Introduction to Stream Protection Practices

Disturbing the natural process of streams and associated wetlands must be avoided whenever possible. The following provides information regarding federal regulations protecting wetlands and streams and should be reviewed before beginning construction projects adjacent to or within stream channels.

Wetlands

Wetlands are defined by 33CFR328 as "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." Ecologically, wetlands provide a number of valuable functions, including habitat and foraging opportunities for many species of animals. From a water quality perspective, wetlands provide attenuation of floodwaters, processing of nutrients, and infiltration of stormwater, all of which improve the water quality of the respective watershed.

Stream Channels

Stream channel morphology and adjacent wetland areas play an important role in water quality, flood attenuation, sediment retention, wildlife and aquatic habitat and species, and endangered and threatened species. Stream channelization causes water flowing through the straightened section to move more rapidly and can lead to further erosion problems downstream of the channelized area. Channelization often necessitates the removal of vegetation along the streambanks and placement of fill within wetland areas. The removal of overhanging vegetation in the bends and pools of a stream can reduce the habitat for fish by decreasing feeding and spawning habitat. Restoring these areas after stream channel construction is important to prevent water quality impairment, improve flood control, and restore fish and wildlife habitat.

Stormwater

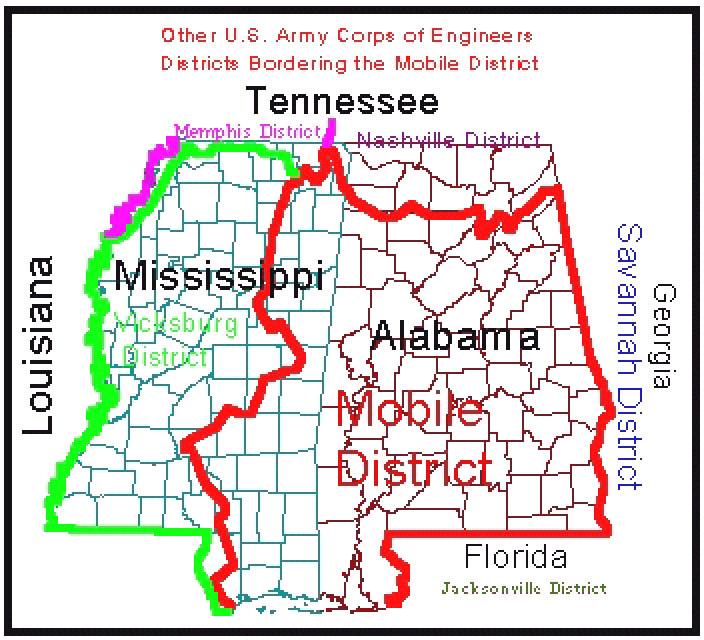
It should be noted that Region 4 of the EPA has established that "the Region will express objections to Section 404 permit applications that propose to construct control structures in waters of the United States for the express purposes of impounding waters to provide storm water treatment or conveyance in lieu of implementation of the required upland controls." However, the Region 4 EPA has stated that "In the case where circumstances preclude the use of upland controls, Region 4 will consider an exceptional case exists." The views of the EPA on in-stream treatment should be carefully considered during the site planning process, as permit authorization will likely be a long process including the satisfaction of the 404(b)(1) guidelines. Upland controls should always be considered first.

Clean Water Act

Section 404 of the Clean Water Act provides regulation of activities affecting waters of the United States. Activities requiring authorization from the U.S. Army Corps of Engineers include the following:

- Construction of piers, marinas, ramps, and cable or pipeline crossings;
- Dredging and excavation in or adjacent to waters of the United States;
- Fill for residential, commercial or recreational developments;
- Construction of revetments, groins, breakwaters, levees, dams, dikes and weirs; and
- Placement of riprap (for channel stabilization)

The U.S. Army Corps of Engineers issues two types of Section 404 permits applicable to the construction industry, General Permits and Individual Permits. It is advisable that you contact the U.S. Army Corps of Engineers District of the proposed project and the MDEQ before site planning to determine if permits are required.



The Section 404 authorization process requires that the developer has taken steps to avoid wetland impacts, minimized the potential impacts on wetlands, and provided compensatory mitigation for any remaining unavoidable impacts. For projects in the Mississippi Coastal Zone (Hancock, Harrison, and Jackson counties) the Mississippi Department of Marine Resources (DMR) acts as the lead regulatory agency, and permit applications are submitted to the DMR Bureau of Wetland Permitting for review. Projects outside of the Mississippi Coastal Zone will submit permit applications to the nearest U.S. Army Corps of Engineers District office.

Section 401 of the Clean Water Act, through the EPA, gives the MDEQ the authority to prohibit an activity, including a construction project, if it can impact water quality or have other unacceptable environmental consequences. Projects which require a 404 permit will also require a 401 Water Quality Certification from the MDEQ.

References

Appendix B: State and Federal Regulations, Permits and Applications

Appendix J: Local Information

U.S. Army Corps of Engineers District Offices:

U.S. Army Corps of Engineers, Mobile District
Attention: CESAM-OP-S
P.O. Box 2288
Mobile, AL 36628-00001
Phone: 334-690-2658
FAX: 334-690-2660

U.S. Army Corps of Engineers, Vicksburg District
Attention: CEMVK-OD-F
4155 Clay Street
Vicksburg, MS 39183-3435
Phone: 601-631-5276
FAX: 601-631-5459

U.S. Army Corps of Engineers, Memphis District
Attention: CEMVM-CO-GR
Clifford Davis Federal Building
Room B-202
Memphis, TN 38103-1894
Phone: 901-544-3471
FAX: 901-544-3266

U.S. Army Corps of Engineers, Nashville District
Attention: CELRN-CO-F
3701 Bell Road
Nashville, TN 37214-2660
Phone: 615-369-7500
FAX: 615-369-7501

Buffer Zone (BZ)

BZ

Figure BZ-1 Buffer Zone in Agricultural Area

Practice Description

A buffer zone is a strip of plants adjacent to land-disturbing sites or bordering streams, lakes, and wetlands that provides streambank stability, reduces scour erosion, reduces storm runoff velocities, and filters sediment in stormwater. This practice applies on construction sites and other disturbed areas that can support vegetation and can be particularly effective on floodplains, next to wetlands, along streambanks, and on steep, unstable slopes.

Planning Considerations

Streams, wetlands, and other waters of United States must be avoided as much as possible in all construction and earth-moving activities. (See the *Introduction to Stream Protection Practice* for more information on the regulations protecting streams, wetlands, and other waters of the United States.)

The width and plant composition of a buffer zone will determine its effectiveness.

There is no ideal width and plant community for buffer zones. A buffer zone 150 feet wide with desirable vegetation is required by the MDEQ to provide significant protection of a perennial stream, water body or wetland. Adjustments can be made to account for the purpose(s) of the buffer and landscape characteristics.

Three zones are typically recognized in the buffer area. If planned to be 45 to 55 feet wide, the recommended width and plant categories are described in the following listings:

Zone 1: The first 15 to 20 feet nearest the stream. Cover is close growing trees (commonly 6 to 10 feet apart).
Zone 2: The next 10 to 15 feet. Cover is trees or trees and shrubs.
Zone 3: The remaining buffer area. Cover is grass or dense groundcover.

Note: All widths are for one side of the stream only and are measured from top of streambank.

Existing vegetation should be considered for retention, especially hardwoods that are in Zones 1 and 2.

Buffer Zone 3 may be established with a grass planting or with close-growing groundcover that will provide dense cover to filter sediment. Where topography accommodates sheet flow from the adjacent landscape, Zone 3 should be retained or developed as a filter strip.

Necessary site preparation and planting for establishing new buffers should be done at a time and manner to ensure survival and growth of selected species.

Buffer zones may become part of the overall landscape of the project.

The layout and density of the buffer should complement natural features and mimic natural riparian forests.

Design Criteria and Construction

Preservation

Evaluate vegetation and landscape features in a proposed buffer zone to determine the potential for the existing plant community to maintain streambank stability, prevent sheet, rill and scour erosion, reduce stormwater velocities, and filter sediment.

Dedicate a vegetated zone to effectively minimize streambank and shoreline erosion, prevent sheet, rill and scour erosion in the buffer zone, and remove sediment from sheet flow from the disturbed area. Initially, estimate a width of 50 feet adjacent to the stream (each side), water body or wetland. Adjust the width to account for slope of the land adjacent to the stream and the purposes of the buffer. If the buffer is planned to trap sediment in sheet flow, the width should be increased 2 feet for every 1% slope measured along a line perpendicular to the streambank and immediately downslope of the disturbed area.

Installation (Plantings)

To determine the width and zone requirements for buffer zone plantings, MDEQ recommends the buffer zone should extend 150 feet from the waterway to be protected. The MDEQ will review cases where the 150-foot buffer zone cannot be achieved. See *Preservation of Vegetation* for more information on width and zone requirements.

Site Preparation

Plan appropriate site preparation to provide a suitable planting medium for grass, or for trees and shrubs.

Plan to install sediment- and erosion-control measures such as a silt fence and diversions if zones are graded before seedbed preparation.

If significant compaction exists, plan for chiseling or subsoiling.

For Zone 3 plantings, clear area of clods, rocks, etc., that would interfere with seedbed preparation; smooth the area, to encourage sheet flow, before the soil amendments are applied and firm the soil after the soil amendments are applied. Follow guidelines in the *Filter Strip Practice* if Zone 3 is to be used to filter sheet flow from the adjacent construction area.

Soil Amendments (Lime and Fertilizer)

Plan soil amendments using design criteria for the appropriate category (see *Permanent Seeding; Tree Planting on Disturbed Areas;* and *Shrub, Vine and Groundcover Planting Practices*). Incorporate amendments to a depth of 4″ to 6″ with a disc or chisel plow.

In the absence of a plan or soil test recommendations, apply agricultural limestone at the rate of 2 tons per acre (90 lbs per ft^2) and 10-10-10 fertilizer at the rate of 1000 lbs per acre (25 lbs per 1000 ft^2). Apply ground agricultural limestone unless a soil test shows pH of 6.0 or greater. Incorporate amendments to a depth of 4″ to 6″ with a disc or chisel plow.

Planting Desired Vegetation

Plan the vegetation for buffer zones using design criteria given in the *Permanent Seeding*, *Tree Planting on Disturbed Areas*, and/or *Shrub, Vine and Groundcover Planting Practices*. No invasive species shall be used. If trees are planted, at least two hardwood species should be used.

Mulching

Spread mulch according to guidelines in the *Mulching Practice*.

Common Problems

Consult with a qualified design professional if any of the following occur:

Soil compaction can prevent adequate plant growth. Compaction should be addressed during site preparation.

Design specifications for plants (variety, seeding/planting dates) and mulch cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Problems that require remedial actions:

Erosion, washout and poor plant establishment – repair eroded surface, reseed, reapply mulch and anchor.

Mulch is lost to wind or stormwater runoff – reapply mulch and anchor.

Maintenance

Replant trees, grass, shrubs or vines where needed to maintain adequate cover for erosion control. Maintain grass plantings with periodic applications of fertilizer and mowing.

References

BMPs from Volume 1

Chapter 4

BMPs from Volume 2

Chapter 4

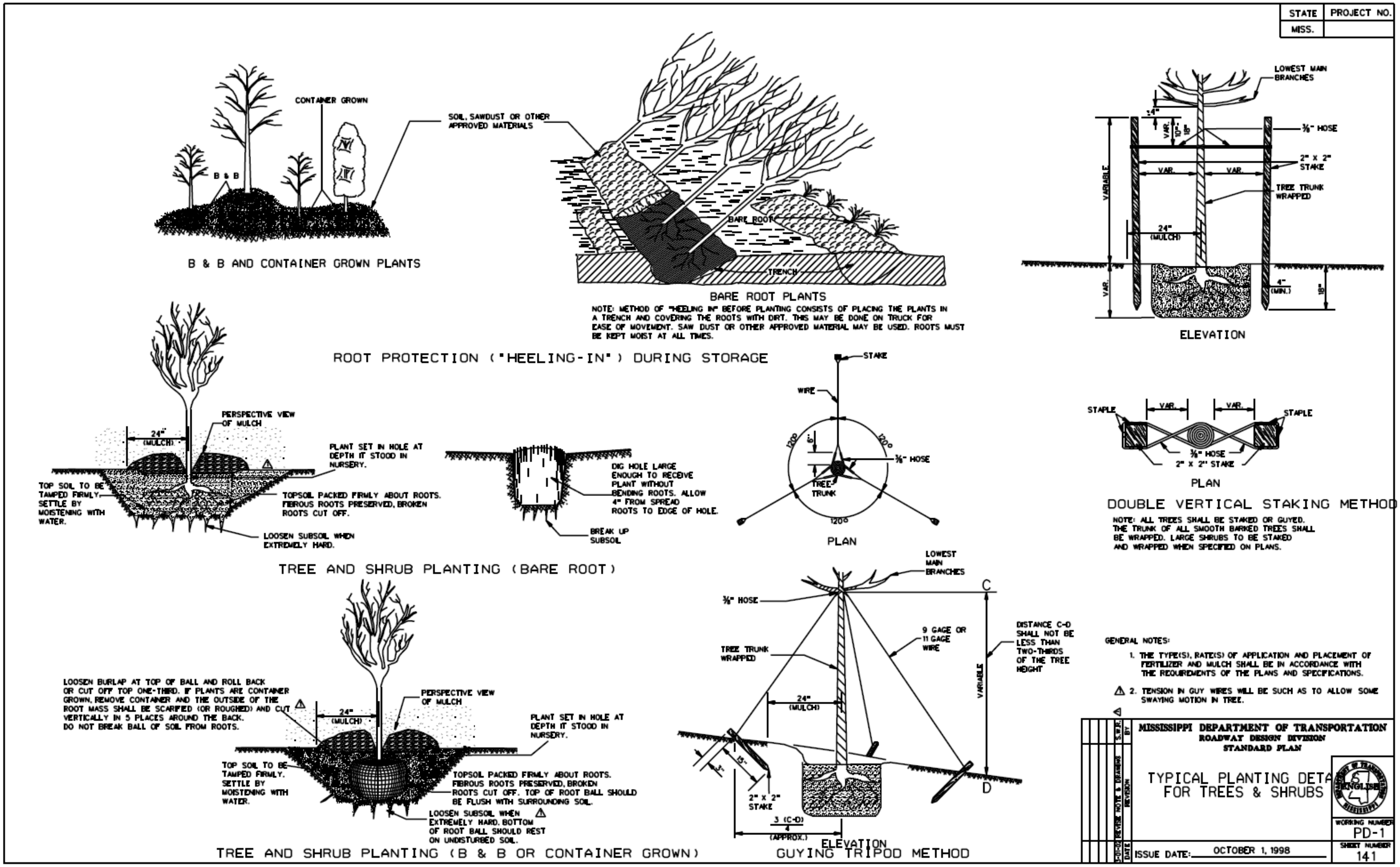
MDOT Drawing PD-1

Additional Resources

Allen, H.H., and Fischenich, J.C. (1999) “Coir geotextile roll and wetland plants for streambank erosion control,” *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-04), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Fischenich, C. (1999). "Irrigation systems for establishing riparian vegetation," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-12), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Fisher, R.A., and Fischenich, J.C. (2000). “Design recommendations for riparian corridors and vegetated buffer strips,” *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-24), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.


