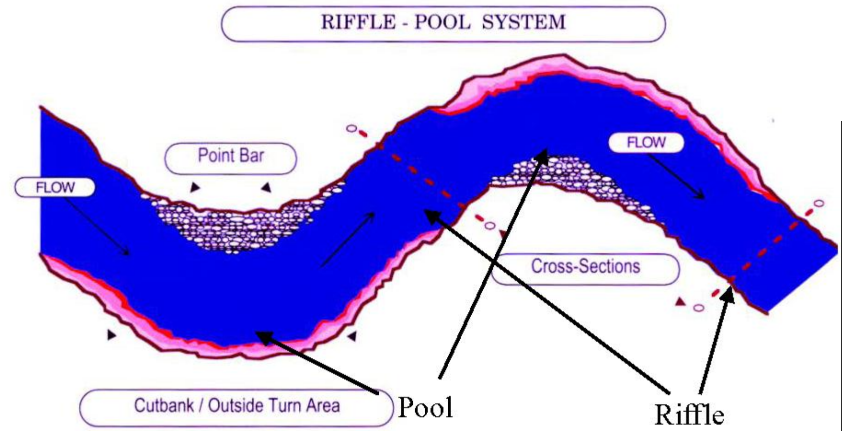
BANKFULL ELEVATION Stage of flow at which water has filled the principal channel and just begins to flow onto the floodplain.

BANKFULL DISCHARGE Bankfull flow is usually associated with about the 1 - 2 year event. Over the long term, bankfull flows shape the channel because bankfull flow is the most prevalent flow that is fast enough to entrain the channel bottom and transport bedload as well as suspend bedload.

When possible, calibration should be done using field determined bankfull stage elevations and corresponding channel dimensions compared to known recurrence intervals at gaging stations. Where gaging station data is not available, approximate calibration can be done through hydraulic modeling. Be sure not to measure bankfull width near culverts or bridges.

It is important that culvert width matches bankfull width to provide stability to the channel. By matching bankfull width, velocity through the culvert will more likely match channel velocity for the bankfull discharge.

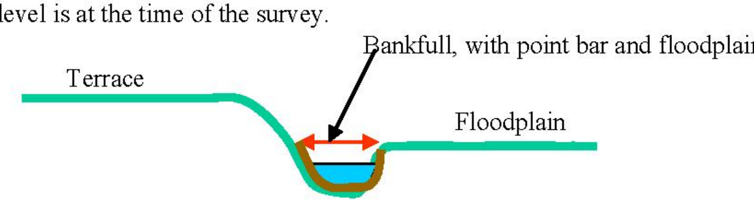
Reference: Rosgen, David L. 1994. A Classification of Natural Rivers. Catena. June, 1994.



DETERMINING BANKFULL ELEVATION Bankfull width can be fairly easy to determine in streams with little to moderate entrenchment (streams with wide, accessible floodplains). In streams that are highly entrenched, determining bankfull width may be difficult (see next page).

The flats on top of the depositional features such as point bars are the best indication of bankfull elevation. To measure bankfull width, measure the width of the stream across the riffles (straight sections) from bankfull elevation to bankfull elevation. This measurement should be taken in the narrowest part of the stream. The riffles are the hydraulic control points on the stream, so the cross-sectional area in riffles is the minimum area needed to maintain stream stability.

Measure at the bankfull or floodplain elevation regardless of where the water level is at the time of the survey.



Be careful not to interpret a terrace, when present, as the bankfull elevation. A terrace is a remnant geomorphic feature.

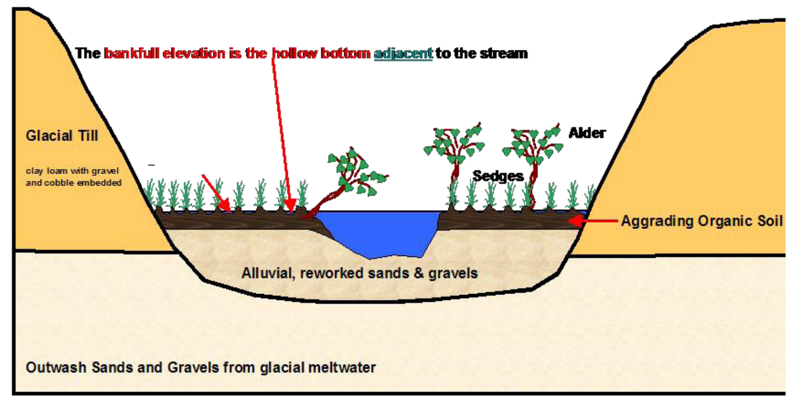
MESBOAC Guidance as often referred to by DNR in NE Minnesota

Bankfull Width Determination (cont.)

Determining Bankfull Elevation in Difficult Circumstances or Stream Types

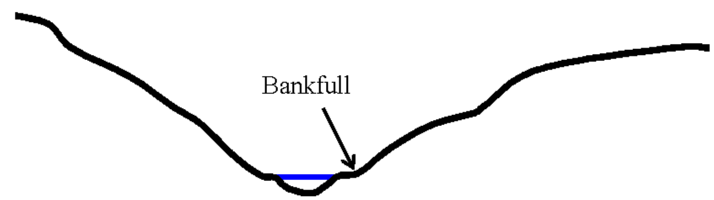
Stream with low, wetland floodplain
(E and C Channel)

The majority of the stream channels will be type C and E channels, which are low gradient (<2%), highly meandered streams with wide floodplains (low entrenchment). Identifying bankfull elevation is relatively easy in these channel types. Many channels will flow through wetland areas, with hummocky sedge growth and perhaps alder. In this case, the low points (hollows), between the hummocks will be the bankfull elevation.



Moderately Entrenched Stream Types
(B Channel)

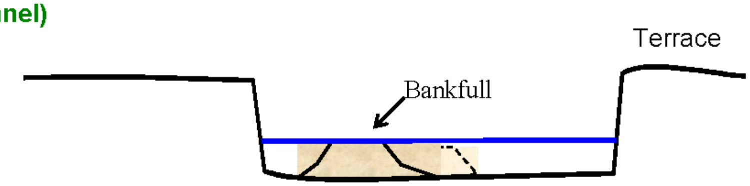
In areas with higher slopes moderately entrenched channels are more common. Small flats adjacent to the stream can often be identified. B channels are typically of moderate gradient (2 -4%), have narrow floodplains (moderately entrenched), have low sinuosity and are usually dominated by step/pool sequence.



Look for small, footprint-sized floodplain flats adjacent to the channel in B stream types

Highly Entrenched Stream Types (Wide and shallow channel)
(F Channel)

In Minnesota, F channels are often unstable sections of stream that have become overwide and are in an intermediate stage of channel evolution in reaction to a past or current disturbance to hydrology or sediment load. F channels have little or no floodplain (highly entrenched), are wide and shallow and are low gradient with moderate sinuosity. The tops of mid-channel bars may be the only indicator of bankfull elevation.



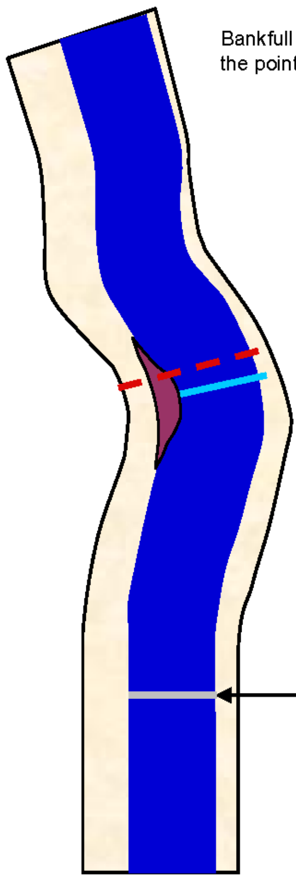
The highest mid-channel bar is the elevation of the bankfull stage.

Bankfull Width Determination (cont.)

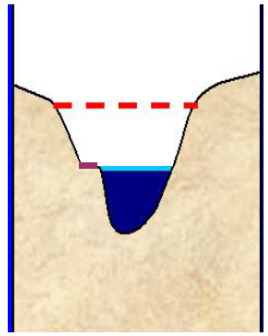
Determining Bankfull Elevation in Difficult Circumstances or Stream Types (Cont.)

Highly Entrenched Stream Types (Narrow and deep channel)

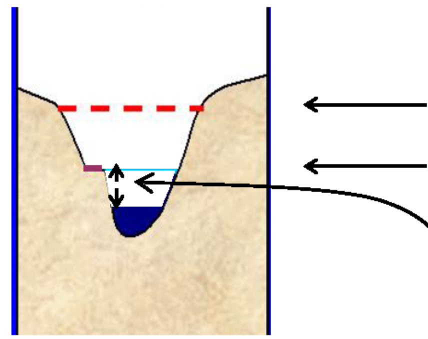
(G Channel)



Bankfull stage and flow showing the forming of the point bar flat (brown area).



Bankfull depositional flat and distance above water on the day measurements are made.



G channel types (gulleys) are moderately steep with slopes between 2% and 4%.
They are relatively straight, but nearly always have some bends in the entrenched valley.
They are so entrenched, the 50-year flood (red, dashed line) can not get out of the valley.
The bankfull elevation occurs about 2 out of 3 years (1.5-yr storm).
This bankfull flow forms rudimentary point bars on the inside of bends.

To estimate bankfull height where it is not evident, measure the distance between the water surface and he top of the point bar flats.

Move up or downstream to the narrowest width of the bankfull channel.

Measure bankfull width at bankfull/point bar elevation (distance measured above water surface) At the elevation of the point bar flat (distance above water) measure the bankfull width.
This bankfull width will pass the bankfull discharge at the channel bankfull flow velocity.
In the steeper G channels the bankfull velocity will likely be in the 3 to 5 feet per second range because of the steeper channels.

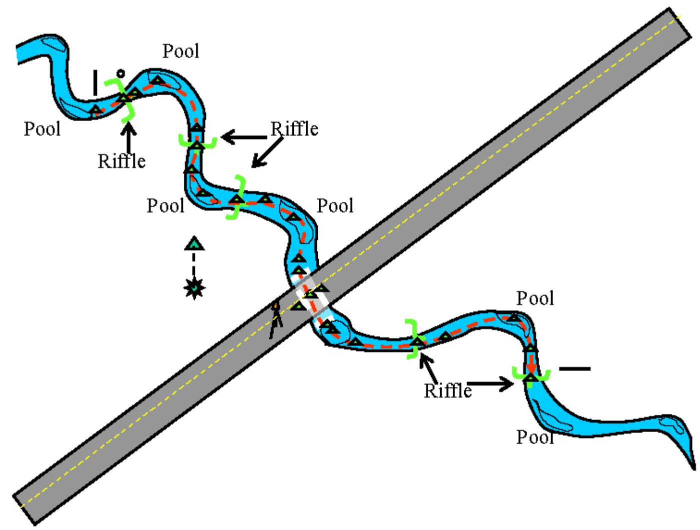
Highly Entrenched Stream Types (Narrow and deep channel- steep slopes)

(A Channel)

A (and A+) channels are high gradient (>4% slope), entrenched channels that are relatively narrow and deep. There is no easy, reliable way to determine bankfull elevation on these types of stream channels. Because A channel segments are rare and likely short in Minnesota, the best technique would be to go upstream or downstream of the A channel and measure bankfull width at that location.

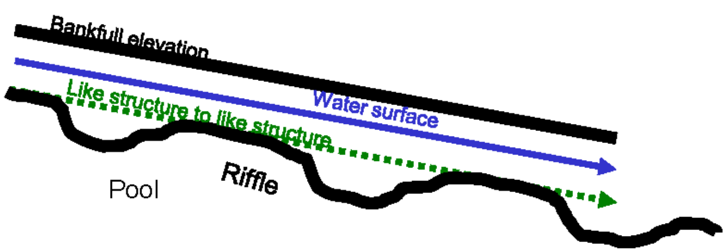
Determining Slope and Elevation

▲ Location of elevation readings for longitudinal profile



Unaltered streams follow a predictable pattern with pools forming along the outsides of bends and riffles (shallowest points in the longitudinal profile of the stream) forming within the straight sections. Riffles control the elevation and slope of the stream; therefore, the riffle elevations (as measured in the thalweg*) should be used to determine culvert elevation and slope. Culverts are usually set in riffles because it is easier to cross a stream in a straight stretch than in a bend and the banks tend to be more stable.

SURVEYING RIFFLES
The easiest way to determine culvert invert elevations is to measure a minimum of two riffles elevations upstream and two downstream of the crossing (avoid the riffle immediately downstream of the culvert). (Every effort should be made to increase the length of your longitudinal profile to get as many riffle elevations as possible.) Elevations should be measured at least at every change in depth, ensuring that all riffles are measured. Measure the stream distance between each reading so slope (elevation vs. distance) can be calculated and note station distance of each existing or proposed culvert invert. Three elevations should be measured at each location; 1. Streambed elevation in thalweg * 2. water surface and 3. bankfull elevation (although not necessary, recording bankfull elevations when possible can help in the analysis).



There are three ways to measure stream slope. Water surface, bankfull and like structure slopes will be the same in stable streams. Culvert elevation determination, is based on riffle elevations (like structure to like structure), as measured in the thalweg.

If you are not confident you can identify pools and riffles, record thalweg elevations frequently through at least three bends both upstream and downstream of the crossing.

Remember to establish a benchmark to tie all your readings together and to use when setting the culvert at the proper elevation.

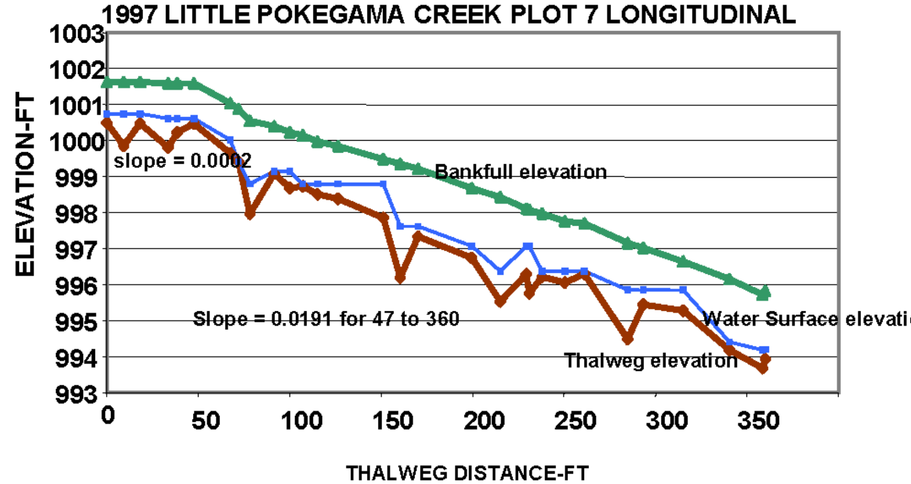
*Thalweg = Deepest point in a channel cross-section, usually found near the center of the channel in riffles and near the outside of the bend in pools.

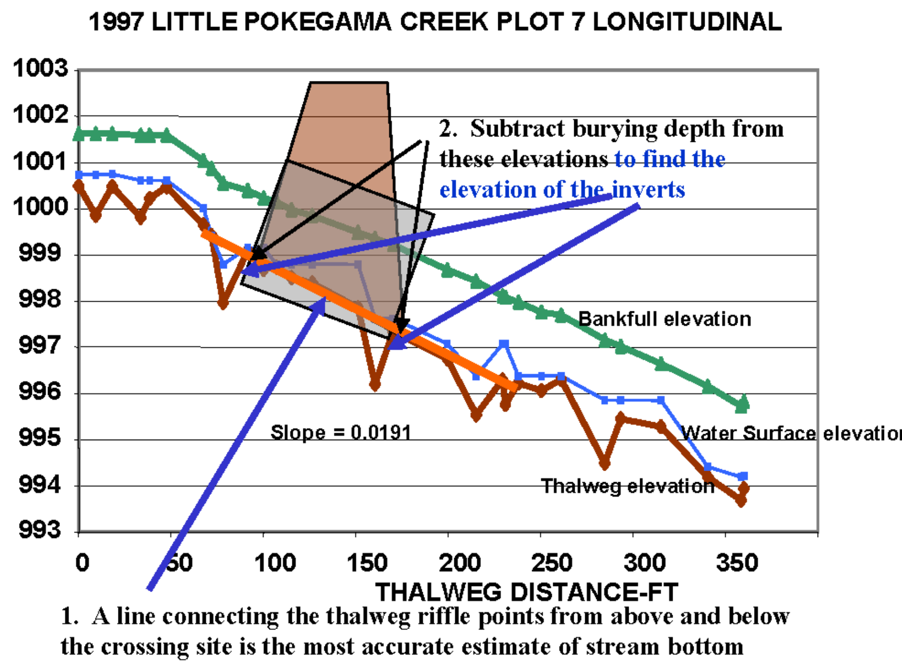
Determining Slope and Elevation (Cont.)

PLOTTING
Once longitudinal profile elevations have been collected, plot the elevations versus distance to calculate the slope (regress). Thalweg, water surface and bankfull slopes should be similar. It should become evident which points are riffles, which are pools and which are intermediate points. To calculate riffle slope and determine elevations of culvert inverts, regress only the riffle points. The invert distances can be inserted into the regression to calculate the stream bottom elevation at the inverts. Once this is done, subtracting 1/6th the bankfull width (1/5th in higher gradient, large substrate streams) from this elevation will yield the proper invert elevation.

If there was an obvious scour pool immediately downstream of the culvert, then there will often be an unusually high riffle immediately downstream of the scour pool. This is likely an indication that the current culvert is undersized and/or set too high. In this case, disregard this riffle when calculating riffle slope and culvert invert elevations.

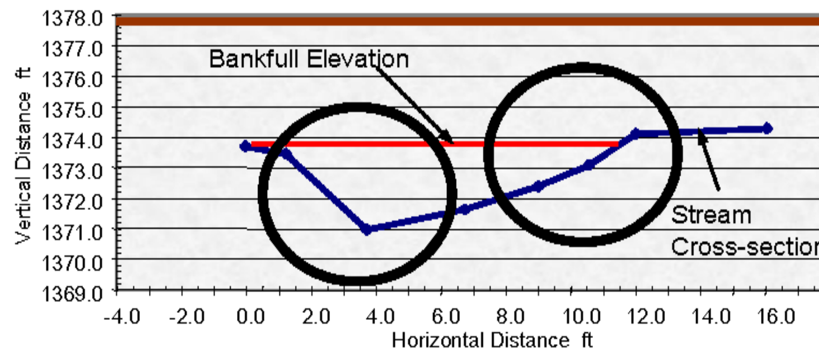
When installing multiple culverts, remember to bury the culvert closest to thalweg to proper depth and place other culvert(s) about a foot higher. Also, when working with small or lightweight culverts (CMP), dig channel for culverts approximately 6 inches deeper than design elevation to account for culvert pushing up during backfilling.





Burying and Offsetting

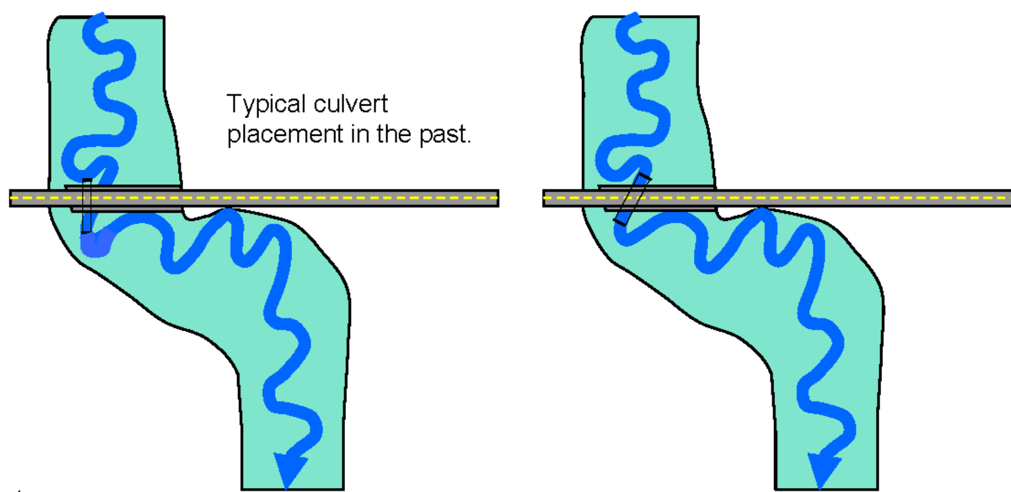
Determining proper elevations of culvert inverts is described in previous pages. When installing multiple culverts, one culvert should be buried to 1/6th the bankfull width as determined by using the longitudinal riffle slope elevation and should be centered on the thalweg (deepest part of the channel cross section). The remaining culvert(s) should be placed one foot higher. Every effort should be made to minimize the number of culverts to maximize capacity and sediment transport.



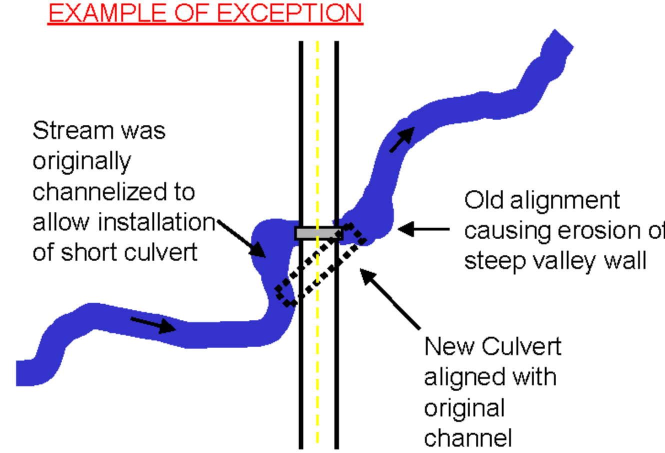
Note; This is the design installation based on a measured cross-section. The stream will adjust its cross-section and will look different after installation. The stream will maintain its cross-sectional area through the culverts, thus resulting in less sediment in the culverts than appears in this diagram.

Alignment

In the past, culverts were typically placed perpendicular to the road, regardless of stream alignment, to minimize the length of the culvert. This saved money in the short term by allowing the shortest possible culvert and was believed to have less impact on fish passage because the distance fish had to swim through the culvert was minimized. However, shortening the stream length increases slope locally, which can destabilize the stream. In addition, the outlets of such culverts often direct the outflow into a bank, rather than down the channel, thus causing bank erosion. These concerns are alleviated by following the channel alignment and other requirements of the permit. By matching bankfull width with culvert width, and burying to allow the culvert to fill with native substrate, fish passage should not be impacted by a longer culvert, and designing for a stable stream will reduce maintenance costs over the long run.



Exceptions to the requirement of following existing stream alignment include replacing culverts that were not in alignment when first installed or situations where the stream is naturally directed into a steep valley wall leading to erosion of the valley wall. An example of the first situation is shown to the right, where a channelized section of stream was restored with a natural meander pattern. When the stream is being directed into a valley wall at the outlet of a culvert, it may be beneficial to redirect the channel away from the valley wall, although each situation is unique and should be looked at individually. Longitudinal slope data must support the proposed change in alignment and plans should be approved by the DNR. Benefits of realigning the channel should be balanced with the impact of installing a longer culvert. Culverts exceeding 100 feet should be avoided.

