RIPARIAN RESTORATION AND STREAMSIDE EROSION CONTROL HANDBOOK

NONPOINT SOURCE
WATER POLLUTION
MANAGEMENT PROGRAM
FOR THE
STATE OF TENNESSEE

Pursuant to the State of Tennessee's policy of non-discrimination, the Tennessee Department of Environment and Conservation does not discriminate on the basis of race, sex, religion, color, national or ethnic origin, age, disability, or military service in its policies, or in the admission or access to, or treatment or employment in, its programs, services or activities.

Equal Employment Opportunity/Affirmative Action/ADA inquiries or complaints should be directed to the Tennessee Department of Environment and Conservation, EEO/AA/ADA Coordinator, 401 Church Street, 21st floor, Nashville, TN 37243, (615)532-0103.

Hearing impaired callers may use the Tennessee Relay Service (1-800-848-0298).

Tennessee Department of Environment and Conservation, Authorization No. 327480, 1,500 copies. This public document was promulgated at a cost of $2.54 per copy. November 1994.

RIPARIAN RESTORATION
AND STREAMSIDE EROSION CONTROL
HANDBOOK

Compiled and written by:

Jennifer N. Thompson,
Don L. Green,
Nonpoint Source Program,
Division of Water Pollution Control

in cooperation with the

Natural Resources Section,
Division of Water Pollution Control

With illustrations by
LeAnne Johnson,
Tennessee State Parks

Department of Environment and Conservation

November, 1994

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The Department is grateful for the overwhelming response given by the many State and Federal agencies to this project. This document is an outgrowth of a commitment made when annual milestones were developed for the State Nonpoint Source Water Pollution Management Program, in May of 1990. Much of the information contained in the document is borrowed from our colleagues and we are most appreciative of their permission to use this information. Many of the contributions to the document are a result of information developed during the ***Riparian Habitat Protection and Reconstruction Symposium*** held at Paris Landing State Park, November 7-11, 1993.

Austin Peay State University's Center for Excellence in Field Biology program, Mack Finley, and Steve Hamilton contributed to the Symposium as well as made contributions to the document, we appreciate these efforts. Additionally, we want to thank Hollis Allen, WES-USCOE; Jim Gore, Troy State University.; Scott Knight, National Sedimentation. Lab., USDA; Don Roseboom, Illinois State Water Survey; and Richard Wehnes, Missouri Department of Conservation for their contributions to the Symposium and the document.

We hope that this document will be used as a source of information for conservation efforts to continue stream restoration, habitat reclamation, and erosion control. The staff devoted many long hours in order to complete the review of the many articles, pamphlets, documents and scientific literature used to support the text. We are grateful for all of the contributions from other state and federal agencies as well as organizations. With their help, we were able to include some of the most complete and informative material on streambank stabilization and reconstruction in the country. We respect the dedication and effort of everyone involved in this project and their commitment to continuing to protect and restore watersheds.

This document is supported in part by grants from the U.S. Environmental Protection Agency, Section 319(h) Nonpoint Source Program and the Tennessee Department of Environment and Conservation. Further use of this text must only be done with permission of the Department's Nonpoint Source Program.

Andrew N. Barrass, Ph.D., Manager
Nonpoint Source Program

I. INTRODUCTION

Freshwater streams and rivers have been used by man over the years to provide nourishment, energy and transportation. We have perceived these resources to be resilient and almost indestructible. But many years of overuse and misuse have resulted in severe damage to the streams and rivers and the ecosystems associated with the running water systems. These ecosystems provide primary habitats for a variety of uniquely adapted plants, invertebrates, and vertebrates. With the worldwide decline in biodiversity, restoration and maintenance of unique stream ecosystems are imperative (Cairns 1988).

Every year, thousands of tons of soil are lost due to stream bank erosion. Farming practices, which denude the bank of vegetation, channelization, gravel dredging and other activities in the streams add to the damage. Lost soil contributes to loss of income, habitat and land. In serious cases, bridges and highways have been destroyed due to improper construction and the instability of stream banks during floods. But there is much that can be done to repair damaged streambank or riparian zones. By using proper streambank management practices, carefully placing instream structures, and replanting and rearmoring streambanks, we can begin to repair the damage caused by man's activities and the forces of nature.

Restoration activities not only maintain a valuable ecological resource but also provide the potential for a manageable, relatively renewable, resource of fresh water. Stream repair is much more complicated than terrestrial repair. Running water ecosystem restoration must also account for systems that interact to produce the lotic environment, i.e., surface pollutant runoff, riparian vegetation restoration and instream channel hydrologic considerations (Cairns 1988).

Whether the cause of streambank damage is natural or manmade, it can be improved by one or a combination of methods. The first step is to understand stream dynamics and to determine what has caused the problem. Correcting the problem may be as simple as removing an obstruction that is impeding streamflow or it may involve soil bioengineering techniques to rebuild damaged habitats quickly. All the techniques described in this handbook can be implemented successfully with a little planning. The price of implementing reconstructive measures will depend upon the method(s) used or what types of plants are selected. The rewards of repairing damaged streambanks and riparian zones are extensive and include: streambank stabilization, creation of fish and wildlife habitat, beautification of home and land, and increased economic security.

It is important to understand that a stream bank may erode for many different reasons and the cause is not always obvious. It might be as simple as lack of bank vegetation to hold the soil in place or as complex as changes in runoff caused by urban runoff, poor logging or farming practices or other activities in the watershed. Landowners should determine why excess gravel is accumulating in the stream. The gravel bars in the stream are usually not the cause of stream bank erosion; they are one result of poor management practices of the riparian zone, watershed and/or stream channel. Addressing only the site of the gravel bar or bank cutting could be an expense of time and money that will have to be repeated if the immediate cause is not addressed.

This handbook was prepared in response to a need by landowners to prevent erosion of private lands and to rehabilitate damaged stream side or riparian zones. This publication is not intended to showcase new technology, but to present successful techniques for planting, bank armoring, in-stream structures and soil bioengineering which have been used by others to stabilize streambanks and restore freshwater ecosystems. These techniques are only recommendations or suggestions that the landowner may choose to implement. The examples shown in this book are representative of these techniques, though there are many others.

Landowners should always check with the Tennessee Department of Environment and Conservation, Division of Water Pollution Control, Natural Resources Section before undertaking any stream alteration activities, to determine if a permit is needed for that activity. (See Aquatic Permits and Regulations, section III.)

There are some general measures that can be taken to prevent Streambank Erosion. The Georgia Soil and Water Commission provides the following tips below in their April 1993 draft document, ***Controlling Streambank Erosion:***

> Preventing streambank erosion problems is less expensive than repairing damage resulting from erosion. It is important to take steps to prevent streambank erosion problems from occurring. Preservation and protection of the native streamside vegetation community is an important key to streambank protection.
>
> Since woody vegetation is the best streambank stabilizer, every effort should be made to maintain existing trees and shrubs. These plants trap sediment from adjacent land and hold the soil in place with their root structures, forming a root mat that reinforces the soil mantle on the streambank. Plants also enhance the appearance of the stream and serve as wildlife habitat. Trees provide additional benefits by shading the stream to maintain the lower summertime water temperatures which are necessary for a healthy aquatic population.
>
> Here are some practical measures that can protect streambanks from erosion:

Maintain an Undisturbed Buffer Zone at Least 25 Feet Wide on Both Sides of the Stream. This area needs the protection of a permanent vegetative root cover and mat to protect and stabilize the soil. Where adjacent slopes are steep, a wider corridor of woody plants and shrubs is appropriate.

Restrict the Operations of Heavy Machinery, Construction, Animal Grazing, and Other Intensive Activities within the Buffer Zone. These activities compact the soil, which decreases infiltration, percolation, and aeration, increases runoff, and thus cause the eventual destruction of plants, soil and habitat.

Use Best Management Practices for Agricultural and Forestry Activities. In agricultural areas, field tillage should follow the contouring method. Maintain an undisturbed riparian corridor next to the stream. Eliminate livestock access to streambanks. Stock watering areas can be used to limit access and should be stabilized by stone or railroad ties which can withstand trampling.

Plant Vegetation. Where existing vegetation is sparse, planting of the site-specific native plants can be less expensive, offer higher survival rates and give more protection than ornamental or non-native plants. Native self-maintaining perennial species can be selected and planted using the guidelines in this booklet.

Don't Straighten Channels. People often think that straightening the channel is the quickest and easiest solution to their erosion problem. However, this procedure is almost never effective in controlling erosion. Past experience has shown that channel straightening will simply change the location and nature of the erosion problem and usually make the problem worse.