STATE
PROJECT NO.
MISS.
CONTAINER GROWN
B & B
SOIL, SAWDUST OR OTHER APPROVED MATERIALS
B & B AND CONTAINER GROWN PLANTS
BARE ROOT
TRENCH
BARE ROOT PLANTS
NOTE: METHOD OF "HEELING IN" BEFORE PLANTING CONSISTS OF PLACING THE PLANTS IN A TRENCH AND COVERING THE ROOTS WITH DIRT. THIS MAY BE DONE ON TRUCK FOR EASE OF MOVEMENT. SAW DUST OR OTHER APPROVED MATERIAL MAY BE USED. ROOTS MUST BE KEPT MOIST AT ALL TIMES.
ROOT PROTECTION ("HEELING-IN") DURING STORAGE
LOWEST MAIN BRANCHES
⅜" HOSE
2" X 2" STAKE
TREE TRUNK WRAPPED
VARIABLE
VAR.
24" (MULCH)
4" (MIN.)
18"
ELEVATION
STAPLE
⅜" HOSE
2" X 2" STAKE
PLAN
DOUBLE VERTICAL STAKING METHOD
NOTE: ALL TREES SHALL BE STAKED OR GUYED. THE TRUNK OF ALL SMOOTH BARKED TREES SHALL BE WRAPPED. LARGE SHRUBS TO BE STAKED AND WRAPPED WHEN SPECIFIED ON PLANS.
PERSPECTIVE VIEW OF MULCH
24" (MULCH)
PLANT SET IN HOLE AT DEPTH IT STOOD IN NURSERY.
TOP SOIL TO BE TAMPED FIRMLY. SETTLE BY MOISTENING WITH WATER.
TOPSOIL PACKED FIRMLY ABOUT ROOTS. FIBROUS ROOTS PRESERVED, BROKEN ROOTS CUT OFF.
LOOSEN SUBSOIL WHEN EXTREMELY HARD.
DIG HOLE LARGE ENOUGH TO RECEIVE PLANT WITHOUT BENDING ROOTS. ALLOW 4" FROM SPREAD ROOTS TO EDGE OF HOLE.
BREAK UP SUBSOIL
TREE AND SHRUB PLANTING (BARE ROOT)
STAKE
WIRE
120°
⅜" HOSE
TREE TRUNK
PLAN
LOOSEN BURLAP AT TOP OF BALL AND ROLL BACK OR CUT OFF TOP ONE-THIRD. IF PLANTS ARE CONTAINER GROWN, REMOVE CONTAINER AND THE OUTSIDE OF THE ROOT MASS SHALL BE SCARIFIED (OR ROUGHED) AND CUT VERTICALLY IN 5 PLACES AROUND THE BACK. DO NOT BREAK BALL OF SOIL FROM ROOTS.
PERSPECTIVE VIEW OF MULCH
24" (MULCH)
PLANT SET IN HOLE AT DEPTH IT STOOD IN NURSERY.
TOP SOIL TO BE TAMPED FIRMLY. SETTLE BY MOISTENING WITH WATER.
TOPSOIL PACKED FIRMLY ABOUT ROOTS. FIBROUS ROOTS PRESERVED, BROKEN ROOTS CUT OFF. TOP OF ROOT BALL SHOULD BE FLUSH WITH SURROUNDING SOIL.
LOOSEN SUBSOIL WHEN EXTREMELY HARD. BOTTOM OF ROOT BALL SHOULD REST ON UNDISTURBED SOIL.
TREE AND SHRUB PLANTING (B & B OR CONTAINER GROWN)
LOWEST MAIN BRANCHES
⅜" HOSE
C
TREE TRUNK WRAPPED
9 GAGE OR 11 GAGE WIRE
DISTANCE C-D SHALL NOT BE LESS THAN TWO-THIRDS OF THE TREE HEIGHT
VARIABLE
24" (MULCH)
15"
3"
2" X 2" STAKE
D
3 (C-D) / 4 (APPROX.)
ELEVATION
GUYING TRIPOD METHOD
GENERAL NOTES:
1. THE TYPE(S), RATE(S) OF APPLICATION AND PLACEMENT OF FERTILIZER AND MULCH SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE PLANS AND SPECIFICATIONS.
2. TENSION IN GUY WIRES WILL BE SUCH AS TO ALLOW SOME SWAYING MOTION IN TREE.
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
ROADWAY DESIGN DIVISION
STANDARD PLAN
TYPICAL PLANTING DETAILS FOR TREES & SHRUBS
ENGLISH
WORKING NUMBER
PD-1
ISSUE DATE: OCTOBER 1, 1998
SHEET NUMBER
141

Channel Stabilization (CS)

Practice Description

Channel stabilization is stabilizing a channel, either natural or artificial, in which water flows with a free surface. The purpose of this practice is to establish a non-erosive channel. This practice applies to the stabilization of open channels and existing streams or ditches with drainage areas less than 1 square mile. Methods of channel stabilization include rock riprap lining, concrete lining, grade stabilization structures, and bioengineered treatments, i.e., combinations of structural and vegetative materials. Vegetative-based structural reinforcements are preferred, especially in cases with fisheries resources and/or water quality issues.

Note: The design of open-channel conveyance structures other than Grass Swale is beyond the scope of this edition of the Mississippi Erosion and Sediment Control Manual, Volume 1, and should be done by a qualified design professional and should meet applicable state, federal, and local regulatory requirements.

Planning Considerations

This practice applies to the improvement or stabilization of open channels and existing streams or ditches with drainage areas less than 1 square mile. Channels with drainage greater than 1 square mile will be designed with appropriate criteria. In all cases, channel stabilization design should be done by a qualified design professional experienced in hydrology and hydraulics.

An adequate outlet for the channel must be available for discharge by gravity flow. Construction or other improvements to the channel should not adversely affect the environmental integrity of the area and must not cause significant erosion upstream or flooding and/or sediment deposition downstream.

The alignment and design of channels and stabilization structures shall give careful consideration to the preservation of valuable fish and wildlife habitat and trees of significant value for aesthetic purposes.

Where construction will adversely affect significant fish or wildlife habitat, mitigation measures should be included in the plan. Mitigation measures may include in-stream structures such as pools, riffles, and woody structures, or streamside measures such as trees, shrubs, and other features that enhance wildlife habitat.

Due to the varied nature of these considerations, an interdisciplinary team consisting of engineers, soil bioengineers, hydrologists, and fishery biologists should prepare the design of streambank protection for each unique channel reach. If instability is occurring over a significant length of stream, the team should consider performing a geomorphic analysis of the stream. All local, state and federal laws, especially laws relating to 404 permits, should be followed during the design and construction process.

Design Criteria and Construction

Prior to the start of construction, channel stabilization should be designed by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the construction process.

Consider the following guidance as construction proceeds.

Realignment

The realignment of channels should be kept to an absolute minimum. Where realignment is unavoidable, the realigned channel should be designed to have a stable grade considering the soil type, vegetation, and new channel length.

Channel Capacity

The design capacity of open channels and stabilization structures should be determined by procedures applicable to the purposes to be served.

Hydraulic Requirements

Manning's formula should be used to determine velocities in channels. The "n" values for use in this formula should be estimated using currently accepted guides along with knowledge and experience regarding the conditions. Acceptable guides can be found in hydrology textbooks.

Channel Cross Section

The required channel cross section of new or realigned channels is determined by the design capacity, the bed and bank materials, vegetation, and the requirements for maintenance. A minimum depth may be required to provide adequate outlets for subsurface drains and tributary channels. To enhance fisheries and wildlife, consider a channel cross section configuration that will ensure concentrated and unobstructed flow during periods of low flow, but one that incorporates bioengineered treatments with adequate habitat features to ensure refugia, etc., for fish and wildlife.

Drop Structure

Drop structures are used to reduce or prevent excessive erosion by reduction of velocities in the watercourse or by providing structures that can withstand and reduce the higher velocities. They may be constructed of concrete, rock, masonry, steel, aluminum or non-toxic treated wood.

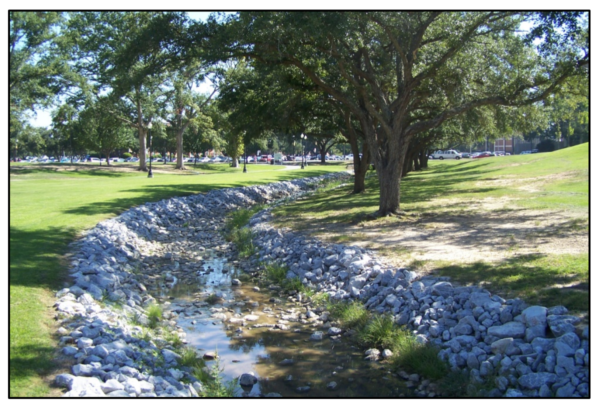
These structures are constructed where the capability of earth and vegetative measures is exceeded in the safe handling of water at permissible velocities, where excessive grades or overall conditions are encountered, or where water is to be lowered structurally from one elevation to another. These structures should generally be planned and installed along with or as part of other erosion-control practices. The structures must be designed hydraulically to adequately carry the channel discharge and structurally to withstand loadings imposed by the site conditions, but must allow fish to traverse if the stream has fish inhabitation. Therefore, a fisheries biologist should be consulted before the design is finalized and the structure installed.

Channel Stability

All channel construction, improvement and modification should be in accord with a design expected to result in a stable channel that can be maintained.

Characteristics of a stable channel are:

- It neither aggrades nor degrades beyond tolerable limits.
- The channel banks do not erode to the extent that the channel cross section is changed appreciably.



- Excessive sediment bars do not develop.
- Excessive erosion does not occur around culverts, bridges or elsewhere.
- Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.
- The determination of channel stability considers "bankfull" flow.
- Bankfull flow is defined as the flow in the channel which creates a water surface that is at or near normal ground elevation for a significant length of a channel reach. Excessive channel depth created by cutting through high ground, such as might result from realignment of the channel, should not be considered in determinations of bankfull flow.

The design for channels in natural materials shall be considered stable if the check velocity is less than the allowable velocities shown in Table CS-l. The check velocity is defined as the lesser of the bankfull velocity or the 10-year frequency peak discharge velocity.

Table CS-1 Allowable Velocities for Various Soil Textures

Soil Texture	**Allowable Velocity (ft/sec.)**
Sand and Sandy Loam (noncolloidal)	2.5
Silt Loam (also high lime clay)	3.0
Sandy Clay Loam	3.5
Clay Loam	4.0
Stiff Clay, Fine Gravel, Graded Loam to Gravel	5.0
Graded Silt to Cobbles (colloidal)	5.5
Shale, Hardpan and Coarse Gravel	6.0

Scheduling

Installation scheduling should be phased according to the following considerations. Hard structures such as rock and other inert materials could be installed during a period not suitable for vegetative establishment whereas vegetation could be planted during the appropriate time for more assurance of its survival. For instance, vegetation would be better established in the late winter/early spring after hard structures have been installed or concurrent with hard structure installation, depending on the design plan. Hard structures could be installed during a construction season prior to vegetative establishment with the vegetation being installed the following spring. For vegetation on high banks (those areas used for the adjoining *Streambank Protection*), schedule that installation during a planting period tailored for optimum survival of the plant species used. In addition, use local weather forecasts to avoid installation activities during rain events that can potentially create abnormal flows and flooding.

Site Preparation

Follow all local, state and federal government regulations on stream modifications.

Determine exact location of all underground activities.

Remove trees, brush, stumps and other objectionable materials according to the design plan. Where possible, vegetation will be left standing and stumps will not be removed.

Spoil material resulting from clearing and grubbing should be disposed of according to the design plan.

The foundation for structures should be cleared of all undesirable materials prior to the installation of the structures.

Channel Linings and Structural Measures

Where channel velocities exceed safe velocities for bare soil, channel linings of rock, concrete, or other durable material may be needed. Grade stabilization structures may also be needed.

Total channel linings covering the entire cross section of the stream are discouraged if the stream is inhabited by fisheries and other biota. Alternatively, a bioengineered stream is preferred that incorporates a zoned approach, such as a rocked toe and then vegetative treatments on the mid- and upper-banks. For more information, please review “Appendix B–Bioengineering for Streambank Erosion Control, Guidelines” of *The WES Stream Investigation and Streambank Stabilization Handbook* referenced at the end of this section. Total covering of ditches with channel linings may be appropriate if they are used solely for drainage and erosion control.

One or more of the following methods can be used to stabilize channels or portions of channels given the above considerations, i.e., whether a stream or a ditch.

Rock Riprap Lining

Rock riprap should be designed to resist displacement when the channel is flowing at the bankfull discharge or the 10-year 24-hour frequency discharge, whichever is the lesser. Rock riprap lining should not be used when channel velocities exceed 10 feet per second unless a detailed engineering analysis is performed using appropriate guidelines.

Use Figure CS-1 to determine the stable basic stone weight (d_{100}). Using the d_{100} size as a d_{90}, select a commercially available riprap gradation as classified by the Mississippi Department of Transportation, from Table CS-2.

Dumped and machine-placed riprap should be installed on slopes flatter than 2 horizontal to 1 vertical. Where riprap is placed by hand, the slopes may be steeper. Stone for riprap should consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone should be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering, and it should be suitable in all other respects for the purpose intended. The specific gravity of the individual stones should be at least 2.5.

A filter blanket should be placed between the riprap and base material, if needed. A filter blanket is a layer of material placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. A filter blanket should be considered where soils have a high piping potential and/or there is significant seepage of groundwater from the bed or banks.

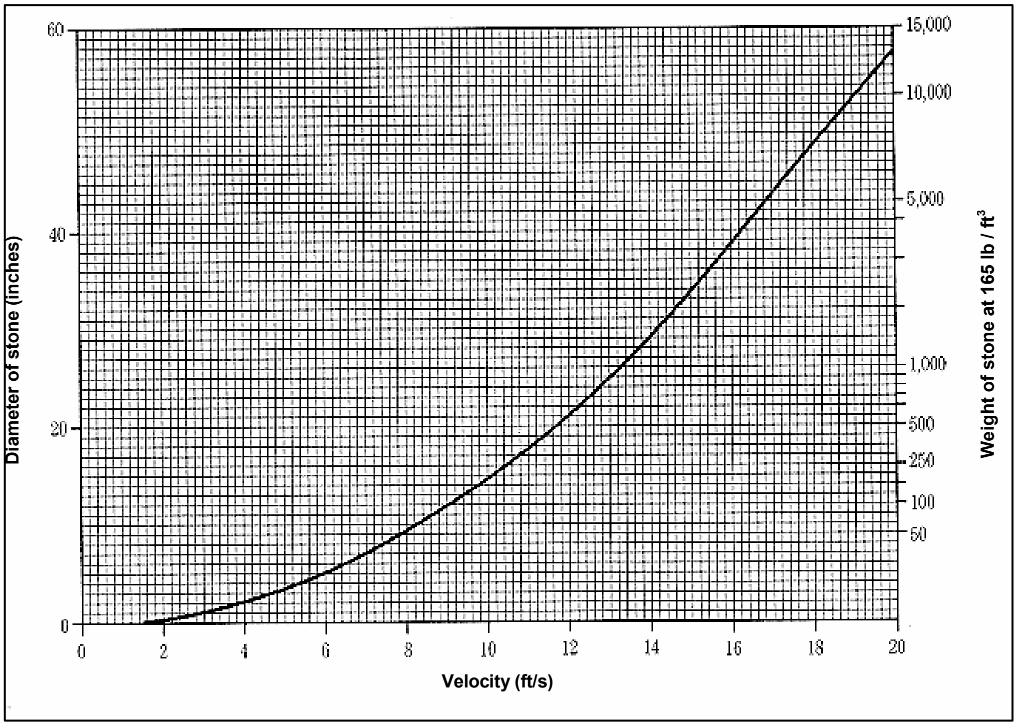


Figure CS-1 Ishbash Curve

Procedure

1) Determine the design velocity.
2) Use design velocity and Figure CS-1 to determine d_{100} rock size.
3) Use d_{100} from Figure CS-1 as d_{90} to select rock gradation from Table CS-2.

Table CS-2 Commercially Available Riprap Gradations

Class	**Weight (lbs.)**					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

A filter blanket can be of two general forms: a gravel layer or a geotextile filter cloth. Gravel filter blankets are to be designed in accordance with the criteria below.

Gravel Filter Blanket

The following relationships must exist:

$$\frac{d_{15}\text{ filter}}{d_{85}\text{ base}} < 5 < \frac{d_{15}\text{ filter}}{d_{15}\text{ base}} < 40$$

$$\frac{d_{50}\text{ filter}}{d_{50}\text{ base}} < 40$$

In these relationships, filter refers to the overlying material and base refers to the underlying material. The relationships must hold between the filter material and the base material and between the riprap and the filter material. In some cases, more than one layer of filter material may be needed. Each layer of filter material should be approximately 6″ thick.

Geotextile Filter Cloth

Geotextile filter cloth may be used in place of or in conjunction with gravel filters. Geotextile will meet the requirements of Class I geotextile as shown in Table CS-4.

Filter blankets should always be provided where seepage from underground sources threatens the stability of the riprap.

Rock Riprap Lining Installation

Where excavation is required, channels will be excavated from one side, leaving vegetation on the opposite side.

Excavation should be at the locations and grades shown on the drawings.

Spoil material resulting from channel excavation should be disposed of according to the design plan.

If required by the plans, place geotextile fabric or a granular filter as a bedding material for the riprap. Install riprap of the specified gradation to the lines and grades shown in the design plan. Ensure that the subgrade for the filter and riprap follows the required lines and grades shown in the plan.

Riprap may be placed by equipment. Care should be taken to avoid punching or tearing of the filter cloth during placement of rock. Repair any damage by removing the riprap and placing another piece of filter cloth over the damaged area. All connecting joints should overlap a minimum of 1.5 feet so that the upstream piece of fabric lies on top of the downstream piece of fabric. If the damage is extensive, replace the entire filter cloth.

Installation usually includes some bank shaping. If bank shaping is included, follow details in the design plan and refer to the construction guidelines in *Streambank Protection Practice.*

Concrete Lining

Concrete linings should be designed according to currently accepted guides for structural and hydraulic adequacy. They must be designed to carry the required discharge and to withstand the loading imposed by site conditions. Concrete linings are generally used when velocities exceed 10 ft/sec. Erosion at the outlet of concrete-lined channels is generally a problem due to the high velocities. Measures should be taken to reduce the velocity and erosion potential at the outlet by use of outlet protection measures (see *Outlet Protection Practice*).

Concrete Lining Installation

Where excavation is required, channels will be excavated from one side, leaving vegetation on the opposite side.

Excavation should be at the locations and grades shown on the drawings.

Spoil material resulting from channel excavation should be disposed of according to the design plan.

Install concrete lining using concrete of the specified design strength according to the lines and grades in the design plan.

Installation of concrete linings usually includes some bank shaping. If bank shaping is included, follow details in the design plan and refer to the construction guidelines in *Streambank Protection Practice*.

Place filter material and weep holes according to the plans. Place concrete according to American Concrete Institute standards. Concrete on sloping surfaces should be placed from the bottom of the slope toward the top, at the required thickness, and with good vibration.