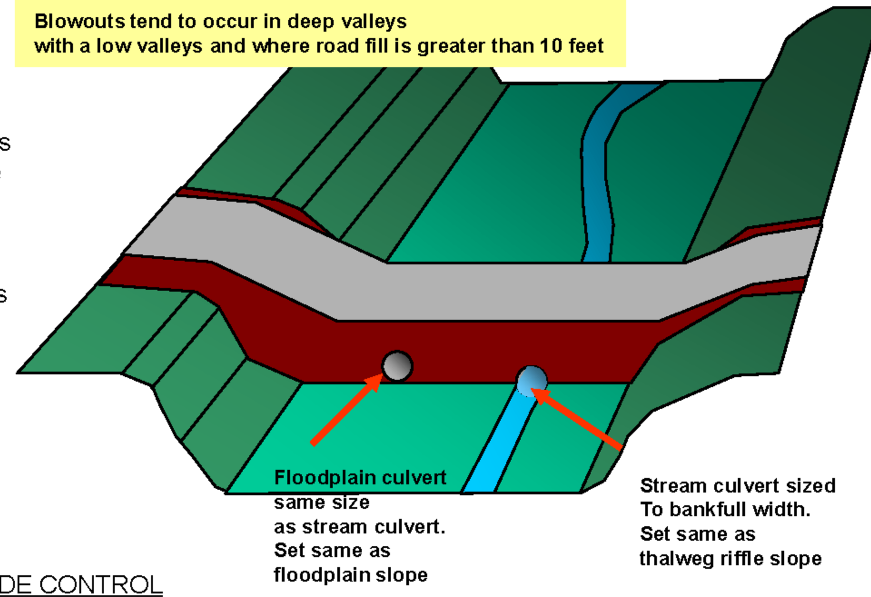


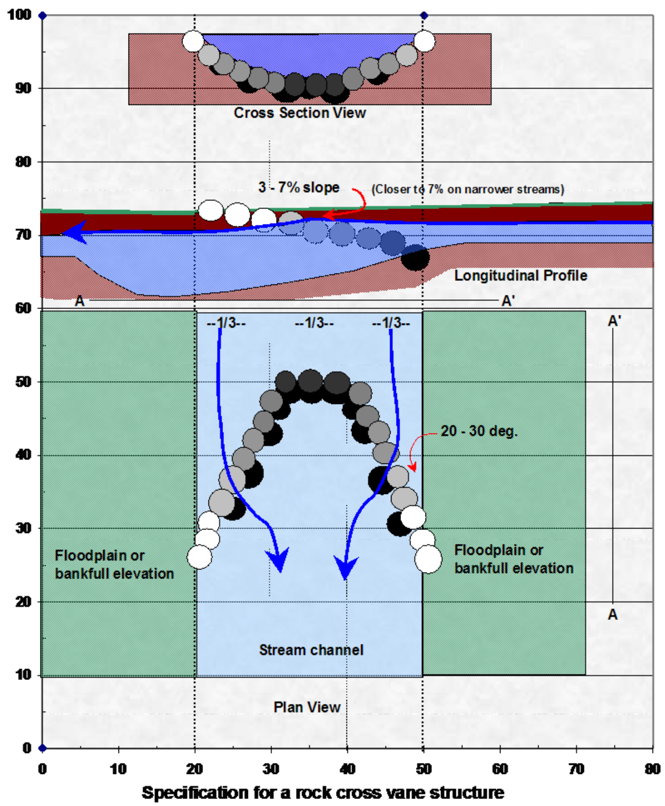
Another exception to consider in replacing existing culverts: There are site conditions where a replacement culvert can be placed adjacent to the existing culvert. Installation is done in the dry, and then the stream is redirected to the new culvert. In many cases this is reverse of how the existing culvert was placed. It is also a good option where there are other resource concerns such as sediment and flow regime during construction.

Always consult with the DNR when considering alignment.

Other Considerations

FLOODPLAIN CULVERTS (See diagram to right)
The requirements in this permit are minimum design specifications. There are circumstances that may require additional design. A healthy stream has full use of its floodplain to release the energy of floods and fish also use the slower velocities in floodplains as refuge during extreme floods. In deep valleys, especially narrow, entrenched ones, adding floodplain culverts not only increases stream stability and aids in fish passage, but reduces the likelihood of road washout. Always consider floodplain culverts in crossings with a history of washouts, or where fish passage is especially critical.





Specification for a rock cross vane structure

GRADE CONTROL
Grade control structures may be beneficial to add to a stream crossing design. They can be used to protect: a) single span bridge pilings from scour, b) provide grade control to prevent head-cutting where past undersized and/or perched culverts have caused upstream aggradation and downstream degradation, c) create slower velocity backwater type habitat for fish passage, or d) direct flow away from a bank (See www/wildlandhydrology.com/assets/cross-vane.pdf for design specifications). W-weirs can be used to protect instream bridge pilings from scour. If grade control greater than about one foot is needed, a rock arch rapids will need to be installed. Design assistance can be provided by the Department of Natural Resources.

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Stream Simulation for Aquatic Organism Passage at Road–Stream Crossings

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Historically, road–stream crossing structures were designed on the basis of the hydraulic capacity of the structure for a specific design flood without consideration of aquatic species or the swimming and jumping abilities of a single target fish species and life stage during its migration, and ignored the movement needs of other adult fish, juvenile fish, and aquatic organisms occupying the stream. Hydraulic designs typically constrict the channel, create flow hydraulics and channel conditions that are markedly dissimilar from those in the natural channel, and impede the movement of most other nontarget fish and aquatic organisms along the stream corridor. The stream simulation approach for designing road–stream crossing structures was recently adopted by the U.S. Department of Agriculture Forest Service as a pragmatic and sustainable long-term solution to maintain passage for all aquatic organisms at all life stages at road–stream crossings while meeting vehicle transportation objectives. This study shows how the stream simulation design process integrates fluvial geomorphology concepts with engineering principles to design a natural and dynamic channel through the road–stream crossing structure. The premise of stream simulation is that the creation of channel dimensions and characteristics similar to those in the adjacent natural channel will enable fish and other aquatic organisms to experience no greater difficulty moving through the structure than if there were no crossing. Stream simulation channels are designed to adjust laterally and vertically to a wide range of floods and sediment or wood inputs without compromising the movement needs of fish and other aquatic organisms or the hydraulic capacity of the structure.

Migration barriers such as dams, irrigation diversions, and road–stream crossings are one of the primary reasons the populations of many aquatic species throughout the world are decreasing in number or are at risk of extinction (*1, 2*). Movement is essential for fish and many other types of aquatic species to gather food, escape poor habitat conditions or predators, and complete phases of their life-cycle such as spawning and rearing (*3*). Recolonization of stream areas by aquatic species after a local extirpation also depends on barrier-free stream movement corridors. Aquatic species isolated by barriers have lower genetic diversity and may be less able to adapt to changing environmental conditions (*4*). Recent movement studies have found that resident salmonid movements are more wide ranging and common than formerly thought, and even small warm-water fish species can no longer be considered sedentary (*5*).

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The National Forest Management Act directed the U.S. Department of Agriculture Forest Service to preserve the diversity of aquatic communities and maintain viable populations of native species on streams within National Forest System lands. The Endangered Species and Clean Water Acts also require that essential behavioral patterns of aquatic species, including their movement, not be disrupted or obstructed. Beginning in the 1970s, the Forest Service began to respond to the issue of road culverts that blocked spawning migrations of salmon and steelhead trout in the Pacific Northwest. Blockages associated with undersized culverts were generally due to high water velocities, excessive turbulence, and shallow water depths in culverts; debris accumulation at the culvert inlet; or high perches of the culvert outlet above the scoured downstream channel (Figure 1; note the distinct perch of the culvert outlet above the channel bed, lack of sediment in the culvert, or aggraded sediment at the culvert inlet).

The Forest Service began replacing older undersized culverts with larger ones designed to provide hydraulic conditions that allowed for passage of adult fish. Hydraulic design has been used for decades to design fish-passable culverts at road–stream crossings along with fishways and other types of passage structures. The objective of a hydraulic design is to create flow conditions through the structure that decrease velocities, decrease turbulence, and increase flow depths for the range of flows in which a particular target species has been shown to be moving. Culvert size, slope, length, and material roughness along the culvert bottom are factored into the hydraulic design method. Baffles, weirs, and rock substrate can be used to increase roughness, decrease flow velocity, and increase flow depth to achieve the design criteria for the target species. However, culverts designed by using the hydraulic method are generally much narrower than the width of the adjacent natural channel.

In the late 1980s, engineers using the hydraulic design approach to design culverts identified several concerns with the method: (*a*) fish swimming performance criteria were lacking for a large number of species, (*b*) the timing and magnitude of flows when fish migrated were uncertain, (*c*) juvenile salmonids could not necessarily navigate the culverts designed for adults of the same species, and (*d*) designing for passage of multiple species that migrate at different times of year and at different flows was impractical. In addition, fish biologists and ecologists began to express the importance that all aquatic species, at all life stages, need to be able to move freely along the stream corridor for the range of flows in which they typically are moving in the natural channel. Moreover, observations that juvenile salmonids were not able to pass through engineered fishways identified the importance of channel substrate and bank heterogeneity in providing critical pathways and resting areas for fish as they moved along the channel (K. K. Bates, Consultant, unpublished data, March 2010).

FIGURE 1 Effects of undersized culverts on channel morphology and fluvial processes: (*a*) upstream view of 6-ft (1.8-m) diameter culvert on Save Creek (Olympic National Forest, Washington), (*b*) downstream view of 3-ft (0.96-m) diameter culvert on North Thompson Creek (White River National Forest, Colorado), (*c*) upstream view of 6-ft (1.8-m) diameter culvert on unnamed stream (White Mountain National Forest, New Hampshire), and (*d*) upstream view of 9-ft (2.7-m) diameter culvert on Peavine Creek (Tahoe National Forest, California).

In addition to the impacts on the movement of fish and other aquatic organisms, culverts smaller than bankfull width are prone to backwatering of the culvert inlet during high flows, causing sediment and debris to accumulate at the inlet. This accumulation of material at the inlet can result in increased maintenance or even failures that disrupt the transportation system, reduce water quality, and degrade channel conditions. In an assessment of the numerous road–stream crossings that failed in the Pacific Northwest from floods between 1996 and 1998, Furniss et al. found that plugging of the culvert by sediment and wood was the primary factor that caused many road–stream crossings to fail (*6*). They concluded that culverts presenting the least change to channel cross section, slope, and alignment through the crossing were most likely to pass sediment and debris, substantially reducing the risk for failure of those crossings. Thus, for both biological and physical reasons, a new paradigm of culvert design, stream simulation, began to evolve.

The concept of stream simulation was first introduced by the Washington Department of Fish and Wildlife in 1999 (*7*). The basic premise of stream simulation is that creation of a structure with channel dimensions and characteristics similar to those in the adjacent natural channel would cause fish and other aquatic organisms to experience no greater difficulty moving through the structure than if there were no crossing. Although the concepts and overarching goals of stream simulation are easily understood, technical guidelines for collecting and interpreting channel data in the vicinity of the road–stream crossing and integrating those data to design a stream simulation channel and structure or roadway had not been thoroughly developed. A 2008 Forest Service publication expands the concept of stream simulation as an ecosystem-based approach to road–stream crossing design and provides detailed guidelines for developing and implementing a stream simulation design (*8*).

Stream simulation designs have a continuous channel through the structure with dimensions and characteristics similar to those in the adjacent natural channel (Figure 2). Water depths, velocities, and pathways in a stream simulation channel are designed to be as similar and diverse as those encountered in the adjacent natural channel, providing for unimpeded passage of fish and other aquatic organisms at all life stages through the structure (*8*). Unlike hydraulic designs, stream simulation designs are not subject to the uncertainties associated with fish swim performance data and migration flows, nor do they depend on the questionable assumption that providing for a target fish species accommodates the needs of other fish and aquatic organisms.

FIGURE 2 Road–stream crossings: (a) culvert built in late 1950s with diameter of 6 ft (1.83 m), length of 90 ft (27.4 m), and gradient of 2.1% before replacement along tributary to Middle Fork Salmon River, Washington; (b) same site as in (a) after the culvert was replaced using stream simulation design approach with open-bottom arch built in late 2005 with span of 18 ft (5.5 m), height of 9 ft (2.7 m), length of 95 ft (28.9 m), and gradient of 4.0%; (c) culvert built in late 1960s with diameter of 3 ft (0.96 m), length of 48 ft (14.6 m), and gradient of 2.0% before replacement along North Thompson Creek, Colorado; and (d) same site as in (c) after culvert was replaced using stream simulation design approach with pipe-arch culvert built in late 2008 with span of 12.2 ft (3.7 m), height of 8.5 ft (2.6 m), length of 48 ft (14.6 m), and gradient of 2.5%.

The various components of the assessment, design, and construction process used in stream simulation are briefly summarized here. Examples of road–stream crossings that were designed using the stream simulation approach are presented along with a brief discussion of site conditions where stream simulation is not appropriate. A more in-depth discussion and list of references on stream simulation may be found elsewhere (*8*).

STREAM SIMULATION DESIGN APPROACH

Stream simulation integrates fluvial geomorphology with engineering principles to design a road–stream crossing that contains a natural and dynamic channel through the structure. This approach requires measurements of site-specific channel characteristics in the adjacent natural channel to ensure that an appropriate reference reach can be identified. Identifying a reference reach is a key component of stream simulation as it provides the natural template for designing a channel through the crossing and determining the size and embedment depth of the replacement structure. The reference reach is typically located in a section of channel that is in close proximity to but not affected by the existing undersized crossing structure and is in the same geomorphic setting as the crossing. The reference reach characterizes channel and floodplain dimensions, channel features and bedforms, and sediment characteristics along a stable, representative reach of the channel. By developing a design channel through a road–stream crossing structure with a gradient, a cross-section shape, bedforms, and sediment size characteristics that are similar to those of the stable nearby reference reach, natural fluvial processes will function through the structure and provide unimpeded aquatic organism passage. The replacement structure, either a bridge or a culvert, is designed around and over the stream simulation channel so that the design channel dimensions determine the dimensions of the structure.

Natural channels constantly adjust their dimension in response to a range of floods and sediment and wood inputs. A stream simulation channel responds similarly to the natural channel and should provide long-term, sustainable geomorphic continuity through the structure and along the stream corridor. To allow for such channel adjustment, flows that transport sediment and wood along the channel should not be constrained by or accelerated inside the crossing structure. The width of a stream simulation design structure is equivalent to or exceeds the bankfull width of the natural channel, which reduces or eliminates backwatering or ponding at the inlet during moderate floods and makes those areas less prone to sediment and debris accumulation. Flow velocities through and exiting the stream simulation structure are similar to those in the downstream channel during a range of floods, preventing excessive scour and degradation of the channel immediately downstream of the structure. In addition, stream simulation structures are less susceptible to damage by high flows and debris blockage because flows are not constricted until they substantially exceed bankfull flow conditions.

Stream simulation design is an interdisciplinary approach requiring those skilled in engineering, hydrology, geomorphology, biology, and construction contract administration. The approach is a multiple-step process that involves (*a*) conducting a watershed and initial reach review, (*b*) conducting a site assessment, (*c*) developing a stream simulation design channel and selecting an appropriate structure, (*d*) finalizing the design and preparing a design contract, and (*e*) constructing the design.

Watershed and Initial Reach Review

Geomorphic processes need to be considered at the watershed scale because channel characteristics and fluvial processes at the local scale are strongly tied to the supply of water and sediment from the upstream watershed and to base-level controls downstream. The interaction and integration of watershed-scale processes control the hydrologic regime (discharge magnitude, duration, and frequency) and sediment regime (quantity and size of sediment supplied) at a given location along the channel, which in turn influence channel characteristics such as channel-bed composition and structure, channel width and depth, channel gradient, sediment transport, and sediment deposition. If watershed-scale processes are not considered in the road–stream crossing channel design, the replacement structure may not adequately handle the temporal variability of water and sediment that passes through the crossing from natural and anthropogenic disturbances, potentially causing unintended passage issues to fish and other aquatic organisms.

By using existing information and data resources, the watershed review identifies (*a*) large-scale natural processes (e.g., landslides, floods, wildfire) and management activities that can influence, have influenced, or will influence channel conditions and geomorphic processes at the crossing; (*b*) the value of aquatic resources at the crossing within a broader, watershed-scale context; and (*c*) current and future transportation requirements, potential roadway constraints, and past road maintenance issues at the crossing.

Once this watershed information is obtained, the interdisciplinary team performs a site reconnaissance at the road–stream crossing. During the site reconnaissance the team gathers preliminary information about the road–stream crossing and qualitatively describes channel characteristics upstream and downstream of the crossing. The team evaluates the alignment of the channel with the current structure and roadway, determines if the crossing can be relocated to a more favorable location, assesses current channel conditions and stability, identifies important geomorphic features of the stream that will need to be surveyed in subsequent phases of the stream simulation process, and identifies potential construction constraints and challenges at the site.

From the information obtained from the watershed review and site reconnaissance, the interdisciplinary team develops preliminary project objectives for replacing the road–stream crossing. Project objectives will become more clearly defined as the team learns more about site conditions and constraints during the site assessment. Preliminary project objectives should address both ecological and transportation needs at the site, reflecting both the risks and resource values associated with the project.

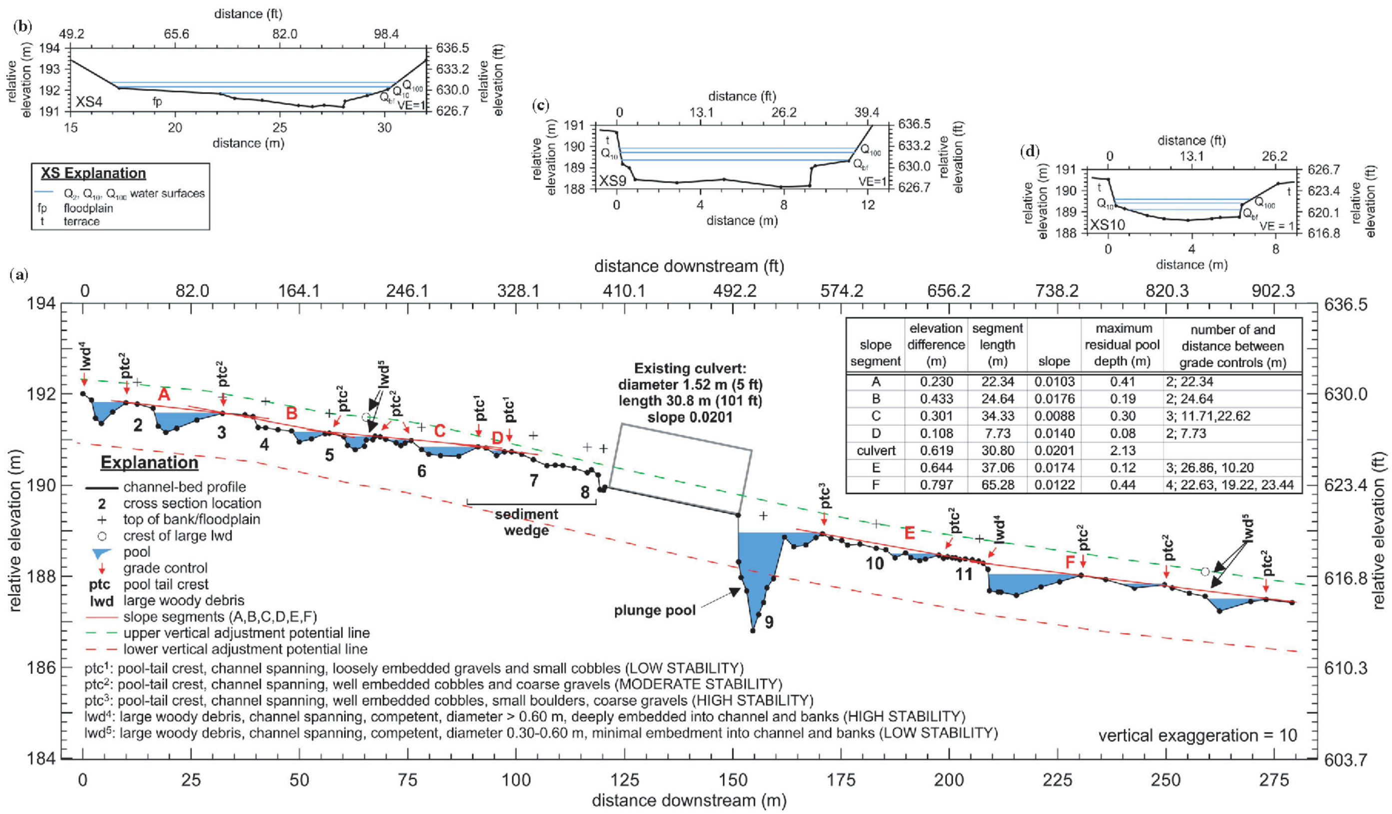
Site Assessment

After preliminary project objectives to replace the road–stream crossing structure have been defined, a detailed site assessment is conducted. During the site assessment, the interdisciplinary team collects data and information to characterize channel features and interpret geomorphic processes 20 to 30 channel widths upstream and downstream from the road–stream crossing. At the crossing, the team also evaluates road travel-way alignment and approaches, right-of-way and property boundary issues, and the presence of utilities.

Data collection for the site assessment requires a site survey to characterize channel, valley, and road topography as well as important geomorphic and road features observed at the site. A longitudinal profile survey of the channel is the most valuable data collected and interpreted in the stream simulation design process because it characterizes the range of channel gradients, type and stability of grade controls, range of pool scour depths, spacing and length of channel units, and potential aggradation surfaces upstream and downstream of the road–stream crossing, as shown in Figure 3*a*. In Figure 3*a*, note the differences between the depth and spacing of pools upstream and downstream of the crossing. The dashed red and green lines bracket the potential range of bed elevations along the channel in response to floods and inputs of sediment and debris over the service life of the structure. The effects of the undersized culvert are illustrated by the sediment wedge upstream of the inlet and the deep plunge pool downstream of the outlet.

Surveying representative cross sections upstream and downstream of the road–stream crossing provides important data on bankfull flow width, flood-prone width, bank height and stability, channel entrenchment, and valley confinement along the channel (Figure 3*b*–*d*).

The site assessment includes interpreting the natural channel pattern through the road–stream crossing, collecting sediment data along the channel bed, and conducting a preliminary geotechnical investigation. Interpreting the original natural channel location and pattern through the road–stream crossing is necessary to determine how the existing crossing structure has affected the length and slope of the channel through the crossing. Characterizing channel-bed composition is important for understanding of bed mobility along the channel, the stability of key feature particle sizes in the channel, and sediment supply to the channel and for determining the size and range of sediment sizes for the design channel through the crossing (Figure 4). A geotechnical field investigation is performed to assess the presence of bedrock, unstable soils, and shallow groundwater at the road–stream



slope segment	elevation difference (m)	segment length (m)	slope	maximum residual pool depth (m)	number of and distance between grade controls (m)
A	0.230	22.34	0.0103	0.41	2; 22.34
B	0.433	24.64	0.0176	0.19	2; 24.64
C	0.301	34.33	0.0088	0.30	3; 11.71,22.62
D	0.108	7.73	0.0140	0.08	2; 7.73
culvert	0.619	30.80	0.0201	2.13	
E	0.644	37.06	0.0174	0.12	3; 26.86, 10.20
F	0.797	65.28	0.0122	0.44	4; 22.63, 19.22, 23.44

FIGURE 3 Longitudinal profile and cross sections: (*a*) longitudinal profile showing range of channel gradients, spacing and length of channel units (pools, riffles, wood-forced small steps), type and stability of grade controls, distribution and distance between grade controls, and range of pool scour depths along a channel upstream and downstream of a road–stream crossing; (*b*) representative cross section upstream of road–stream crossing characterizing channel dimensions at various flows; (*c*) cross section at plunge pool showing channel dimensions at various flows; and (*d*) representative cross section downstream of road–stream crossing characterizing channel dimensions at various flows.