It is important to consider the types of equipment you will be using for your project, safety, design, cost and cleanup. The following pointers are offered by the Georgia Soil and Water Conservation Commission in their April 1993 draft document, ***Controlling Streambank Erosion:***

1. Identify the Cause and Nature of the Problem - Identify upstream activities which may affect streamflow, observe upstream bank conditions, consult with up and downstream neighbors, contact your Soil conservation Service office, identify the type and severity of your bank erosion problems (see section on Streambank Erosion) and upstream causes.

2. Evaluate Alternatives and Select Appropriate Streambank Erosion Protection Measure(s)

3. Determine When You Will Do the Project - Some practices must be installed during the dormant season or grass growing season.

4. Locate Underground Services Which Could Be Affected by Construction Activities - Sewer lines, underground utilities, wells, septic tanks and drainfields, etc.

5. Plan or Design Erosion Protection Measures - Using the descriptions of the streambank protection measures (in the following section) that you have selected, design necessary structures, and lay out practices on a sketch of your stream and streambanks. The sketch should be sufficiently accurate to allow you to estimate the amount of materials which will be needed for the project. Be sure to include erosion control measures such as silt fence and hay bales.

6. List and Acquire Materials and Necessary Tools - Estimate and develop a list of the number or amount of materials and tools (purchase or rental) necessary to complete the project. Determine the source of tools and materials. In some cases you may have to locate and secure permission to harvest suitable sources of plant materials or find a plant nursery which handles appropriate species.

7. Access and Clean Up Cost - Be sure to consider access to the stream for machinery and vehicles on to your property and possibly your neighbor's. Typically, due to landscaping and site services, etc., urban sites have major access considerations. The costs for repairing construction damage need to be calculated.

8. Develop a Safety Plan - You may be working with power tools in wooded areas and adjacent to flowing and, sometimes, deep water. Have appropriate safety devices such as goggles, leather work gloves and chaps for chainsaw use. Consider insect and snake hazards, and avoid deep or storm water flows.

But before you install your project, consider the following tips:

1. Contact the local unit of government where you live for required permits (i.e. public works, engineering or planning and zoning offices). They can direct you to state and federal agencies if additional authorization is required.

2. Speak to your upstream and downstream neighbors to determine if they too have problems, and if they would participate in a repair project.

3. Take steps to ensure that soil does not get pushed or washed into the stream during this project. Install and maintain sediment control devices where needed.

4. Start your work at the upstream end and work your way downstream.

5. Do not implement measures that restrict the size of the channel. Practices that restrict channel flow can cause flooding or increase erosion. **[Editor's note: instream structures such as wings or channel constrictors do direct the flow to the center of the stream, causing the channel to deepen in the middle and create scour pools for habitat for fish. (This is shown in Section VI-F, Habitat Restoration.) In some cases, such practices are the preferred choice. This is one reason it is always best to consult a professional.]**

6. Do not use materials which may be poisonous to fish and aquatic life such as asphalt for riprap or wood treated with creosote.

7. Keep the stream channel and the banks as natural as possible to maintain habitats for fish, aquatic organisms, birds and animals.

8. Begin and end all streambank protection projects at stable points along the bank. This may be a point at which the main thrust of the flow is parallel to the bank, or at a stable structure such as a bridge or culvert. This may require cooperative efforts by several landowners.

9. Divert intensive sources of runoff such as gutter downspouts or street drainage away from the area to be treated, and be sure to include appropriate drainage facilities for this flow.

10. Make sure you have protected the submerged part of the bank, all the way to the channel bottom, and in some cases where undercutting has occurred, below the bottom. Otherwise the current may undermine the erosion control measures installed.

11. Be prepared to maintain your project. Inspect the project regularly, particularly after heavy rains and high flows, and make necessary repairs as soon as possible.

12. Re-establish streambank vegetation and trees using native plants.

II. RIPARIAN ZONE MANAGEMENT

One of the first steps to controlling erosion and repairing damaged habitats is to understand what a watershed is and how it works. Bill Turner, with Missouri Department of Conservation defines a watershed in the publication, ***Understanding Streams:***

> The watershed is an area of land that drains into a stream. This includes both the surface runoff and groundwater. Because a stream is made up of drainage water it is a product of the land above it.
>
> If the land is misused or pollutants are spilled, the receiving stream will be degraded. Although simple, the most important concept in stream management is that every stream is the product of its watershed and each of us lives in a watershed. Each one of us is linked to a stream regardless of our occupation or way of life. How we use the land is ultimately reflected in the condition of the stream.
>
> Watershed management includes all of the land uses and activities of rural and urban living. Each watershed has its own runoff patterns which are dependent upon the types of plants and trees and the natural slope of the land.
>
> A timbered or native grass watershed delivers its runoff slowly and over a long time period. Watersheds with a lot of timber clearing or the construction of many paved streets and parking lots allow water to run off fast, which results in larger, more frequent floods. Faster runoff increases erosion both on the land and in the stream channels below.
>
> Simple removal of nonpoint pollutants is not enough to improve the quality of water resources. A balanced, integrated, adaptive community of riparian and aquatic organisms comparable to the natural systems of the region with stability and capacity for self repair must be reestablished. The restoration of a healthy aquatic ecosystem from the headwaters to the estuaries to the oceans requires the re-establishment of significant amounts of riparian forest.

> Control of point source pollutants was a start; control of nonpoint pollutants and repair of the aquatic ecosystem through re-establishment of the streamside forest is a logical next step in improving the quality of our water resources.

It is important to try to maintain a healthy riparian or streamside buffer zone between the land and streams. Riparian zones are areas of trees, shrubs, grasses and plants which grow along the banks of streams, lakes and rivers. The plant root systems are critical in controlling streamside erosion. They do this by slowing down the water and allowing sediment, gravel and sand to drop out before the storm runoff reaches the stream. Root systems also hold the soil complex of the bank in place. The vegetation in riparian zones will aid in stopping pollutants from overland runoff which can become toxic to plants and animals. The tree canopy and leaf layer also serve to protect the soil from the direct force of rain drops. A wide vegetated corridor will ensure stability of the stream even when flood waters destroy some of the bank vegetation. Riparian zones provide habitat for wildlife such as turtles, muskrats, deer and waterfowl. Tree root systems supply instream cover for fish and other aquatic organisms.

They also aid in enhancing the beauty of the land. The U.S. Department of Agriculture, Forest Service in their publication, ***Riparian Forest Buffers***, describes specifications for managing a riparian zone on the following page.

1. Streambed forests should be used in conjunction with sound land management systems that include nutrient management and sediment and erosion control.

2. Sediment removal-The streamside forest must be wide enough to filter sediment from surface runoff. Maximal effectiveness depends on uniform shallow overland flow. Percent removal of total suspended solids is a good indicator of effectiveness.

3. Nutrient removal-periodic flooding and the presence of forest litter contribute to conversion of nitrate to gaseous nitrogen by denitrification. Plant uptake also accounts for significant removal of nitrogen. . .

4. Periodic minor ground shaping may be necessary to encourage dispersed flow and prevent concentrated flow.

5. A portion of the riparian forest immediately adjacent to the stream should be managed to maintain a stable streamside ecosystem and to provide detritus and large stable debris to the stream.

6. Crown cover should be managed to minimize fluctuations in stream temperature and to maintain stream temperatures within the range necessary for instream aquatic habitat.

7. Instream slash and debris removal practices should be revised to conserve existing large stable debris by retaining useful stable portions of jams whenever possible. Unstable tops and smaller debris with potential to form problem jams should be removed a sufficient distance to prevent re-entry during storm events.

The following, from a report in the ***Watershed Restoration Sourcebook***, put together by the Anacostia Restoration Team, Metropolitan Council of Governments in Washington, D.C., offers some other ideas to consider when planting and maintaining a riparian zone:

Existing Cover:

The first factor to investigate is adjacent or reference forests. This will provide a target forest for use in species selection. One can either investigate historical data on forest cover, or compare adjacent relatively undisturbed forest types. The reference forest description should include herbaceous, understory and dominant plant species.

Existing cover should also be evaluated for its ability to provide shading and bank stability. Visual estimates of canopy coverage both over the stream and planting areas can provide a qualitative assessment of this factor (see Maryland Forest Conservation Manual for procedures). If an abundance of exotic species are found on site, one may direct reforestation efforts to other sites, or it may be necessary to employ intensive site clearing and maintenance activities.

The third factor to evaluate is the potential for natural regeneration. Natural regeneration is the ability of a forest stand to perpetuate itself through native soil and standing crop seed sources, and sprouting. It is typically measured through examination of the number of free-to-grow seedlings found in the understory, evaluation of the adjacent forest stand and other site conditions. This will be of assistance when evaluating reforestation techniques. A professional forester should be consulted in this assessment.