As required by the design plan, install expansion joints at the locations shown in the plan.

As required by the design plan, install welded wire fabric in the concrete forms before placing concrete.

Divert flow around the concrete lining until the concrete has reached 75% of its design strength (usually 7 days after concrete placement).

Table CS-4 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [3]
Tensile strength (lb) [1]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%) [1]	ASTM D 4632	≥ 50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. #40 [2]	As specified max. #40 [2]	As specified max. #40 [2]	As specified max. #40 [2]
Permittivity sec^{-1}	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

1 Minimum average roll value (weakest principal direction).
2 U.S. standard sieve size.
3 Heat-bonded or resin-bonded geotextile may be used for Classes III and IV. They are particularly well suited to class IV. Needle-punched geotextile is required for all other classes.

Grade Stabilization Structures

For streams with fish inhabitation, a fisheries biologist should be consulted before the design is finalized and the structure installed, to ensure fish transport will not be adversely affected by the structure.

Where excavation is required, channels will be excavated from one side, leaving vegetation on the opposite side.

Excavation should be at the locations and grades shown on the drawings.

Spoil material resulting from clearing, grubbing and channel excavation should be disposed of according to the design plan.

Install the structure to the lines and grades shown in the design plan.

If earthfill is required, install according to the design plan and refer to the construction guidelines for *Sediment Basin* embankments.

If rock riprap is required, install according to the design plan and refer to the installation requirements listed earlier for *Riprap-Lined Swale*.

Other products used, including concrete, masonry, steel, aluminum or treated wood, should be installed according to details in the design plan. Installation usually includes some bank shaping. If bank shaping is included, follow details in the design plan and refer to the construction guidelines in the *Streambank Protection Practice*.

Erosion Control

Seeding, fertilizing and mulching of the disturbed areas should be done immediately after construction and should conform to the guidelines in the design plan. If vegetation establishment specifications are not included in the design plan, see the appropriate practice (*Permanent* or *Temporary Seeding*) for guidelines. If planting needs to be deferred until the next planting season, the disturbed areas should be protected with mulch (see *Mulching Practice* if details are not included in the design plan).

Safety

Store all construction materials well away from the stream. Consider weather forecasts when determining risks of damage by flooding.

Equipment used to construct channel stabilization measures should be free of leaks of fuel and hydraulic fluids to prevent contamination of surface waters. Operation of equipment in the stream should be minimized. At the completion of each workday, move all construction equipment away from the stream to prevent damage to equipment by flooding. Consider weather forecasts when determining risks of flooding.

The following precautions should be taken:

- Exercise caution on steep slopes.
- Fence the area and post warning signs if trespassing is likely.
- All equipment used for practice installation should be free of leaks of gas, oil, and hydraulic fluid. Measures should be in place to prevent accidental spills from entering the stream.
- Equipment should not be operated within flowing water in the stream.

Construction Verification

Check material and finished grades to determine if job meets specifications in the design plan.

Common Problems

Variations in site conditions indicate practice will not function as intended; changes in plan may be needed.

Design specifications for materials cannot be met; substitution may be required. Unapproved substitutions could result in failure of the practice.

Maintenance

All structures should be maintained in an “as built” condition.

Check the stream channel at the construction site after each major event until the job is considered mature and a success.

Structural damage caused by storm events should be repaired as soon as possible to prevent further damage to the structure or erosion of the streambank.

Unwanted brush or excessive sediment that will impede flow should be removed to maintain design conditions.

References

BMPs from Volume 1

Chapter 4

BMPs from Volume 2

Chapter 4

Riparian/Forested Buffer

Vegetated Filter Strip

Additional Resources

Allen, H.H., and Fischenich, J.C. (1999) “Coir geotextile roll and wetland plants for streambank erosion control,” *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-04), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Biedenharn, D.S., Elliot. C.M., and Watson, C.C. (1997) “The WES Stream Investigation and Streambank Stabilization Handbook.” http://chl.erdc.usace.army.mil/Media/2/8/7/StreambankManual.pdf.

Fischenich, C. (1999). "Irrigation systems for establishing riparian vegetation," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-12), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Fisher, R.A., and Fischenich, J.C. (2000). “Design recommendations for riparian corridors and vegetated buffer strips,” *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-24), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Stream Diversion Channel (SDC)

Practice Description

A stream diversion channel is a temporary practice to convey stream flow in an environmentally safe manner around or through a construction site while a permanent structure or conveyance is being installed in the stream channel.

Planning Considerations

Construction projects often cross and impact live streams, creating a potential for excessive sediment delivery into the stream. In cases where in-stream work is unavoidable, a temporary stream diversion channel should be planned. In-stream projects of this nature are subject to the rules and regulations of the U.S. Army Corps of Engineers for in-stream modifications (Clean Water Act Section 404 permit) and, if applicable, MDEQ CWA Section 401 water quality certification. Temporary stream diversions shall be used only on streams with a drainage area less than 1 square mile (640 acres). Detailed engineering analysis and design should be used for larger drainage areas to ensure a stable diversion channel. For sites with very small drainage areas, the designer may consider temporary blocking and overland pumping of the stream. To avoid crossing a live stream, the planner or designer should consider allowing access for construction of the permanent structure only from the side opposite the stream diversion channel. At locations where access from both sides of the stream is required to construct the permanent structure in the stream channel, a *Temporary Stream Crossing (TSC)* may be necessary. It is best to locate this crossing either up- or down-stream of the stream diversion channel.

Vegetation along the existing stream channel should be left undisturbed and protected with effective sediment-control practices until such time as the diversion channel is constructed and can safely convey stream flows. Construction equipment should not be allowed to operate in flowing waters and should be operated and maintained according to the *Housekeeping (HK) Practice*. Excavated materials should be stockpiled away from the stream and diversion channel and protected to ensure the material does not erode and enter the stream system. The stream diversion channel should be planned and installed in such a manner and time (dry season) that the impact to fisheries and the aquatic environment is minimized. A pictorial representation of a stream diversion channel is shown in Figure SDC-1.

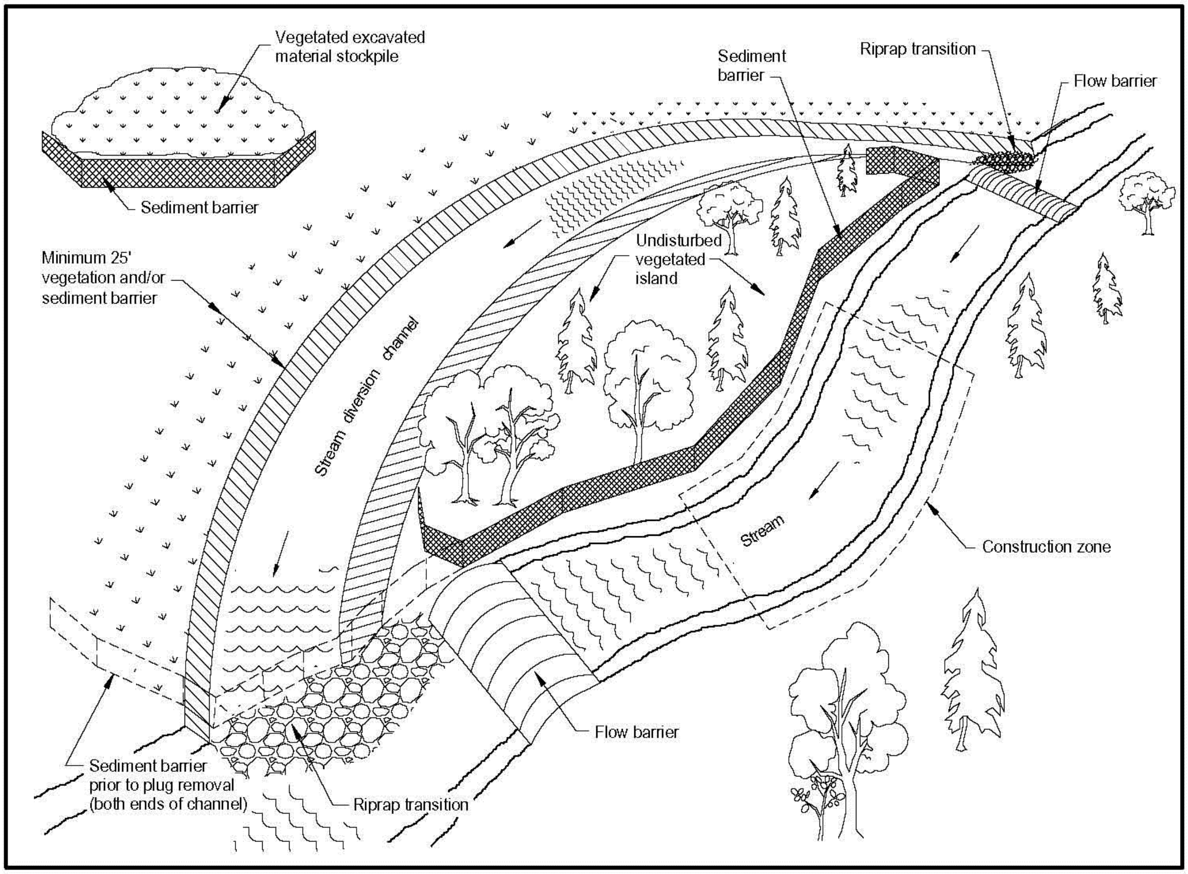


Figure SDC-1 Typical Stream Diversion Channel Layout

Design Criteria and Construction

Prior to the start of construction, stream diversion channels are required to be designed by a qualified design engineer registered in the State of Mississippi.

Size

The combination of bottom width, depth, and gradient shall be sufficient to provide the required flow capacity. The minimum bottom width of the stream diversion channel shall be 6 feet or equal to the bottom width of the existing stream bed, whichever is greater. The bottom surface should be shaped or configured to ensure adequate concentrated and unobstructed flow of water during periods of low flow.

Side Slope

Side slopes of the stream diversion channel shall be no steeper than 2 horizontal to 1 vertical (2:1).

Gradient

The diversion bottom grade may be variable, dependent on site conditions, but shall be sufficient to ensure continuous flow of water in the diversion at velocities not exceeding the allowable velocities for the selected channel lining material. The stream diversion channel length should be the same or greater than the length of the stream diverted.

Capacity

The capacity of the stream diversion channel shall be at least bankfull capacity of the existing stream. Consideration should be given to providing greater capacity where construction is expected to extend over several weeks or months.

Channel Lining

The stream diversion channel shall be lined to prevent erosion of the channel and sedimentation in the stream. The lining should be selected based on the velocity at bankfull flow. Use Table SDC-1 for general guidance on the type of lining to be used. Pre-manufactured products, like turf reinforcement mats (TRM), cellular blocks, and similar products, shall be designed and installed according to the manufacturer's recommendations.

Table SDC-1 Stream Diversion Channel Linings

Lining Materials	Acceptable Velocity Range
Geotextile fabric, polyethylene film, light-weight TRM, block sod	0 – 2.5 fps
Geotextile fabric, heavy-weight TRM	2.5 – 9.0 fps
Class I riprap and geotextile	9.0 – 13.0 fps

Riprap linings shall be designed in accordance with the guidance contained in the *Channel Stabilization (CS) Practice*. Class I non-woven geotextile shall be used underneath riprap lining for high-velocity applications.

When rolled products such as polyethylene film or geotextile fabric are used as a channel lining, the product should be placed so that one width of material will cover the entire channel bottom and slopes, while also providing enough material for a minimum 6-inch anchorage at the top of the bank. The upstream end of the material shall be buried at least 2 feet from top-of-bank to top-of-bank with additional trench anchorages of at least 1 foot by 1 foot at 50-foot intervals. Upstream sections of material shall overlap downstream sections by at least 2 feet, and overlap should occur at a trench anchorage location. Polyethylene film shall be at least 6 mil thick and capable of maintaining strength against the effects of ultraviolet light for a period of at least 60 days.

Block sod shall be covered with erosion-control netting and staked at minimal 3-foot by 3-foot spacing, and also staked at the upstream edge of each piece of sod.

Transitions

Additional protection such as riprap may be needed at the entrance and exit portion of the stream diversion channel to ensure velocities do not scour the existing stream bed or bank.

Sequence of Construction

To minimize detrimental effects to the environment and the aquatic community, the stream diversion channel should be quickly and carefully installed, well maintained, and removed as soon as possible when the construction area is stable. A sequence of construction should be specified in the contract work. While the sequence of construction should be tailored to the specific site, the general process should be as follows:

- Install sediment barrier at locations alongside stream to intercept runoff from the construction of the stream diversion channel.
- Install sediment barrier around or downstream of stockpile location.
- Maintain vegetation around stream.
- Clear downstream portion of stream diversion channel except for the area of the temporary plug.
- Begin excavation of the stream diversion channel at least 25 feet from the outlet and maintain this undisturbed plug.
- Stockpile excavated material at designated location and clear additional portions of the stream diversion channel as needed for excavation operations.
- Complete the excavation and leave at least a 25-foot undisturbed plug at the entrance to the stream diversion channel.
- Dewater the excavated area as needed for installation of the lining, and pump the dewatered material to a settling basin before any discharge is allowed.
- Install the lining in diversion channel.
- Excavate the downstream plug and install the transition riprap.
- Adjust sediment barrier locations as needed for stream protection.
- Excavate the upstream plug and install the transition riprap.
- Install an upstream flow barrier, forcing flow into the diversion channel.
- Allow time for aquatic organisms to move or migrate downstream.
- Install a downstream flow barrier if needed.
- Seed and mulch the stockpile and the disturbed area around the stream diversion channel.
- Complete the “in-stream” work.
- Divert flow into the completed “in-stream” conveyance system.
- Place sediment barriers for protection while decommissioning the stream diversion channel.
- Remove channel linings as needed, recycle or properly dispose of the material.
- Place excavated material into diversion channel.
- Apply seed and mulch to disturbed areas.

Site Preparation

Determine exact location of underground utilities.

Maintain vegetation around the stream until the stream diversion channel has been fully completed including vegetation. Clear only enough of the stream-diversion channel area for the next day’s work.

The centerline of the stream diversion channel should be established in the plans or by the responsible engineer. Slope and grade stakes should be established for use during excavation.

Erosion and Sediment Control

Sediment barrier or other sediment-control practices to protect the stream from the construction of the diversion channel should be installed prior to any land disturbance. The stockpile for excavated material should be located well away from the work area with sediment-control practices installed prior to placement of stockpiled materials. All construction areas should be seeded and mulched as soon as work is complete. Maintain a minimum 25-foot vegetated grass filter around the stream diversion channel.

Excavation

A 25-foot undisturbed plug should be left at the exit and entrance of the stream diversion channel until the diversion channel itself has been finished. The stream diversion channel should be excavated according to the dimensions and grade shown in the construction plans, beginning at the downstream end next to the plug and continuing in an upstream direction. The grade of the stream diversion channel should be uniform and continuous in order to tie into the existing stream bottom elevations without any overfalls that would create turbulence. Construction equipment should not be allowed to operate in flowing waters. Construction equipment should be well maintained to prevent drip/leaks of oil, hydraulic fluid, etc. Water that collects in the stream diversion channel excavation should be pumped as necessary to a settling basin prior to its discharge. The excavated material should be hauled to the stockpile location.

Lining Placement

Different lining materials can be specified for the stream diversion channel. Install the selected linings according to the construction specifications.

When rolled products like polyethylene film or geotextile fabric are specified for use as a channel lining, the product should be placed so that one width of material will cover the entire channel bottom and slopes while also providing enough material for a minimum 6-inch anchorage at the top of the bank. The upstream end of the material shall be buried at least 2 feet from top-of-bank to top-of-bank with additional trench anchorages of at least 1 foot by 1 foot at 50-foot intervals. Upstream sections of material shall overlap downstream sections by at least 2 feet and occur at a trench anchorage location. Polyethylene film shall be at least 6 mil thick and capable of maintaining strength against the effects of ultraviolet light for a period of at least 60 days.

Pre-manufactured products, such as turf reinforcement mats (TRM), cellular blocks, and other similar products, shall be designed and installed according to the manufacturer's recommendations.

Block sod shall be covered with erosion-control netting and staked at minimal 3-foot by 3-foot spacing, and also at the upstream edge of each piece of sod.

Generally, Class I non-woven geotextile fabric is used underneath riprap linings. Additional protection such as riprap may be needed at the entrance and exit portions of the stream diversion channel to ensure scour does not occur in the existing stream bed or bank.

Stream Diversion

After the lining between the upstream and downstream plugs has been installed, the downstream plug should be removed first and the transition installation completed. Next, the upstream plug should be removed and the transition installation completed. Finally, the stream flow should be diverted into the stream diversion channel using an upstream flow barrier, as specified in the plans and in such a manner as to minimize sediment delivery into the stream. Allow time for the stream to drain so that aquatic organisms have an opportunity to move or migrate downstream. The downstream flow barrier, if required, can then be installed so that work can commence for the installation of the permanent structure.

Construction Verification

Check finished grades and cross sections throughout the length of the stream diversion channel.

Verify the stream diversion channel cross-section dimensions at several locations to confirm plan specifications.

Common Problems

Consult with a qualified design professional if any of the following occur:

The topography of the site does not allow the practice to function as intended and changes in the plan are needed.