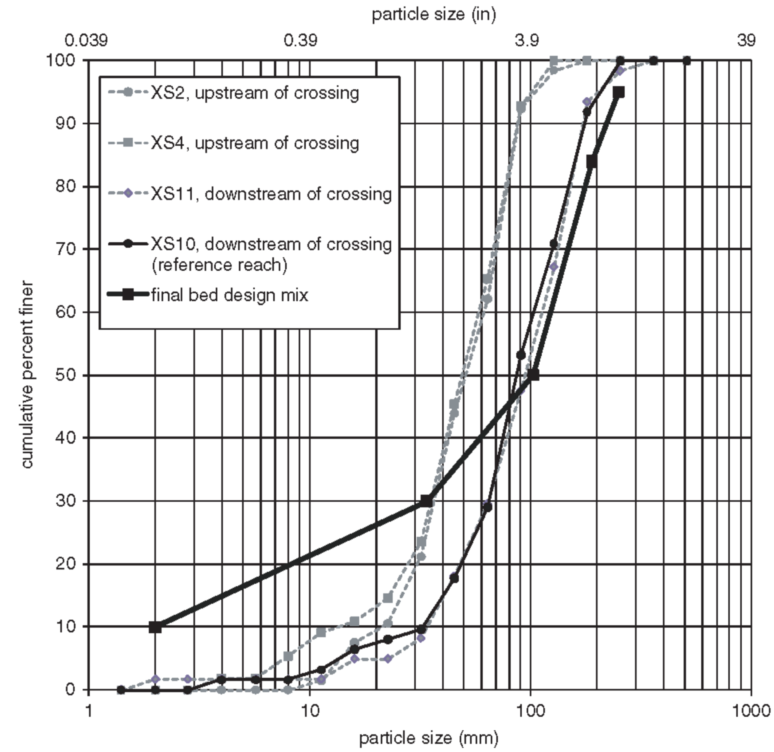


FIGURE 4 Particle-size distributions collected at four cross sections along channel upstream and downstream from road–stream crossing site described in Figures 3 and 5. Solid line represents final bed design mix for design based on bed mobility analysis and inclusion of fines to reflect presence of fines in subsurface. For design channel to have similar mobility as reference reach channel, particles larger than D50-percentile particle size were increased by factor of 1.2 in design channel when compared with reference reach particle sizes.

crossing and to determine if a more in-depth subsurface investigation is necessary.

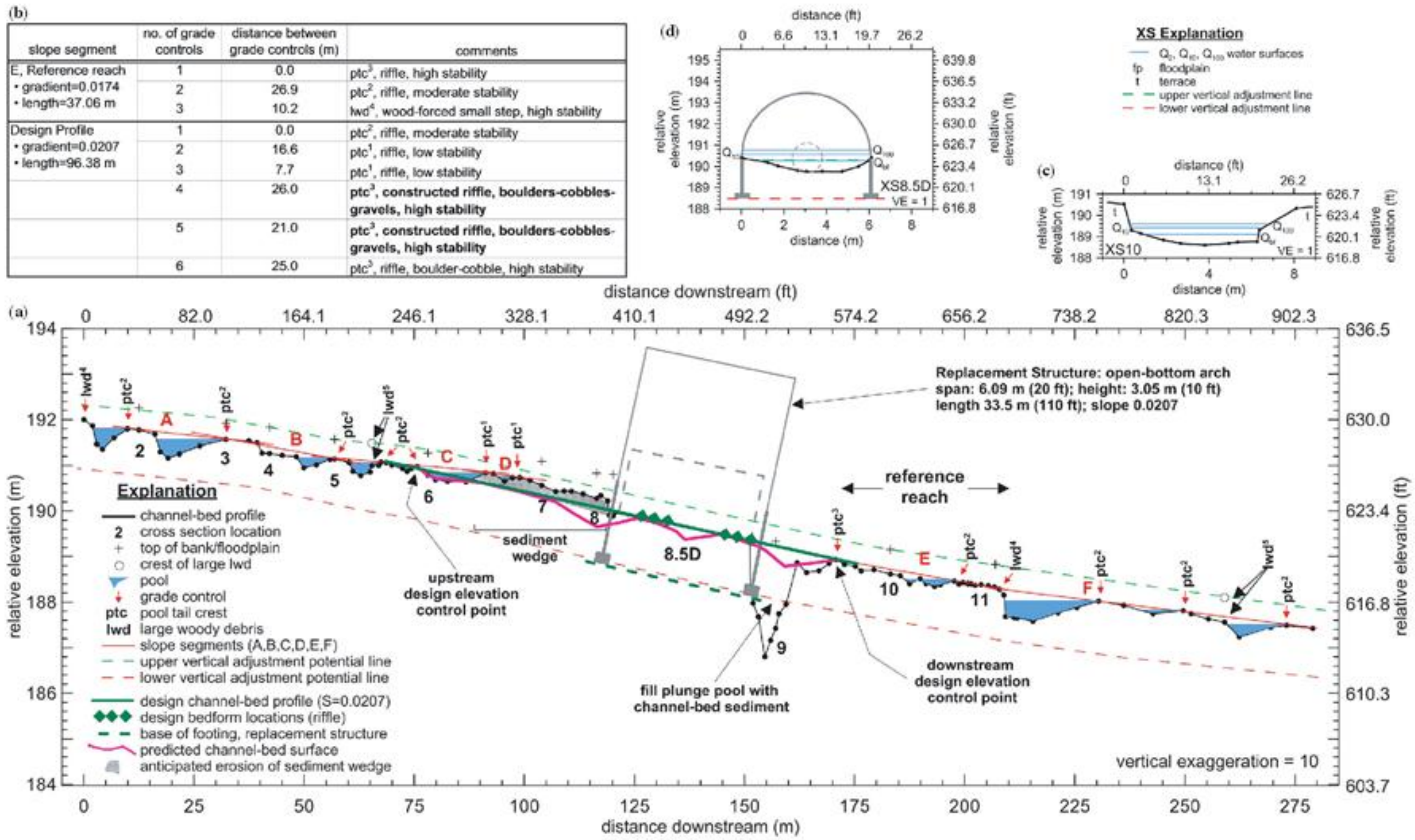
On the basis of the analyses and interpretations of the various site assessment data, potential channel responses and risks are predicted when the existing structure is replaced. Channel responses and site risks that need to be addressed at the road–stream crossing include the stability or instability of the channel, floodplain-conveyance issues, and the potential for headcutting, vertical channel adjustments, lateral channel adjustments, and debris loading.

Stream Simulation Design

During the stream simulation design phase, the information and data obtained during the site assessment are used to develop a stream simulation channel through the road–stream crossing that is based on a reference reach in the adjacent natural channel. The key components of the stream simulation design process include optimizing horizontal alignment relative to the road, developing a longitudinal profile of the design channel through the crossing, developing the cross-section shape of the design channel, and developing the size and arrangement of bed material for the design channel.

On the basis of the interpreted natural channel pattern through the crossing, the structure orientation and road alignment are evaluated to determine if they can be modified to improve the hydraulic transition between the channel and the structure. Special design options such as headwalls or dips in the road that shorten the length of the replacement structure should be considered and used to develop the best alignment between the structure and the channel.

Developing the design longitudinal profile through the road–stream crossing is the most important step in the stream simulation design process (Figure 5*a*, *b*). The design profile in Figure 5 shows the proposed structure and embedment depth, that the plunge pool is to be filled with channel-bed sediment, that the sediment wedge surface will be eroded and lowered by natural flood processes, and the predicted channel-bed surface after a period of adjustment (see Figure 3*a* for additional information about prereplacement conditions). The design longitudinal profile represents the surface that will be constructed through the project reach so that geomorphic continuity is provided between the upstream and downstream channels. This process involves (*a*) developing a design channel gradient that is anchored to stable grade controls upstream and downstream of the crossing, (*b*) identifying a reference reach in an adjacent natural channel that is similar in gradient and length to the design channel,



slope segment	no. of grade controls	distance between grade controls (m)	comments
E, Reference reach • gradient=0.0174 • length=37.06 m	1	0.0	ptc³, riffle, high stability
	2	26.9	ptc², riffle, moderate stability
	3	10.2	lwd⁴, wood-forced small step, high stability
Design Profile • gradient=0.0207 • length=96.38 m	1	0.0	ptc², riffle, moderate stability
	2	16.6	ptc¹, riffle, low stability
	3	7.7	ptc¹, riffle, low stability
	4	26.0	**ptc³, constructed riffle, boulders-cobbles-gravels, high stability**
	5	21.0	**ptc³, constructed riffle, boulders-cobbles-gravels, high stability**
	6	25.0	ptc³, riffle, boulder-cobble, high stability

FIGURE 5 Longitudinal profile and cross sections: (*a*) stream simulation design profile at crossing (solid green line) tied to stable elevation grade controls upstream and downstream of crossing; design profile is similar in gradient to reference reach channel segment, and diamond symbols on design profile are grade controls (constructed riffles) similar in dimension and characteristics to those in reference reach; (*b*) summary of type, stability, and spacing of bedforms in reference reach and design channel; (*c*) representative cross section from reference reach characterizing channel dimensions at various flows downstream of road–stream crossing; and (*d*) representative cross section of design channel and replacement structure.

(*c*) determining the spacing and dimensions of bedforms in the design channel that are similar to those measured in the reference reach, (*d*) ensuring that the design channel provides geomorphic continuity between the upstream and downstream channel, (*e*) determining the structure embedment depth based on pool scour depths measured along the channel and interpreted scour depths at the crossing, and (*f*) interpreting the potential ranges of channel-bed surface elevations that may occur over the service life of the structure.

The cross-section shape for the stream simulation design channel is based on finding a shape that best fits the shape of cross sections in the reference reach (Figure 5*c*) and is feasible to describe in a contract and to construct. This shape is used later in the design process to determine the size and type of structure that are best suited for the site.

The particle-size mix for the stream simulation design channel is initially determined by using the particle-size distribution of the channel bed in the reference reach. Typically, the percentage of smaller particles is increased in the particle-size distribution to reflect the presence of those sediment sizes in the subsurface that fill the voids between the larger particles (Figure 4). The particle sizes needed to construct key features in the stream simulation design channel (e.g., grade controls, bedforms, banks, large roughness elements) are initially determined from measurements of the 10 to 25 largest particles of key features in the reference reach channel. Later in the stream simulation design process, the initial particle sizes selected may be modified on the basis of bed mobility and stability analyses, site risk factors, and site conditions.

Final Design and Contract Preparation

The final design and contract preparation phase of the stream simulation design process involves

1. Selecting a structure,
2. Analyzing the mobility of the stream simulation design channel bed,
3. Analyzing the stability of key pieces and bedforms in the design channel bed for the design flood,
4. Evaluating the hydraulic capacity of the selected structure for the design flood,
5. Developing final bed material specifications for the stream simulation design channel,
6. Developing erosion control and dewatering plans, and
7. Preparing the documents necessary for soliciting construction bids.

After the shape and dimensions of the stream simulation design channel are determined (width, depth, range of potential vertical bed changes, bank geometry), the replacement structure is selected and the roadway is designed. The type and size of crossing structure selected are determined by fitting them around the design channel and allowing for additional space to accommodate potential vertical and lateral adjustments over the service life of the structure (Figure 5*d*). A wide variety of structures such as circular culverts, arch culverts, concrete or metal open-bottom arches, and bridges may be suitable at the road–stream crossing. Engineering considerations at the crossing (right-of-way and property boundary issues, limitations on changing the road travel-way alignment and approach, limitations on moving utilities) combined with economic costs, materials and equipment available, value of the aquatic resource, and funds available will influence the type and size of the structure selected at a given site.

After the structure type and its dimensions have been selected, the mobility of the design bed material, stability of key particles in grade controls, and hydraulic capacity of the proposed structure are analyzed. The purpose of the bed mobility analysis is to determine if the initial bed material sizes selected are mobilized at the same flows as those in the reference reach. If they are not, the initial bed material sizes are increased until similar bed mobility between the design channel and reference reach channel is obtained (Figure 4). Bed mobility in the stream simulation design channel needs to be similar to that of the reference reach during low and moderate floods to ensure that excessive aggradation and degradation do not occur in the design channel.

The purpose of the bed stability analysis is to determine if the initial key feature particle sizes selected for the stream simulation design channel are stable for the design flood. Key pieces for features such as steps, riffles, and banks that are used to control channel form and flow hydraulics need to be stable for the design flood. This stability is important since the particle sizes of key features in the design channel are not easily replenished or replaced if mobilized. Banks for both low- and high-gradient channels are designed to be permanent for the design life of the structure. The stability of most natural banks is a function of the root structure of bank vegetation, the particle sizes and stratigraphy of the banks, and cohesive nature of the banks. Because vegetation growth inside the structure is not attainable, bank material must be sized appropriately to emulate the function of vegetation for bank stability in the design channel during the design flood discharge. From the results of the bed mobility and stability analyses, a final bed material gradation for the overall bed and the key pieces is determined and specified in the contract.

The proposed design structure is then evaluated to determine if it has sufficient hydraulic capacity and debris clearance during the design flood. Stream simulation design structures are required to have headwater-to-depth ratios less than 0.80. This requirement reduces the likelihood that pressurized flow will occur at the inlet and provides clearance for debris being transported during large-magnitude floods. Observations and analyses of stream simulation structures show that the headwater-to-depth ratio for the 100-year design flood discharge is typically less than 0.60.

Finalizing the engineering design for the contract includes specifying the road reconstruction and fill requirements, providing documentation outlining special contract provisions needed to control the size of bed material used and how it is placed in the design channel, providing details on how to protect aquatic species and water quality during construction activities, and specifying dewatering and pollution control plans.

Construction

The long-term success of a stream simulation project depends on the effective implementation of the design during construction. Successful implementation requires that those involved in construction have a solid understanding of the project objectives and critical design elements. Construction for a stream simulation design is somewhat different from other road–stream crossing design approaches because it involves building a three-dimensional channel bed. Precision in determining channel elevation control can be crucial to the success of the project, especially on steeper channels.

Installation of the physical structure of a stream simulation design is the same as that for any other road–stream crossing design and must be in accordance with the installation specifications of the selected structure. The most critical aspects of stream simulation construction are the placement and arrangement of the bed material, grade control features (e.g., steps, riffles), and banks (Figures 2*b*, *d*, and 5*a*). The material used to construct the stream simulation channel bed is built in multiple lifts or layers. The thickness of the lifts is a function of the larger particles in the bed gradation (D84- to D95-percentile particle sizes) since those sizes affect placement and compaction. The large particles used to construct the key features should be incorporated and embedded into the surrounding bed material. The bed material is compacted around the key features to help lock them in place. Proper channel-bed construction techniques include keying in the base of structural elements (steps, riffles, banks), interlocking and packing key particles against each other to maximize the stability of those features, incorporating smaller particles between the voids of larger particles to reduce bed permeability and achieve a dense interlocking channel bed, and conducting quality control measurements to ensure that the sediment sizes specified in the design are being used. Bed material must be well graded and contain a sufficient quantity of fines (generally between 5% and 10%) so that the voids between larger rocks can be filled. As lifts are compacted, fines can be jetted into the surface of the channel to effectively fill the voids throughout the constructed bed. If the bed material does not include enough fines, flows can infiltrate into the bed, unnaturally drying sections of the channel during critical low flow periods when aquatic species need to move. Experience has shown that the voids between large particles do not necessarily fill naturally over time.

Dewatering the construction area is an important step, and it can be challenging because some structures can take weeks or months to build. The dewatering system must accommodate any high flows that may occur during the construction period. Also, projects in habitat occupied by threatened, endangered, or other critical species often require special care in removing organisms that would otherwise be killed during construction. Dewatering of the channel needs to be done slowly to allow crews to catch and move aquatic species out of the construction area. Slow rewatering of the channel after construction is necessary to avoid releasing a pulse of sediment that could bury habitats and harm aquatic organisms downstream of the construction site.

Proper and successful construction of key features requires adequate oversight at multiple times to ensure that materials meet gradation requirements, particles are properly packed and interlocked, and voids are sufficiently filled with fines. Other critical aspects of construction that require oversight and inspection include foundation preparation, dewatering of the site, and material development. In addition, erosion and pollution control measures, traffic control, and public safety measures need to be in place at all times during construction.

LIMITATIONS AND CHALLENGES

Although the stream simulation approach can be used to assess and design most road–stream crossings where aquatic organism passage is an issue, there are environments that make achieving the objectives of stream simulation unlikely. These environments include

1. Unstable, incised channels downstream of road–stream crossings;
2. Road–stream crossings located on active alluvial fans;
3. Road-impounded wetlands that form sediment sinks upstream of road–stream crossings; and
4. Roads that cross channels prone to debris flows or other mass wasting events.

These types of environments are identified during the watershed review and site reconnaissance of the stream simulation design process. In these cases, the physical differences between the design channel and reference-reach channel may be too great to achieve the objectives of stream simulation. However, the collection of channel data and analyses performed during site assessment of the stream simulation process can be used to develop an alternative, geomorphic-based channel design that reconnects the upstream and downstream channel while meeting the needs of most fish and other aquatic organism movement.

Stream simulation requires critical inspection of the design channel when it is being built. The actual process of constructing a channel bed with bedforms, banks, and key features is new to many contractors and Forest Service personnel. In some instances, this lack of familiarity has resulted in improperly built design channels that are dissimilar to those in the adjacent natural channel and are possibly not providing passage for fish and other aquatic organisms at all life stages. Contract administrators and inspectors may require additional training to ensure that critical elements of the stream simulation design channel are built as specified in the contract.

Road–stream crossing structures designed with the stream simulation approach initially cost about 20% to 30% more than those designed with hydraulic design methods because the structures are wider and placed deeper below the channel bed, and a channel with bedforms and banks is built through the structure. However, stream simulation structures are anticipated to require little or no maintenance and last longer than structures designed using the hydraulic design methods, resulting in lower total costs over the service life of the structure. Monitoring and anecdotal information provided by field offices reports that stream simulation road–stream crossing designs have lower maintenance needs than the culverts they replaced.

SUMMARY

The stream simulation approach for designing road–stream crossing structures is applied on all Forest Service roads where restoring ecological continuity along the stream corridor is an objective. Since the turn of the century, the Forest Service has successfully designed and installed hundreds of road–stream crossings on national forests using the stream simulation approach. Although more time is needed to evaluate the long-term effectiveness of stream simulation designs, the Forest Service believes that the approach is a pragmatic and sustainable long-term solution to maintain passage for all aquatic organisms at all life stages at road–stream crossings while meeting vehicle transportation objectives. Moreover, the stream simulation design approach to road–stream crossings allows the Forest Service to meet requirements of not disrupting or obstructing the movement and habitat needs of aquatic species as outlined in the National Forest Management Act, the Endangered Species Act, and the Clean Water Act.

The stream simulation design approach at road–stream crossings integrates fluvial geomorphology concepts with engineering principles to design a natural and dynamic channel through the road–stream crossing structure. By using reference reach metrics in the stream simulation design channel, the morphology and hydraulic characteristics of the design channel should provide no greater obstacle to the movement needs of fish and other aquatic organisms occupying the stream. Because the dimensions and characteristics of stream simulation channels through the road–stream crossing are similar to those in the natural channel, stream simulation channels are capable of laterally and vertically adjusting to a wide range of floods and sediment or wood inputs without compromising the movement needs of fish and other aquatic organisms or hydraulic capacity of the structure. In addition, stream simulation structures are less susceptible to damage by high flows and debris blockage because they do not constrict the channel until flows substantially exceed bankfull flow conditions. More details and discussion on the stream simulation assessment, design, and construction process may be found in the 2008 Forest Service technical guide (*8*).

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Flood Effects on Road-Stream Crossing Infrastructure: Economic and Ecological Benefits of Stream Simulation Designs

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ABSTRACT
Stream simulation design is a geomorphic, engineering, and ecologically based approach to designing road–stream crossings that creates a natural and dynamic channel through the crossing structure similar in dimensions and characteristics to the adjacent natural channel, allowing for unimpeded passage of aquatic organisms, debris, and water during various flow conditions, including floods. A retrospective case study of the survival and failure of road–stream crossings was conducted in the upper White River watershed and the Green Mountain National Forest in Vermont following record flooding from Tropical Storm Irene in August 2011. Damage was largely avoided at two road–stream crossings where stream simulation design was implemented and extensive at multiple road–stream crossings constructed using traditional undersized hydraulic designs. Cost analyses suggest that relatively modest increases in initial investment to implement stream simulation designs yield substantial societal and economic benefits. Recommendations are presented to help agencies and stakeholders improve road–stream crossings, including increasing coordination to adopt stream simulation design methodology, increasing funding and flexibility for agencies and partners to upgrade failed crossings for flood resiliency, and expanding training workshops targeting federal, state, and local stakeholders.

REDUCING LOCALIZED IMPACTS TO RIVER SYSTEMS THROUGH PROPER GEOMORPHIC SIZING OF ON-CHANNEL AND FLOODPLAIN OPENINGS AT ROAD/RIVER INTERSECTIONS

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November, 2013

DNR Stream Habitat Program website: http://www.dnr.state.mn.us/eco/streamhab/index.html
Publication: http://files.dnr.state.mn.us/eco/streamhab/geomorphology/reducing-rior.pdf

Minnesota Pollution Control Agency | www.pca.state.mn.us

Perimeter control

National Pollutant Discharge Elimination System/State Disposal System Permit Guidance on the use of perimeter control

Silt fence used as perimeter control

Perimeter control is a method of sediment control best management practices (BMPs) that acts as a barrier to retain sediment on a construction site. Sediment control BMPs are intended to slow and hold flow, filter runoff, and promote the settling of sediment out of runoff, via ponding behind the sediment control BMP.

What is required by the National Pollutant Discharge Elimination System/State Disposal System Construction Stormwater Permit?

The National Pollutant Discharge Elimination System/State Disposal System (NPDES/SDS) Construction Stormwater Permit (Permit) requires that certain sediment control BMPs are utilized to minimize sediment from leaving a construction site. Some sediment controls, such as ditch checks, may be needed to promote sheet flow and prevent rills and gullies from forming on steeper slopes or ditch bottoms. The Permit also requires additional sediment controls to be utilized at the base of soil piles to contain sediment. Sediment controls located at down gradient boundaries of the construction site are referred to as “perimeter controls”. The location and type of perimeter control BMPs, along with other sediment control BMPs required by the Permit, must be identified in the site’s Stormwater Pollution Prevention Plan (SWPPP).

The perimeter sediment control BMPs must be established on all down gradient perimeters and up-gradient of buffer zones before any land disturbing activities begin. These BMPs shall remain in place until final stabilization has been established. If the down gradient perimeter controls are overloaded, additional up gradient controls may be necessary to prevent further overloading. The selection of perimeter control BMPs is the permittee’s decision, but it must be effective at keeping sediment on the site. If it is determined through inspection that the selected method is not effective, then the BMP must be upgraded to a method that is effective at keeping sediment on the site.

The timing of the perimeter control installation may be adjusted to accommodate short term activities such as clearing and grubbing, and passage of vehicles. This means these BMPs may be taken down as necessary to allow vehicle on and off areas of the site or to allow work such as utilities to be installed through the perimeter BMP. These short term activities must be completed as quickly as possible and the perimeter control BMPs must be reinstalled immediately after the activity is finished. All perimeter control BMPs, however, must be in place before the next precipitation event, even if the activity is not complete. For full details of the Permit requirements, a copy of the NPDES/SDS Permit can be found at www.pca.state.mn.us/water/stormwater/stormwater-c.html.