Bank Stability:

An assessment of the stability of the streambanks is an important factor in reforestation planning. Flash flows, characteristic of urban streams, often result in severe erosion, reforestation projects may have to be delayed until structural bank stabilization is accomplished. Overly steep banks, frequent and recent tree fall, and poor bank vegetation near base flow level are signs of active erosion. Also, through visual assessment of trunk displacement and the branching patterns of new growth, one can qualitatively note the history of bank erosion.

Less severe erosion, as might be found in areas of intensive turf management abutting streambanks, may be effectively handled through riparian reforestation. By creating "no-mow" zone along streams can in many cases provide adequate structure to the eroding banks. Decisions, such as these should be made through interdisciplinary teams of hydrologists, engineers and foresters.

Soils:

Urban soils are highly variable and often bear little resemblance to native parent materials found in the subsoil. For that reason, it is highly recommended that a thorough evaluation of soils be consulted prior to plant selection and site preparation. Probably the most useful soil analysis to conduct is a 36" soil probe through which obstructions, urban debris and general soil compaction can be noted. Other qualitative data such as assessments of structure, density, moisture, presence of hydric soils or fill can also be collected through these methods. A representative collection of soil samples should also be evaluated through a laboratory evaluation to determine soil contamination and recommendations for soil amendments. A detailed discussion of soils evaluation is included in the ***Maryland Forest Conservation Manual*** (MWCOG, 1991).

Hydrology:

Reforestation planning should also take into account flooding or overbank flow frequency as defined through published hydrologic data or other local resources. Depth to water table should be determined using USDA Soil Conservation surveys or field surveys. Urban riparian areas, in spite of their proximity to open water, are often disconnected from the water table. Knowledge of hydrological conditions will insure proper selection of plant materials based on moisture conditions.

Adjacent Land Uses:

Areas of high recreational use adjacent to planting sites may affect the survivability of planted materials or potential for vandalism. Aesthetics may play a larger part of reforestation design because of added visibility. The density of plantings in high use [areas] may have to be lower to provide a more park-like setting or open areas.

Competing land uses such as use of stream corridors for flood control or utility right of way should also be determined. In the case of flood control structures, planting may be limited to very low densities and narrow width because of potential loss of flood control storage. Over time, flood management agencies such as the Army Corps of Engineers have begun to develop alternative management policies, such as allowing for selective clearing and snagging instead of the traditional clearing of riparian zones. Utility lines should also be investigated on site.

The ***Watershed Restoration Sourcebook*** also gives some tips for maintaining riparian zones:

Success in saving priority forests on site requires the incorporation of various protective measures. The first is to determine the area around trees that must remain undisturbed, referred to as the critical root zone. Most guidance on construction around trees defines the critical root zone as the area within a canopy's dripline. Recent studies have shown that, depending on soils, species, growth patterns, etc., the most important roots are likely to grow considerably beyond a tree's dripline (Schnelle et al. 1989). It is important to protect the entire Critical Root Zone and not just those roots within the dripline.

The keys to protecting trees during construction include good on-site communication and timing. On-site construction personnel must be informed of the purpose and plans of any tree protection program. All information should be documented on the site plans directly. Liability and responsibility should be clearly defined so construction personnel, including the people on the bulldozers, understand that they may have a stake in the success of the project.

The other important factor to consider is the use of the best technology available. This means using good stress reduction techniques (crown and root pruning) where possible, especially on specimen trees adjacent to disturbance. For example, when pruning roots, it is crucial to cut roots cleanly, and not to tear them apart with a backhoe. Using temporary tree protection fencing with highly visible flagging and signs informs everyone of protection intentions. Permanent protection systems may also be considered with highly impacted trees. These include aeration systems for the roots or retaining walls to minimize grading.

Providing Future Protection

The final and most important step is insuring the survival of protected forests for the long term. Without proper legal protection and property owner education, protected forests can be "encroached to death." Adequate protection is accomplished through homeowner association covenants, conservation easements, and approved forest conservation and management plans.

Figure 1. on the following page, illustrates surface and ground water flow and defines streamside forest buffer zones.

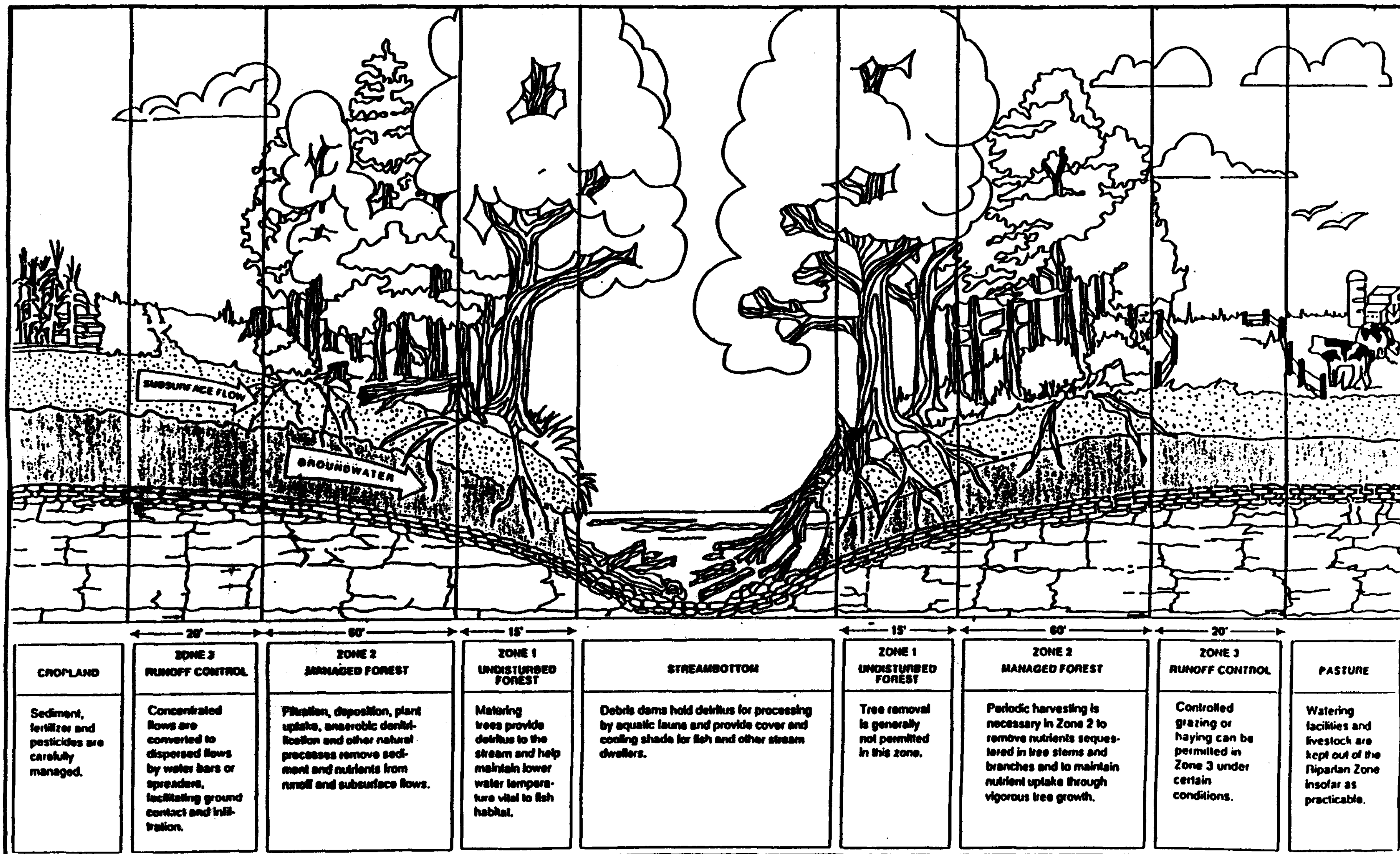


Figure 1. The Streamside Forest Buffer. *Riparian Forest Buffers*. U.S. Department of Agriculture Forest Service.

III. AQUATIC PERMITS AND REGULATIONS

A GUIDE TO PERMITS REQUIRED FOR WORK WITHIN STREAMS IN THE STATE OF TENNESSEE

STATE OF TENNESSEE WATER QUALITY PERMITS

Aquatic Resource Alteration Permit (ARAP)
General Permits
Schedule of Fees
How to Obtain an ARAP application
Section 401 Water Quality Certification

ASSOCIATED FEDERAL PERMITS

Army Corps of Engineers Section 404 permit
Army Corps of Engineers Section 10 permit

This information has been compiled by the Division of Water Pollution Control as a guide to the State of Tennessee and associated federal permits required for work within streams.