The design specifications for materials cannot be met and substitutions may be necessary. Unapproved substitutions could result in an unstable diversion channel.

Maintenance

Inspect the stream diversion channel at regular intervals and especially after storm events; check for lining displacement, erosion of the lining, and erosion at the transition areas.

Repair damaged lining and erosion promptly.

Once the permanent structure has been completed, flow can be diverted into the new conveyance structure and the stream diversion channel decommissioned. The decommissioning should occur in such a manner as to minimize erosion and sediment runoff into the stream system. Lining materials should be recycled or disposed of properly.

References

BMPs from Volume 1

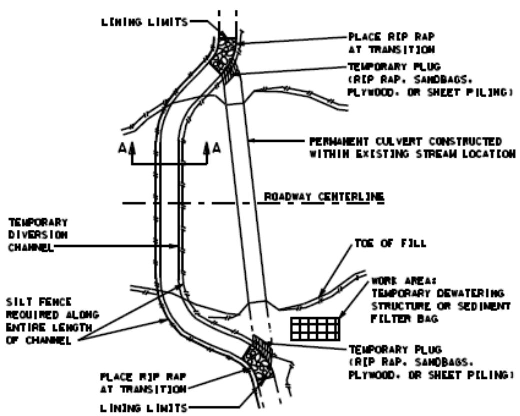
Chapter 4

Housekeeping (HK)	4-43
Channel Stabilization (CS)	4-342
Temporary Stream Crossing (TSC)	4-382

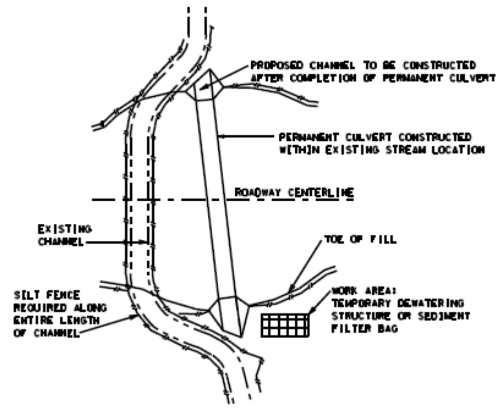
MDOT Drawing ECD-17

MDOT Drawing ECD-18

STATE	PROJECT NO.
MISS.	



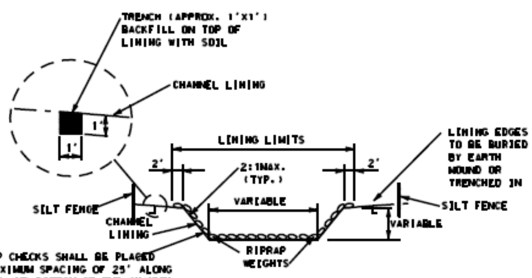
CULVERT CONSTRUCTED
WITHIN EXISTING STREAM



CULVERT CONSTRUCTED
OUTSIDE EXISTING STREAM

NOTES:

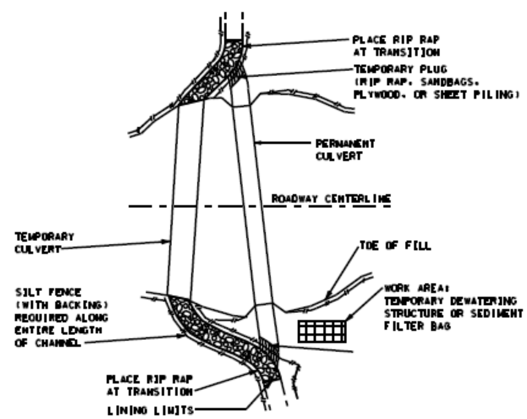
1. TEMPORARY DIVERSION CHANNELS MAY BE USED TO DIVERT NORMAL STREAM PATH FLOW FROM AN ERODIBLE AREA UNTIL SUCH AREAS CAN BE STABILIZED.
2. TYPE III FILTER FABRIC OR PRE-FAB DITCH LINER MAY BE USED FOR CHANNEL LINING.
3. RIP-RAP WITH FILTER FABRIC MAY BE USED FOR CHANNEL FLOW VELOCITIES OF 3.0 FPS TO 9.0 FPS. THE RIP-RAP SHALL BE SIZED 300 LB
4. LOCATIONS OR TYPES OF TEMPORARY DIVERSION WILL NOT BE SHOWN ON THE PLANS
5. DIVERSION CHANNEL SHALL BE STABILIZED AND INSPECTED BY THE ENGINEER BEFORE FLOW IS DIVERTED.
6. DURING CONSTRUCTION OF DIVERSION CHANNEL, DAMAGE TO THE EXISTING STREAM, CANOPY REMOVAL, AND DEPTH OF THE CHANNEL CONSTRUCTION SHALL BE MINIMIZED.
7. CONSTRUCTION OF THE CHANNEL RELOCATIONS AND CULVERTS SHALL PROCEED AS FOLLOWS:
   - 7.1. CONSTRUCT A MEANDERING TEMPORARY CHANNEL CHANGE ADJACENT TO THE PROPOSED CULVERT TO DIVERT WATER TEMPORARILY DURING THE CULVERT CONSTRUCTION. TEMPORARY EROSION CONTROL MEASURES SHALL BE INSTALLED IN ACCORDANCE WITH THE STANDARD SPECIFICATIONS.
   - 7.2. RELOCATE CHANNEL AND CONSTRUCT CULVERT SIMULTANEOUSLY.
   - 7.3. SOD AND/OR RIP-RAP RECONSTRUCTED BANKS AT TRANSITIONS. THE UPPER CHANNEL PLUG IS TO REMAIN IN PLACE UNTIL SUBNOTE (7.1) THROUGH (7.4) UNDER THIS HEADING ARE COMPLETED TO INSURE THAT ALL CONSTRUCTION IS IN THE DRY.
   - 7.4. IF AN EARTH PLUG IS NECESSARY AT THE DOWNSTREAM END OF THE CHANNEL IT SHOULD BE REMOVED FIRST, THEN REMOVE THE UPPER PLUG TO RELEASE WATER INTO THE RECONSTRUCTED CHANNEL.
   - 7.5 PLUGS SHOULD REMAIN IN PLACE UNTIL PERMANENT STABILIZATION OF THE NEW WATER COURSE IS COMPLETED. REMOVAL OF PLUGS SHOULD ONLY BE PERFORMED FOLLOWING ACCEPTANCE OF ALL STABILIZATION WORK BY THE ENGINEER.
8. THE DETAILS PROVIDED DEPICT TYPICAL TEMPORARY DIVERSION CHANNELS.
9. THE CONTRACTOR MAY PROPOSE THE USE OF OTHER DIVERSION OPTIONS SUCH AS PIPING, PUMPING OR STAGED CONSTRUCTION.
10. THE EFFECTIVE AREA OF FLOW IN THE TEMPORARY CHANNEL OR CULVERT SHALL BE AT LEAST ONE-HALF THAT OF THE EXISTING STRUCTURE.



RIPRAP CHECKS SHALL BE PLACED AT A MAXIMUM SPACING OF 25' ALONG THE SIDES AND BOTTOM OF THE CHANNEL IN ORDER TO PROPERLY SECURE THE FABRIC. RIPRAP SHOULD BE PLACED AT LEAST 2 FEET WIDE AND 1 FOOT HIGH.

SECTION A-A

TEMPORARY DIVERSION CHANNEL
WITH GEOTEXTILE FABRIC



TEMPORARY CULVERT
USED DURING CONSTRUCTION

MISSISSIPPI DEPARTMENT OF TRANSPORTATION
TEMPORARY STREAM DIVERSION

WORKING NUMBER
ECD-17
SHEET NUMBER

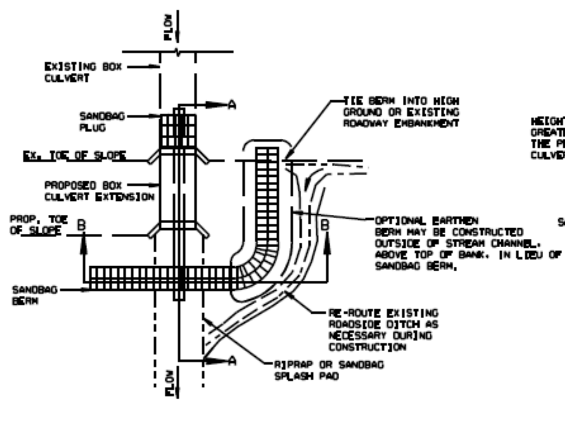
FILENAME: EROSION CONTROL\ECD-17.DGN
DESIGN TEAM ____ CHECKED ____ DATE ____

STATE	PROJECT NO.
MISS.	

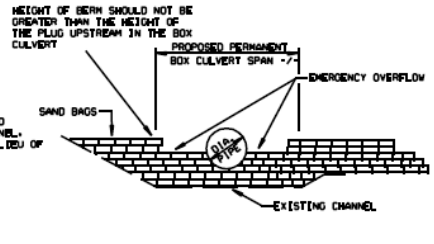
DIAMETER OF PIPE (IN.)	STEEL THICKNESS (IN.)				
	0.064	0.079	0.109	0.138	0.168
	2" X 1/2" CORRUGATION				
24	13	15	20		
36	12	15	20	25	
48	11	14	19	25	30
60		14	19	24	29
72			18	24	29
	5" X 1" OR 3" X 1" CORRUGATION				
36	9	11			
48	9	11	15		
60	8	10	14	18	
72	8	10	14	18	22

MAXIMUM SPAN FOR PIPE SUPPORTS, FEET

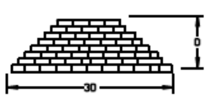
FOR PIPE SIZES NOT SHOWN REFER TO NEXT LARGER SIZE



PLAN VIEW

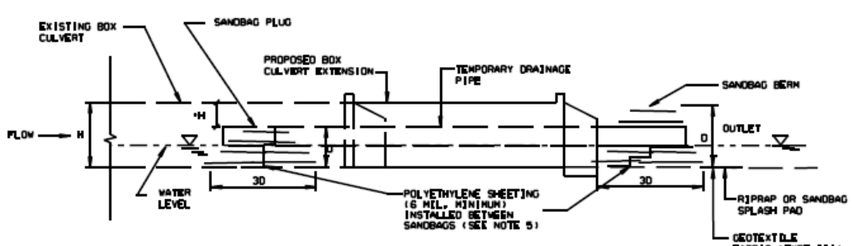


SECTION B-B



SAND BAG PLUG & BERM CROSS SECTION

(SEE NOTE 4)



SECTION A-A

GENERAL NOTES

1 SUSPENDED PIPE DIVERSIONS MAY BE USED TO ALLOW BOX CULVERT EXTENSIONS TO BE CONSTRUCTED, WHILE SEPARATED FROM FLOWING WATER, THUS REDUCING SEDIMENTATION. OPTIONAL FLEXIBLE PIPE DIVERSION MAY BE UTILIZED ON STREAMS WITH INTERMITTENT FLOW WHERE THE DURATION OF CONSTRUCTION IS EXPECTED TO BE BRIEF.

2 EXCAVATION SLOPES FOR BOX CULVERT EXTENSIONS SHALL BE PROTECTED WITH TYPE III FILTER FABRIC PRIOR TO CONSTRUCTION OF THE BOX.

3 SUSPENDED PIPE DIVERSIONS MAY BE USED WHERE ADVERSE IMPACTS WILL NOT BE CAUSED BY WATER PONDED UPSTREAM OF THE PIPE.

4 THE SANDBAG PLUG AT THE UPSTREAM END OF THE SUSPENDED PIPE DIVERSION SHOULD BE CONSTRUCTED TO A HEIGHT EQUAL TO THREE QUARTERS OF THE RISE OF THE BOX CULVERT.

5 POLYETHYLENE SHEETING (6 MIL. MINIMUM) SHALL BE PLACED INSIDE THE SANDBAG PLUG IN THE BOX CULVERT AND IN THE SAND BAG BERM WITHIN THE CHANNEL IN ORDER TO PROVIDE THE BEST POSSIBLE SEAL. SANDBAGS ON THE DOWNSTREAM SIDE OF THE SHEETING SHOULD BE PLACED FIRST, AND THEN SHEETING PLACED ON THESE BAGS.AS MUCH AS POSSIBLE, THE SHEETING SHOULD BE FITTED AROUND THE PIPE. THE REMAINING SANDBAGS WOULD THEN BE PLACED ON THE SHEETING. WHERE MULTIPLE SHEETS ARE USED, THEY SHOULD OVERLAP A MINIMUM OF 18 INCHES.

6 THE PROPOSED CULVERT CONSTRUCTION SHALL BE SEALED FROM THE EXISTING STREAM BY MEANS OF A SANDBAG BERM WHICH SHOULD BE AT THE SAME HEIGHT AS THE PLUG INSIDE THE BOX CULVERT. THIS BERM SHALL BE TIED INTO EITHER HIGH GROUND ADJACENT TO THE CHANNEL OR THE EXISTING ROADWAY EMBANKMENT. IT SHALL BE PROVIDED WITH A SPILLWAY EQUAL IN WIDTH TO THE BOX CULVERT AND AT A HEIGHT LOWER THAN THE REST OF THE BERM.

7 THE TEMPORARY DRAINAGE PIPE SHALL BE SUPPORTED AT ALL JOINTS AND AT INTERVALS NOT TO EXCEED MAXIMUM VALUES SPECIFIED IN THE TABLE "MINIMUM SPAN FOR SUPPORTS." SUPPORTS MAY CONSIST OF SANDBAGS, CONCRETE BLOCKS, WOODEN FRAMES, OR ANY OTHER MATERIAL SUFFICIENT TO SUPPORT THE WEIGHT OF THE PIPE WHEN IT IS FLOWING FULL. SUPPORTS AT JOINTS SHALL BE A MINIMUM OF 18 INCHES IN LENGTH, ALONG THE TEMPORARY DRAINAGE PIPE AND CENTERED ON THE JOINT. SUPPORTS SHOULD "CRADLE" THE TEMPORARY DRAINAGE PIPE TO ENSURE THAT IT WILL NOT ROLL DURING CONSTRUCTION OF THE BOX CULVERT.

8 ALL PIPE JOINTS SHALL BE PROPERLY BANDED OR OTHERWISE PROVIDED WITH A REASONABLE SEAL AGAINST LEAKAGE.

9 THE OPTIONAL FLEXIBLE PIPE DIVERSION USING PUMPS MAY BE USED AS AN ALTERNATE FOR SUSPENDED PIPE DIVERSIONS (UPSTREAM AND DOWNSTREAM).

10 CONSTRUCTION SHALL PROCEED AS FOLLOWS:
10A. INSTALL TEMPORARY DRAINAGE PIPE ON ITS SUPPORTS INSIDE THE CULVERT TO BE EXTENDED.
10B. CONSTRUCT THE SANDBAG PLUG AT THE UPSTREAM END OF THE SUSPENDED PIPE DIVERSION.
10C. CONSTRUCT THE SANDBAG BERM AT THE DOWNSTREAM END OF THE SUSPENDED PIPE DIVERSION.
10D. ONCE THE BOX CULVERT EXTENSION HAS BEEN COMPLETED, REMOVE THE DOWNSTREAM SANDBAG STRUCTURE. EXCEPT FOR THOSE BAGS NEEDED TO SUPPORT THE END OF THE PIPE. THE UPSTREAM SANDBAG STRUCTURE SHOULD THEN BE REMOVED GRADUALLY, IN ORDER TO ALLOW THE UPSTREAM WATER LEVEL TO DRAW DOWN AT A SAFE RATE.
10E. REMOVE THE TEMPORARY DRAINAGE PIPE, SUPPORTS AND ANY REMAINING SANDBAGS.

11 TEMPORARY DRAINAGE PIPE, SANDBAG PLUGS, BERMS, AND SUPPORTS SHALL BE INSPECTED WEEKLY OR AFTER EVERY RAIN EVENT. ANY NEEDED REPAIRS SHALL BE DONE IMMEDIATELY. ANY DEBRIS WHICH HAS ACCUMULATED AT THE INLET OF THE SUSPENDED PIPE DIVERSION SHALL BE IMMEDIATELY REMOVED.

12 RIP RAP MAY BE SUBSTITUTED FOR SAND BAGS

BY | REVISION | DATE

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

TEMPORARY STREAM DIVERSION (BOX EXTENSIONS)

WORKING NUMBER ECD-18

SHEET NUMBER

FILENAME: EROSION CONTROL\ECD-18.DGN

DESIGN TEAM CHECKED DATE

Streambank Protection (SP)

Practice Description

Streambank protection is the stabilization of the side slopes of a stream. Streambank protection can be vegetative, structural, or a combined method (bioengineering) in which live plant materials are incorporated into a structure. Vegetative protection is the least costly and the most compatible with natural stream characteristics. Additional protection is required when hydrologic conditions have been greatly altered and stream velocities are excessively high. Streambank protection is often necessary where failure mechanisms cause erosion. According to Fischenich and Allen (2000), banks fail and erode because they exist in a dynamic environment that is constantly subjected to various forces. River banks fail in one of four ways: 1) hydraulic forces remove erodible bed or bank material; 2) geotechnical instabilities result in bank failures; 3) mechanical actions cause a reduction in the strength of the bank; or 4) a combination of the above factors causes failure. These modes of failure have distinct characteristics. An investigation must be conducted to determine the specific mode of failure because this is indicative of the problem. These modes of failure are further discussed in Fischenich and Allen (2000). Streambank protection is often necessary in areas where development has occurred in the upstream watershed and full channel flow occurs several times a year.