Types of perimeter sediment control

Silt fence is a commonly known method of perimeter control. However, other types of perimeter controls exist that can be equally or even more effective depending on the construction site circumstances. The following sediment control BMPs are commonly used as perimeter control on construction sites of all sizes:

- ditch checks
- rock logs
- compost berms, logs, and rolls
- biorolls
- sand bags
- vegetated or stabilized soil berms
- geotextile wrapped jersey barriers
- existing vegetation
- silt fence
  - super duty
  - heavy duty
  - preassembled

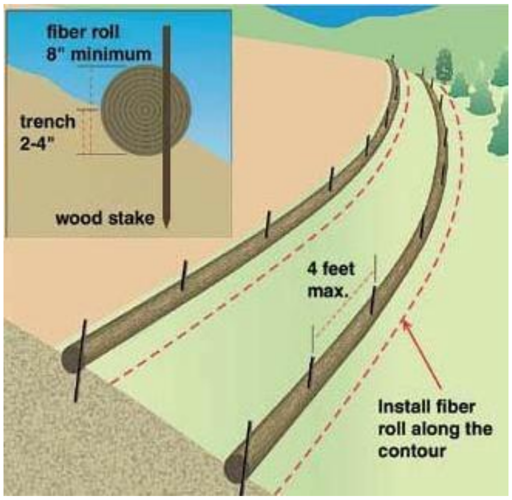
Planning perimeter sediment control

Perimeter controls should be planned as a system, taking the entire site into consideration and installed prior to any land disturbing activity, and only need to be installed in locations down gradient of the construction. The design of a site's perimeter control system should anticipate ponding that will occur up gradient of the controls and provide sufficient storage and deposition areas and stabilized outlets to prevent flows from over topping the controls. The SWPPP must account for the following factors in designing the temporary erosion prevention and sediment control BMPs including perimeter controls:

1. The expected amount, frequency, intensity, and duration of precipitation.
2. The nature of stormwater runoff and run-on at the site, including factors such as expected flow from impervious surfaces, slopes, and site drainage features.
3. If any stormwater flow will be channelized at the site, the Permitte(s) must design BMPs to control both peak flow rates and total stormwater volume to minimize erosion at outlets and to minimize downstream channel and stream bank erosion.
4. The range of soil particle sizes expected to be present on the site.

Flows should be strategically directed to specified deposition areas through appropriate positioning of the perimeter controls and site grading. Sometimes additional perimeter controls need to be added or moved to different locations on a project as conditions change. For example, perimeter control is installed above street curbs once the curb and gutter system is installed to keep sediment out of the water conveyance. Some perimeter controls can be relocated as needed, such as biorolls, rock logs, sand bags, and triangular silt dikes. Keeping a vegetated buffer between disturbed areas on a construction site and the down gradient perimeter control BMP can help the BMP perform better and need less maintenance.

Perimeter control BMPs serve no function along ridges or drainage divides where there is little movement of water. Perimeter controls should be installed on the contour of slopes, and the ends of the BMP should bend up slope forming a crescent shape or a "J- hook" rather than a straight line. This will prevent runoff from flowing around the ends of the controls.



Install biorolls or other sediment controls along the contour of the slope.

"J-hooked" silt fencing

Maintenance considerations

The NPDES/SDS Permit requires that all BMPs are inspected once every seven days or within 24 hours of a rainfall event greater than 0.5 inches in 24 hours. All non-functioning BMPs must be replaced, repaired or supplemented with functional BMPs within 24 hours of discovery or as soon as field conditions allow access. Generally, sediment controls must be repaired, replaced, or supplemented when they become nonfunctional, or sediment reaches 1/3 the height of the control.

After the contributing drainage area has been stabilized, all sediment controls and the associated sediment build up must be removed and disposed of properly. Care should be taken to dispose of sediment in a location that is not susceptible to erosion.

Cold weather considerations

It is important to consider winter conditions when planning a perimeter control system. All construction sites must remain in compliance with the NPDES/SDS Permit throughout the winter even if no construction is occurring. It is imperative that properly functioning sediment controls are in place during minor thaws and for the large spring snowmelt to prevent transport of sediment to area surface waters. For this reason, the BMPs must be installed and functional prior to winter freeze up. The BMPs must be inspected and maintained immediately following intermittent snow melt or rainfall that occurs in winter months. If construction resumes during the winter, then the weekly inspection schedule must also resume.

The best way to ensure proper functioning of perimeter controls throughout the winter is to have all sediment controls installed prior to the first freeze. Stakes needed for some sediment control BMPs will be difficult, if not impossible to install into frozen ground. The site's SWPPP should clearly outline the strategy to prepare the site for the winter months.

Regular maintenance is needed to ensure that a site's perimeter control is functioning properly.

If construction is going to continue during the winter and new areas will be disturbed that requires new sediment controls; materials such as compost berms, logs and rolls, fiber rolls, rock bags and rock filters can be installed over the snow cover. These installations will need extra care and frequent inspections to assure continued effectiveness.

Use of down gradient perimeter sediment control for work in or near open water

It is critical to ensure down gradient perimeter controls are utilized during work on stream banks and lake shores to keep sediment from washing into open water. Sediment discharges resulting from this type of construction can result in enforceable water quality violations.

Sites that include work in public waters permits from the Department of Natural Resources (DNR) that also have coverage under the Minnesota Pollution Control Agency's (MPCA) general construction stormwater permit are required to comply with the conditions in both permits, including the use of down gradient perimeter controls to minimize sediment discharges.

More specialized types of sediment control BMPs may be needed to protect surface waters during construction that extends below the water surface. Whenever possible, work below the Ordinary High Water table (OHW) should be done in a manner that keeps water out of the work area, or separated from flowing water. For example, coffer dams made of sheet pilings or other materials to isolate the work from the water or water diversions to divert water around the work area may be the best choices during bridge construction or any work that encroaches into open water.

Coffer dams made of sheet metal to isolate the work area from the surface water.

Biorolls, rock logs, sand bags, triangular silt dikes, geotextile wrapped jersey barriers or stabilized soil berms that can easily be relocated may be best during stream bank restoration work. The perimeter control method may need to change as work changes at the site. Therefore, multiple perimeter control methods may be employed at one site at different times or at the same time.

If the work is conducted on an MPCA designated special water, such as a trout stream or scenic and recreational river segment, redundant BMPs must be employed when an existing 100 foot buffer is encroached. In this case, more than one method of perimeter control is employed or a super duty perimeter control method may be required to adequately protect the surface water.

Protection of wildlife

Perimeter controls have been known to trap amphibians, reptiles, and small mammals within a construction area. Of concern is the inadvertent harm to rare species. Inspectors of perimeter controls should move rare species out of harm's way if they appear trapped or are in imminent danger. If not in danger, they should be left alone. In areas of known rare species populations, silt fence may also be helpful in keeping these animals out the construction area. In all cases it is critical that silt fencing be removed after the area has been re-vegetated. More information on Minnesota's rare species can be found on the DNR website: http://www.dnr.state.mn.us/ets/index.html.

Floating curtain is not perimeter control

Frequently, floating silt curtains are employed during work in water. However, it is important to note that floating curtains will not satisfy MPCA's NPDES/SDS Permit requirement for down gradient

Relying on floating curtain as down gradient perimeter control will result in permit violations for failure to install sediment control and in most cases will result in water quality violations.

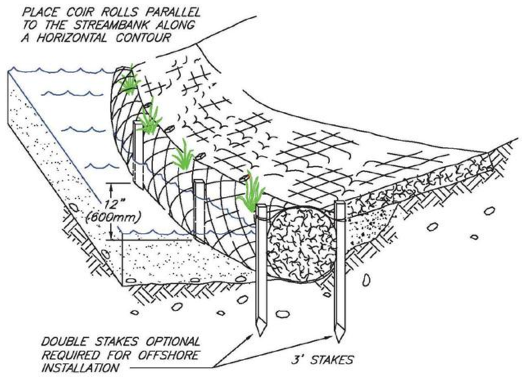
perimeter control. Even if a floating curtain is utilized, down gradient perimeter control must still be installed between the work and the surface water to prevent sediment from entering the surface water. A nuisance condition (as described in Minn. R. 7050.0210 sub. 2) caused by allowing sediment runoff into the water body is a water quality violation.

Floating silt curtain is not designed to prevent sediment from entering surface water. It is designed to help contain suspended sediment within the water column until it has settled to the bottom of the water body. Therefore, floating curtain's only use may be for work that cannot be done outside the water or as a secondary containment to minimize the impact of a water quality violation and keep the damage to the water body near the shore and the sediment recoverable.

Use floating silt curtain for work in the water as secondary containment to contain sediment close to the work area.

Proper placement of perimeter sediment controls near water

Perimeter controls need to be installed before upgradient work begins. The perimeter control should be placed at the water's edge during work on the bank or shoreline. If possible, vegetation should be left between disturbed areas and the sediment control BMP. As work is completed on the bank and the bank is fully stabilized, the perimeter controls can be moved upward away from the water's edge above the vegetated or rip rapped areas.



Fiber roll installation at shoreline.

Move perimeter controls up the bank as the bank is stabilized.

Additional resources

Additional information on the use of perimeter controls; including use of floating silt curtain, water diversions, coffer dams and other perimeter control BMPs for work in or near waters as well as all other applications can be found in the *MPCA Protecting Water Quality in Urban Areas – Manual* http://www.pca.state.mn.us/index.php/view-document.html?gid=7157.

Minnesota DNR species protection information http://files.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_chapter1.pdf.

MPCA Stormwater Construction Inspection Guide http://www.pca.state.mn.us/publications/wq-strm2-10.pdf.

United States Environmental Protection Agency NPDES Menu of BMPs –Construction Site Sediment Control – *Silt Fences* http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=56&minmeasure=4.

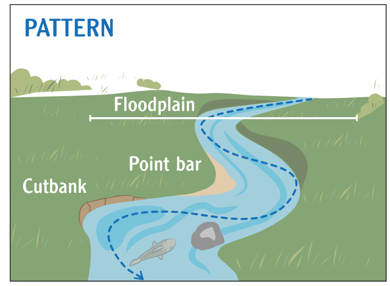
Understanding Our Streams and Rivers

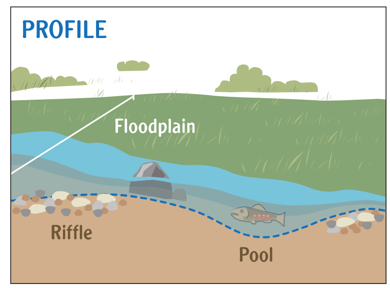
Are Minnesota Streams Healthy?

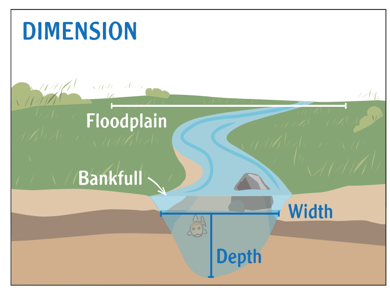
Just as our human health is determined by the factors that influence our bodies, including environment, lifestyle, and healthcare, so too is stream health determined by the combined factors of the stream's configuration, environment, resilience, and our stewardship. A stream, like the human body, has several interdependent features that indicate health of the stream. These features can be grouped into the following **five** components: *shape*, *flow*, *connectivity*, *biology*, and *water quality*.

1. Stream shape

A stream's shape is formed over time through the continuous interaction between water and the watershed, including its size, climate (wet or dry), topography, soil types, and vegetation. The channel is shaped by the predominant floodflow, known as *bankfull* flow, in which the water fills the banks and just begins to overflow onto the floodplain. Natural streams of all types and sizes have a tendency toward a balanced, stable state. In this state, streams transport water and sediment and dissipate the water's energy while maintaining over time their shape: pattern, profile, and dimension (see graphics at right). In other words, when erosion and deposition and scour and fill are balanced, the channel does not widen or narrow, nor does the streambed rise (*aggrade*) or deepen (*degrade*).



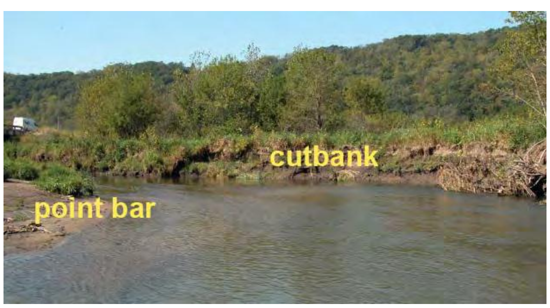




This does not mean a stream channel's position is permanent; instead, the channel is able to adjust over time as the bends, or meanders, of the channel slowly migrate down the valley. Naturally shaped streams provide aquatic organisms a variety of habitats, like *riffles* (shallow, rocky rapids), pools, sandbars, and backwaters, because of variations in stream depth, width, water currents, and streambed materials.

2. Streamflows

Streamflows vary seasonally and interannually depending on snow melt, rain-on-snow events, growing season rains, drought, and climatic changes such as increasing temperatures. Variations in seasonal and annual precipitation yield a range of flows that are fundamental to sustaining river ecosystems. Aquatic organisms such as spawning fish have evolved to these seasonal cues. Streamflows are also altered by land-use changes, from agriculture and urbanization to timber harvest. These changes generally inhibit infiltration of precipitation into the ground. Reduced infiltration increases runoff, which increases the volume of water that streams must transport, resulting in stream instability and excessive erosion.

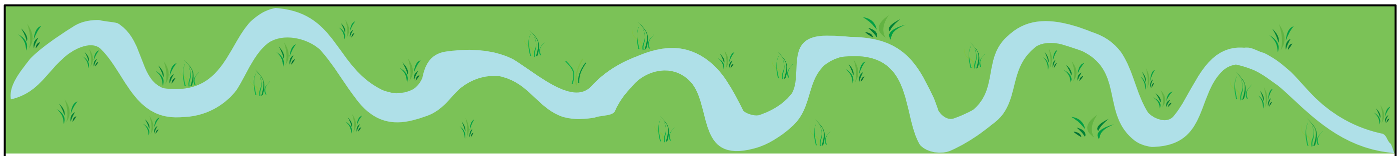


Streamflow is faster along the outer bend of a stream and will erode a streambank lacking stabilizing native vegetation, creating a cutbank. Excessive erosion increases the sediment load of the stream. Streamflow is slower on the inside of the bend, which allows sediment to settle and form a point bar.

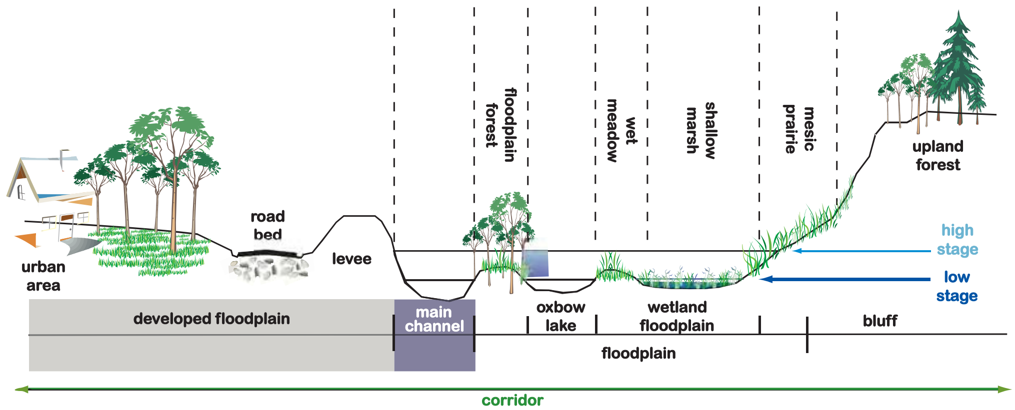
In the stream channel, flows vary because of stream features such as *sinuosity* (curving shape), width, depth, and bed and bank materials (e.g., sand, gravel, boulders, vegetation). For example, flows are faster along the outside of bends and slower along the inside of bends. Consequently, strong erosional forces along outside bends form pools, or scours, and cutbanks if the banks are weak; slower flows along inside bends deposit sediment, forming point bars (see photo at left). Streams create bends to reduce the speed of the flows just as a downhill skier carves from side to side down the hillside. Also like a skier gaining speed, the tighter the turns, the deeper the scours or pools left by the streamflow. The strongest streamflow generally follows the *thalweg* (deepest part of the channel), travels from pool to pool or bend to bend, and crosses from one side of the channel to the other depositing sediment, which creates riffles.

3. Stream connectivity

Fragmenting streams with dams and culverts disrupts the *longitudinal connectivity* of a stream. Uninterrupted flow along the entire length of the stream is essential for the proper flow and exchange of water, energy, sediments, nutrients, and organisms. Structures that fragment streams disrupt the progression of stream habitats from small, shaded, rocky, steep headwater streams to large, sandy, flat, warm, slow-flowing valley streams.



Lateral connectivity between the stream channel and its floodplain is crucial to stream health and stability. Floodplains play an important role because this land reduces the floodwater's energy with plants and trees and provides temporary storage space for floodwaters and sediment. Floodplains also provide habitat for various plant and wildlife communities, some of which depend on flood events to reproduce and grow. Floodwaters nourish floodplains with sediments and nutrients and provide temporary aquatic habitat for invertebrate communities, amphibians, reptiles, and spawning fish.



Lateral connectivity: The stream is connected to its floodplain on the right but is disconnected on the left by development. At various stream stages, the stream and its floodplain provide a range of habitat settings.

4. Stream biology

Streams are complex networks of terrestrial and aquatic communities. Streams and their floodplains provide diverse habitats including uplands, riparian zones (streambanks), floodplain forests, marshes, fens, oxbow lakes, riffles and pools. The diverse habitats and their plant and animal species are key to maintaining healthy ecosystems.

Terrestrial plants, aquatic plants, and aquatic animals in the stream are important to the stream's health. Terrestrial plants in the floodplain and riparian zones strengthen and stabilize the soil; intercept runoff; filter out nutrients, sediment, and other pollutants; and provide habitat. Similarly, aquatic plants protect the shoreline, stabilize the streambed, are a food source, provide refuge, absorb nutrients and contaminants from the water, and produce oxygen. Aquatic animals such as freshwater mussels are important to aquatic systems because they stabilize the streambed by anchoring themselves into the sediment, clean the water of particles and chemicals during their feeding process, and are a source of food and habitat for fish and invertebrates. They also use fish as hosts for their larvae, relying on fish health, abundance, and migration for dispersal. This demonstrates the interconnections of aquatic systems.

5. Water quality

Water quality includes the chemical, biological, and physical characteristics of water. Good water quality is maintained by natural channel shapes and flows, naturally vegetated riparian zones, a healthy biological community, and proper stewardship. The most common pollution sources in Minnesota are sediment, herbicides, insecticides, industrial chemicals, sewage effluent (outflow), and fertilizers. Some of these sources such as industrial and sewage effluent are point sources, which are identifiable, local sources that are relatively easy to monitor and regulate. Others are nonpoint sources such as herbicides and fertilizers, which are contaminants from sources that are much harder to assess and regulate.

Healthy stream systems ensure good water quality and are paramount to human and ecological health. This crucial resource provides drinking water from lakes and rivers for many cities, in addition to habitat for wildlife, fish, and aquatic organisms, some of which are valuable food sources.

Freshwater mussels are sedentary, long-lived (some more than 100 years) mollusks that nestle in sediments while filtering particles and oxygen from the water to feed and breathe. Mussels are vulnerable to stream habitat disturbances (dams, channelization, pollution, exotics) and are good biological indicators of stream health. They are one of the most endangered animals in North America.

Naturally vegetated streambanks protect streams and stream organisms. Desirable woody vegetation includes willow, cottonwood, and dogwood. Beneficial forbs and grasses include monkey flower, blue vervain, fox sedge, swamp milkweed, and river bulrush.

How do stream alterations affect the five components of stream health?

Structures in a stream, such as dams and culverts, and some land use practices in a watershed can significantly affect the five components of natural, healthy streams: shape, flow, connectivity, biology, and water quality.

How structures affect stream health

1. **Shape**: Dams, culverts, and handmade structures alter the natural stream pattern, dimensions, and profile. The water flowing over a dam is "sediment hungry," leading to scouring or down cutting the streambed and erosion of streambanks. Dams also create unnatural reservoirs upstream that slowly fill with settling sediment.
2. **Flow**: Dams and improperly sized or placed culverts limit the flow of water, energy, sediments, and nutrients downstream. These structures also lock the channel in place, which restricts the stream from adjusting to maintain stability.
3. **Connectivity**: Dams and perched culverts create barriers that disrupt the flow downstream and prevent fish migration upstream to spawning, over-wintering, or other habitat areas. Levees and dikes disconnect the channel from the floodplain, forcing the channel to carry floodflows.
4. **Biology**: Dams create reservoirs or impoundments that initially flood and eventually bury critical wildlife habitat. Dams and levees also disrupt the flow and exchange of material longitudinally and laterally on which biological communities depend.
5. **Water quality**: In the upstream reservoirs, contaminants and nutrients accumulate, which ultimately degrades water quality.

Dams and culverts: (above) A handmade dam disconnects fish from upstream migration and alters the stream flow. (below) A perched culvert also inhibits fish passage and disrupts the longitudinal connectivity of the stream.

How land use practices affect stream health

1. **Shape**: Digging ditches converts headwater streams into unstable straight trenches and increases the stream slope. This leads to excessive erosion upstream and sediment deposition downstream of the ditched area. Removal and degradation of natural riparian vegetation weakens streambanks, resulting in excessive erosion and ultimately a change in stream shape.
2. **Flow**: Irrigation from streams can lower stream flows to potentially critical levels, especially during dry periods when water levels are low and aquatic communities need refuge. Urbanization and tiling on farmland funnel excess rainwater directly into streams, forcing the streams to carry higher, flashier flows.
3. **Connectivity**: Connection to the floodplain is commonly degraded or removed. Floodplains converted to farmland, pasture, or developments do not effectively dissipate or store floodwaters. Riparian zones that are farmed, mowed, grazed, deforested, or developed replace natural and diverse vegetation with crops, lawns, bare soil, and pavement.
4. **Water quality, and 5. Biology**: Excessive erosion of topsoil commonly degrades water quality, primarily by decreasing water clarity. Field and lawn fertilizer and manure inputs add excess nutrients to streams, causing extreme plant and algal growth followed by decomposition that extracts oxygen from the water. Pesticides, herbicides, and insecticides have been found at dangerous levels in streams. Research indicates that these chemicals kill aquatic organisms, inhibit reproduction, and upset hormones in animals in addition to a multitude of adverse physiological effects.

Land use: (above) Parking lot runoff, (below left) eroded fields, and (below right) unvegetated ditches transport pollutants and excess sediment to streams.

To what extent have we disturbed Minnesota streams and watersheds?

Reconnecting the Red River: Since the early 1800s, more than 500 dams have been built on the Red River of the North and its tributaries. Lake sturgeon could no longer migrate to critical spawning habitat in the higher gradient tributaries. By the mid-1900s, the sturgeon were gone, victims of a fragmented river that no longer provided the habitat the fish needed to reproduce. The DNR is working with local communities to "reconnect the Red" by removing or modifying dams into artificial rapids. This has successfully opened hundreds of miles of streams to migrating fish.

Minnesotans take great pride in and enjoy the state's 92,000 miles of large and small streams. However, throughout our history, humans have had a growing impact on our streams and watersheds due to a booming population and technological advancements. The following are a few examples of the extreme changes that have degraded stream health in Minnesota:

- Nearly one-third of the streams have been converted to ditches.
- Nearly 18,000 miles of tile are added to farmland in Minnesota every year. That is nearly three-fourths of the circumference of the earth.
- More than 900 dams greater than 6 feet in height and hundreds of smaller (low-head) dams have been built on Minnesota streams.
- More than 56 percent of the landscape has been converted from native prairies, wetlands, and forests to farmland and urban areas.