Many of the most commonly asked questions about both the state and federal permit programs are outlined. Additional information may be obtained by writing the Division of Water Pollution Control, 6th Floor L & C Annex, 401 Church Street, Nashville, TN 37243-1534; or calling the Division at (615) 532-0625.

Performing unauthorized work in waters of the state and/or waters of the United States or failing to comply with permit terms and conditions may result in civil penalties and/or ordered mitigation of the area.

When in doubt as to whether a planned activity needs a permit, contact the nearest Division of Water Pollution Control field office or the central office in Nashville. Field offices are located in Memphis, Jackson, Nashville, Knoxville, Chattanooga, and Johnson City. The complete list of address and phone numbers for these offices is included in this section.

STATE OF TENNESSEE WATER QUALITY PERMITS

Aquatic Resource Alteration Permit (ARAP)

The Tennessee Water Quality Control Act of 1977, Section 69-3-108(b)(1), states in part:

> It shall be unlawful for any person . . .
> to alter the physical, chemical, radiological,
> biological, or bacteriological properties of any
> waters of the state, except in accordance with the
> conditions of a valid permit.

Streams, lakes, reservoirs, groundwater, and wetlands of any size are considered waters of the State pursuant to the Act. Private farm ponds without an inlet, outlet or groundwater source are not regulated under the Act.

Any activity which involves the alteration of waters of the State will require some type of state and, possibly, federal permit. Federal permits, under Section 404 of the Clean Water Act, and subsequent state certification, under Section 401, are required for projects involving the discharge of dredged or fill material into waters of the U.S. or wetlands. Aquatic Resource Alteration permits are required for any alteration of waters of the State including wetlands if a 404 permit is not required. Examples of stream alteration activities requiring permits include:

1. dredging, widening, straightening, bank stabilization,
2. levee construction,
3. channel relocation,
4. water diversions or dams,
5. water withdrawals,
6. flooding, excavating, or draining a wetland.

General Permits For Alteration of Aquatic Resources

General permits are available for certain activities that involve alterations of waters of the State. General permits provide authorization for activities which cause minimal individual or cumulative impacts to water quality. The regulations establish specific, enforceable standards of pollution control for work authorized by them. General permits are available for the following activities:

1. Construction of launching ramps,
2. Alteration of wet weather conveyances,
3. Minor road stream crossings,
4. Utility line stream crossings,
5. Bank stabilization (of streams),
6. Sand and gravel dredging, within the stream corridor,
7. Debris removal.

Notification of intent must be made to the Division of Water Pollution Control prior to commencement of work for all of the general permitted activities above except alteration of wet weather conveyances, utility line crossings, and debris removal. Each of these activities has specific limitations for work, but if they can be done in compliance with the requirements, the landowner can begin work immediately. If the activity cannot be accomplished under the conditions of the general permit, an individual Aquatic Resource Alteration Permit will be required. An individual permit requires that the applicant's proposal be made available for public comment for a period of 30 days, and will usually take from 60 to 90 days to process.

Debris removal is authorized under the general permit and anyone can remove trees, logs, trash, debris, etc. anytime they wish without notifying the Division as long as they comply with the conditions of the general permit.

Copies of general permits can be obtained by contacting the Department's Division of Water Pollution Control, Natural Resources Section in Nashville, TN at (615) 532-0625.

Schedule of Fees

As of July 1, 1992, application fees for 401 certifications and ARAP permits must be submitted with the application prior to project review and issuance of a permit. There are no fees for the general permits described above except gravel dredging. The following fee schedule applies for all individual permits and gravel dredging general permits:

ARAP or 401 Cert. for 404 permit:

(a) Commercial Applicant equal to or greater than 10 acres or equal to or greater than 1000 feet	$3000
(b) Commercial Applicant less than 10 acres and/or less than 1000 feet of stream work	$1000
(c) Gravel Dredging-Commercial (Annual Maintenance Fee)	$ 100
(d) Individual Applicant (Non-commercial)	$ 50
(e) Gravel Dredging-Individual	$ 0

Commercial Applicant is an applicant for an activity which is performed in the course of the applicant's business or service (businesses, governmental entities, etc.).

Individual Applicant is an applicant for an activity which is non-commercial and is to be conducted on the applicant's property.

How to Obtain An Application for an Aquatic Resource Alteration Permit

Information and applications for an Aquatic Resource Alteration Permits may be obtained from any of the Tennessee Department of Environment and Conservation's Division of Water Pollution Control field offices located in Memphis, Jackson, Nashville, Knoxville, Chattanooga and Johnson City:

Division of Water Pollution Control
Memphis Field Office
Perimeter Park, 2500 Mt. Moriah-Suite E645
Memphis, TN 38115-1520
(901) 368-7939

Division of Water Pollution Control
Jackson Field Office
295 Summar
Jackson, TN 38301
(901) 661-6200

Division of Water Pollution Control
Nashville Field Office
537 Brick Church Park Drive
Nashville, TN 37247-1550
(615) 741-7391

Division of Water Pollution Control
Natural Resources Section
6th Floor L & C Annex
401 Church St.
Nashville, TN 37243-1534
(615) 532-0625

Division of Water Pollution Control
Knoxville Field Office
2700 Middlebrook Pk.
Suite 220
Knoxville, TN 37921
(615) 594-6035

Division of Water Pollution Control
Chattanooga Field Office
550 McCallie Ave. Suite 550.
Chattanooga, TN 37402
(615) 634-5745

Division of Water Pollution Control
Johnson City Field Office
2305 Silverdale Rd.
Johnson City, TN 37601
(615) 854-5400

After a complete ARAP application and the correct fee are received for an activity that requires an individual permit, a description of the proposed project will be issued in a public notice. This involves a 30 day comment period in which any interested party can make comments on possible impacts of the project.

After the 30 day comment period, if it is determined that the proposed activity will not cause pollution, a permit will be issued that will contain conditions to protect water quality. The applicant must comply with the permit conditions.

Section 401 Water Quality Certification

Section 401 of the Federal Clean Water Act requires that any applicant for a Federal license or permit to conduct an activity which will result in a discharge into waters of the United States, shall provide the federal agency from which a permit is sought a certificate from the state water pollution control agency that any such discharge will comply with applicable water quality standards. Federal permits which require Water Quality Certification from the Tennessee Division of Water Pollution Control include 404 permits from the U.S. Army Corps of Engineers for the discharge of dredged or fill material, 26A permits from the Tennessee Valley Authority, and permits for hydroelectric projects from the Federal Energy Regulatory Commission.

ASSOCIATED FEDERAL PERMITS

Activities that Require a Section 404 Permit

A section 404 permit application can be obtained from the Corps of Engineers (COE) District Engineer's office. Offices in Tennessee are located in Memphis (901) 544-3471 and Nashville (615) 736-5181.

After a 404 permit application has been submitted to them, the Corps will issue a Public Notice describing the project and its purpose. Corps personnel may visit the site to determine existing conditions and delineate the boundaries of any wetlands which might be present.

The public notice will be prepared by the District Corps of Engineer's office which has jurisdiction. This public notice is sent to the Division of Water Pollution Control, other state and federal agencies, and interested parties. There is a 30 day period to allow comments to be submitted to the Corps concerning possible impacts to the waterbody or wetlands, suggested mitigation for impacts resulting from the project, and other related information.

The Division of Water Pollution Control will request the applicant to submit the correct fee when it receives a copy of the Public Notice from the Corps. After receipt of the correct fee, the Division will review the proposed project to determine its effects on water quality. If the proposal is acceptable, the Division will issue Section 401 Certification to the applicant within 90 days of receipt of the fee. Before the Division can make a determination, the applicant must address such issues as avoidance of wetlands, minimization of impacts, and compensatory mitigation for any unavoidable loss of wetlands due to the proposed project. The certification will contain conditions under which the project must be completed and the applicant must comply with them.

Once Section 401 certification has been issued to the applicant by the Division, the Corps can issue a Section 404 permit to the applicant. The issuance of 401 Certification by the State does not guarantee that the Corps will issue a 404 Permit. The Corps uses different criteria for permitting decisions and must consider issues other than just water quality.

U.S. Army Corps of Engineers Section 10 Permit

Activities that require a Section 10 permit include:

1. dredge and fill activities within navigable waters of the United States,
2. excavating within navigable waters of the United States,
3. Transporting dredged material, for the purpose of dumping it into ocean waters.

Applications for a Section 10 permit and a list of navigable waters in Tennessee can be obtained at your nearest Army Corps of Engineers (COE) District office. Field offices are located in Memphis and Nashville.