Planning Considerations

Since there are several different methods of streambank protection, the first step in the design process is a determination of the type protection to be used at the site. Items to consider include:

- Overall condition of the stream within and adjacent to the reach to be stabilized.
- Current and future watershed conditions.

- Amount of discharge at the site.
- Flow velocity at the site.
- Sediment load in the stream.
- Channel slope.
- Controls for bottom scour.
- Soil conditions.
- Present and anticipated channel roughness.
- Compatibility of selected protection with other improvements at the site.
- Changes in channel alignment.
- Fish and wildlife habitat.

Due to the varied nature of these considerations, an interdisciplinary team consisting of engineers, soil bioengineers, hydrologists, and fishery biologists should prepare the design of streambank protection for each unique channel reach. If instability is occurring over a significant length of stream, the team should consider performing a geomorphic analysis of the stream. All local, state, and federal laws, especially laws relating to Clean Water Act Section 404 permits, should be followed during the design and construction process.

Design Criteria and Construction

Velocities

As a general rule, use vegetation alone with velocities up to 6 ft/sec if the stream bottom is stable. Use structural (to include soil bioengineered) protection for velocities greater than 6 ft/sec. The design velocity should be the velocity associated with the peak discharge of the design storm for the channel. Any protection method should take into consideration a variety of site conditions, to include an analysis of failure mechanisms, and should be designed and/or reviewed by the aforementioned interdisciplinary team.

Channel Bottom

The channel bottom must be stabilized before installing bank protection. Grade control in the channel bottom may be needed to prevent downcutting (see *Channel Stabilization Practice*).

Permits

All local, state, and federal laws should be complied with during the design and construction of bank protection. If fill is to be placed in wetlands or streams, the U.S. Army Corps of Engineers should be contacted regarding a 404 permit for the work.

Aquatic Zone

This area includes the stream bed and is normally submerged at all times. No planting is required in this zone.

Wetland Plants/Shrub Zone

This zone is on the bank slopes above mean water level and is normally dry except during floods. Plants with high root densities, high root shear and tensile strength, and an ability to transpire water at high rates are recommended for this zone. Willows, silver maples, and poplars are examples of species to use here.

Normally, grasses are not used in this area, but they can be if velocities are low and the grass will not be submerged frequently or for long periods of time. Wetland plants such as various sedges, rushes, and bulrushes can be utilized just below the shrub zone and are often used in bioengineering techniques.

Tree Zone

This area is at the top of the streambank. Plants in this area usually provide shade for the stream and riparian habitat for wildlife. Upland but flood-tolerant species should be planted in this location.

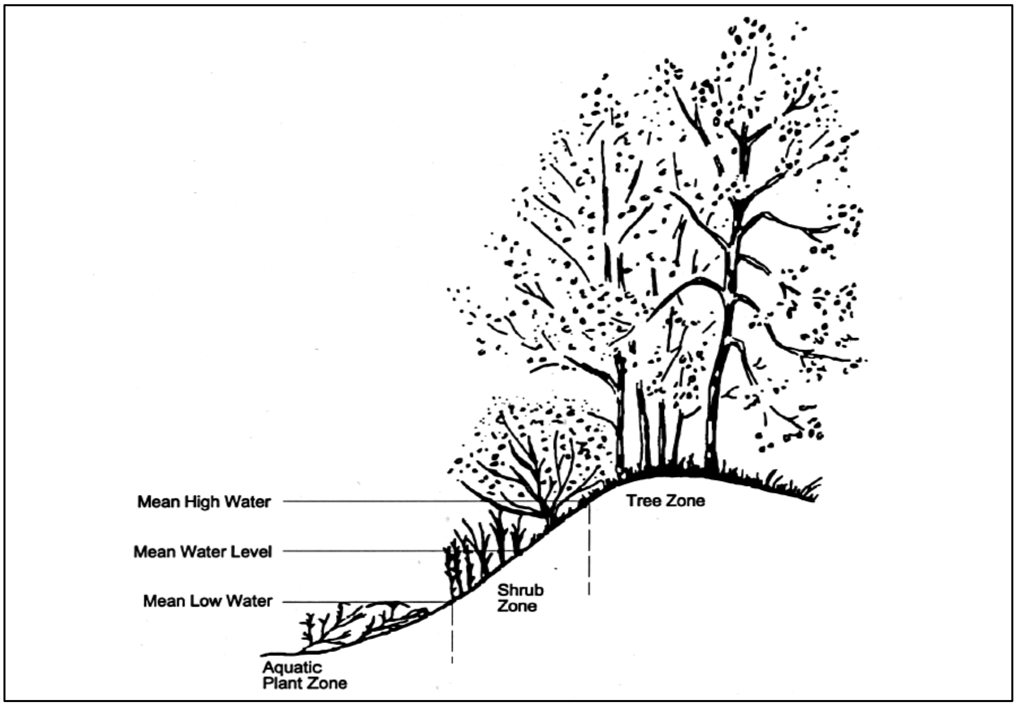


Figure SP-1 Vegetative Zones for Streambank Protection

Vegetative Measures

When vegetation is used alone, without toe protection, this practice can be used when velocities are less than 6 ft/sec. Greater velocities can be tolerated given adequate toe and flank protection at the upper and lower ends of the practice, but each stream reach addressed should be analyzed and designed by the interdisciplinary team. The design team should consider the natural zones of a streambank community when selecting vegetation for use in the protection design. Native plant materials should be used for establishment and long-term success. No exotic or invasive species should be used.

Prior to start of construction, streambank protection, for each unique channel reach, should be designed by a qualified design professional and/or an interdisciplinary team. Plans and specifications should be referred to by field personnel throughout the construction process.

Scheduling

Installation scheduling should be phased according to the following considerations. Hard structures such as rock and other inert materials could be installed during a period not suitable for vegetative establishment, whereas vegetation could be planted during the appropriate time for more assurance of its survival. For instance, vegetation would be better established in the late winter/early spring after hard structures have been installed or concurrent with hard-structure installation, depending on the design plan. Hard structures could be installed during a construction season prior to vegetative establishment, with the vegetation being installed the following spring. For vegetation on high banks, schedule that installation during a planting period tailored for optimum survival of the plant species used. In addition, use local weather forecasts to avoid installation activities during rain events that can potentially create abnormal flows and flooding.

Site Preparation

Follow all local, state, and federal government regulations on stream modifications.

Determine exact location of all underground activities.

Stabilize the channel bottom as specified in the design plan before streambank protection measures are installed.

Installation

Plant live plant materials, cuttings, or other forms of plant materials according to the planting plan. Options for protective vegetation measures are described in detail in the upcoming soil bioengineering section.

Safety

The following precautions should be taken:

Exercise caution on steep slopes.

Fence the area and post warning signs if trespassing is likely.

Store equipment, tools, and materials well away from the stream during non-work periods. Consider weather forecasts when determining risks of damage to equipment, tools, and materials by flooding.

All equipment used for practice installation should be free of leaks of gas, oil, and hydraulic fluid. Measures should be in place to prevent accidental spills from entering the stream.

Equipment should not be operated within flowing water in the stream.

Construction Verification

Check to see that planting and seeding was done in compliance with the design specifications.

Structural Measures

Structural Protection

Structural protection is used in areas where velocities exceed 6 feet per second, along channel bends, in areas with highly erodible soils, and in areas of steep channel slopes. Common measures are riprap, gabions, fabric-formed revetments, and reinforced concrete.

Prior to start of construction, streambank protection, for each unique channel reach, should be designed by a qualified design professional and/or an interdisciplinary team. Plans and specifications should be referred to by field personnel throughout the construction process.

Scheduling

Schedule installation during a period that is least likely to have flooding and that includes the planting season for the species that are to be established in association with the structural measures.

Site Preparation

Follow all local, state, and federal government regulations on stream modifications.

Determine exact location of all underground activities.

Stabilize the channel bottom as specified in the design plan before streambank protection measures are installed.

Remove brush and trees only if absolutely necessary to make the site suitable to install the planned measures.

Grade or excavate the areas specified in the design plan, but limit earthmoving to that absolutely necessary to make the site suitable to install the planned measures

Riprap

This is the most commonly used material for streambank protection. The following criteria should be used when designing riprap bank protection.

Riprap should be designed to be stable under the design flow conditions using the following procedure:

Determine the design velocity.

1) Use velocity and Figure SP-2 to determine d_{100} rock size.
2) Use d_{100} from Figure SP-2 as d_{90} to select rock gradation from Table SP-1.

Streambanks should be sloped at 2:1 or flatter.

Where needed to prevent movement of soil from the channel bank into the riprap, place a filter fabric between the soil and riprap. Filter fabric should meet the requirements for Class I geotextile as shown in Table SP-3.

The toe of the riprap should extend a minimum of 1 foot below the stream channel bottom or anticipated scour depth to prevent failure of the riprap protection.

The top of the riprap should extend up to the 2-year water surface elevation as a minimum, unless it is determined that a lesser height in combination with vegetative measures will provide the needed protection. The remainder of the bank above the riprap can be vegetated.

Install riprap of the specified gradation to the lines and grades shown in the design plan. Installation usually includes some bank shaping.

Place geotextile fabric or a granular filter between the riprap and the natural soil and placement of the rock.

Ensure that the subgrade for the filter and riprap follows the required lines and grades shown in the plan. Low areas in the subgrade on undisturbed soil may also be filled by increasing the riprap thickness.

Riprap may be placed by equipment. Care should be taken to avoid punching or tearing of the geotextile fabric cloth during placement of rock. Avoid dropping rock onto the fabric more than 1/2-1 foot from the equipment delivering the rock. This will more amply prevent punching or tearing the fabric. Repair any damage by removing the riprap and placing another piece of filter cloth over the damaged area. All connecting joints should overlap a minimum of 1.5 feet with the upstream edge over the downstream edge. If the damage is extensive, replace the entire geotextile fabric.

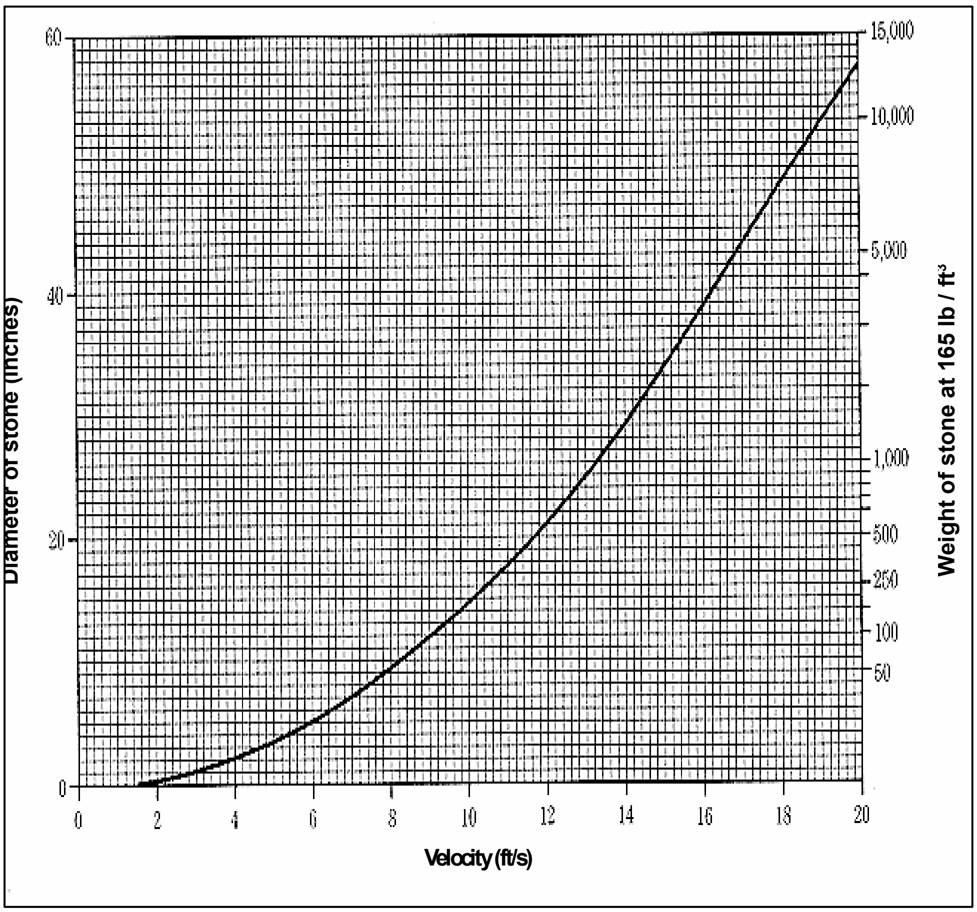


Figure SP-2 Isbash Curve

Table SP-1 Graded Riprap

Class	Weight (lbs.)					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

Table SP-2 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [3]
Tensile strength (lb) [1]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%) [1]	ASTM D 4632	≥ 50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. #40 [2]	As specified max. #40 [2]	As specified max. #40 [2]	As specified max. #40 [2]
Permittivity sec^{-1}	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

1 Minimum average roll value (weakest principal direction).
2 U.S. standard sieve size.
3 Heat-bonded or resin-bonded geotextile may be used for Classes III and IV. They are particularly well suited to Class IV. Needle-punched geotextile is required for all other classes.

Gabions

These rock-filled wire baskets are very labor intensive to construct, but they are semi-flexible and permeable. Gabions should be designed and constructed according to manufacturer's guidelines and recommendations. They should be filled with durable rock. Use only durable crushed limestone, dolomite, or granite rock. Shale, siltstone, and weathered limestone should not be used. If needed, a filter fabric can be used between the gabions and the soil subgrade. Fabric will be selected from the table for geotextiles shown above.

Fabric-Formed Revetments

These are manufactured, large, quilted envelopes that can be sewn or zipped together at the site to form continuous coverage of the area to be protected. Once the fabric is in place, it is pumped full of grout to form a solid, hard and semi-impervious cover. Revetments should be designed and installed according to manufacturer's recommendations.

Reinforced Concrete

A qualified design professional using sound and accepted engineering procedures should design this protection method. Installation usually includes some bank shaping, placing a filter fabric or a granular filter between the streambank material and the retaining wall or bulkhead, and anchoring. The design should include a solid foundation for the retaining wall and a method of draining excess water from behind the wall.

Anchor the foundation for these structures to a stable, nonerodible base material such as bedrock. Also, water stops should be installed at all joints in concrete retaining walls.

All structural protection methods should begin and end along stable reaches of the stream.

Combined Methods of Protection

Combinations of vegetative and structural protection can be used in any area where a structural measure would be used. An example of exceptions would in the vicinity of highway bridges and culverts where heavy armorment with rocks, concrete, etc., is required to prevent erosion of the highway. Common measures include cellular matrix confinement systems, grid pavers, and bioengineering techniques. As with structural measures, all combined methods should begin and end along stable reaches of the stream. See Figures SP-3 and SP-4 for examples of combined methods of protection.

Figure SP-3 Retrofitted urban stream using a bioengineered approach. Note hard, encapsulated-rock toe in lower zone and then coir geotextile rolls to be planted with wetland plants in upper-bank zones.

Figure SP-4 Same stream, after bioengineered restoration. This type of bioengineered stream improves habitat, water quality, and numerous other functions that cannot be achieved with hardened stream channels.

Cellular Confinement Matrices

These are commercially available products made of heavy-duty polyethylene formed into a honeycomb type matrix. The product is flexible to conform to surface irregularities. The combs may be filled with soil, sand, gravel, or cement. Where soil is used to fill the combs, vegetation may also be established. These systems should be designed and installed according to manufacturer's recommendations.

Grid Pavers

These are modular concrete units with interspaced voids. They are used to armor the bank and provide an area for vegetation as well. Pavers come in a variety of shapes and sizes with various anchoring methods. They should be designed and installed according to manufacturer's recommendations.

Soil Bioengineering

Soil bioengineering is the combination of biological, mechanical, and ecological techniques to control erosion and stabilize soil through the use of vegetation alone or in combination with engineered structures and materials. This may include the use of both woody and herbaceous vegetation. An interdisciplinary team of engineers, soil bioengineers, hydrologists, and fishery biologists should be consulted for the planning and design required for soil bioengineering projects. This method of stream protection is more complex than the scope of this manual permits; however, additional resources are listed at the end of this section and in **Appendix I**. Examples of the more commonly used techniques are listed below.

Woody Vegetation

Plant Species

Use native, locally harvested species that root easily and are suitable for the intended use and adapted to site conditions, such as willow. Plants are usually harvested from a nearby local area.

Woody Vegetation Cutting Size

Normally ⅜″ to 2″ in diameter and from 2 to 6 feet long (length will depend on project requirements). Three types of cuttings are common:

- Pole cuttings, generally from shrubs and trees ½ to 3 inches in diameter;
- Post cuttings, trees larger than 3 inches in diameter but smaller than 6 inches; and
- Bundled cuttings that contain shrub and tree cuttings smaller than ½ inch but no smaller than ⅜″

Harvesting

Cut plant materials at a blunt angle, 8″ to 10″ from the ground, leaving enough trunk so that cut plants will regrow.