These land-use changes and resulting changes in stream shape lead to excessive streambank or streambed erosion and degraded stream health. These impacts, in addition to climate change, lead to increased erosion and deposition, altered hydrology, more frequent and destructive flooding, degradation of aquatic and riparian habitat, and decrease in species diversity. Moreover, these effects have huge economic impacts. In the deep loess soils (highly erodible, windblown fine sediments) of western Iowa there has been an estimated $1.1 billion in damage to private and public infrastructure due to channelization and ditching. In Minnesota, flowing water carries off more than 60 million tons of upland topsoil each year. That amount would fill the Metrodome with topsoil 21 times every year. Consequently, stream stability is crucial to our environment and our own well being.

(above) *Buffered*: The vegetated buffer along the Pelican River decreases the contaminants and sediment carried by runoff to the stream.
(below) *Unbuffered*: The South Branch of the Buffalo River lacks such protection from runoff.

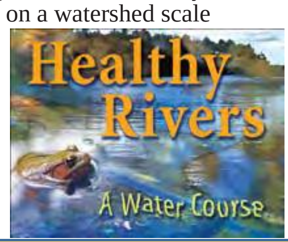
How can you and the community correct stream disturbances and improve stream health?

As individuals, riparian landowners can restore, protect, and maintain naturally vegetated riparian buffers and floodplains realizing that rivers are dynamic. However, many stream health problems are the result of widespread land use issues. In these cases, communitywide efforts are needed for recovery to begin.

Watershed planning engages citizens, landowners, businesses, local governments, interest organizations, and other agencies. Watershed protection and planning becomes effective through cooperation toward long-term goals like improving water quality, reducing surface runoff, reducing soil loss, improving habitat, restoring natural biodiversity, and allowing for sustainable development. Furthermore, focusing on a watershed scale makes it easier to integrate social, economic, and cultural factors into planning and implementation efforts.

Additional information

The Healthy Rivers instructional CD and resource sheets on stream health, such as techniques to stabilize a streambank, are on the DNR web site. Research sources are available on request.



DNR Contact Information

DNR Stream Habitat Program is described on the Ecological Services website:
http://mndnr.gov/eco/streamhab
The DNR Waters website:
http://mndnr.gov/waters

DNR address in St. Paul:
500 Lafayette Road
St. Paul, MN 55155
DNR Ecological Services: (651) 259-5100
DNR Waters: (651) 259-5700

DNR Information Center

Twin Cities: (651) 296-6157
Minnesota toll free: 1-888-646-6367
Telecommunication device for the deaf (TDD): (651) 296-5484
TDD toll free: 1-800-657-3929

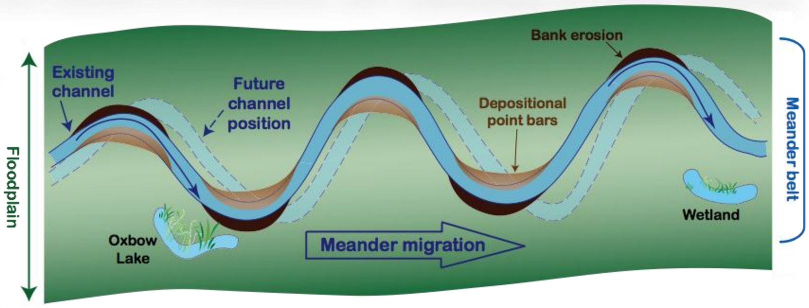
This information is available in an alternative format on request. Equal opportunity to participate in and benefit from programs of the Minnesota Department of Natural Resources is available regardless of race, color, national origin, sex, sexual orientation, marital status, status with regard to public assistance, age, or disability. Discrimination inquiries should be sent to Minnesota DNR, 500 Lafayette Road, St. Paul, MN 55155-4049; or the Equal Opportunity Office, Department of the Interior, Washington, DC 20240.

Resource Sheet 1: Streambank Erosion and Restoration

Why is my streambank eroding?

In order to determine why a streambank is eroding and to develop a restoration approach, it is necessary to understand stream behavior. All streams are dynamic, gradually changing shape as they erode, transport, and deposit sediment. A natural stream will have slowly eroding banks, developing sandbars, migrating meanders, and channels reshaped by flood flows. They are in a state of *dynamic equilibrium*, where the stream is able to maintain a stable shape (dimension, pattern, and profile) over time without excessive erosion or sedimentation even as natural changes or artificial changes occur in the watershed (see informational sheet Understanding Our Streams and Rivers).

A stream system maintains this dynamic equilibrium when its natural flexibility and a functional connection to the floodplain are preserved (see figure).



A natural, healthy stream channel meanders from bend to bend within a *meander belt*. This meandering (seen here from above) is known as the stream's *pattern*.

Many streams are artificially confined; consequently, they cannot adjust or regain their equilibrium within their meander belt or floodplain after a disturbance. Streams are increasingly confined by agriculture, infrastructure, and development in the floodplain. When ditches and levees, roads, bridges and culverts, rock revetments, and other structures are placed in the floodplain, the state of dynamic equilibrium is interrupted. Confined streams can no longer self-mend, which results in instability where bed and bank erosion is a common consequence.

Land use change and channelization: The floodplain and stream corridor are impinged by agricultural fields. The meanders are disconnected after straightening by channelization.

Common causes of stream instability

Land use changes

Land use activities throughout the watershed lead to stream instability by changing the watershed's *hydrology*. Land use changes force a stream to adjust to changes in *discharge*, water *velocities*, or *sediment load*. For example, both urban storm drains and agricultural tile funnel rainfall quickly and directly into streams. These practices dramatically increase the peak discharge and water velocity of a stream. Additionally, this direct flow is low-sediment or "sediment-hungry" runoff and is very erosive. Another land use change that impacts hydrology is draining wetlands. By removing natural water storage, streams are further burdened with water that is no longer retained on the landscape. Consequently, affected streams are unstable, usually degraded and incised, and must eventually adjust their shape to accommodate the flashy discharge events with un-naturally high peak flows.

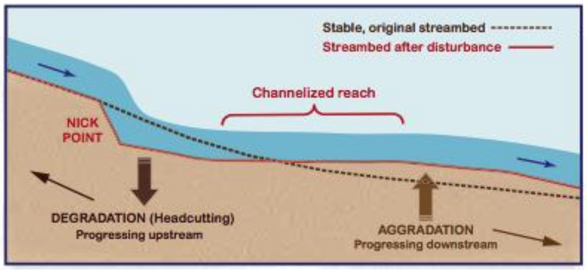
Vegetation changes

Streambank instability, erosion, and bank failure also result from a lack or loss of natural vegetation along streambanks. Deep, dense-rooting, and flood-tolerant native plants strengthen and stabilize the banks and slow floodwaters. (See additional benefits explained in Resource Sheet #2.) The loss or degradation of natural riparian vegetation can be caused by livestock overgrazing, row crops without vegetative buffers, herbicide applications, deforestation, or development. Once streambanks are degraded the potential for accelerated erosion is greatly increased because the banks are weak and unstable. Common practices of repairing banks with riprap are expensive, less stable, and lack the biological benefits of a vegetated bank.

Definitions:
aggradation: *rising streambed, sedimentation*
degradation: *lowering streambed, erosion*
discharge: *volume of water carried by a stream per unit time*
headcut: *downcutting of streambed in upstream direction*
hydrology: *movement of water through the hydrologic cycle*
nickpoint: *sudden change in the slope of the streambed*
sediment load: *amount of sediment carried by a stream*
slumping: *block(s) of bank slips down*
velocity: *speed of flow*

In-channel changes

In-channel alterations of stream shape directly disrupt stream balance resulting in *aggradation* and *degradation*. For instance, ditching or channelizing a stream replaces a long, sinuous stream reach with a short, straight, smooth channel. Such a change steepens the slope and removes roughness from the streambed. The sudden increase in speed and erosive energy of the streamflow will degrade the streambed within the straightened reach. Upstream the channel will begin to incise at the *nickpoint*. This forms an active *headcut* that migrates upstream (referred to as headcutting). Over time, the streambed continues to deepen and the entire stream reach becomes incised and disconnected from its floodplain.



In-channel changes: As shown in this side view, channelizing a stream may cause headcutting upstream and aggradation downstream.

The effects of channelization are widespread and impact the entire stream network. A headcut can initiate headcuts in the tributaries. This leads to excessive erosion and instability upstream into the basin. As excessive sediment is released into the stream system, the instability will extend downstream as the newly eroded sediment aggrades in flatter valley reaches.

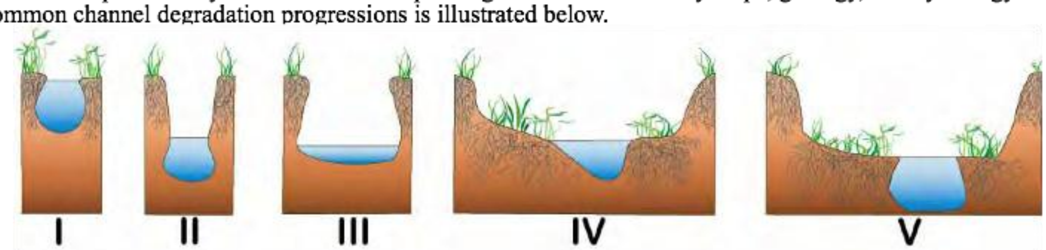
Headcut & nickpoint: An active headcut degrades the bed of an Illinois stream.

In-channel structures such as dams, bridges, and culverts interrupt the natural stream shape by creating unnatural reservoirs or passageways. For instance, culverts are commonly too small, set improperly, and do not emulate the natural channel pattern. Stream instability is the result as demonstrated by flooding upstream and erosion downstream of these structures.

Stream responses to disturbances

A disturbance such as ditching, development, or deforestation that changes the hydrology, stream shape, or riparian vegetation causes a stream to lose its equilibrium. When a stream is in disequilibrium, the stream channel actively adjusts toward a more stable form by going through transitional phases. Channel evolution can progress through many phases, where each phase could persist for years to centuries depending on stream and valley slope, geology, and hydrology. One of the more common channel degradation progressions is illustrated below.

Channel evolution



I. A properly shaped stream in **equilibrium** and connected to its floodplain prior to disturbance.
II. Channel incision from ditching or by a headcut originating in a channelized reach due to increased slope and flow.
III. Channel widening as the channel begins to meander again.
IV. A more properly shaped stream as it evolves to re-establish equilibrium and rebuild a new floodplain.
V. A new, properly shaped channel in equilibrium with a lowered floodplain.

The first section below describes an undisturbed stream in equilibrium. The next three sections describe common responses to stream instability after a disturbance. These responses vary greatly in extent and duration depending on the disturbance and the channel's recovery potential.

Equilibrium

A stream in equilibrium (Stage I in Channel evolution figure above) can transport water and sediment and dissipate the water's energy while maintaining its shape over time without excessive degradation or aggradation. A stream channel in equilibrium has these shape features:

- Pattern: a sinuous pattern that increases the stream's length, thereby decreasing its gradient and stream flows
- Profile: an alternation between riffles that help control stream gradient and pools that absorb the water's energy
- Dimension: the proper width and depth to effectively transport water and sediment supplied by the watershed

Furthermore, the channel is connected to the floodplain during high flows, the riparian zone is well vegetated, and the channel is not confined throughout the meander belt. As a result, channel movement (meander migration) and streambed and streambank erosion are minimal.

Resource Sheet 1: Streambank Erosion and Restoration

Channel incision

When a channel is incising (Stage II in Channel evolution figure), the streambed is actively eroding, downcutting, or degrading in response to disturbances such as:

- changes in the watershed (urban stormwater drains, ditching, tiling, draining wetlands) that introduce higher volumes of water or low-sediment ("sediment hungry") runoff,
- erosion by low-sediment water flowing over a dam or out of a reservoir,
- improperly sized or placed bridges or culverts that constrict flow and effectively act as dams,
- increased streamflow velocities because of disturbances such as channelization or urbanization, or
- a headcut that originated downstream.

An incised channel is disconnected from its floodplain. During high flows, the channel must transport the total volume of water because it cannot access the floodplain that, under natural conditions, could store and slow down the floodwaters. The banks of an incised channel are actively eroding (see Channel widening, below). Consequently, excessive erosion of the streambed and streambanks occurs and often results in long-term instability. As degradation continues, streambank heights and angles increase, which further reduces bank stability resulting in weak banks prone to failure and *slumping*.

Channel widening

Channel widening is lateral erosion of the streambanks (Stage III in Channel evolution figure). It can be caused by one or more of the following: channel incision; scour below culverts, bridges, or dams; flood flows in incised channels; weakened banks; increased streamflows due to watershed changes; aggradation; or construction of over-wide channels.

Channel widening occurs in an incised or scoured stream reach that attempts to find a new equilibrium by reforming and amplifying meanders to decrease the slope of the streambed and stream velocities. Also during this process, developing point bars establish a new floodplain that corresponds to the channel's new, lower streambed elevation. (For more detail, refer to the MN DNR website for the brochure, "The Shape of Healthy Rivers.")

Restoration philosophy

Incision is a common stream channel condition in Minnesota due to the prevalence of activities such as ditching and draining wetlands. It is also a systemic problem that results in stream instabilities throughout the watershed. During this response stage the channel will continue to unwind (degrade) until a new equilibrium is established. To reach equilibrium, the channel will go through successional stages that erode the banks to develop meanders, rebuild a new floodplain, and develop a properly sized channel that can effectively transport water and sediment. This process can be advanced artificially by constructing a properly shaped channel with a new lowered floodplain. Another method involves installing riffles and rock weirs that incrementally elevate the streambed to reconnect the channel to the original floodplain. These structures, unlike check dams, maintain sediment transport and are submerged during a bankfull event.

Widening is a successional stage following incision or aggradation when the channel is in disequilibrium. Restoration approaches depend on the cause, the extent of incision or aggradation, and future impacts. A restoration design could include the following:

- address upstream impacts by restoring upstream reaches (e.g. replace improperly placed culverts),
- restoring riparian vegetation,
- installing woody material and structures to add roughness, narrow the channel, and protect the banks,
- reshaping cutbanks with a bankfull bench,
- installing tree or rootwad revetments,
- excavating a properly shaped channel, or
- excavating a new floodplain.

Aggradation in Minnesota most commonly occurs downstream of channelized reaches. To re-establish equilibrium, an aggraded stream reach must develop a properly shaped channel (sinuous, deep, and narrow) through the aggraded sediment, which becomes the new floodplain. A restoration approach would be similar to that described above for an over-wide channel and similarly would depend on the cause, the extent of aggradation, recovery potential, and future circumstances.

(left) *Incision*: Extreme field erosion and an active headcut resulting from unbuffered runoff. (right) *Aggradation*: Downstream of the headcut, the flow of water slowed where the terrain flattened and deposited sediment, forming a delta.

Channel aggradation

Channel aggradation is the raising of the streambed elevation as sediment is deposited from upstream erosion along the flatter valley reaches, making the channel too shallow or over-wide. An aggraded stream reach will continue to fill and widen because the channel dimensions are out of balance with the amount of sediment that needs to be transported by the stream. More sediment settles out, further aggrading the stream bed. The channel becomes increasingly shallow, water extends laterally and erodes the banks, and stream flows more readily cause flooding.

Resource Sheet 1: Streambank Erosion and Restoration

What are the steps to address streambank erosion?

Extreme streambank erosion indicates an unstable, unhealthy stream. The instability stems from a change in the stream's shape, flow, or connectivity (see info sheet Understanding Our Streams and Rivers). These changes can be direct (ditching, dredging, straightening, dams) or the results of land use changes within the watershed (degradation of natural riparian vegetation, urbanization, logging, agriculture). Explained below are the recommended steps for restoring an eroding streambank with naturally designed approaches.

Identify the underlying cause

The first step is to determine the cause of stream instability. Are there disturbances in or along the stream; or are there destabilizing activities in the watershed? Individual landowners may not be able to control activities in a watershed that affect a stream, but landowners and citizens can have a voice in promoting and advocating natural channel design. In any situation, restoration and protection of natural riparian zones is a positive step for landowners to take to prevent or reduce streambank erosion and promote good stewardship of the watershed.

Additional adverse impacts to stream health

Channel incision, widening, and aggradation not only affect stream **shape** and **flow** but also degrade the other components of stream health:

- **Biology.** Loss and degradation of aquatic and riparian habitat (e.g. sedimentation in riffles and pools, degraded riparian vegetation).
- **Water quality.** Higher turbidity and nutrient concentrations from erosion and land inputs. Warmer water temperatures in aggraded reaches and in reservoirs.
- **Connectivity.** Disconnection from floodplain habitat (lateral) in incised streams. Disconnection from upstream and downstream reaches (longitudinal) due to dams and culverts. Increased flood risk in aggraded streams.

Adopt a natural design approach

Below is a list of recommended designs and approaches that can be used in combination to stabilize the soils in a streambank, protect the banks and floodplain, accelerate recovery, and ultimately restore stream stability. The keys to a successful bank stabilization project are:

- Allow the stream to maintain its dynamic equilibrium by not confining the channel.
- Design streambank structures to temporarily protect the banks while they stabilize.
- Consider future watershed conditions in a project design to assess how the stream will need to adjust with time.

The structures and materials listed in the box below are explained in more detail in following resource sheets.

Natural design approaches

Landscape scale
- Preserve and re-establish natural riparian and floodplain vegetation buffers
- Re-establish and protect the floodplain with compatible land use practices

Streambank stabilization and protection *(Resouce Sheet #2)*
- Vegetation: seed or plant native, deep-rooting vegetation on banks
- Biodegradable erosion-control blankets or hydroseeding
- Brush mattresses
- Biologs, wattles, or fiber rolls
- Tree revetments
- Toe wood-sod mat

In-stream bank protection
- Root wad revetments
- Bankfull bench
- J-hooks and rock vanes

Grade control (to decrease slope and reconnect channel to floodplain)
- Riffles and rock weirs

Large-scale restoration
- Re-meander straightened reach
- Remove or modify dams or improperly place culverts
- Excavate properly shaped channel
- Excavate new floodplain
- Reestablish and protect a functional floodplain with compatible land use practices
- Promote best management practices for runoff including: wetland restoration; minimum tillage; grassed waterways on agricultural land; and rain gardens and pervious pavement in urban areas

*These approaches are described in following resource sheets in this **Understanding Our Streams** series (in development).*

Consult with a professional and determine what permits you need

Contact a representative of the Stream Habitat Program from DNR Ecological Resources, your Area Hydrologist from DNR Waters, or your local soil and water conservation district to discuss what you can do on your streambank and within the watershed to minimize or correct streambank erosion. Before attempting any stabilization project, obtain the applicable permits from the DNR or other agencies. The permits you need can be identified when you contact your DNR Area Hydrologist and representatives from other agencies.

Contact Information

DNR Ecological Resources in St. Paul: 500 Lafayette Road, Box 25, St. Paul, MN 55155, (651) 259-5900
Stream Habitat Program website: http://mndnr.gov/eco/streamhab
DNR Waters in St. Paul: 500 Lafayette Road, Box 32, St. Paul, MN 55155, (651) 259-5700
DNR Waters website: http://mndnr.gov/waters

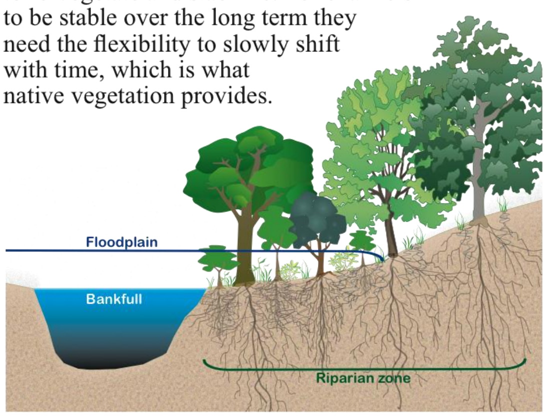
(http://www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_manual.html)

Resource Sheet 2: The Value and Use of Vegetation

Why is vegetation so important?

Naturally vegetated stream banks, riparian zones, and floodplains are crucial to streambank and channel stability, stream condition and function, water quality, and overall ecosystem health. Healthy streams provide, among many things, clean drinking water and a diversity of fish. The loss and degradation of native riparian vegetation through human activities is a common cause of streambank erosion and failure. These activities include cultivation, deforestation, watershed development, livestock overgrazing, herbicide application, and streambank armoring.

The most simple, inexpensive, and valuable form of streambank stabilization is the preservation and restoration of native riparian and floodplain vegetation. Vegetation, in addition to natural materials and structures, are rudiments of the natural channel design approach that naturally stabilize and protect streambanks. Larger materials such as logs and root wads provide strength and structure and gradually decompose giving streambanks time to re-vegetate and stabilize. For channels to be stable over the long term they need the flexibility to slowly shift with time, which is what native vegetation provides.



The benefits of streambank vegetation

Riparian zones, or buffers, along the banks naturally consist of deep-rooting, flood-tolerant plants and trees that provide multiple benefits:

Streambank stabilization
- Native riparian vegetation has dense, deep, intertwined root systems that physically strengthen soils.
- Riparian root systems remove excess moisture from the soil, making banks more resistant to erosion or slumping.
- Exposed root systems provide roughness that dissipates the water's erosive energy along the banks while the plant stems and leaves provide roughness during flood flows.

Water quality protection
- Vegetated buffers intercept and filter out much of the overland flow of water, nutrients, sediment, and pollutants; accordingly, wider corridors are more effective at protecting water quality and promoting ground-water recharge.

Riparian habitat benefits
- Diverse riparian vegetation provides shade, shelter, leafy or woody debris, and other nutrients needed by fish and other aquatic organisms.
- Wide, continuous, vegetated floodplains help dissipate flood flows, provide storage for floodwaters, retain sediment and nutrients, and provide shelter, forage, and migration corridors for wildlife.

Natural channel design fundamentals

Restoring and conserving native vegetation in the riparian zone and throughout the floodplain and meander belt is fundamental to bank stability and stream health because of the many benefits provided (see text box above). In situations where erosion is not severe and the grade is not too steep, restoring vegetation may be the only step required. In cases where erosion is more severe (e.g. cutbanks, incised channel), re-vegetation remains an essential component of a restoration involving more complex methods and structures, which are explained in following resource sheets.

Prior to planting native vegetation, non-native and nuisance species must be completely removed and the bank may need to be re-graded if the bank slope is too steep or unstable. Re-vegetation techniques include planting seeds, seedlings/saplings, live cuttings, and shrubs and hydroseeding. Live cuttings are branches cut from readily sprouting tree species, such as black willow or dogwood, preferably from nearby vegetation that is adapted to the site. These species will grow and root quickly, thereby providing immediate soil strength and erosion protection. The seeds, plants, disturbed soil, and bank toe should be protected from runoff and stream flow during the rooting process. Such erosion control products and methods are described next.

Disadvantages of hard armoring

Hard armoring banks with rock (riprap), timber walls, sheet piling, or waste concrete (which is not allowed) is a common bank protection approach; however, there are many disadvantages and undesirable impacts.
- Hard armored banks transfer the problem downstream by strengthening and redirecting stream flows downstream of the armor and into the next bend or meander resulting in bank erosion and failure, particularly along downstream bend(s).
- From an ecological standpoint, armoring does not provide aquatic or terrestrial habitat (shade, shelter, food) and has no ability to filter or process nutrients and sediments, which negatively impacts stream health.
- Armored banks can negatively affect long-term stability because they lock the channel into place preventing it from adjusting to changes in the watershed.
- Lastly, riprap is expensive to install and looks unnatural.