IV. STREAM DYNAMICS

Streams are inherently dynamic systems. It is their nature to flood and to change their course. Erosion of stream banks and redeposition of stream bed materials is a natural parts of this process. Historically, man has endeavored to alter streamflow. Often this is done with a goal of reducing natural flooding or stabilizing shifting channels.

Some aspects of the dynamic nature of streams are not apparent from observations made over the relatively short span of a few years. Even streams which seem to have a stable, well defined channel constantly shift and meander when viewed over long time periods.

In the terms of physics, moving water has kinetic energy which will inevitably do work. The faster the water moves, the more energy within the system. For centuries, humans have capitalized on this ability of moving water to do work by using it to power mills and more recently, to generate electricity. The energy of streams is naturally expended by transporting stream bed materials and by shifting channel alignments by bank erosion and deposition.

Typically, the activities of humans accelerate the natural processes of steam dynamics. Clearing of forest cover and development of hard surfaces such as roof tops and pavement increase runoff rates and nonpoint source pollutant loading. Flood control efforts such as levee construction and channel straightening or enlargement confine water to the channel during higher flow periods. All of these activities increase the volume and velocity of water within a stream during high flow periods. This increased energy worsens channel erosion and increases rates of bank failure and down-cutting. The excess material transported by streams under such conditions is deposited at a point downstream where the rate of flow is slowed because of changes in gradient, blockages or other flow restrictions.

Almost without exception, localized efforts to control the periodic flooding and natural shifting of channels results in the worsening of the very "problems" we seek to correct. The more stream management problems are addressed in the context of an entire watershed, and the better we are able to understand and accommodate natural stream processes, the more successful our efforts will be.

The production of this guide acknowledges the need to address localized bank erosion problems. It is an effort to present background information and workable solutions which will protect water quality and maintain stream benefits and aquatic habitat. The growing body of research and experience indicates that management techniques which emulate nature and work with natural stream processes are more successful and economical.

The following illustration shows how stream dynamics affects streambank erosion and deposition:

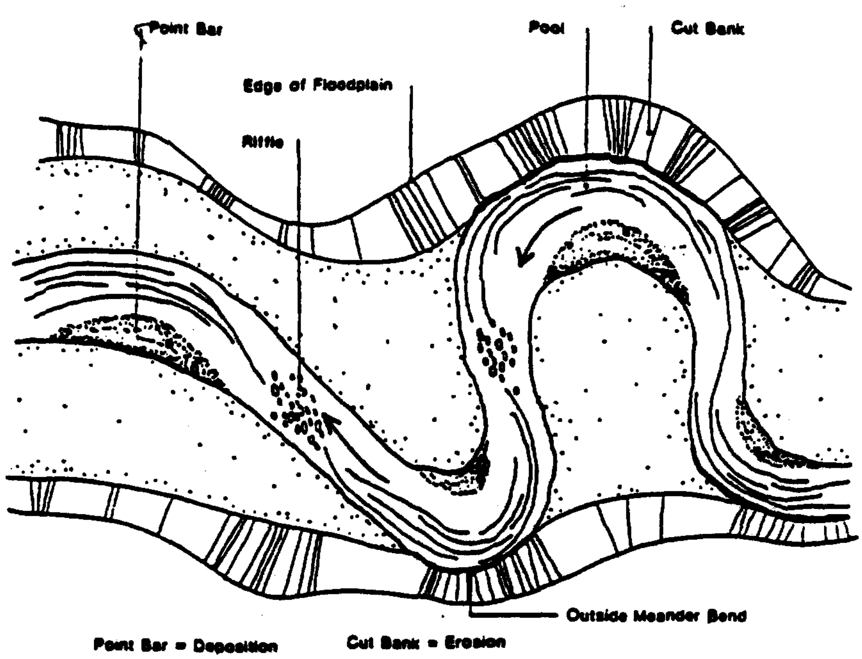


Figure 2. Streambank erosion and deposition. ***Streambank Stabilization and Management Guide***, Commonwealth of Pennsylvania Department of Environmental Resources.

V. REMOVING OBSTRUCTIONS

Log jams in the stream can contribute to degrading habitat and water quality by trapping debris and sediment and restricting flow. In general, it is always best to use the smallest equipment possible when removing obstructions and try not to disturb vegetation. If it is necessary to remove vegetation, disturbed areas should be replanted or sodded. (See chapter VI-D., Conventional Vegetation).

According to the **Minnesota Department of Natural Resources Division of Waters**, in their publication, *Streambank Erosion. . Gaining A Greater Understanding,*:

> Obstacles in the stream can be either natural or manmade. A natural obstacle could be a tree that has fallen into the stream, or the mass of soil that enters the channel when a bank collapses, for example. Examples of man-made obstacles are bridges, dams, or any other type of structure that will affect the flow in the stream. The effect of an obstacle is to alter the natural flow of water in the stream. Erosion or deposition can occur in the stream channel if the streamflow is altered significantly. If a tree that has fallen into the stream slows the velocity of the flow, then the suspended sediment will be deposited, forming a pointbar. Or perhaps some other type of obstacle will divert the flow from its normal path into the bank of a stream, causing severe erosion of the bank. Either one of these situations can cause problems directly, or they can indirectly create problems downstream as the stream adjusts itself to these new conditions imposed upon it.

The same handbook also points out that it is important to remove potential obstacles before they become a problem:

> A dead tree hanging over the stream can be considered a potential obstacle. By removing a potential obstacle before it falls into the stream, future erosion problems can be prevented, or the problem that was just eliminated can be prevented from occurring again. When a dead tree is removed, the stump and roots should be left in place, so that the roots can continue to provide support for the streambank.

Figure 3, from ***Stream Obstruction Removal Guidelines***, by the American Fisheries Society, illustrates how streams are affected by different types of obstructions and includes general and specific criteria for clearing obstructions.

Definition of Stream Obstruction Conditions

Condition One

These stream segments have acceptable flow and no work would be required. They may contain various amounts of instream debris and fine sediment, such as silt, sand, gravel, rubble, boulders, logs and brush. In certain situations flow may be impeded, but due to stream and land classification or adjacent land-use, this is not a problem.

Condition Two

These stream segments currently have no major flow impediments, but existing conditions are such that obstructions are likely to form in the near future, causing unacceptable problems. This condition is generally characterized by small accumulations of logs and/or other debris which occasionally span the entire stream width. Accumulations are isolated, not massive and do not presently cause upstream ponding damages.

Condition Three

These stream segments have unacceptable flow problems. Obstructions are generally characterized by large accumulations of lodged trees, root wads, and/or other debris that frequently span the entire stream width. Although impeded, some flow moves through the obstruction. Large amounts of fine sediment have not covered or lodged in the obstruction.

Condition Four

These stream segments are characterized by major blockages causing unacceptable flow problems. Obstructions consist of compacted debris and/or sediment that severely restricts flow.

Condition Five

These stream segments possess unique, sensitive, or especially valuable biotic resources and should be dealt with on a case-by-case basis. Examples include, but are not limited to: Areas harboring rare or endangered species, shellfish beds, fish spawning and rearing areas, and rookeries.

General Criteria

No stream work, including bank clearing, repositioning, or removal of material, should be allowed except at specific locations where unacceptable flow problems occur or may occur in the near future. Where stream work is needed, access routes for equipment should be selected to minimize disturbance to the floodplain and riparian areas (Figure 12). Channel excavation and debris removal also should be accomplished in a manner that minimizes clearing of vegetation. The smallest equipment feasible should be used. If tributaries or distributaries must be disturbed by the project, they shall be restored when the work is completed. All disturbed areas shall be reseeded or replanted with plant species which will stabilize soils and benefit fish and wildlife.