Transportation and Handling

Bundle cuttings together on harvest site, removing side branches. Keep material moist. Handle carefully during loading and unloading to prevent damage. Cover to protect cuttings from drying out.

Installation Timing

Deliver to construction site within 8 hours of harvest and install immediately, especially when temperatures are above 50º F. Store up to 2 days if cuttings are submerged, "heeled in" moist soil, shaded, and protected from wind.

Season

Install during plants' dormant season, generally late October to March.

Soil

Must be able to support plant growth. Compact backfill to eliminate voids, and maintain good branch cutting-to-soil contact.

Herbaceous Vegetation

Plant Species

Use native, locally harvested species that root easily and are suitable for the intended use and adapted to site conditions. Plants are usually harvested from a nearby local area. Herbaceous plants such as sedges and bulrushes can be planted as seeds, clumps, or rhizomes depending on the species.

Planting Methods

Herbaceous plantings can be established through a variety of techniques: container stock, bare root plants, transplant plugs, rhizomes, clumps, and seeds. Methods of planting will be dependent on the plant species as well as the habitat specifics. The *Surface Stabilization Practices* in this volume discuss vegetation suitable for Mississippi in greater detail and should be referenced before any planting project.

Harvesting

Plant materials for herbaceous plantings have the following harvesting recommendations:

- Transport plugs: Plugs are often used for wetland plants and therefore should remain moist. Plugs should be 3-12 inches in diameter, excavated 5-6 inches deep. Extraction rate should not exceed 1 square foot in a 10-foot area. Plugs should be kept moist at all times.
- Rhizomes: These are the underground horizontal stems and can be collected in the early spring or at the end of the growing season. Rhizomes can be dug up and divided into sections. Rhizomes should be kept cool.
- Clumps: Clumps of herbaceous vegetation are generally harvested using a backhoe. Digging in 12-15 inches deep is sufficient for most plants collected with this method. Clump plantings should be kept moist.

Transportation and Handling

Transportation and handling of herbaceous plants depends somewhat on the planting method chosen. For container stock plants, refer to the provider or plant nursery's suggestions on acclimating and moisture needs. For harvested plants, see the notes listed in the Harvesting section above.

Season

Install during plants' dormant season, generally late October to March.

Soil

Must be able to support plant growth. Compact backfill to eliminate voids and maintain good branch cutting-to-soil contact.

Protective Vegetation

Live staking, live fascines, brush layers, and branchpacking are soil bioengineering practices that use the stems or branches of living plants as a soil reinforcing and stabilizing material. Eventually the vegetation becomes a major structural component of the bioengineered system.

Live Staking

Live staking is the use of live, rootable vegetative cuttings, inserted and tamped into the ground. As the stakes grow, they create a living root mat that stabilizes the soil. Use live stakes to peg down surface erosion-control materials. Most native willow species root rapidly and can be used to repair small earth slips and slumps in wet areas.

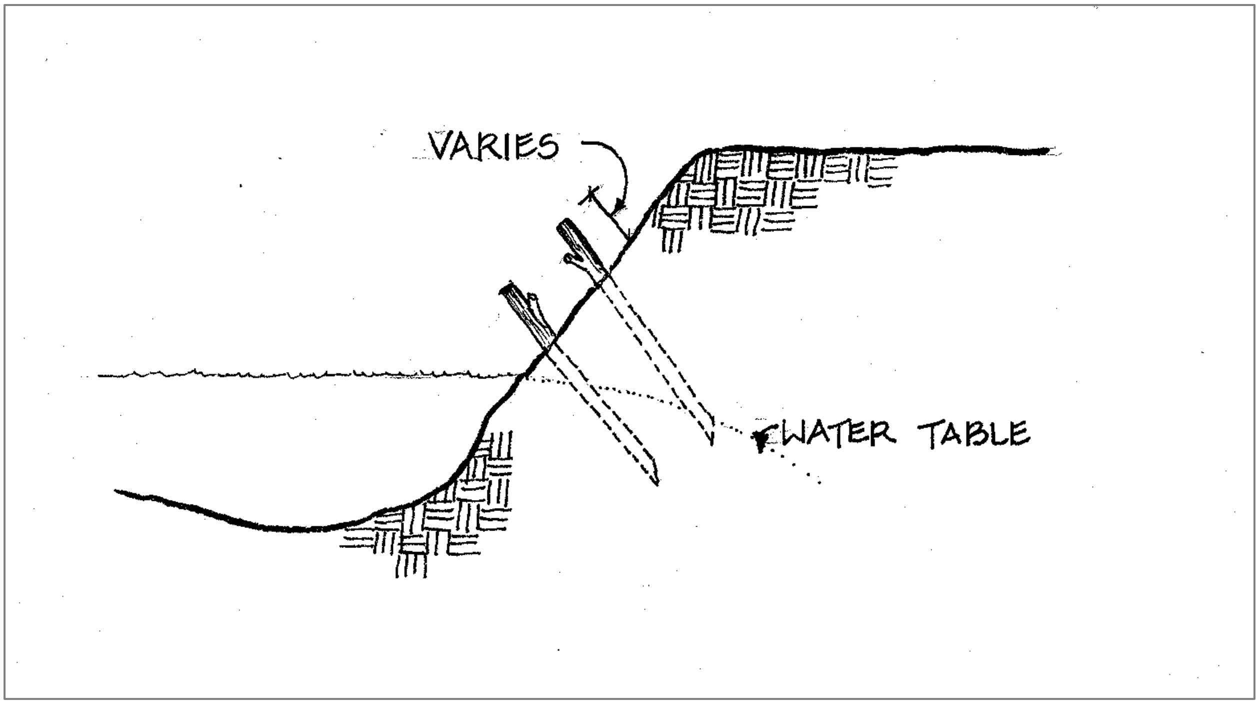


Figure SP-5 Pole Plantings – End of stake should reach water table, while the height above the ground will vary (Bentrup, 1998)

To prepare live material, cleanly remove side branches, leaving the bark intact. Use cuttings ½″ to 1½″ in diameter and 2 to 3 feet long. Cut bottom ends at an angle to insert into soil. Cut top square. Tamp the live stake into the ground at right angles to the slope, starting at any point on the slope face. Buds should point up. Install stakes 2 to 3 feet apart using triangular spacing with from 2 to 4 stakes per square yard. An iron bar can be used to make a pilot hole in firm soil. Drive the stake into the ground with a dead blow hammer (hammerhead filled with shot or sand). Four-fifths of the live stake should be underground with soil packed firmly around it after installation. Replace stakes that split during installation.

Live Fascines

Live fascines are long bundles of branch cuttings bound together into sausage-like structures. They should be placed in shallow contour trenches and at an angle on wet slopes to reduce erosion and shallow face sliding. This practice is suited to steep, rocky slopes, where digging is difficult.

To prepare live materials, make cuttings from species such as young willows or shrub dogwoods that root easily and have long, straight branches. Make stakes 2½ feet long for cut slopes and 3 feet long for fill slopes. Make bundles of varying lengths from 5 to

30 feet or longer, depending on site conditions and limitations in handling. Use untreated twine for bundling. Completed bundles should be 6″ to 8″ in diameter. Orient growing tips in the same direction. Stagger cuttings so that root ends are evenly distributed throughout the length of the bundle. Install live fascine bundles the same day they are prepared. Prepare dead stakes 2½ feet long, untreated 2″ by 4″ lumber, cut diagonally lengthwise to make two stakes. Live stakes will also work. Beginning at the base of the slope, dig a trench on the contour large enough to contain the live fascine. Vary width of trench from 12″ to 18″, depending on angle of the slope. Trench depth will be 6″ to 8″, depending on size of the bundle. Place the live fascine into the trench. Drive the dead stakes directly through the bundle every 2 to 3 feet. Use extra stakes at connections or bundle overlap. Leave the top of the stakes flush with the bundle. Install live stakes on the downslope side of the bundle between the dead stakes.

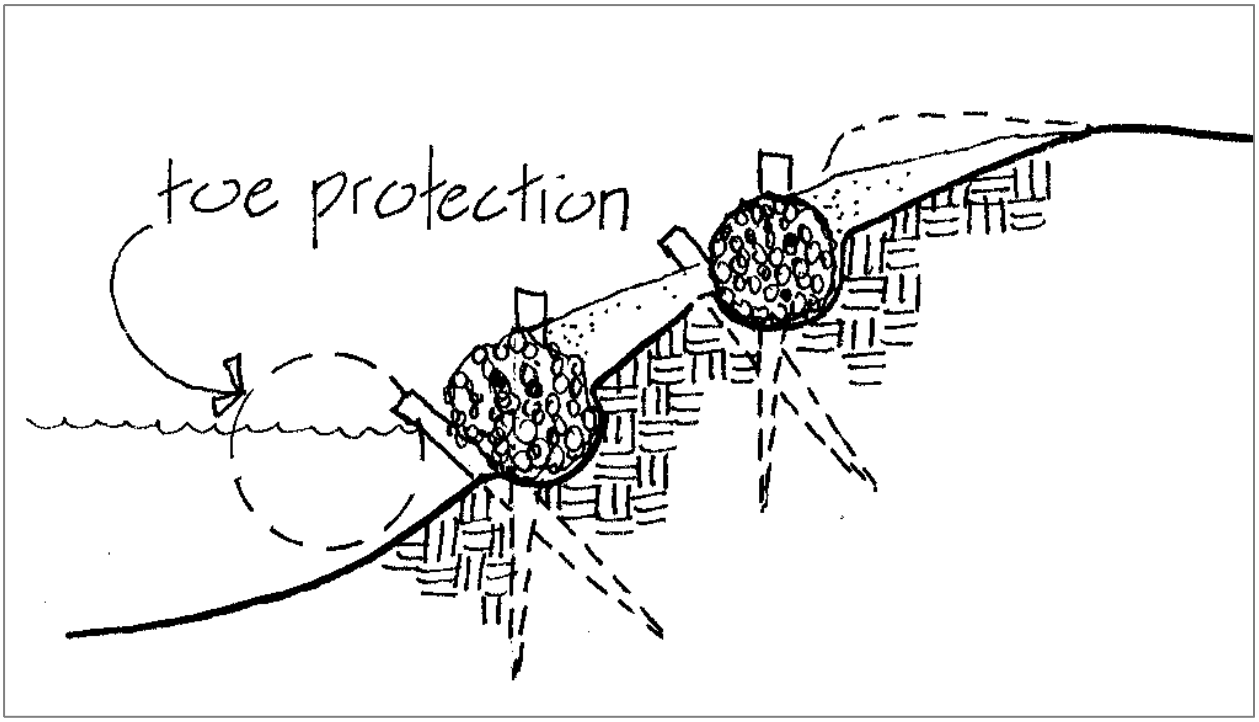


Figure SP- 6 Fascine placement (Bentrup, 1998)

Brush Layering

Brush layering is similar to live fascine systems. Both involve placing live branch cuttings on slopes. However, in brush layering, the cuttings are oriented at right angles to the slope contour. Also, the cuttings used in brush layering are not bound in bundles like fascines. Brush layering can be used on slopes up to 2:1 (horizontal: vertical) in steepness.

Install toe protection if needed to prevent undercutting. Then, starting at the toe of the slope, excavate benches horizontally, on the contour, or angled slightly down the slope to aid drainage. Construct benches 2 to 3 feet wide. Slope each bench so that the outside edge is higher than the inside.

Crisscross or overlap live branch cuttings on each bench. Place growing tips toward the outside of the bench. The branches should not extend more than 18″ from the bank to prevent damage during high flows. Place backfill on top of the root ends and compact to eliminate air spaces. Growing tips should extend slightly beyond the fill to filter sediment. Soil for backfill can be obtained from excavating the bench above. Space brush layer rows 3 to 5 feet apart, depending upon the slope angle and stability.

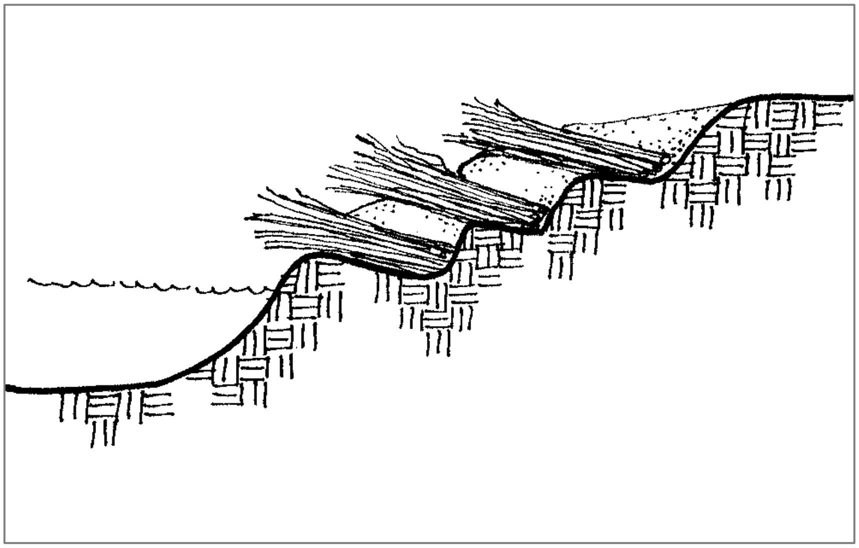


Figure SP-7 Brush Layering (Source: Bentrup, 1998)

Brush layering can be used between encapsulated soil lifts; lifts are encapsulated in erosion-control fabric (or similar material such as burlap). This setup can be used where space is limited and a more vertical structure is required.

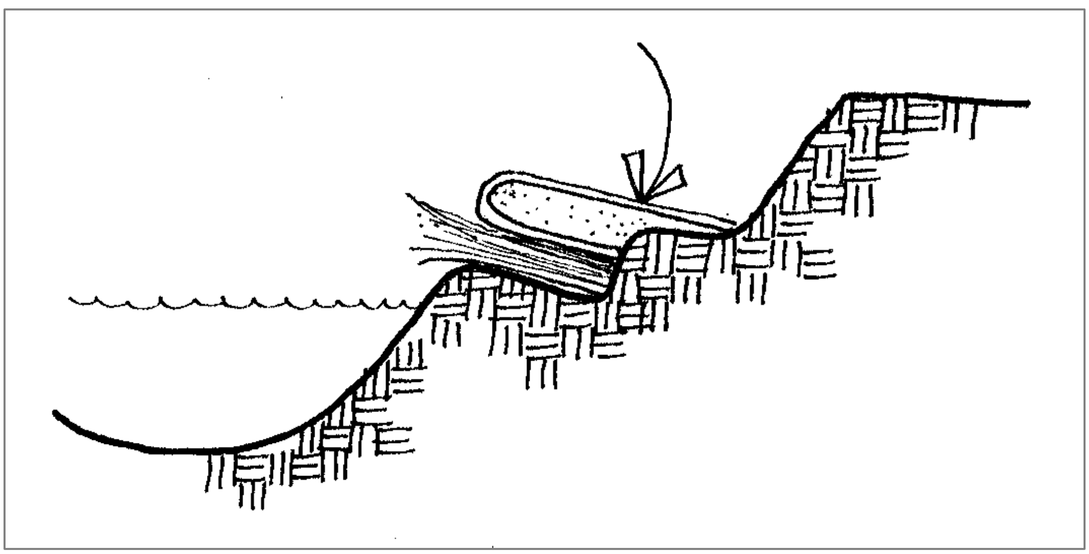


Figure SP-8 Brush Layering with Erosion Control Fabric (Source: Bentrup, 1998)

Branchpacking

Branchpacking consists of alternating layers of live branch cuttings and compacted backfill to repair small localized slumps and holes in slopes (no greater than 4 feet deep or 5 feet wide). Use for earth reinforcement and mass stability of small earthen fill sites.

Make live branch cuttings from ½″ to 2″ in diameter and long enough to reach from soil at the back of the trench to extend slightly from the front of the rebuilt slope face.

Make wooden stakes 5 to 8 feet long from 2″ by 4″ lumber or 3″ to 4″ diameter poles. Start at the lowest point and drive wooden stakes vertically 3 to 4 feet into the ground. Set them 1 to 1½ feet apart. Place a layer of living branches 4″ to 6″ thick in the bottom of the hole, between the vertical stakes, and at right angles to the slope face. Place live branches in a crisscross arrangement with the growing tips oriented toward the slope face. Some of the root ends of the branches should touch the back of the hole. Follow each layer of branches with a layer of compacted soil to ensure soil contact with the branch cuttings. The final installation should match the existing slope. Branches should protrude only slightly from the rebuilt slope face.

The soil should be moist or moistened to ensure that live branches do not dry out.

Woody Vegetation with Inert Structures

Live cribwalls, vegetated rock gabions, and joint plantings are soil bioengineering practices that combine a porous structure with vegetative cuttings. The structures provide immediate erosion, sliding, and washout protection. As the vegetation becomes established, the structural elements become less important.

Live Cribwall

A live cribwall consists of a hollow, box-like interlocking arrangement of untreated logs or timber. Use at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness or where space is limited and a more vertical structure is required. It should be tilted back if the system is built on a smooth, evenly sloped surface.