Resource Sheet 2: The Value and Use of Vegetation

In choosing suitable native plant species, consider local habitat type (e.g. forest, prairie, wetland) and habitat components such as shade, soil type, moisture, and climate. Resources available to identify plant species suitable for various habitat types and desired purposes, such as erosion control, aesthetics, and wildlife habitat include: local nurseries, extension offices, soil and water conservation districts, the "Restore Your Shore" CD-ROM (info at http://mndnr.gov/restoreyourshore) and MN DNR website http://mndnr.gov/gardens/nativeplants. Vegetative stabilization has all the benefits of restoring native vegetation (strengthen and stabilize stream banks, runoff buffer, provide habitat, aesthetic value) in addition to low cost, low maintenance, lack of structural complexity, and endurance. Below is a list of plant species native to Minnesota that are recommended for streambank restorations.

Common name	Scientific name	Life form	Habitat
Blue vervain	*Verbena hastata*	F	W, UM
Canada anemone	*Anemone canadensis*	F	W, UM
Golden alexanders	*Zizia aurea*	F	W, UM
Grass-leaved goldenrod	*Euthamia graminifolia*	F	W, UM
Monkey flower	*Mimulus ringens*	F	W
Obedient plant	*Physostegia virginiana*	F	W, UM
Swamp milkweed	*Asclepias incarnata*	F	W, UM
Fowl manna grass	*Glyceria striata*	G	W
Fox sedge	*Carex vulpinoidea*	G	W, UM
Hardstem bulrush	*Scirpus acutus*	G	A, W
Porcupine sedge	*Carex hystericina*	G	W
River bulrush	*Scirpus fluviatilis*	G	A, W
Softstem bulrush	*Scirpus validus*	G	A, W
Tall manna grass	*Glyceria grandis*	G	W
Virginia wild-rye	*Elymus virginicus*	G	W
Basswood	*Tilia americana*	T	UM, UD
Black willow	*Salix nigra*	T	W
Red-osier dogwood	*Cornus sericea (stolonifera)*	T	W, UM, UD
Silver maple	*Acer saccharinum*	T	W, UM

Native Minnesota plant species recommended for stream bank restorations throughout the state (sorted by Life form then Common name).
***F**: forb (flower)* ***G**: grass or grass-like* ***T**: woody vegetation*
***A**: aquatic* ***W**: wet/transitional* ***UM**: upland moist* ***UD**: upland dry*

Natural materials and structures

Natural materials and structures can be used in addition to native vegetation to:

- ☆ protect seed & plantings from overland and stream flows,
- ☆ protect the toe of the streambank,
- ☆ prevent erosion on slopes,
- ☆ promote trapping of sediment,
- ☆ quickly develop dense roots and sprouts, & provide habitat.

The following six techniques are effective on small to medium streams. They are of moderate cost and can be installed by most landowners with a bit of direction. Landowners should consult an area hydrologist as project approval or a permit is required by the DNR and other agencies.

Biodegradable erosion control blankets (ECBs)

» Biodegradable ECBs are made of: jute (a vegetable fiber) mesh (*in photo*), coconut/coir fiber, straw, or excelsior (fine wood fiber) that are woven into a fiber matrix. ECBs are designed to temporarily provide erosion protection and assist with vegetation establishment as they degrade over 1-3 years leaving a vegetated bank. Products with polypropylene materials are not recommended because they do not degrade and can entangle wildlife in the rigid knitting.

× ECBs are placed over re-graded and re-seeded streambanks (use more durable netting for steeper banks). Wood stakes or live cuttings are used to secure the fabric in place (instead of metal anchor pins). Blankets should be installed promptly after the restoration to provide immediate erosion protection.

Resource Sheet 2: The Value and Use of Vegetation

Broadcast seeding and hydroseeding

» Broadcast seeding is the scattering of native seed mixes by hand or mechanically over prepared soil. Good seed to soil contact, protection (ECBs, mulch, oats or rye as a cover crop), and watering are important.

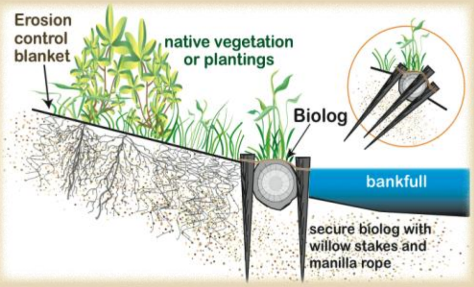
» Hydroseeding is a planting process that uses a mixture of water, seed, fertilizer, mulch, and tackifiers that is sprayed over renovated banks or slopes. Native seeds that are suitable to the habitat should be used in the mix. This mixture can be applied to the upper slopes, even on steeper slopes. The mixture should not be applied too close to the channel to avoid fertilizer from polluting the stream or seed from being washed away.

Staking and live cuttings

» Stakes and live cuttings from readily sprouting, local, healthy tree species such as black willow, dogwood, and alder are used to quickly vegetate restored streambanks. Staking can be applied on all types of banks and in addition to other techniques.

× The cuttings or stakes (branch sections without twigs or leaves) are cut and planted while dormant, late fall through early spring. Stakes are 2'+ in length and ½ - 3" in diameter with one end cut at a 45° angle. Stakes are planted 1 - 2' deep in soft soils or into a pilot hole in harder soils ensuring the stake is deep enough to reach permanently wet soils. Stakes are planted 1 - 2' apart depending on the size of the stakes to ensure successful survival and sufficient cover.

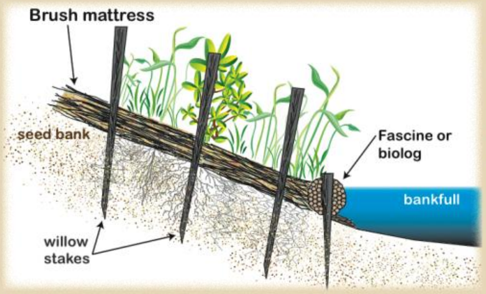
Biologs, coir fiber rolls, wattles, fascines



» Biologs and coir fiber rolls are made of coconut fiber, straw, or excelsior fiber. Wattles and fascines are cylindrical bundles of wheat or rice straw or cuttings. They are strong, flexible rolls (8-10' long, 8-12" diameter) of biodegradable material used to protect the toe of banks and to stabilize slopes . These structures work best where scour is not too severe and where flows will infrequently flow over the toe protection.

× The logs, rolls, or bundles are staked and tied into a shallow trench along the toe of the streambank to deflect flows and wave energy, retain sediment, and provide a stable structure for plant growth (substrate). Native vegetation is planted on and around the structures, then as the vegetation or cuttings becomes established, the natural materials will degrade in 2 to 6 years leaving a vegetated bank.

× Additional rows can be installed (placed in shallow trenches secured by wood stakes) upslope parallel to the toe of the bank for additional bank stabilization.

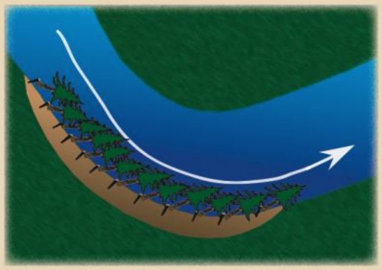


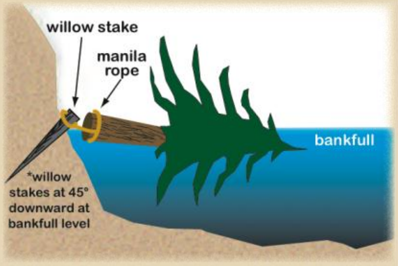
Brush mattresses

» Brush mattresses consist of a layer of interlaced dormant cuttings (e.g. willow, dogwood, alder) that are laid perpendicular to the toe and staked over a gently sloped streambank, often with a fascine or biolog at the base as toe protection.

× These structures work on most banks. They require good soil contact to support brush growth; base flows to keep the basal ends of the cuttings moist; and installation during the non-growing season, preferably early spring.

Tree revetments





» Tree revetments involve anchoring coniferous (such as Christmas trees) or hardwood trees along an outside bend where erosion is excessive.

× The trees are tied by the trunks with natural filament rope to wooden stakes placed at the bankfull level with the treetops pointing downstream. Tree revetments dissipate outside meander flows and collect sediment, thereby reducing erosion and promoting deposition.

× Tree revetments work best in small to medium streams with high sand or gravel loads because sediment deposition is important to the long-range goal of rebuilding and protecting the bank.

⇨ These structures provide habitat and as they degrade and accumulate sediment they become a natural, structural part of the bank.

Resource Sheet 2: The Value and Use of Vegetation

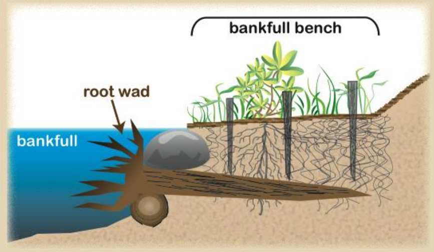
Root wad revetments

» Root wad revetments are more complex structures built into exposed cutbanks where erosion is actively cutting away the bank. These revetments commonly involve the construction of a bankfull bench to help accommodate and dissipate flood flows. This design is especially useful where there is infrastructure on the bank that needs to be protected from bank loss or slumping. These revetments can be scaled to the size of the stream (e.g., root wads can be stacked in large streams). They are not recommended in sandy soils where it is difficult to drive the trunks into the bank and the sand is more erodible.

× Large tree trunks with root wads are driven into a renovated cutbank so that the trunks angle upstream and the root wads are positioned below bankfull level directed into the flow. The trunks are secured with large boulders and a matrix of logs. Live cuttings are staked, natural vegetation planted or seeded, and erosion control fabric is staked on the bankfull bench and restored bank.

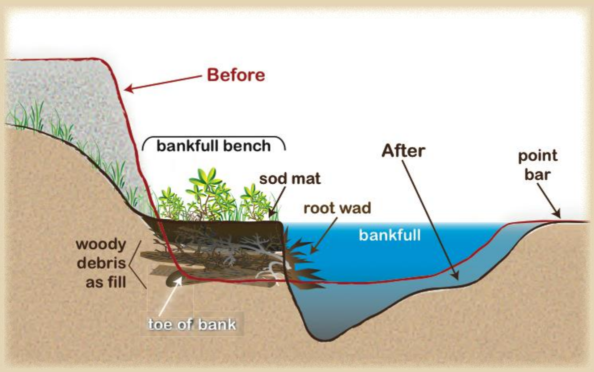
⇨These revetments protect the banks over a range of flows, provide substrate for invertebrates and refuge for fish, and will slowly degrade while becoming a natural part of the streambank.

**Variations of this design have been used through the years. For more specific design details see Applied River Morphology by Dave Rosgen, 1996.*



Installation of root wads using an excavator to drive tree trunks into the bankfull bench (looking upstream).

Root wad revetment and a revegetated bankfull bench built to stabilize a cutbank encroaching on Interstate 94, two years after construction (looking downstream).



Toe wood-sod mats *(see fact sheet for more details)*

» Toe wood-sod mats involve similar design elements to the root wad revetments. This approach can be scaled to all stream sizes.

× Cutbanks are renovated with a bankfull bench consisting of layers of logs, branches, brush, roots, and fill. Root wads can be incorporated to provide additional roughness and habitat. These layers are then covered with sod mats, willow cuttings, and transplants set at bankfull stage.

⇨ This structure design restores the connection to the floodplain with a bankfull shelf, restores channel dimensions, protects a once vulnerable and unstable cutbank, provides habitat (both aquatic and terrestrial), and is relatively inexpensive.

**Variations of this design have been used through the years. General design details are credited to Dave Rosgen of Wildland Hydrology.*

Review and advanced restoration designs

Bank restorations utilizing vegetation, erosion-control blankets, biologs, wattles, revetments, and mats or combinations thereof, can effectively protect and rebuild banks if properly placed and established. These approaches utilize all natural materials that do not artificially confine the channel, they are relatively inexpensive, and can be applied to all stream varieties (forested, prairie, steep, gentle, rocky, sandy). As explained in Resource Sheet #1, the cause(s) of stream instability and future watershed conditions should be considered. Most projects will need permits and professional assistance.

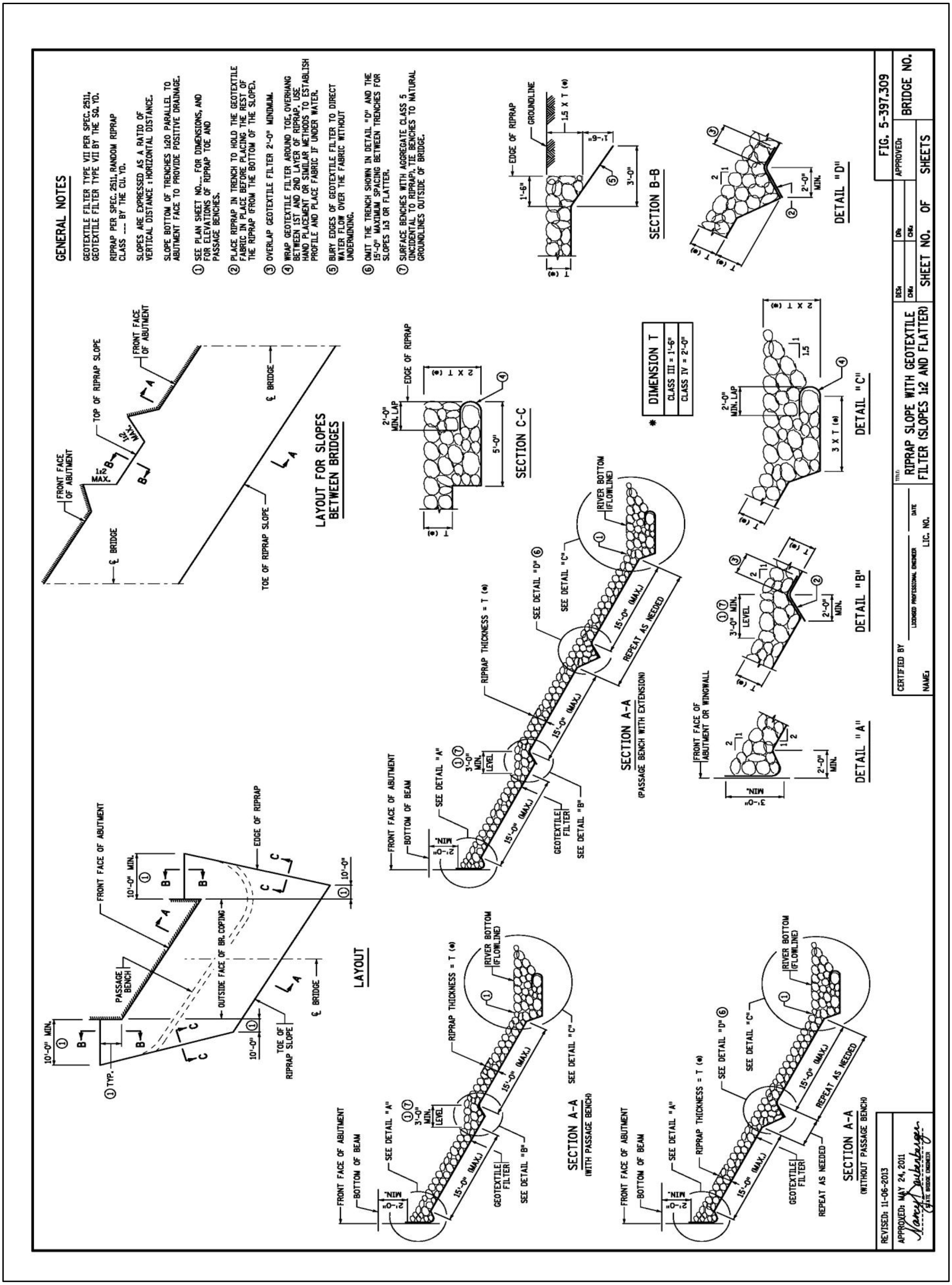
In some cases in-channel structures can also be used to protect restored or unstable banks. These include rock structures such as rock vanes, J-hooks, and riffles that are effective at properly slowing and deflecting flows from the streambanks. Installation of these structures requires professional assistance because proper placement is absolutely essential for successful streambank protection and restoration. This requires stream and watershed monitoring and assessments. These in-channel structures are explained in more detail in the following resource sheets.

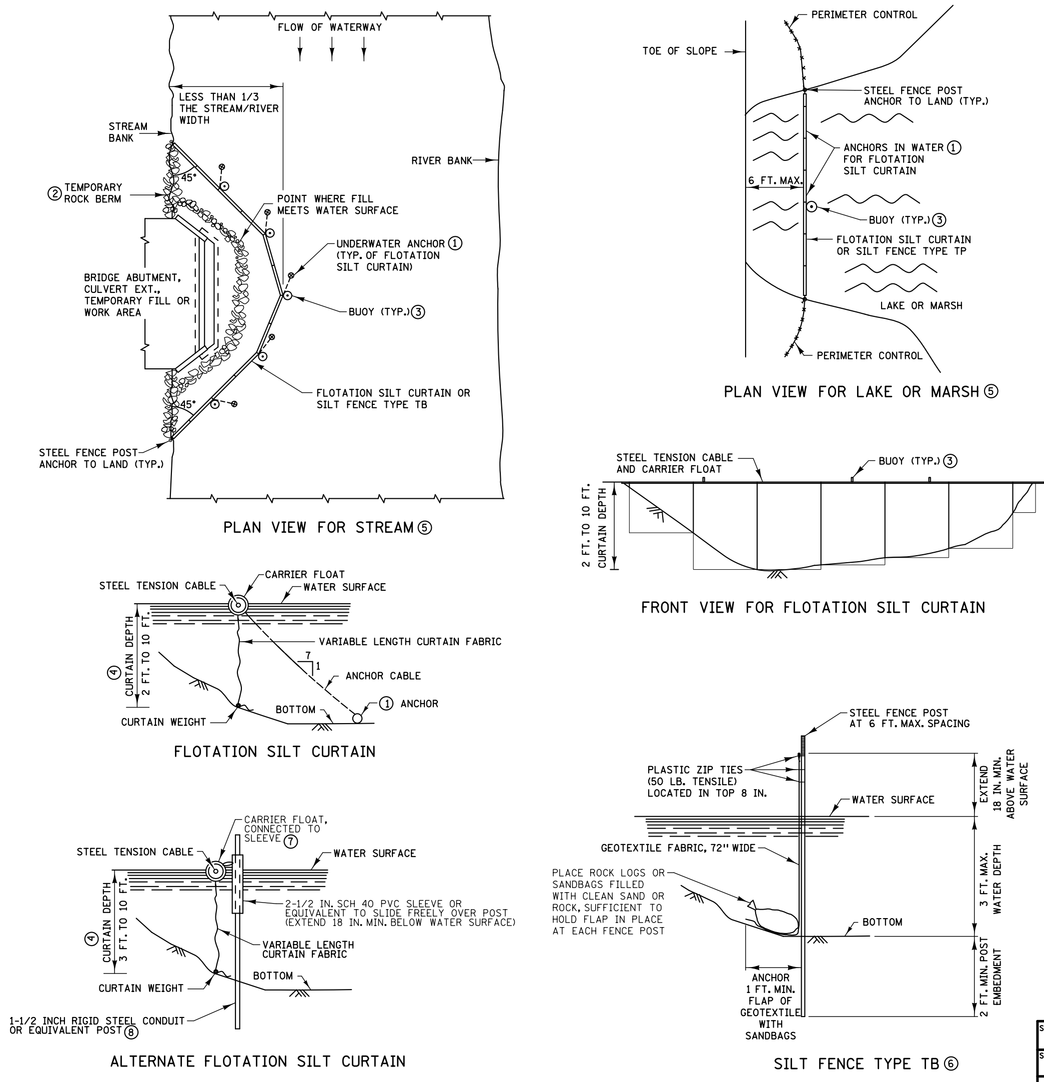
Contact Information

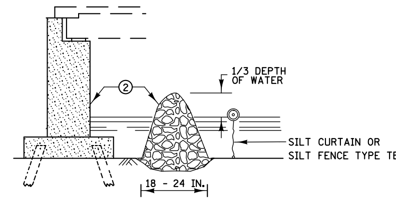
DNR Ecological Resources:
Stream Habitat Program
Ecosystem Restoration
500 Lafayette Road, Box 25
St. Paul, MN 55155
(651) 259-5900

DNR Waters:
Public Water Permit Requirements
500 Lafayette Road, Box 32
St. Paul, MN 55155
(651) 259-5700

DNR website:
http://mndnr.gov


GENERAL NOTES
GEOTEXTILE FILTER TYPE VII PER SPEC. 2511, GEOTEXTILE FILTER TYPE VII BY THE SQ. YD.
RIPRAP PER SPEC. 2511, RANDOM RIPRAP CLASS ___ BY THE CU. YD.
SLOPES ARE EXPRESSED AS A RATIO OF VERTICAL DISTANCE : HORIZONTAL DISTANCE.
SLOPE BOTTOM OF TRENCHES 1:20 PARALLEL TO ABUTMENT FACE TO PROVIDE POSITIVE DRAINAGE.
① SEE PLAN SHEET NO.___ FOR DIMENSIONS, AND FOR ELEVATIONS OF RIPRAP TOE AND PASSAGE BENCHES.
② PLACE RIPRAP IN TRENCH TO HOLD THE GEOTEXTILE FABRIC IN PLACE BEFORE PLACING THE REST OF THE RIPRAP (FROM THE BOTTOM OF THE SLOPE).
③ OVERLAP GEOTEXTILE FILTER 2'-0" MINIMUM.
④ WRAP GEOTEXTILE FILTER AROUND TOE, OVERHANG BETWEEN 1ST AND 2ND LAYER OF RIPRAP. USE HAND PLACEMENT OR SIMILAR METHODS TO ESTABLISH PROFILE AND PLACE FABRIC IF UNDER WATER.
⑤ BURY EDGES OF GEOTEXTILE FILTER TO DIRECT WATER FLOW OVER THE FABRIC WITHOUT UNDERMINING.
⑥ OMIT THE TRENCH SHOWN IN DETAIL "D" AND THE 15'-0" MAXIMUM SPACING BETWEEN TRENCHES FOR SLOPES 1:3 OR FLATTER.
⑦ SURFACE BENCHES WITH AGGREGATE CLASS 5 (INCIDENTAL TO RIPRAP), TIE BENCHES TO NATURAL GROUNDLINES OUTSIDE OF BRIDGE.
LAYOUT
LAYOUT FOR SLOPES BETWEEN BRIDGES
SECTION A-A (WITH PASSAGE BENCH)
SECTION A-A (WITHOUT PASSAGE BENCH)
SECTION A-A (PASSAGE BENCH WITH EXTENSION)
SECTION B-B
SECTION C-C
DETAIL "A"
DETAIL "B"
DETAIL "C"
DETAIL "D"
DIMENSION T
CLASS III = 1'-6"
CLASS IV = 2'-0"
FRONT FACE OF ABUTMENT
BOTTOM OF BEAM
RIPRAP THICKNESS = T (*)
RIVER BOTTOM (FLOWLINE)
GEOTEXTILE FILTER
REPEAT AS NEEDED
15'-0" (MAX.)
TOE OF RIPRAP SLOPE
TOP OF RIPRAP SLOPE
EDGE OF RIPRAP
GROUNDLINE
PASSAGE BENCH
OUTSIDE FACE OF BR. COPING
℄ BRIDGE
RIPRAP SLOPE WITH GEOTEXTILE FILTER (SLOPES 1:2 AND FLATTER)
FIG. 5-397.309
REVISED: 11-06-2013
APPROVED: MAY 24, 2011
SHEET NO. OF SHEETS
BRIDGE NO.





TEMPORARY ROCK BERM
FOR SEDIMENT CONTROL

INSTALLATION GUIDELINES
SILT FENCE TYPE TB
MINIMUM WATER DEPTH: 1 FT.
MAXIMUM WATER DEPTH: 3 FT.
MAXIMUM WATER VELOCITY: 5 FT./SEC.