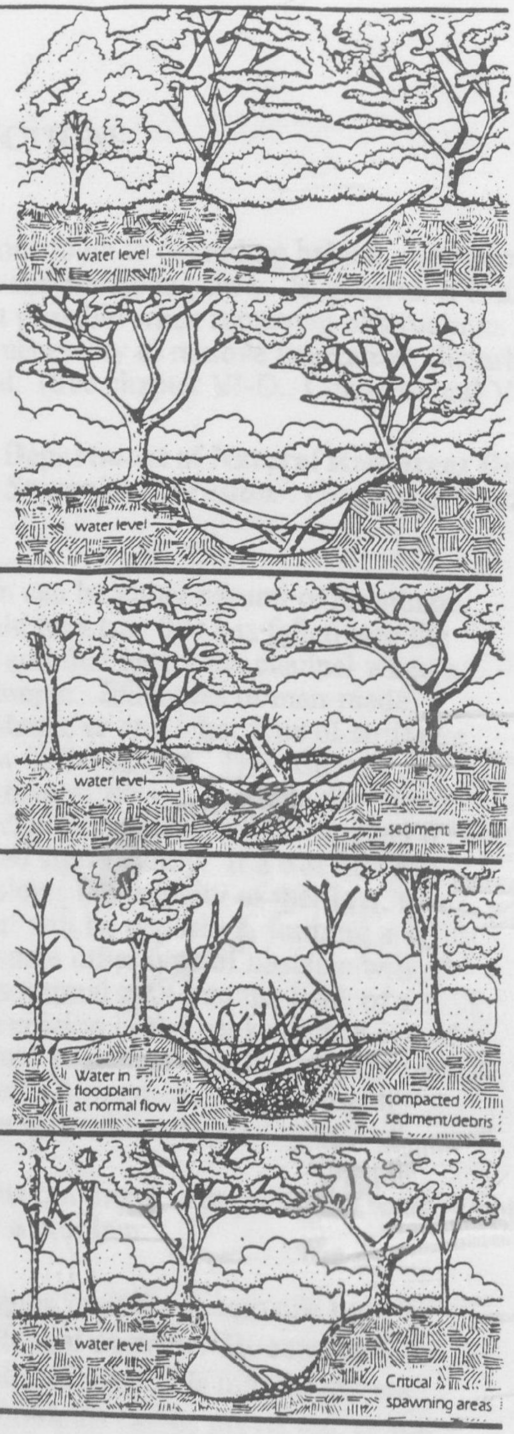
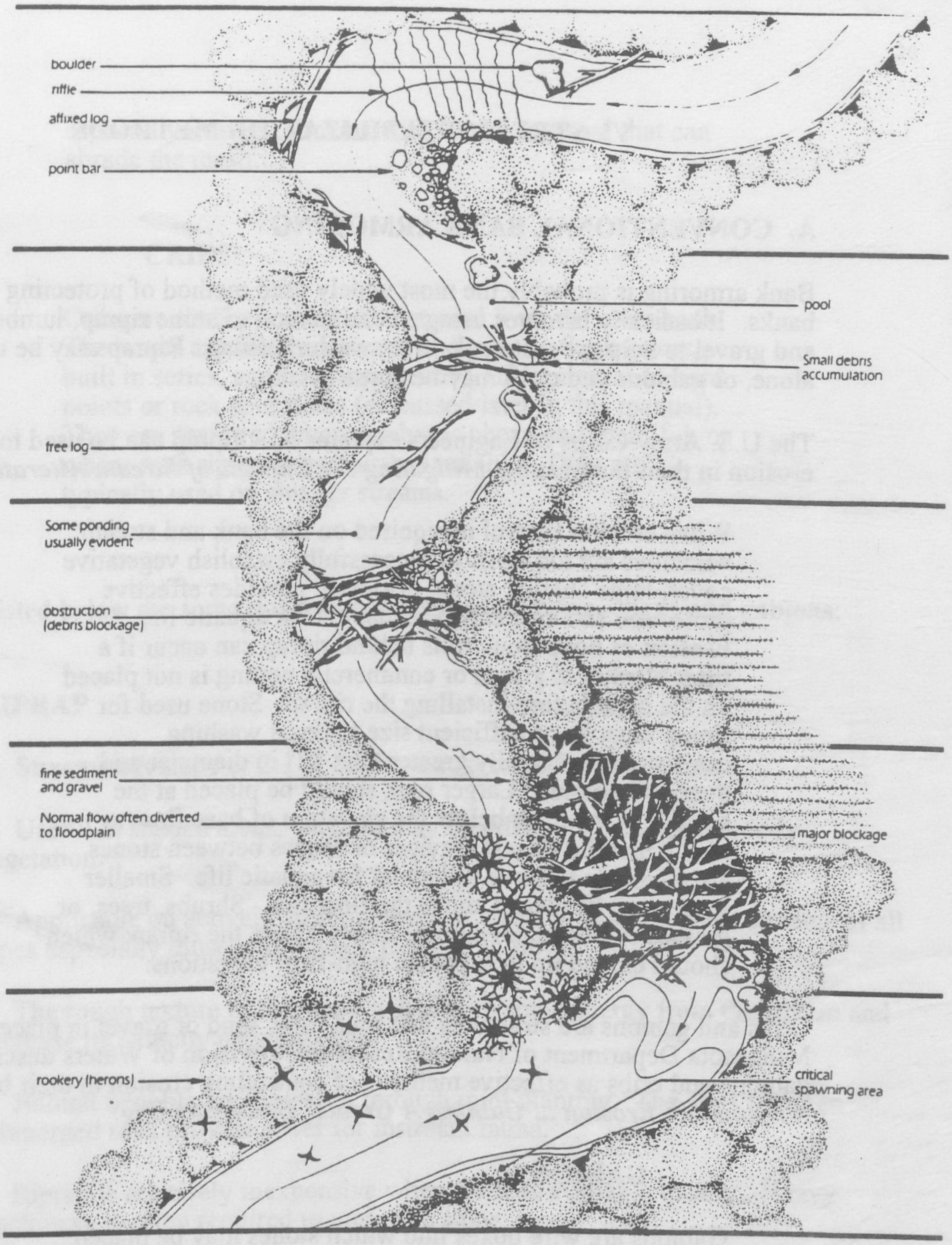


Figure 3. Stream Obstruction Removal Criteria, "Stream Obstruction Removal Guidelines," American Fisheries Society and the Wildlife Society.



Specific Criteria

Condition One Segments. No work shall be conducted in Condition One Segments.

Condition Two Segments. Equipment that will cause the least damage to the environment shall be selected for performing the work. First consideration will be given to the use of hand operated equipment such as axes, chain saws, and winches to remove accumulations (Figure 13). Boats with motors may be used where needed (Figure 14). When the use of hand operated equipment is not feasible, heavier equipment may be used. Examples include: small tractors, backhoes, bulldozers, log skidders, and low PSI equipment (Figure 15). Equipment shall be operated in a manner that results in the least damage to vegetation and soils of the project area. In some cases explosives may be used resulting in less damage. Debris designated for removal from the stream or floodway should be removed or secured in such a manner as to restrict its re-entry into the channel. Generally, it should be positioned so as to reduce flood flow impediment.

Condition Three Segments. Equipment limitations will be the same as for condition two segments. Work shall be accomplished within the channel or from one side of the channel where possible (Figure 16). Selective tree clearing shall be limited to the minimum clearing necessary for equipment access and efficient operation of equipment on the worked side of the channel. Disposal of material may be accomplished by removing it from the floodplain or by burning, burying, or piling, as appropriate, with the minimum amount of disturbance to vegetation. Piled debris shall be gapped at frequent intervals and at all tributaries and distributaries.

Condition Four Segments. Blockage removal may employ any equipment necessary to accomplish the work in the least damaging manner (Figure 17). Work should be accomplished from one side of the channel, where practical. Material shall be disposed in accordance with guidelines presented above for condition three segments (Figure 18). Spoil piles should be constructed as high as sediment properties allow. The placement of spoil around the bases of mature trees should be avoided.

Condition Five Segments. Special provisions for protecting unique, sensitive, or productive biotic resources shall be developed by appropriate professionals on a case by case basis.

VI. STREAM STABILIZATION METHODS

A. CONVENTIONAL BANK ARMORING

Bank armoring is probably the most widely used method of protecting eroding banks. It basically involves using a combination of stone riprap, lumber, sand, and gravel to help prevent banks from washing away. Riprap may be used alone, or gabions and cribs may be constructed.

The U.S. Army Corps of Engineers explains how riprap can be used to control erosion in their publication, ***Mitigating the Impacts of Stream Alterations***:

> When erosion control is required on the bank and stream velocities are too swift to successfully establish vegetative cover, large angular stone, or riprap, provides effective protection and also enhances habitat for aquatic life. Erosion of nonporous soils behind riprap can occur if a filter blanket of gravel or commercial netting is not placed on the bank before installing the riprap. Stone used for riprap must be of sufficient size to resist washing downstream-generally greater than 12" in diameter and over 100 pounds. Larger rock should be placed at the bottom of the bank below the elevation of base flow to insure that the largest crevices or spaces between stones are available to serve as habitat for aquatic life. Smaller stones can be placed above the flow line. Shrubs, trees, or grasses can be planted immediately above the riprap, which should extend up to expected high-flow elevations.