Make live branch cuttings ½″ to 2″ in diameter and long enough to reach the back of the wooden crib structure. Build the constructed crib of logs or timbers from 4″ to 6″ in diameter or width. The length will vary with the size of the crib structure. Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability. Place the first course of logs or timbers at the front and back of the excavated foundation, approximately 4 to 5 feet apart and parallel to the slope contour. Place the next set of logs or timbers at right angles to the slope on top of the previous set. Place each set of timbers in the same manner and nail to the preceding set. Place live branch cuttings on each set to the top of the cribwall structure with growing tips oriented toward the slope face. Backfill the cribwall, compact the soil for good root-to-soil contact, then apply seed and mulch.

Vegetated Rock Gabions

Vegetated gabions combine layers of live branches and gabions (rectangular baskets filled with rock). This practice is appropriate at the base of a slope where a low wall is required to stabilize the toe of the slope and reduce its steepness. It is not designed to resist large, lateral earth stresses. Use where space is limited and a more vertical structure is required. Overall height, including the footing, should be less than 5 feet.

Make live branch cuttings from ½″ to 1″ in diameter and long enough to reach beyond the rock basket structure into the backfill. Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability and ensure rooting. Place the wire baskets in the bottom of the excavation and fill with rock. Backfill between and behind the wire baskets. Place live branch cuttings on the wire baskets at right angles to the slope with the growing tips oriented away from the slope and extending slightly beyond the gabions. Root ends must extend beyond the backs of the wire baskets into the fill material. Place soil over the cuttings and compact it. Repeat the construction sequence until the structure reaches the required height.

Joint Planting

Joint planting or vegetated riprap involves tamping or pushing live cuttings into soil between the joints or open spaces in rocks that have previously been placed on a slope. Use where rock riprap is required. Joint planting is used to remove soil moisture, to prevent soil from washing out below the rock, and to increase slope stability over riprap alone.

Make live branch cuttings from ½″ to 1½″ in diameter and long enough to extend into soil below the rock surface. Remove side branches from cuttings leaving the bark intact. Tamp or push live branch cuttings into the openings of the rock during or after construction. Care should be taken to avoid splitting the cutting by tamping. The root ends should extend into the soil behind the riprap. Mechanical probes may be needed to create pilot holes for the live cuttings so that they can be pushed into substrate without stripping their bark or splitting the cutting by tamping. It is critical to ensure the soil is packed around the cutting to prevent air pockets. "Mudding" (filling the hole with water and then adding soil to make a mud slurry) can remove air pockets. Place cuttings at right angles to the slope with growing tips protruding from the finished face of the rock.

Safety

Store all construction materials well away from the stream. Consider weather forecasts when determining risks of damage by flooding.

At the completion of each workday, move all construction equipment out of and away from the stream to prevent damage to equipment by flooding. Consider weather forecasts when determining risks of flooding.

The following precautions should be taken:

Exercise caution on steep slopes.

Fence the area and post warning signs if trespassing is likely.

All equipment used for practice installation should be free of leaks of gas, oil, and hydraulic fluid. Measures should be in place to prevent accidental spills from entering the stream.

Equipment should not be operated within flowing water in the stream.

Construction Verification

Check cross section of the channel, thickness of structural product used, and confirm the presence of filter cloth between the product and the streambank.

Check to see that planting and seeding was done in compliance with the design specifications.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate practice will not function as intended; changes in plan may be needed.

Design specifications for vegetative or structural protection cannot be met; substitution may be required. Unapproved substitutions could result in erosion damage to the streambank.

Maintenance

Check the streambank for rill and gully erosion after every storm event.

Repair eroded areas with appropriate plantings, structural materials, or new plants.

Check the streambank for signs of voids beneath gabions, riprap, and concrete. Deterioration of the filter fabric or granular material should be repaired; make needed repairs with similar material.

Protect new plantings from livestock.

Check the streambank for reduction in stream capacity, caused by overgrowth of vegetation on the streambank. Selectively remove overgrown vegetation at regular intervals to maintain capacity and to maintain desired plant communities.

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BMPs from Volume 1

Chapter 4

MDOT Drawing PD-1

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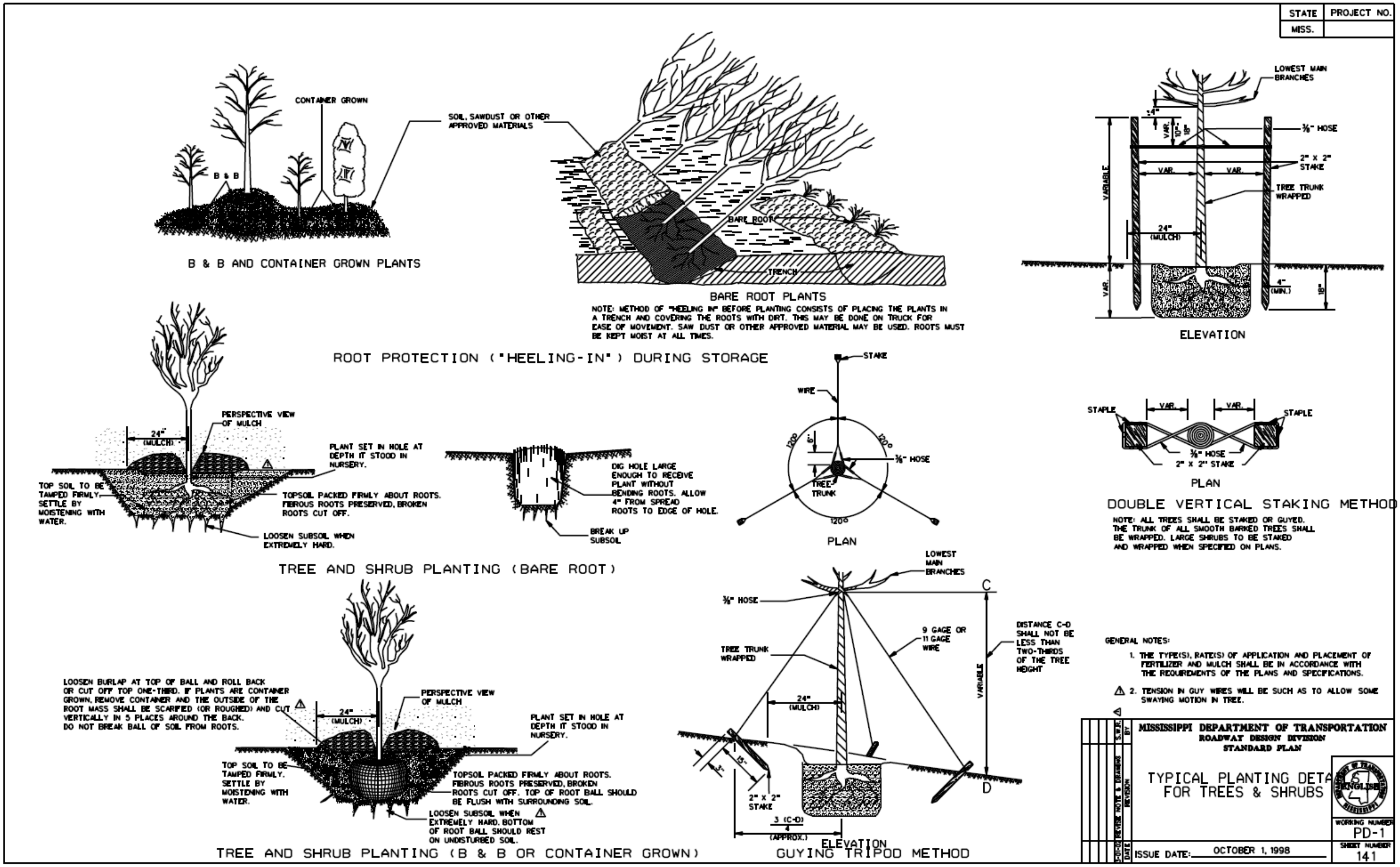

STATE
PROJECT NO.
MISS.
CONTAINER GROWN
B & B
SOIL, SAWDUST OR OTHER APPROVED MATERIALS
B & B AND CONTAINER GROWN PLANTS
BARE ROOT
TRENCH
BARE ROOT PLANTS
NOTE: METHOD OF "HEELING IN" BEFORE PLANTING CONSISTS OF PLACING THE PLANTS IN A TRENCH AND COVERING THE ROOTS WITH DIRT. THIS MAY BE DONE ON TRUCK FOR EASE OF MOVEMENT. SAW DUST OR OTHER APPROVED MATERIAL MAY BE USED. ROOTS MUST BE KEPT MOIST AT ALL TIMES.
ROOT PROTECTION ("HEELING-IN") DURING STORAGE
LOWEST MAIN BRANCHES
⅜" HOSE
2" X 2" STAKE
TREE TRUNK WRAPPED
VARIABLE
VAR.
24" (MULCH)
4" (MIN.)
18"
ELEVATION
PERSPECTIVE VIEW OF MULCH
24" (MULCH)
PLANT SET IN HOLE AT DEPTH IT STOOD IN NURSERY.
TOP SOIL TO BE TAMPED FIRMLY, SETTLE BY MOISTENING WITH WATER.
TOPSOIL PACKED FIRMLY ABOUT ROOTS. FIBROUS ROOTS PRESERVED, BROKEN ROOTS CUT OFF.
LOOSEN SUBSOIL WHEN EXTREMELY HARD.
DIG HOLE LARGE ENOUGH TO RECEIVE PLANT WITHOUT BENDING ROOTS. ALLOW 4" FROM SPREAD ROOTS TO EDGE OF HOLE.
BREAK UP SUBSOIL
TREE AND SHRUB PLANTING (BARE ROOT)
STAKE
WIRE
120°
⅜" HOSE
TREE TRUNK
PLAN
STAPLE
⅜" HOSE
2" X 2" STAKE
PLAN
DOUBLE VERTICAL STAKING METHOD
NOTE: ALL TREES SHALL BE STAKED OR GUYED. THE TRUNK OF ALL SMOOTH BARKED TREES SHALL BE WRAPPED. LARGE SHRUBS TO BE STAKED AND WRAPPED WHEN SPECIFIED ON PLANS.
LOWEST MAIN BRANCHES
⅜" HOSE
C
9 GAGE OR 11 GAGE WIRE
DISTANCE C-D SHALL NOT BE LESS THAN TWO-THIRDS OF THE TREE HEIGHT
TREE TRUNK WRAPPED
VARIABLE
24" (MULCH)
D
2" X 2" STAKE
3 (C-D) / 4 (APPROX.)
ELEVATION
GUYING TRIPOD METHOD
LOOSEN BURLAP AT TOP OF BALL AND ROLL BACK OR CUT OFF TOP ONE-THIRD. IF PLANTS ARE CONTAINER GROWN, REMOVE CONTAINER AND THE OUTSIDE OF THE ROOT MASS SHALL BE SCARFIED (OR ROUGHED) AND CUT VERTICALLY IN 5 PLACES AROUND THE BACK. DO NOT BREAK BALL OF SOIL FROM ROOTS.
PERSPECTIVE VIEW OF MULCH
24" (MULCH)
PLANT SET IN HOLE AT DEPTH IT STOOD IN NURSERY.
TOP SOIL TO BE TAMPED FIRMLY. SETTLE BY MOISTENING WITH WATER.
TOPSOIL PACKED FIRMLY ABOUT ROOTS. FIBROUS ROOTS PRESERVED, BROKEN ROOTS CUT OFF. TOP OF ROOT BALL SHOULD BE FLUSH WITH SURROUNDING SOIL.
LOOSEN SUBSOIL WHEN EXTREMELY HARD. BOTTOM OF ROOT BALL SHOULD REST ON UNDISTURBED SOIL.
TREE AND SHRUB PLANTING (B & B OR CONTAINER GROWN)
GENERAL NOTES:
1. THE TYPE(S), RATE(S) OF APPLICATION AND PLACEMENT OF FERTILIZER AND MULCH SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE PLANS AND SPECIFICATIONS.
2. TENSION IN GUY WIRES WILL BE SUCH AS TO ALLOW SOME SWAYING MOTION IN TREE.
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
ROADWAY DESIGN DIVISION
STANDARD PLAN
TYPICAL PLANTING DETAILS FOR TREES & SHRUBS
ENGLISH
WORKING NUMBER
PD-1
ISSUE DATE: OCTOBER 1, 1998
SHEET NUMBER
141

Temporary Stream Crossing (TSC)

Practice Description

A temporary stream crossing is a short-term road crossing constructed over a stream for use by construction traffic to prevent turbidity and stream-bed disturbance caused by traffic. A temporary stream crossing can be a low-water crossing, a culvert crossing, or a bridge with or without embankment approaches. Temporary stream crossings are applicable on construction sites where traffic must cross steams during construction.

Planning Considerations

A stream crossing can be an open ford, a pipe (culvert), or bridge crossing. Stream crossings can be a useful practice to provide a means for construction traffic to cross flowing streams without damaging the channel or banks or causing flooding, and to keep sediment generated by construction traffic out of the stream. Stream crossings are generally applicable to flowing streams with drainage areas less than 1 square mile. A qualified design professional should design permanent structures to handle flow from larger drainage areas.

Careful planning can minimize the need for stream crossings, and the qualified design professional should always try to avoid crossing streams. Whenever possible, complete the development separately on each side and leave a natural buffer zone along the stream. Temporary stream crossings are a direct source of water pollution; they may create flooding and safety hazards; they can be expensive to construct; and they cause costly construction delays if damaged by flooding.

Temporary stream crossings are necessary to prevent construction vehicles from damaging streambanks and continually tracking sediment and other pollutants into the flow regime. However, these structures are also undesirable in that they could cause a channel constriction, which can cause flow backups or washouts during periods of high flow. For this reason, the temporary nature of stream crossings is stressed. They should be planned to be in service for the shortest practical period of time and to be removed as soon as their function is completed.

Fords made of stabilizing material such as rock are often used in steep areas subject to flash flooding, where normal flow is shallow (less than 3″) or intermittent. Fords should only be used where crossings are infrequent. Fords are especially adapted for crossing wide, shallow watercourses. Generally, do not use fords where bank height exceeds 5 ft. Rock material used for the ford may be washed out during large storm events and require the rock to be replaced. Mud and other contaminants are brought into the stream on vehicles using ford crossings unless crossings are limited to no-flow conditions.

The criteria contained in this practice pertain primarily to flow capacity and resistance to washout of the structure. From a safety and utility standpoint, the qualified design professional must also be sure that the structure is capable of withstanding the expected loads from heavy construction equipment. The qualified design professional must also be aware that such structures are subject to the rules and regulations of the U.S. Army Corps of Engineers for in-stream modifications (404 permits).

Design Criteria and Construction

Prior to start of construction, a temporary stream crossing should be designed by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the construction process.

Scheduling

To minimize stream disturbance, attempt to construct temporary stream crossings during dry periods and relatively low flows. Use local weather forecasts to avoid installation during rain events that can potentially create turbidity.

Site Preparation

Ensure that all necessary materials are on the site before any work begins. If planned, construct a bypass channel and dewater the construction site before undertaking other work.

Installation and Removal Low Water Crossing

Excavate the foundation for the temporary crossing according to the design plan and in such a manner that the final finished surface is level with the stream bed.

Excavate roadways through the abutment approaches (bank) to the crossing according to the design plan.

Place the specified type of geotextile over the width and length of the crossing subgrade and anchor it in place as specified in the plans. Next, place riprap of the specified gradation to the required thickness across the channel. Finally, place a wearing course of gravel or crushed rock of the specified gradation to the required thickness over the riprap.

Remove gravel and excess rock riprap as soon as it is no longer needed. Restore original contours to the channel, leaving rock riprap level with the stream bed.

Culvert Crossings or Spans (Bridges)

The structure should be large enough to convey the flow expected from a 2-year frequency, 24-hour duration storm without appreciably altering the stream flow characteristics. The structure may be a span or culvert. If culverts are used, see Table TSC-1 for aid in selecting the appropriate size. (Multiple culverts may be used in place of one large culvert, if they have the equivalent capacity of the larger one). The minimum-sized culvert that may be used is 18″.

Where culverts are installed (Figure TSC-1), compacted soil will be used to form the crossing. The depth of soil cover over the culvert should be equal to ½ the diameter of the culvert or 24″, whichever is greater. To protect the sides of the fill from erosion, riprap shall be used and designed in accordance with the practice *Outlet Protection*.

The length of the culvert should be adequate to extend the full width of the crossing, including side slopes.

The grade of the culvert pipe should be at least 0.25″ per foot.

The top of the compacted fill should be covered with 6″ of Mississippi Department of Transportation coarse aggregate No. 1 stone (3/4″ to 4″).

The approaches to the structure should consist of stone pads meeting the following specifications:

Stone: Mississippi Department of Transportation coarse aggregate No. 1.

Minimum thickness: 6″.

Minimum width: equal to the width of the structure.

Minimum approach lengths: 25 feet.

Place a 4″ layer of moist, clayey, workable soil (not pervious material such as sand, gravel, or silt) around the culvert. Compact by hand to at least the density of the embankment soil. (Do not raise the culvert from the foundation when compacting under the culvert haunches.) Continue with backfill of the pipe in 4″ to 6″ uncompacted layers, scarifying the surface between each compacted layer. All backfill material within 2 feet of the pipe (beside the pipe and above the pipe) should be compacted with hand tampers only.