INSTALLATION GUIDELINES ④
FLOTATION SILT CURTAIN
TYPE: STILL WATER
MINIMUM WATER DEPTH: 3 FT.
MAXIMUM WATER DEPTH: 10 FT.
MAXIMUM WATER VELOCITY: 2 FT./SEC.
MAXIMUM WAVE HEIGHT: 1 FT

INSTALLATION GUIDELINES ④
FLOTATION SILT CURTAIN
TYPE: MOVING WATER
MINIMUM WATER DEPTH: 3 FT.
MAXIMUM WATER DEPTH: 10 FT.
MAXIMUM WATER VELOCITY: 5 FT./SEC.
MAXIMUM WAVE HEIGHT: 2 FT.

NOTES:

SEE SPECS. 2573, 3886, 3887 & 3893.

① FOR ANCHOR SPACING AND WEIGHT REQUIREMENTS, SEE SPEC. 2573.

② IN AREAS WHERE THE PLAN CALLS FOR RIPRAP AT A BRIDGE, CULVERT, OR SLOPE, A TEMPORARY ROCK BERM CONSTRUCTED FROM THE RIPRAP CAN BE USED TO PROVIDE ADDITIONAL PROTECTION. WHEN THE WORK IS COMPLETE THE RIPRAP CAN THEN BE MOVED TO THE PERMANENT LOCATION INDICATED IN THE PLANS. THE TEMPORARY ROCK BERM IS INCIDENTAL.

③ ON U.S. COAST GUARD OR OTHER MOTORIZED WATERWAYS, BUOYS ARE REQUIRED TO MARK THE ENDS AND SPECIAL AREAS FOR VISIBILITY. PLACE BUOYS AS REQUIRED FOR NAVIGATIONAL PURPOSES.

④ MINIMUM WATER DEPTH APPLIES TO THE DEEPEST POINT ALONG THE FLOTATION SILT CURTAIN OR SILT FENCE TYPE TB FOR DETERMINING APPLICABILITY OF FLOTATION SILT CURTAIN OR SILT FENCE TYPE TB.

⑤ SILT CURTAIN SHOULD BE REMOVED WHEN THE AREA CONTRIBUTING DIRECT RUNOFF HAS BEEN TEMPORARILY OR PERMANENTLY STABILIZED. SILT CURTAIN SHOULD ALSO BE REMOVED BEFORE WINTER IF ICE UP OR ICE FLOW IS ANTICIPATED.

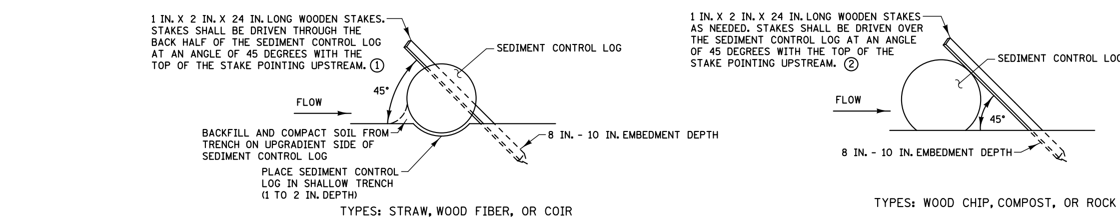
⑥ EMBED POST INTO BOTTOM A MINIMUM OF 40% OF THE WATER DEPTH (INCLUDING WAVE HEIGHT), BUT IN NO CASE SHALL EMBEDMENT BE LESS THAN 2 FEET.

⑦ ANCHOR FLOAT MUST BE CONNECTED SECURELY TO SLEEVE WITH A MINIMUM TENSILE STRENGTH OF 100 LBS. CONNECTION METHOD MUST ALLOW FOR SLEEVE TO MOVE FREELY ON POST.

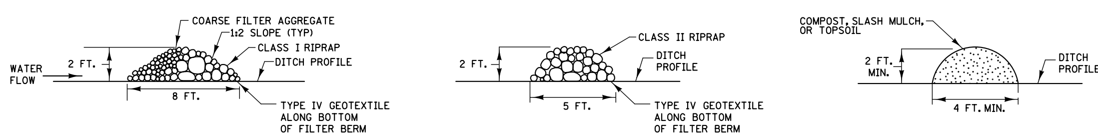
⑧ PROVIDE SUFFICIENT NUMBER OF POST ANCHORS TO MAINTAIN SILT CURTAIN POSITION.

STANDARD SHEET NO. 5-297.405 (1 OF 7)	TITLE: TEMPORARY SEDIMENT CONTROL SILT CURTAIN OR SILT FENCE TYPE TB
STANDARD APPROVED: DECEMBER 11, 2013	
STATE PROJ. NO.	(TH) SHEET NO. OF SHEETS

DECEMBER 11, 2013 5-297.405 (1 OF 7)



SEDIMENT CONTROL LOGS

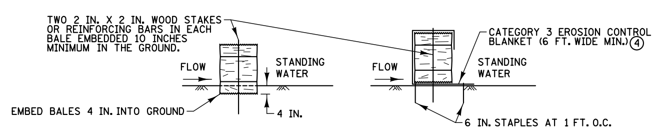


TYPE 3 (ROCK WEEPER)

TYPE 5 (ROCK)

TYPE 1 (COMPOST), TYPE 2 (SLASH MULCH), OR TYPE 4 (TOPSOIL)

FILTER BERMS



EMBEDMENT METHOD

BLANKET METHOD (ALTERNATE)

BALE BARRIERS ③

NOTES:

SEE SPECS. 2573, 3149, 3874, 3882, 3886, & 3897.

① SPACE BETWEEN STAKES SHALL BE A MAXIMUM OF 1 FOOT FOR DITCH CHECKS OR 2 FEET FOR OTHER APPLICATIONS.

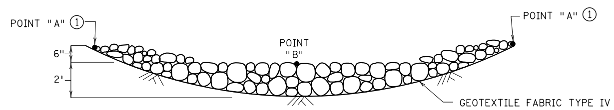
② PLACE STAKES AS NEEDED TO PREVENT MOVEMENT OF SEDIMENT CONTROL LOGS PLACED ON SLOPES OR AS NEEDED DUE TO OTHER FACTORS. STAKES SHALL BE INCIDENTAL.

③ TO BE USED FOR CRITICAL PERIMETER CONTROL AREAS WHERE STANDING WATER OCCURS (6 INCH MAX. DEPTH). BALES SHALL CONSIST OF TYPE 1 MULCH OF APPROXIMATELY 14 IN. X 18 IN. X 36 IN. LONG. BALES SHALL BE PLACED ON EDGE AND BUTTED TIGHT TO ADJACENT BALES.

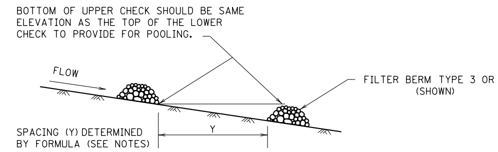
④ INSTEAD OF TRENCHING, PLACE BALE ON THE BLANKET AND WRAP BLANKET AROUND THE BALE. PLACE STAKE THROUGH BALE AND BLANKET.

STANDARD SHEET NO. 5-297.405 (2 OF 7) STANDARD APPROVED: DECEMBER 11, 2013	TEMPORARY SEDIMENT CONTROL FILTER BERMS, SEDIMENT CONTROL LOGS, AND BALE BARRIERS
STATE PROJ. NO.	(TH) SHEET NO. OF SHEETS

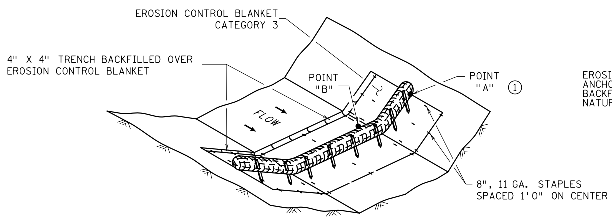
DECEMBER 11, 2013 5-297.405 (2 OF 7)

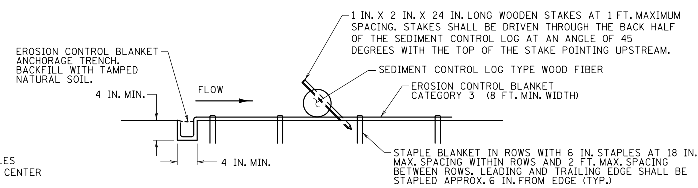


ROCK DITCH CHECKS
FILTER BERMS TYPE 3 (ROCK WEEPER) OR FILTER TYPE 5 (ROCK) ② ③
(FOR USE ON ROUGH GRADED AREAS)

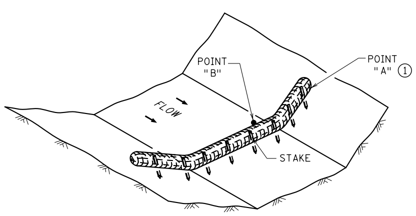


DITCH CHECK SPACING
(FOR ALL FILTER BERM TYPES)





SEDIMENT CONTROL LOG TYPE BLANKET SYSTEM ④



SEDIMENT CONTROL LOG TYPE WOOD FIBER, OR TYPE COMPOST ⑤
(FOR USE ON ROUGH GRADED AREAS)

NOTES:

SEE SPECS. 2573, 3601, 3733, 3885, 3886 & 3889.

FOR DITCH CHECKS, PLACE SEDIMENT CONTROL LOG PERPENDICULAR TO FLOW AND IN A CRESCENT SHAPE WITH THE ENDS FACING UPSTREAM.

APPROXIMATE SPACING BETWEEN EACH DITCH CHECK SHOULD BE DETERMINED FROM THE FOLLOWING SPACING FORMULA:

$$\text{APPROXIMATE SPACING OF DITCH CHECKS (FT.)} = Y = \frac{\text{DITCH CHECK HEIGHT (FT)}}{\text{\% CHANNEL SLOPE}} \times 100$$

① POINT "A" MUST BE A MINIMUM OF 6 INCHES HIGHER THAN POINT "B" TO ENSURE THAT WATER FLOWS OVER THE DIKE AND NOT AROUND THE ENDS.

② PERMANENT ROCK DITCH CHECKS PLACED WITHIN THE CLEAR ZONE ARE TO BE 18" OR LESS IN HEIGHT. A 1:6 APPROACH AND DEPARTURE SLOPE SHALL BE PROVIDED.

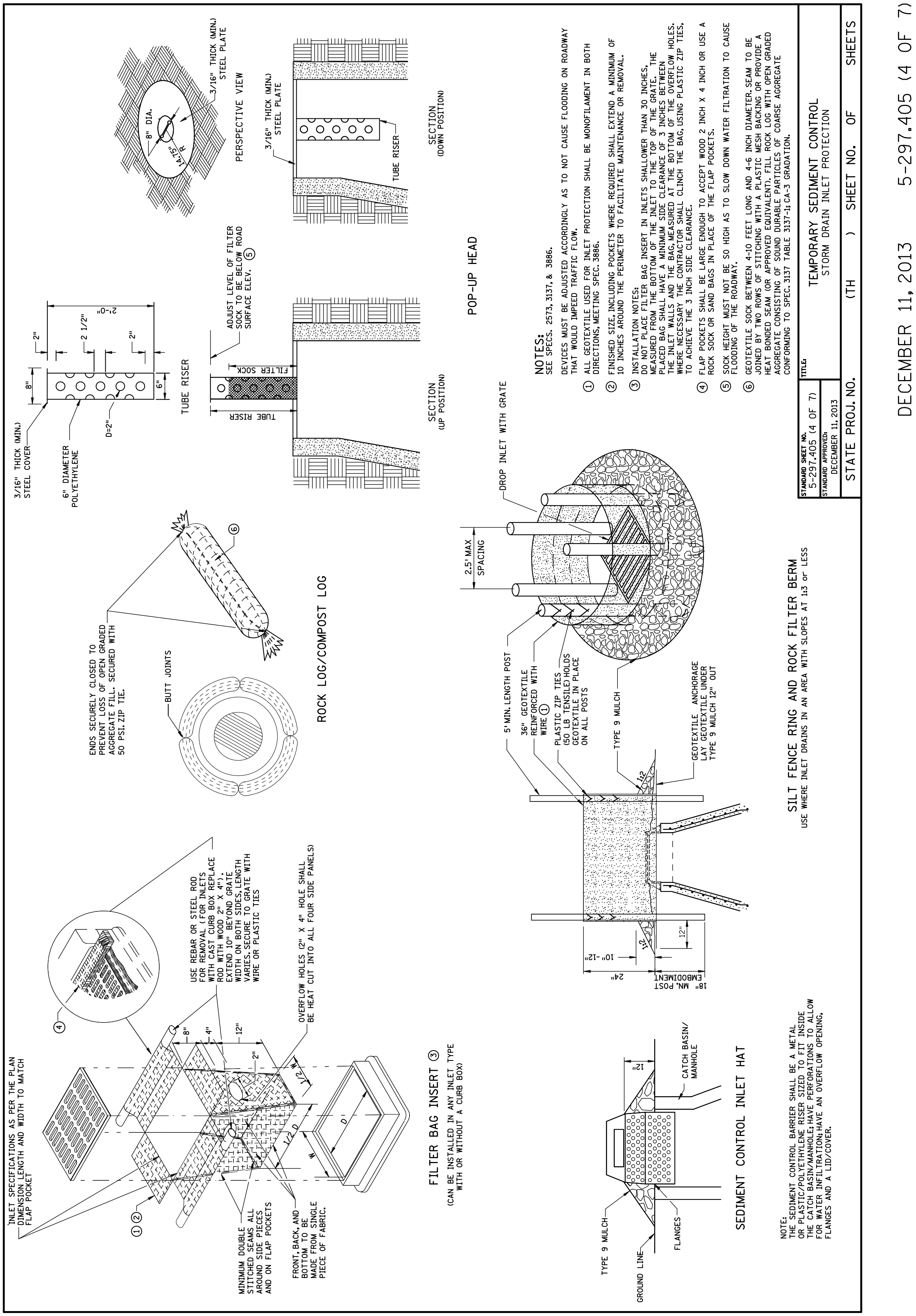
③ DITCH GRADE 3% - 5%, MAX. FLOW VELOCITY 12 FT./SEC..

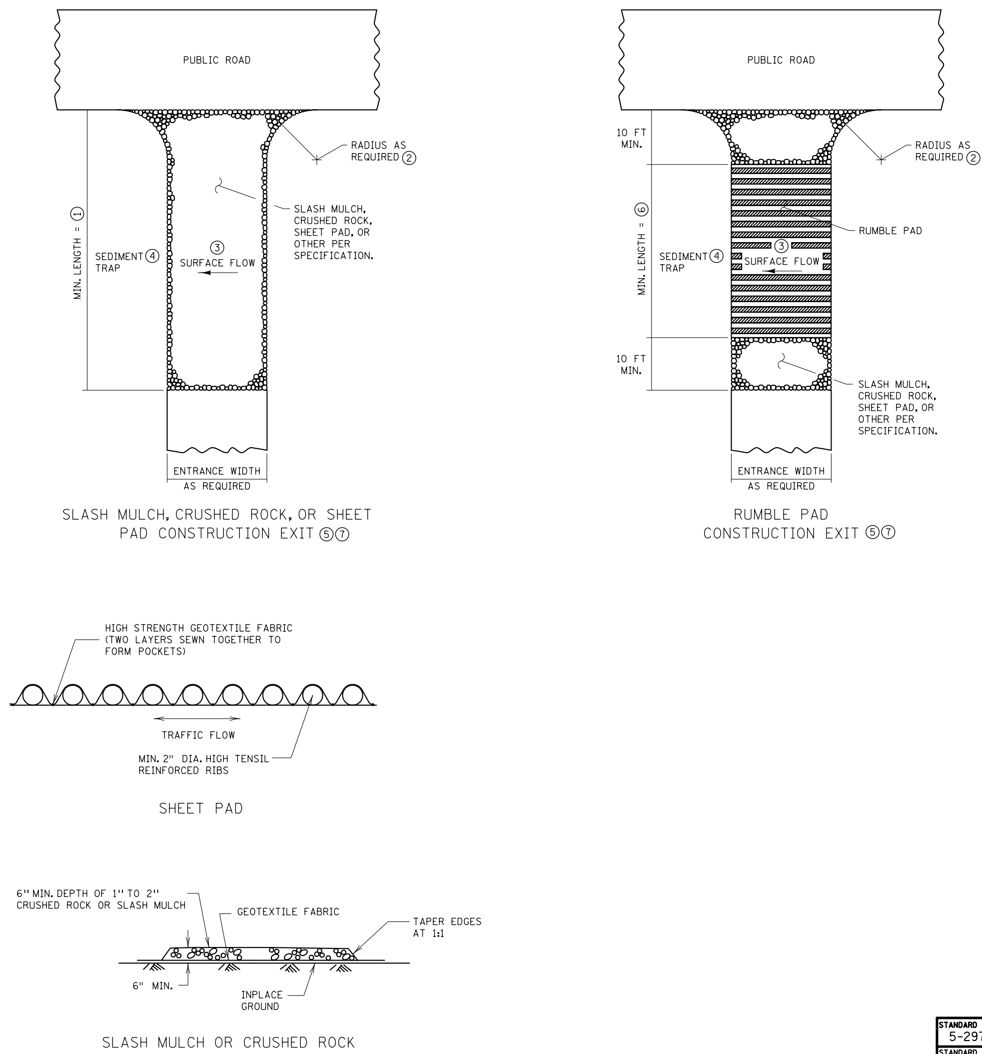
④ DITCH GRADE 1.5% - 3%, MAX. FLOW VELOCITY 4.5 FT./SEC..

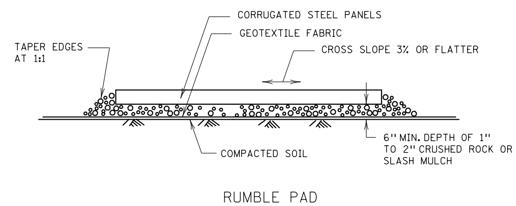
⑤ DITCH GRADE 1.5% - 3%, MAX. FLOW VELOCITY 1.5 FT./SEC..

STANDARD SHEET NO. 5-297.405 (3 OF 7) / STANDARD APPROVED: DECEMBER 11, 2013	TEMPORARY SEDIMENT CONTROL DITCH CHECK
STATE PROJ. NO.	(TH) SHEET NO. OF SHEETS

DECEMBER 11, 2013 5-297.405 (3 OF 7)


INLET SPECIFICATIONS AS PER THE PLAN
DIMENSION LENGTH AND WIDTH TO MATCH
FLAP POCKET
① ②
④
MINIMUM DOUBLE STITCHED SEAMS ALL AROUND SIDE PIECES AND ON FLAP POCKETS
FRONT, BACK, AND BOTTOM TO BE MADE FROM SINGLE PIECE OF FABRIC.
8"
4"
12"
2"
1/2 D
1/2 W
W
D'
USE REBAR OR STEEL ROD FOR REMOVAL (FOR INLETS WITH CAST CURB BOX REPLACE ROD WITH WOOD 2" X 4"). EXTEND 10" BEYOND GRATE WIDTH ON BOTH SIDES, LENGTH VARIES. SECURE TO GRATE WITH WIRE OR PLASTIC TIES
OVERFLOW HOLES (2" X 4" HOLE SHALL BE HEAT CUT INTO ALL FOUR SIDE PANELS)
FILTER BAG INSERT ③
(CAN BE INSTALLED IN ANY INLET TYPE WITH OR WITHOUT A CURB BOX)
ENDS SECURELY CLOSED TO PREVENT LOSS OF OPEN GRADED AGGREGATE FILL. SECURED WITH 50 PSI. ZIP TIE.
BUTT JOINTS
⑥
ROCK LOG/COMPOST LOG
3/16" THICK (MIN.) STEEL COVER
6" DIAMETER POLYETHYLENE
D=2"
8"
2"
2 1/2"
2'-0"
6"
TUBE RISER
ADJUST LEVEL OF FILTER SOCK TO BE BELOW ROAD SURFACE ELEV. ⑤
FILTER SOCK
SECTION
(UP POSITION)
8" DIA.
14.75" R
3/16" THICK (MIN.) STEEL PLATE
PERSPECTIVE VIEW
3/16" THICK (MIN.) STEEL PLATE
SECTION
(DOWN POSITION)
POP-UP HEAD
TYPE 9 MULCH
GROUND LINE
FLANGES
CATCH BASIN/ MANHOLE
SEDIMENT CONTROL INLET HAT
NOTE:
THE SEDIMENT CONTROL BARRIER SHALL BE A METAL OR PLASTIC/POLYETHYLENE RISER SIZED TO FIT INSIDE THE CATCH BASIN/MANHOLE; HAVE PERFORATIONS TO ALLOW FOR WATER INFILTRATION; HAVE AN OVERFLOW OPENING, FLANGES AND A LID/COVER.
2.5' MAX SPACING
5' MIN. LENGTH POST
36" GEOTEXTILE REINFORCED WITH WIRE ①
PLASTIC ZIP TIES (50 LB TENSILE) HOLDS GEOTEXTILE IN PLACE ON ALL POSTS
DROP INLET WITH GRATE
TYPE 9 MULCH
24"
10"-12"
1:2
18" MN. POST EMBODIMENT
GEOTEXTILE ANCHORAGE LAY GEOTEXTILE UNDER TYPE 9 MULCH 12" OUT
SILT FENCE RING AND ROCK FILTER BERM
USE WHERE INLET DRAINS IN AN AREA WITH SLOPES AT 1:3 or LESS
NOTES:
SEE SPECS. 2573, 3137, & 3886.
DEVICES MUST BE ADJUSTED ACCORDINGLY AS TO NOT CAUSE FLOODING ON ROADWAY THAT WOULD IMPEED TRAFFIC FLOW.
① ALL GEOTEXTILE USED FOR INLET PROTECTION SHALL BE MONOFILAMENT IN BOTH DIRECTIONS, MEETING SPEC. 3886.
② FINISHED SIZE, INCLUDING POCKETS WHERE REQUIRED SHALL EXTEND A MINIMUM OF 10 INCHES AROUND THE PERIMETER TO FACILITATE MAINTENANCE OR REMOVAL.
③ INSTALLATION NOTES: DO NOT PLACE FILTER BAG INSERT IN INLETS SHALLOWER THAN 30 INCHES, MEASURED FROM THE BOTTOM OF THE INLET TO THE TOP OF THE GRATE. THE PLACED BAG SHALL HAVE A MINIMUM SIDE CLEARANCE OF 3 INCHES BETWEEN THE INLET WALLS AND THE BAG, MEASURED AT THE BOTTOM OF THE OVERFLOW HOLES. WHERE NECESSARY THE CONTRACTOR SHALL CLINCH THE BAG, USING PLASTIC ZIP TIES, TO ACHIEVE THE 3 INCH SIDE CLEARANCE.
④ FLAP POCKETS SHALL BE LARGE ENOUGH TO ACCEPT WOOD 2 INCH X 4 INCH OR USE A ROCK SOCK OR SAND BAGS IN PLACE OF THE FLAP POCKETS.
⑤ SOCK HEIGHT MUST NOT BE SO HIGH AS TO SLOW DOWN WATER FILTRATION TO CAUSE FLOODING OF THE ROADWAY.
⑥ GEOTEXTILE SOCK BETWEEN 4-10 FEET LONG AND 4-6 INCH DIAMETER. SEAM TO BE JOINED BY TWO ROWS OF STITCHING WITH A PLASTIC MESH BACKING OR PROVIDE A HEAT BONDED SEAM (OR APPROVED EQUIVALENT). FILL ROCK LOG WITH OPEN GRADED AGGREGATE CONSISTING OF SOUND DURABLE PARTICLES OF COARSE AGGREGATE CONFORMING TO SPEC. 3137 TABLE 3137-1; CA-3 GRADATION.
STANDARD SHEET NO. 5-297.405 (4 OF 7)
STANDARD APPROVED: DECEMBER 11, 2013
TITLE: TEMPORARY SEDIMENT CONTROL
STORM DRAIN INLET PROTECTION
STATE PROJ. NO. (TH) SHEET NO. OF SHEETS
DECEMBER 11, 2013 5-297.405 (4 OF 7)





NOTES:

SEE SPECS. 2573 & 3882.