Cribs and gabions are structures that hold rock, sand or gravel in place. The Minnesota Department of Natural Resources, Division of Waters describes gabions and cribs as effective methods of controlling erosion in their book, ***Streambank Erosion ... Gaining A Greater Understanding:***

> **GABIONS:**
>
> Gabions are wire boxes into which stones may be placed. They are a commonly used substitute for riprap. The advantages are that smaller stones may be used in cases where suitable riprap material is either too expensive or not available, and the placement of the gabions is easier than placing riprap. The boxes may be stacked along the bank in whatever manner is most suitable to prevent collapse. No filter layer is required for the use of gabions, as opposed to riprap. Periodic inspections should be made, as the wire is subject to deterioration over the years,

especially in steep streams with coarse material that can abrade the mesh.

CRIBS:

Cribs are timber boxes built outward from the river bank. The boxes are filled with sand and gravel. Such boxes, built in series, can have a protective effect similar to hard points or rock spur dikes (discussed later in this manual). They are preferred where timber is cheap and plentiful, or where rock riprap is not easily available. They are typically used on smaller streams.

Listed below are some tips for constructing and using **riprap** and **gabions**:

RIPRAP

1. Streambank slope of 2:1 or flatter is suggested for best results.

2. Useful in shaded areas, where it may be difficult to establish woody vegetation.

3. Applicable on actively eroding banks of small to medium sized streams of all types especially those with widely fluctuating flows.

4. The rough texture of the stone will absorb some energy from the stream and decrease its velocity near the bank.

5. Habitat benefits are increased through joint planting. The gaps between submerged rock provide cover for instream fauna.

6. Riprap is relatively inexpensive when stone is available locally. Heavy machinery is often required to move the stone.

7. Because rock absorbs solar radiation readily it can thermally impact a stream especially in unshaded areas.

8. One-half of the bottom layer of stone should be below stream grade.

GABIONS

1. The effectiveness of gabions for stabilizing streambanks is improved when vegetation is incorporated.

2. Soil retention is improved when filter fabric is sandwiched between the soil and gabion basket. Some filter fabrics may inhibit the establishment of vegetation.

3. Appearance of the structure is improved through joint plantings. For successful plant growth, infertile soil must be covered with topsoil.

4. Maintenance costs increase with age as the wire baskets become corroded and abraded.

5. Gabions are useful for protecting steep banks where scouring or undercutting are problems.

6. Gabions are applicable on medium to large size streams of all types.

7. Rusting and corrosion of the wire baskets reduce the long-term durability of these structures.

Figures 4 and 5 illustrate examples of bank armoring techniques.

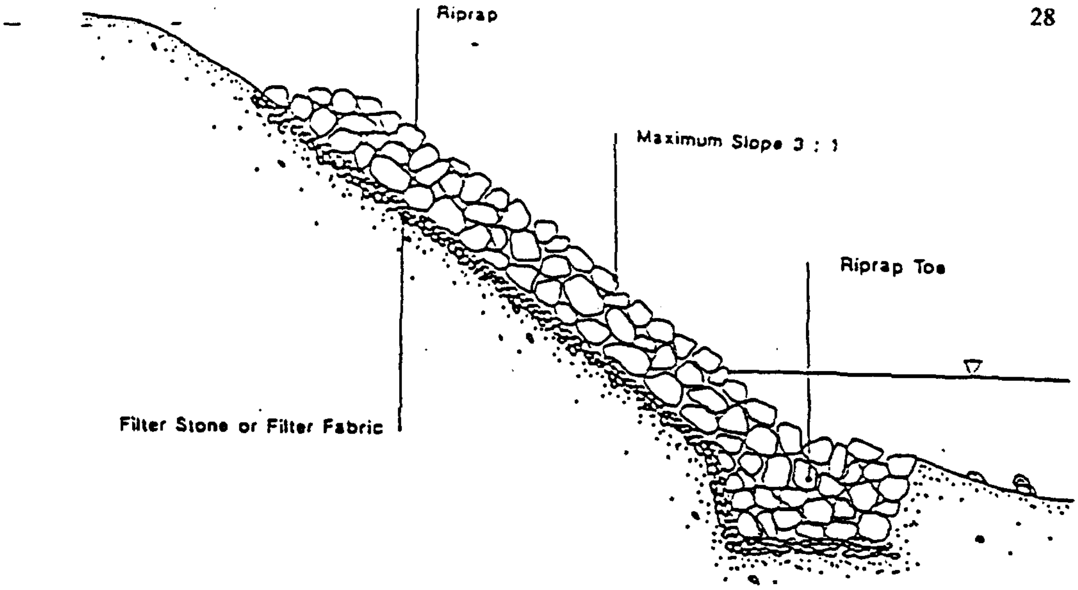


Figure 4. Riprap Construction, *Controlling Streambank Erosion*, April 1993 Draft, Georgia Soil and Water Commission.

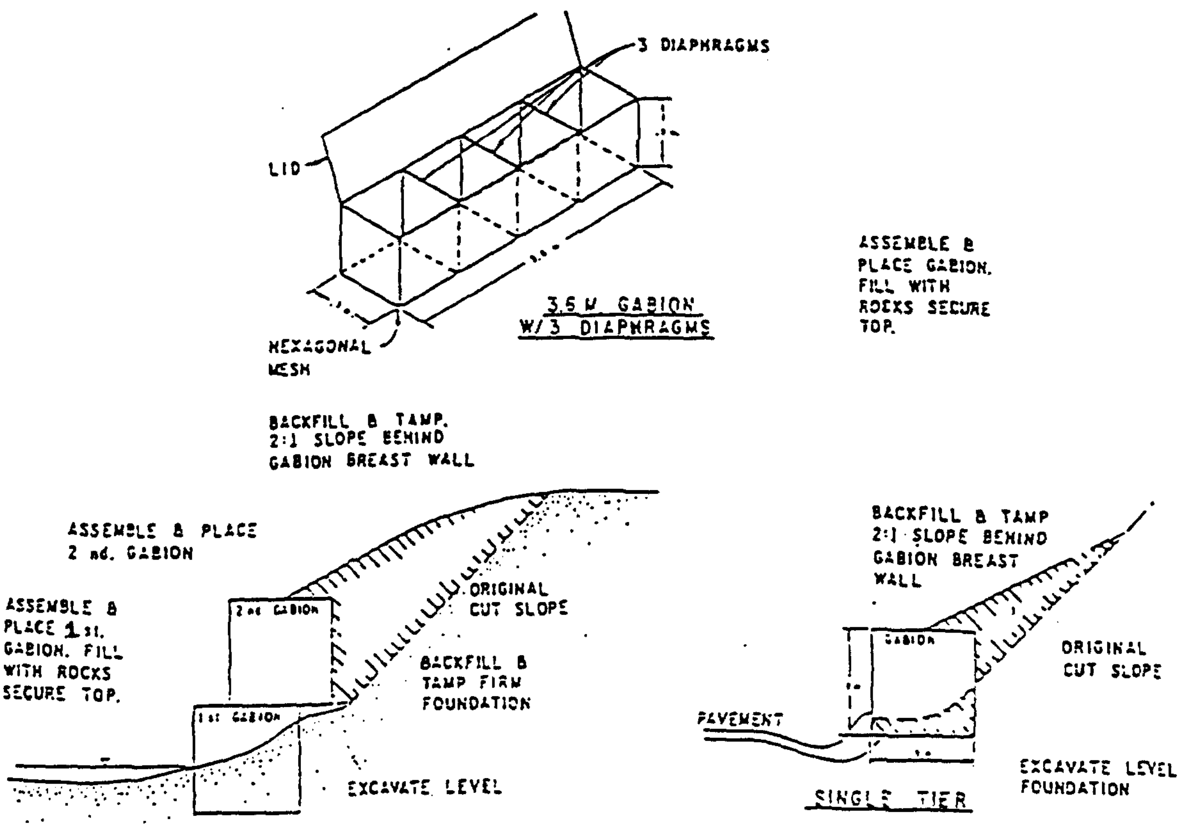


Figure 5. Gabion Construction, *Controlling Streambank Erosion*, April 1993 Draft, Georgia Soil and Water Commission.

B. STREAM STABILIZATION STRUCTURES

Severely eroded banks may benefit from stabilization structures built into the bank, such as hard points, jacks and posts, spur dikes, fences, and sheet pilings and walls. All of these structures function in a similar manner by trapping sediment and debris. The deposition of sediment allows trees, shrubs, and grasses to grow, which help to reduce erosion even more.

The Minnesota Department of Natural Resources Division of Water gives examples of stream stabilization methods such as fences, spur dikes, pile dikes, hard points, and jacks and posts publication, ***"Streambank Erosion ... Gaining a Greater Understanding"***:

FENCES

Fences composed of boards or wires can be used on small streams to serve a similar function as jacks and posts. The overall effect is to reduce flow velocities and induce deposition. The fences are placed in series much like jacks and posts, but may be placed either along the bank parallel to the current, or out into the channel like hard points.