Extend the end of the culvert 2 feet beyond the toe of the fill slope. The outlet end of the culvert should be placed on a stable natural stream bed. If this is not possible, install a riprap apron at least 5 feet wide and 10 feet long to a stable grade.

All backfill material within 2 feet of a culvert (beside the pipe and above the pipe) should be compacted with hand tampers only. Heavy equipment should not be allowed on top of the culvert until a minimum of 2 feet of hand-compacted material is placed.

If an embankment is required, use fill from predetermined borrow areas. It should be clean, stable mineral soil free of roots, woody vegetation, rocks, and other debris. It must be wet enough when placed to form a ball without crumbling yet not so wet that water can be squeezed out. Compact the fill material in 6″ to 8″ continuous layers over the length of the embankment. One way is by routing construction equipment over the embankment so that each layer is traversed by at least one wheel of the equipment. Construct and compact the culvert-crossing embankment to 10% above the design height to allow for settling.

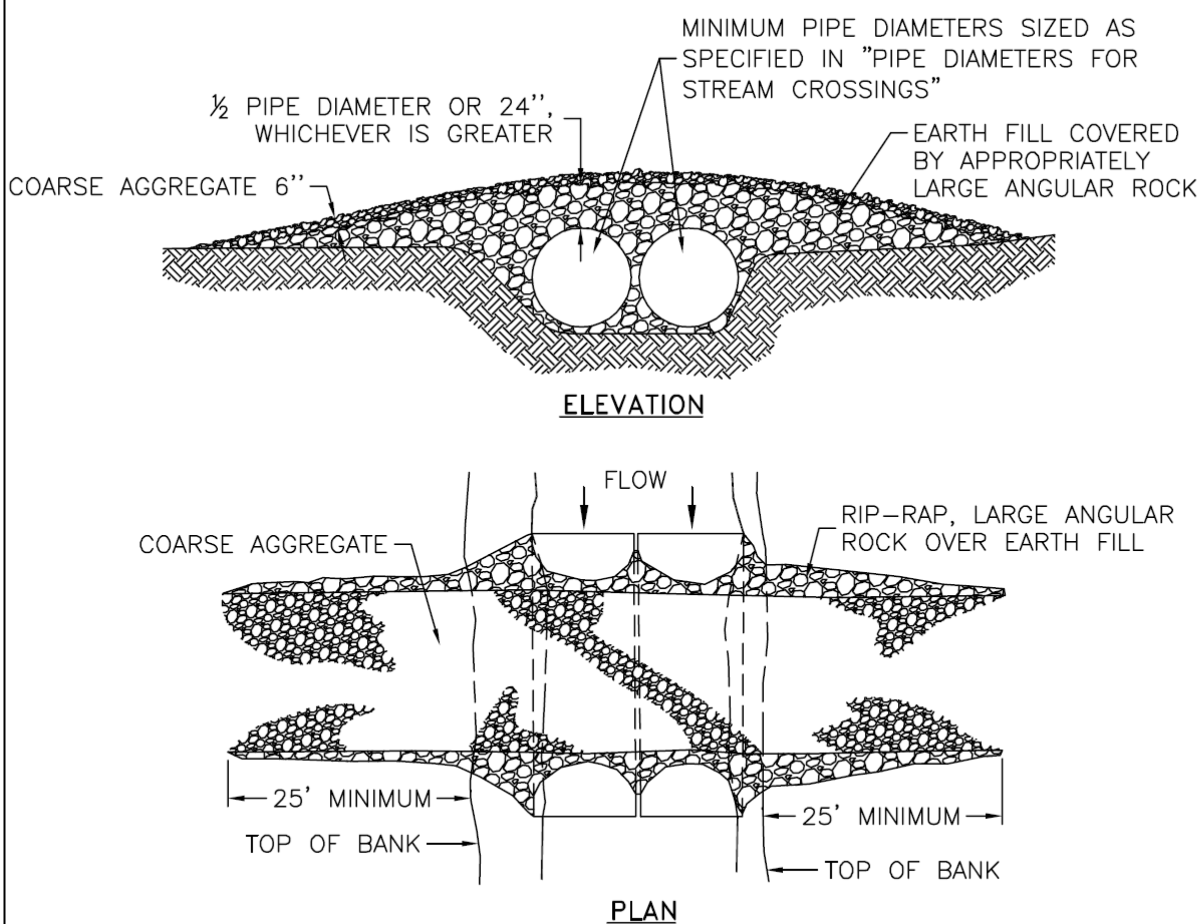
Remove culvert as soon as it is no longer needed and restore stream bed to original contour.

Table TSC-1 Culvert Selection Guide (pipe, diameter, inches)

Drainage Area (Acres)	**Average Slope of Watershed**			
	1%	4%	8%	16%
1-25	30	30	36	36
26-50	30	36	42	48
51-100	36	48	48	54
101-150	42	48	60	60
151-200	42	54	72	72
201-250	48	60	72	72
251-300	48	60	72	72
301-350	48	60	72	2X60
351-400	54	72	2X60	2X60
401-450	54	72	2X60	2X60
451-500	54	72	2X60	2X72
501-550	60	72	2X60	2X72
551-600	60	72	2X60	2X72
601-640	60	72	2X60	2X72

Assumptions for determining USDA-NRCS Peak Discharge Method; CN = 70; Rainfall depth (average for Mississippi) = 4.3″ for 2-year/24-hour storm; No tailwater exists; and the depth of water at the inlet invert is 1.5 X diameter.

Culvert crossings and spans should be designed with features that will prevent damage, destruction or removal during major flood events (i.e., cabling, emergency bypass, etc.).



NOTES:
1. NOT TO SCALE.
2. THIS TYPE OF CROSSING CAN BE INSTALLED IN BOTH A WET OR DRY WEATHER STREAM CONDITION WHERE THE DRAINAGE AREA EXCEEDS 10 ACRES.
3. REMOVE DURING CLEAN-UP.

Figure TSC-1 Culvert Stream Crossing

Fords (see Figure TSC-2)

Streambanks should be excavated to provide approach sections of 5:1 or flatter.

The width of the ford crossings should be wide enough for the construction equipment to use safely.

Filter fabric material designed for use under riprap (see *Channel Stabilization Practice*) should be installed on the excavated surface of the ford according to the manufacturer's recommendations. The fabric should extend across the bottom of the stream and at least 25 feet up each approach section. All edges of the fabric should be keyed in a minimum of 1 foot.

Mississippi Department of Transportation coarse aggregate No. 1 stone, 6″ thick should be installed on the filter fabric and also should be used to fill the 1-foot keyed edges of the fabric.

The final surface of the stone in the bottom of the watercourse should be the same elevation as the watercourse bottom to eliminate any overfall and possible scour problems.

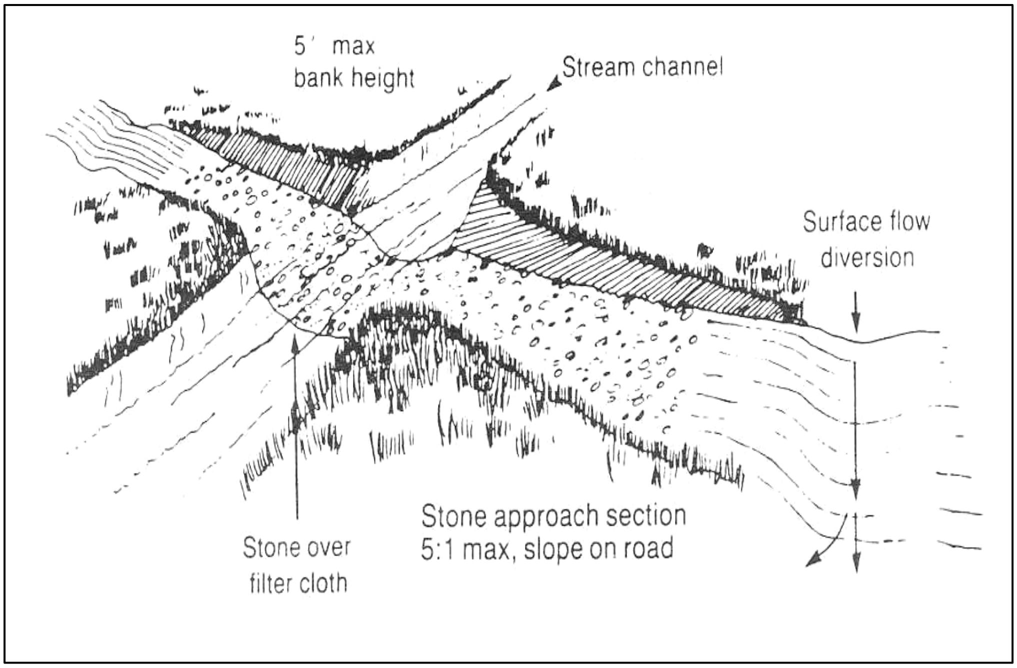


Figure TSC-2 Ford Stream Crossing

Bridge Excavation

If excavation is required, excavate roadways through the abutment approaches (bank) according to the design plan.

Construct the bridge or install a prefabricated structure according to the design plan. A cable should be tied to one corner of the bridge frame, with the other end fastened to a secure object to prevent flood flows from carrying the bridge downstream.

Embankment

Use fill from predetermined borrow areas. It should be clean, stable mineral soil free of roots, woody vegetation, rocks, and other debris and must be wet enough to form a ball without crumbling yet not so wet that water can be squeezed out.

Compact the fill material in 6″ to 8″ continuous layers over the length of the embankment. One way is by routing construction equipment over the embankment so that each layer is traversed by at least one wheel of the equipment.

Construct and compact the temporary stream crossing embankment to 10% above the design height to allow for settling.

Erosion Control (all kinds of temporary stream crossings)

Minimize the size of all disturbed areas and vegetate as soon as each phase of construction is complete. Riprap or establish vegetation on the slopes of the embankment of the temporary stream crossing. Riprap should be placed on the entrance slope of culvert systems according to the design plan.

Direct all overland flow at low velocity to the ditches along the approach roads.

Safety

Store all construction materials well away from the stream. Consider weather forecasts when determining risks of damage by flooding.

Equipment used to construct stream crossings should be free of leaks of fuel and hydraulic fluids to prevent contamination of surface waters. Operation of equipment in the stream should be minimized. At the completion of each workday, move all construction equipment away from the stream to prevent damage to equipment by flooding. Consider weather forecasts when determining risks of flooding.

The following precautions should be taken:

- Exercise caution on steep slopes.
- Fence the area and post warning signs if trespassing is likely.
- All equipment used for practice installation should be free of leaks of gas, oil, and hydraulic fluid. Measures should be in place to prevent accidental spills from entering the stream.
- Equipment should not be operated within flowing water in the stream.

Construction Verification

Check finished grade and size of culvert. Check to see if culvert is free of obstructions.

Common Problems

Consult with qualified design professional if any of the following occur:

Variations in topography on site indicate crossing will not function as intended; changes in plan may be needed.

Design specifications for fill or conduit cannot be met; substitution may be required. Unapproved substitutions could result in the crossing being washed out.

Maintenance

Inspect the temporary stream crossing for damage to the structure or the vegetation after each storm event.

Repair any damages found during inspections.

Remove debris, trash, and other materials that restrict flow from the culvert or bridge

References

Additional BMPs from Volume 1

Chapter 4

Outlet Protection (OP) 4-199
Channel Stabilization (CS) 4-342

MDOT Drawing ECD-16

Temporary Culvert Stream Crossing 4-390

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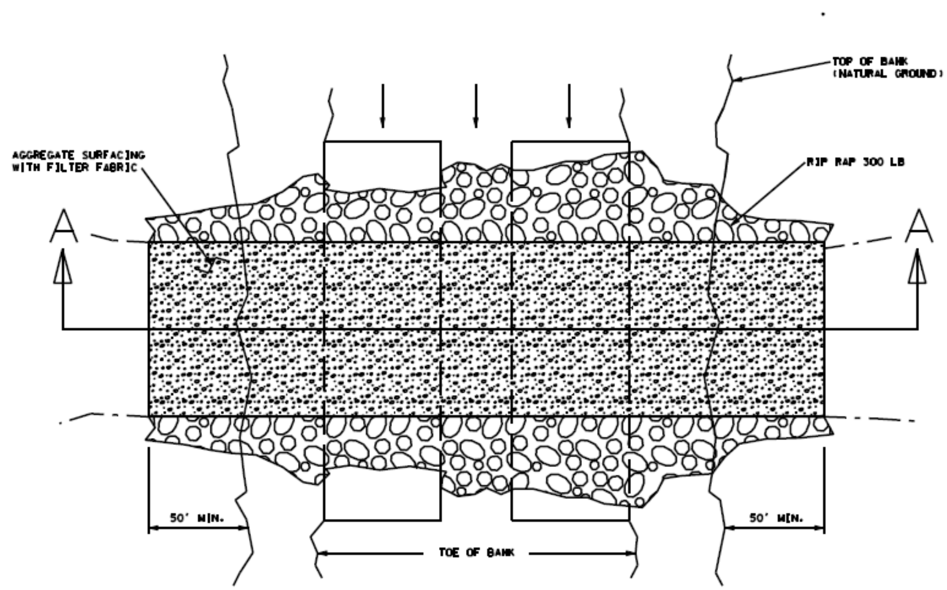
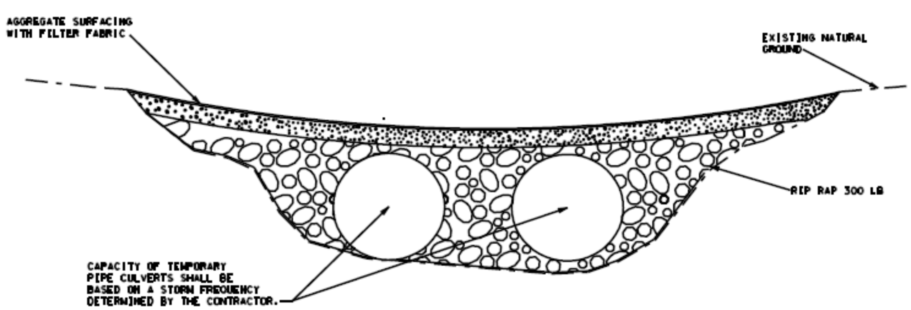


PLAN VIEW

TEMPORARY CULVERT STREAM CROSSING

TEMPORARY CULVERT STREAM CROSSING



SECTION A-A

NOTES:

1. TEMPORARY CULVERT STREAM CROSSINGS PROVIDE A MEANS FOR VEHICLES AND EQUIPMENT TO SAFELY CROSS A WATERCOURSE WHILE MINIMIZING DAMAGE TO THE CHANNEL AND/OR BANKS.

2. TEMPORARY CULVERT STREAM CROSSINGS, WHEN PERMITTED BY THE ENGINEER, SHALL BE CONSTRUCTED TO SAFELY PASS EXPECTED MEAN WATER FLOW OF THE STREAM FOR THE TIME OF YEAR AND LENGTH OF TIME THAT THEY ARE INSTALLED.

3. TEMPORARY STREAM CROSSINGS SHALL BE DESIGNED TO ENSURE STRUCTURAL INTEGRITY AND STABILITY, AND MAINTAIN NORMAL DOWNSTREAM FLOWS. THE USE OF INSTREAM CROSSINGS AND INSTREAM AGGREGATE FILL SHALL BE MINIMIZED TO THE EXTENT PRACTICABLE.

4. A CONTINUOUS PROGRAM OF EFFECTIVE EROSION AND SEDIMENT CONTROL MEASURES SHALL BE IMPLEMENTED PRIOR TO AND CONCURRENT WITH ANY TYPE OF CONSTRUCTION ACTIVITY WITHIN THE BANKS OF A STREAM. WHEN A CROSSING IS NO LONGER NEEDED, THE STREAMBED AND STREAM BANKS SHALL BE RESTORED TO PRE-DISTURBANCE CONDITIONS, OR SUCH A CONDITION THAT PROVIDES SUBSTANTIALLY EQUIVALENT PROTECTION OF WATER QUALITY.

5. LOCATIONS OR TYPES OF TEMPORARY CULVERT STREAM CROSSINGS WILL NOT BE SHOWN ON THE PLANS AS REQUIRED ITEMS .

6. THE CONTRACTOR MAY PROPOSE OTHER OPTIONS FOR TEMPORARY STREAM CROSSINGS SUCH AS STEEL/TIMBER BRIDGE OR MATS.

7. THE DETAILS PROVIDED DEPICT A TYPICAL TEMPORARY CULVERT STREAM CROSSING.

8. TEMPORARY STREAM CROSSINGS WILL NOT BE MEASURED FOR SEPERATE PAYMENT. ALL COSTS FOR MATERIALS, LABOR, EQUIPMENT, CONSTRUCTION, REMOVAL AND MAINTENANCE SHALL BE ABSORBED IN OTHER ITEMS OF WORK

BY | REVISION | DATE

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

TEMPORARY CULVERT
STREAM CROSSING

WORKING NUMBER
ECD-16

FILENAME: EROSION CONTROL\ECD-16.DGN

DESIGN TEAM ________ CHECKED ________ DATE ________

SHEET NUMBER