① MINIMUM LENGTH SHALL BE THE GREATER OF 50 FEET OR A LENGTH SUFFICIENT TO ALLOW A MINIMUM OF 5 TIRE ROTATIONS ON THE PROVIDED PAD. MINIMUM LENGTH SHALL BE CALCULATED USING THE LARGEST TIRE WHICH WILL BE USED IN TYPICAL OPERATIONS.

② PROVIDE RADIUS OR WIDEN PAD SUFFICIENTLY TO PREVENT VEHICLE TIRES FROM TRACKING OFF OF PAD WHEN LEAVING SITE.

③ IF RUNOFF FROM DISTURBED AREAS FLOWS TOWARD CONSTRUCTION EXITS, PREVENT RUNOFF FROM DRAINING DIRECTLY TO PUBLIC ROAD OVER CONSTRUCTION EXIT BY CROWNING THE EXIT OR SLOPING TO ONE SIDE. IF SURFACE GRADING IS INSUFFICIENT, PROVIDE OTHER MEANS OF INTERCEPTING RUNOFF.

④ IF RUNOFF FROM CONSTRUCTION EXITS WILL DRAIN OFF OF PROJECT SITE, PROVIDE SEDIMENT TRAP WITH STABILIZED OVERFLOW.

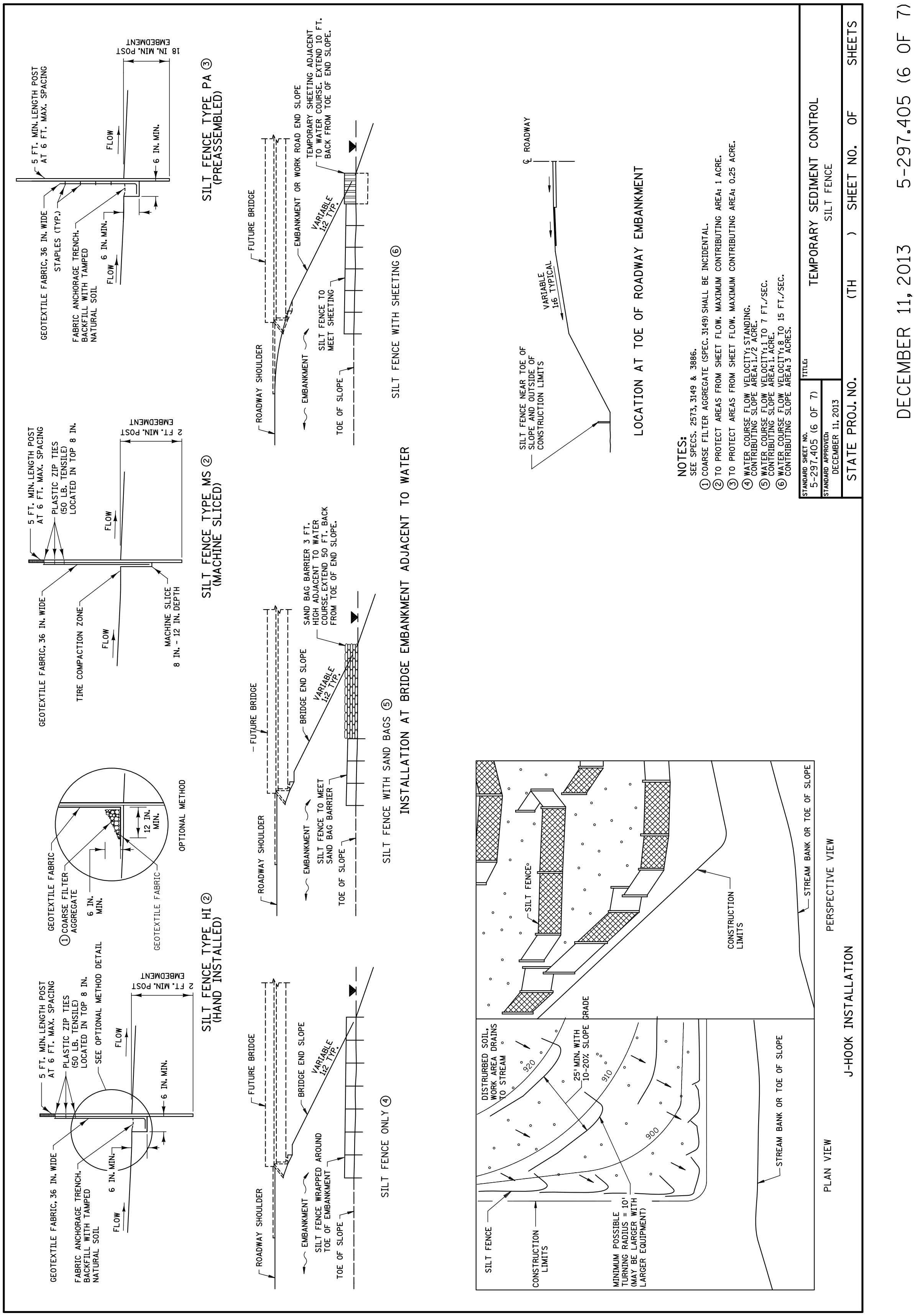
⑤ IF A TIRE WASH OFF IS REQUIRED THE CONSTRUCTION EXITS SHALL BE GRADED TO DRAIN THE WASH WATER TO A SEDIMENT TRAP.

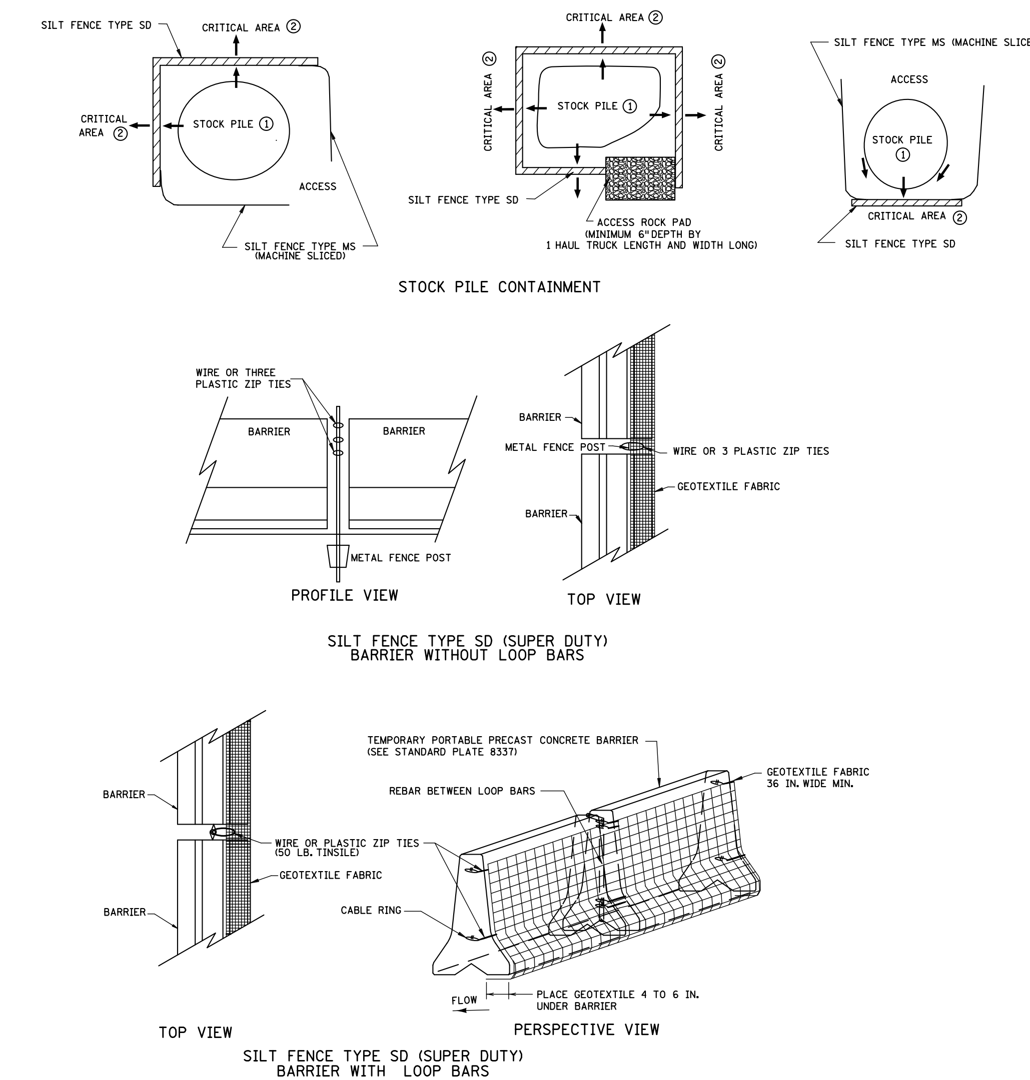
⑥ MINIMUM LENGTH OF RUMBLE PAD SHALL BE 20 FEET, OR AS REQUIRED TO REMOVE SEDIMENT FROM TIRES. IF SIGNIFICANT SEDIMENT IS TRACKED FROM THE SITE, THE RUMBLE PAD SHALL BE LENGTHENED OR THE DESIGN MODIFIED TO PROVIDE ADDITIONAL VIBRATION. WASH-OFF LENGTH SHALL BE AS REQUIRED TO EFFECTIVELY REMOVE CONSTRUCTION SEDIMENT FROM VEHICLE TIRES.

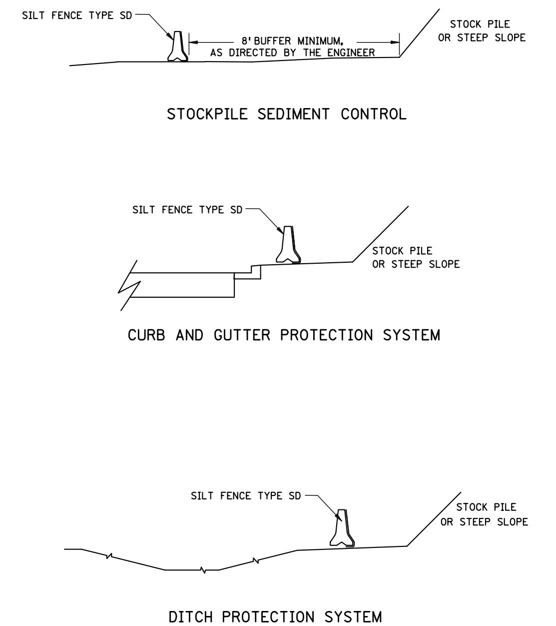
⑦ MAINTENANCE OF CONSTRUCTION EXITS SHALL OCCUR WHEN THE EFFECTIVENESS OF SEDIMENT REMOVAL HAS BEEN REDUCED. MAINTENANCE SHALL CONSIST OF REMOVING SEDIMENT AND CLEANING THE MATERIALS OR PLACING ADDITIONAL MATERIAL (SLASH MULCH OR CRUSHED ROCK) OVER SEDIMENT FILLED MATERIAL TO RESTORE EFFECTIVENESS.

STANDARD SHEET NO. 5-297.405 (5 OF 7) STANDARD APPROVED: DECEMBER 11, 2013	TITLE: TEMPORARY SEDIMENT CONTROL CONSTRUCTION EXITS
STATE PROJ. NO.	(TH) SHEET NO. OF SHEETS

DECEMBER 11, 2013 5-297.405 (5 OF 7)


SILT FENCE TYPE HI ② (HAND INSTALLED)
SILT FENCE TYPE MS ② (MACHINE SLICED)
SILT FENCE TYPE PA ③ (PREASSEMBLED)
GEOTEXTILE FABRIC, 36 IN. WIDE
5 FT. MIN. LENGTH POST AT 6 FT. MAX. SPACING
PLASTIC ZIP TIES (50 LB. TENSILE) LOCATED IN TOP 8 IN.
SEE OPTIONAL METHOD DETAIL
FABRIC ANCHORAGE TRENCH. BACKFILL WITH TAMPED NATURAL SOIL
FLOW
6 IN. MIN.
2 FT. MIN. POST EMBEDMENT
18 IN. MIN. POST EMBEDMENT
① COARSE FILTER AGGREGATE
OPTIONAL METHOD
12 IN. MIN.
TIRE COMPACTION ZONE
MACHINE SLICE 8 IN. - 12 IN. DEPTH
STAPLES (TYP.)
ROADWAY SHOULDER
FUTURE BRIDGE
BRIDGE END SLOPE
VARIABLE 1:2 TYP.
EMBANKMENT
SILT FENCE WRAPPED AROUND TOE OF EMBANKMENT
TOE OF SLOPE
SILT FENCE ONLY ④
SILT FENCE TO MEET SAND BAG BARRIER
SAND BAG BARRIER 3 FT. HIGH ADJACENT TO WATER COURSE. EXTEND 50 FT. BACK FROM TOE OF END SLOPE.
SILT FENCE WITH SAND BAGS ⑤
EMBANKMENT OR WORK ROAD END SLOPE
TEMPORARY SHEETING ADJACENT TO WATER COURSE. EXTEND 10 FT. BACK FROM TOE OF END SLOPE.
SILT FENCE TO MEET SHEETING
SILT FENCE WITH SHEETING ⑥
INSTALLATION AT BRIDGE EMBANKMENT ADJACENT TO WATER
SILT FENCE NEAR TOE OF SLOPE AND OUTSIDE OF CONSTRUCTION LIMITS
VARIABLE 1:6 TYPICAL
℄ ROADWAY
LOCATION AT TOE OF ROADWAY EMBANKMENT
SILT FENCE
CONSTRUCTION LIMITS
MINIMUM POSSIBLE TURNING RADIUS = 10' (MAY BE LARGER WITH LARGER EQUIPMENT)
DISTURBED SOIL, WORK AREA DRAINS TO STREAM
25' MIN. WITH 10-20% SLOPE GRADE
STREAM BANK OR TOE OF SLOPE
PLAN VIEW
PERSPECTIVE VIEW
J-HOOK INSTALLATION
NOTES:
SEE SPECS. 2573, 3149 & 3886.
① COARSE FILTER AGGREGATE (SPEC. 3149) SHALL BE INCIDENTAL.
② TO PROTECT AREAS FROM SHEET FLOW. MAXIMUM CONTRIBUTING AREA: 1 ACRE.
③ TO PROTECT AREAS FROM SHEET FLOW. MAXIMUM CONTRIBUTING AREA: 0.25 ACRE.
④ WATER COURSE FLOW VELOCITY: STANDING. CONTRIBUTING SLOPE AREA: 1/2 ACRE.
⑤ WATER COURSE FLOW VELOCITY: 1 TO 7 FT./SEC. CONTRIBUTING SLOPE AREA: 1 ACRE.
⑥ WATER COURSE FLOW VELOCITY: 8 TO 15 FT./SEC. CONTRIBUTING SLOPE AREA: 3 ACRES.
STANDARD SHEET NO. 5-297.405 (6 OF 7)
STANDARD APPROVED: DECEMBER 11, 2013
TITLE: TEMPORARY SEDIMENT CONTROL
SILT FENCE
STATE PROJ. NO. (TH) SHEET NO. OF SHEETS
DECEMBER 11, 2013
5-297.405 (6 OF 7)





NOTES:

SEE SPECS. 2533, 2573 & 3886.

SILT FENCE TYPE SD USED TO PROTECT CRITICAL AREAS FROM SHEET FLOW, AND AREAS WHERE OTHER SILT FENCES CANNOT BE INSTALLED. MAXIMUM CONTRIBUTING AREA: 1 ACRE.

PLACE SILT FENCE TYPE SD ALONG A CONSTANT ELEVATION.

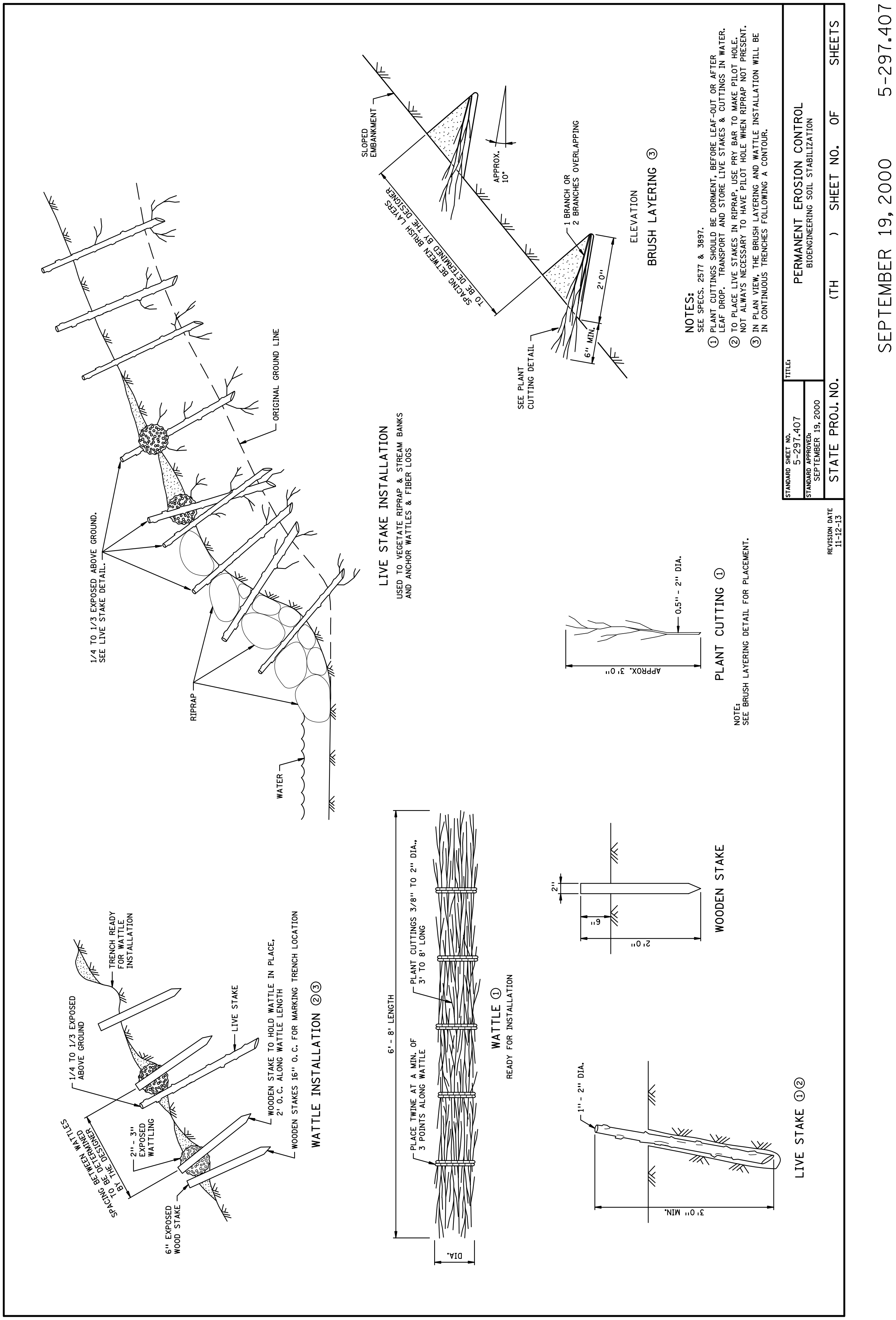
SILT FENCE TYPE SD CAN UTILIZE EITHER A CONCRETE, OR WATER FILLED, TEMPORARY MEDIAN BARRIER.

① PLACING STOCK PILES NEXT TO AN ENVIRONMENTALLY SENSITIVE AREA IS NOT RECOMMENDED. WHEN THERE ARE NO FEASIBLE ALTERNATIVES, PLACE SILT FENCE SD AS SHOWN OR AS DIRECTED BY THE ENGINEER.

② CRITICAL AREAS INCLUDE WETLANDS, JUDICIAL DITCHES, STREAMS, WATER BODIES, AND OTHER AREAS REQUIRING PROTECTION.

STANDARD SHEET NO. 5-297.405 (7 OF 7) STANDARD APPROVED: DECEMBER 11, 2013	TITLE: TEMPORARY SEDIMENT CONTROL SUPER DUTY SILT FENCE
STATE PROJ. NO.	(TH) SHEET NO. OF SHEETS

DECEMBER 11, 2013 5-297.405 (7 OF 7)



1/4 TO 1/3 EXPOSED ABOVE GROUND. SEE LIVE STAKE DETAIL.
ORIGINAL GROUND LINE
RIPRAP
WATER
LIVE STAKE INSTALLATION
USED TO VEGETATE RIPRAP & STREAM BANKS AND ANCHOR WATTLES & FIBER LOGS
SLOPED EMBANKMENT
SPACING BETWEEN BRUSH LAYERS TO BE DETERMINED BY THE DESIGNER
APPROX. 10°
1 BRANCH OR 2 BRANCHES OVERLAPPING
SEE PLANT CUTTING DETAIL
6" MIN.
2'0"
ELEVATION
BRUSH LAYERING ③
NOTES:
SEE SPECS. 2577 & 3897.
① PLANT CUTTINGS SHOULD BE DORMENT, BEFORE LEAF-OUT OR AFTER LEAF DROP. TRANSPORT AND STORE LIVE STAKES & CUTTINGS IN WATER.
② TO PLACE LIVE STAKES IN RIPRAP, USE PRY BAR TO MAKE PILOT HOLE. NOT ALWAYS NECESSARY TO HAVE PILOT HOLE WHEN RIPRAP NOT PRESENT.
③ IN PLAN VIEW, THE BRUSH LAYERING AND WATTLE INSTALLATION WILL BE IN CONTINUOUS TRENCHES FOLLOWING A CONTOUR.
0.5" - 2" DIA.
APPROX. 3'0"
PLANT CUTTING ①
NOTE: SEE BRUSH LAYERING DETAIL FOR PLACEMENT.
TRENCH READY FOR WATTLE INSTALLATION
1/4 TO 1/3 EXPOSED ABOVE GROUND
LIVE STAKE
SPACING BETWEEN WATTLES TO BE DETERMINED BY THE DESIGNER
2" - 3" EXPOSED WATTLING
6" EXPOSED WOOD STAKE
WOODEN STAKE TO HOLD WATTLE IN PLACE, 2' O.C. ALONG WATTLE LENGTH
WOODEN STAKES 16" O.C. FOR MARKING TRENCH LOCATION
WATTLE INSTALLATION ②③
6' - 8' LENGTH
PLANT CUTTINGS 3/8" TO 2" DIA., 3' TO 8' LONG
PLACE TWINE AT A MIN. OF 3 POINTS ALONG WATTLE
DIA.
WATTLE ①
READY FOR INSTALLATION
2"
6"
2'0"
WOODEN STAKE
1" - 2" DIA.
3'0" MIN.
LIVE STAKE ①②
STANDARD SHEET NO. 5-297.407
STANDARD APPROVED: SEPTEMBER 19, 2000
REVISION DATE 11-12-13
STATE PROJ. NO.
TITLE:
PERMANENT EROSION CONTROL
BIOENGINEERING SOIL STABILIZATION
(TH) SHEET NO. OF SHEETS
SEPTEMBER 19, 2000
5-297.407