Fences protect the upper portions of a bank only, and should not be used in cases where bank undercutting and bank toe erosion is a problem.

SPUR DIKES

Rock spur dikes are similar to hard points, except that they extend further into the stream. Their purpose is to deflect the zone of high velocity flow well away from the bank they are designed to protect. They may occasionally be used singly, as near a bridge site, but are usually used in a field. The spur dike furthermost upstream is often designed to be rather short, and to be angled in the downstream direction. The spur dikes farther downstream may be longer and more nearly perpendicular to the flow. A rough guideline for the design of spur dikes is that each dike protects a length of bank that is about twice the distance to which the dike protrudes into the stream.

Rock spur dikes are typically constructed by end dumping from trucks. A properly designed dike field can require less rock, and be less expensive, than riprap. On the other hand, the tip of each rock dike usually needs to be supplied with an extra stockpile of stone in order to counter severe local scour during floods.

PILE DIKES

Pile dikes are permeable dikes that consist of tied rows of timber piles driven into the streambed from the streambank outward into the stream channel. Like rock spur dikes, they are typically constructed in fields of more than one dike. They allow for considerable flow between the piles. The effect of the piles, however, is to slow the flow velocity in the region of the piles, which reduces the erosive force on the bank. An added benefit is the tendency for river-borne sediment to collect between the dikes. This action can result in the gradual re-deposition of a severely eroded bank. Pile dikes are suitable for sandy-bottomed streams with a good supply of suspended sediment. They are less suitable for coarse, steep rivers, where rock spur dikes are preferred.

HARD POINTS

Hard points are short spurs of rock or stone that extend from the bank into the stream. The purpose of a hard point is to stabilize the stream bank by creating a low velocity zone along the bank downstream of the hard point. In this way, hardpoints protect a streambank by reducing the velocity of the flow along the bank to a level that will not cause erosion. A hard point will protect approximately 5 feet of bank for each foot of hard point spur protruding into the stream. For example, a spur that reaches 20 ft. into the stream will protect 100 ft. of bank downstream of the hard point.

A hard point is made of two parts, the extension into the stream and the "root" that is buried into the bank of the channel. The root is typically the same length as the extension. Hard points are typically placed as a series of spurs in which erosion between the structures continues until equilibrium is reached. Because this erosion continues for a time after the structures are completed, hard points are not suitable for locations where no further erosion is acceptable. [See Figure 6.]

JACKS AND POSTS

Jacks and posts are structures placed along the bank of a stream which reduce flow velocities and induce deposition of sediment. The structures are joined together and placed along the bank to form a "field". Flow velocities are slowed within the fields due to the increase in resistance caused by the field. The sediment that is deposited as a result of this reduction in flow velocity serves as a suitable area for the growth of trees such as willows and cottonwoods, and underbrush. The growth of this vegetation further serves to protect the streambank by increasing its stability.

Jacks usually are constructed with concrete or steel beams (sometimes wood), with the most common configuration being three beams bolted together at right angles at their middles.
They resemble "teepees", which are then placed in fields by constructing one or more rows along the bank, and [are] anchored to both the bank and the channel bottom.

Posts serve the same function as jacks, but are not configured in the "teepee" shape. They are planted as vertical posts along the bank in the same type of fields as are jacks.

Steel cables are often strung between the jacks or posts to strengthen the field. These cables also catch debris, which serves to induce more deposition.

Jacks and posts are subject to damage caused by large debris and floating ice, as well as high-velocity flows which can lift the jacks or posts from the stream bed. Jacks and posts are ineffective in high velocity streams, and streams with low sediment loads because not enough deposition occurs. [See Figure 7.]

The methods described in this section help control erosion by providing a protective barrier between stream and bank, and by actually slowing the flow and directing the current away from streambanks. The methods used will depend upon stream conditions: jacks and posts are used on steep banks, while shallower channels can be improved simply by using hard points or dikes, which are easier to construct.

The following figures illustrate stream stabilization structures:

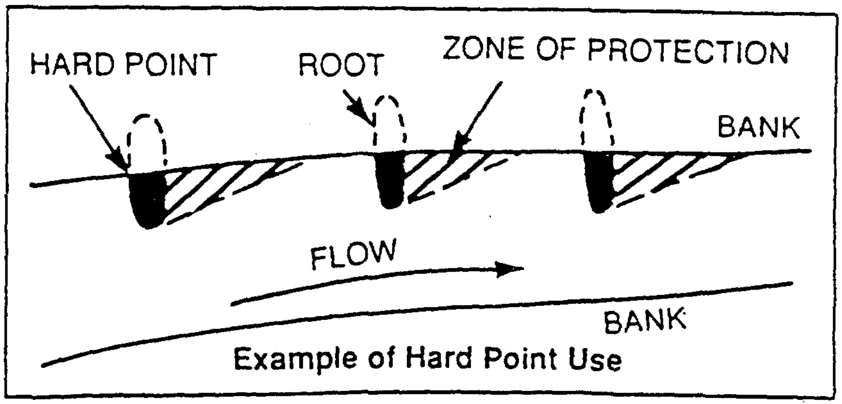


Figure 6 - Example of Hardpoints. ***Streambank Erosion... Gaining a Greater Understanding***, Minnesota Department of Natural Resources.

Figure 7 - Jacks and Posts. ***Streambank Erosion ... Gaining A Greater Understanding***, Minnesota Department of Natural Resources.

C. IN-STREAM STRUCTURES

Earlier in this book, obstruction removal methods were described. However, sometimes it is helpful to place trees *in* the streams. Tree revetments are carefully placed in the stream and anchored firmly in place (see Figure 8). The Missouri Department of Conservation describes tree revetments as "an inexpensive, effective way of stopping streambank erosion." Their publication, ***Tree Revetment for Streambank Stabilization***, describes how tree revetments help control erosion:

> The trees greatly slow the current along the eroding bank; this decreases erosion and allows silt and sand to be deposited along the bank and within the tree branches. The deposited material forms a good seed bed in which the seeds of river trees such as cottonwood and sycamore can sprout and grow. The resulting trees spread roots throughout the revetment and streambank. By the time the revetment trees have decayed, the bank should be stabilized by the roots of the living trees. As an added benefit, tree revetments provide excellent fish and wildlife cover. [See Figure 31.]

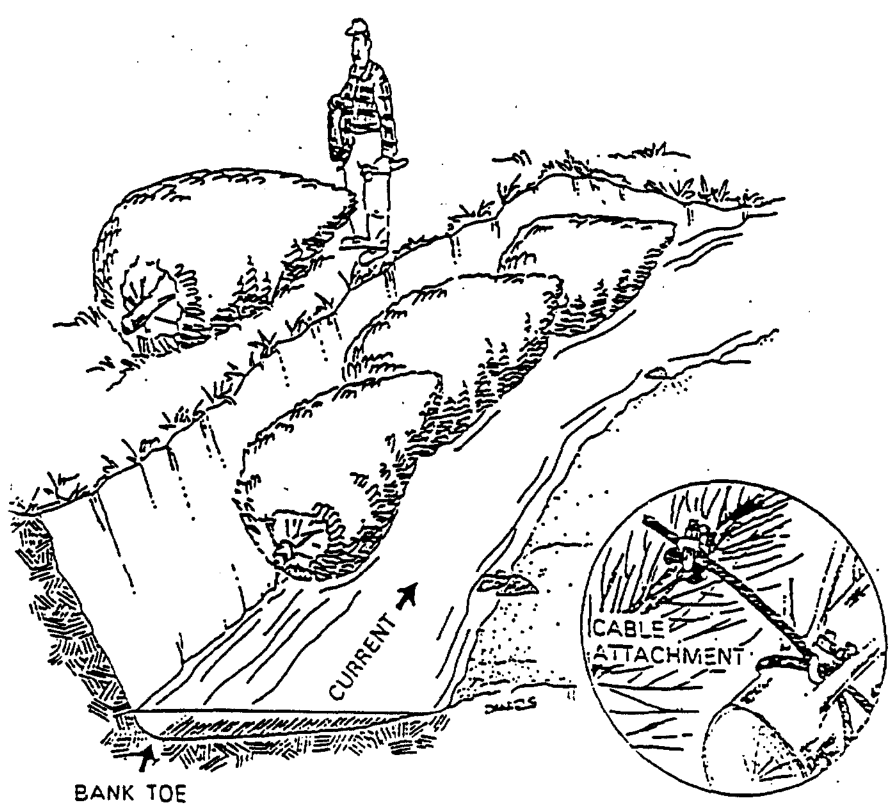


Figure 8. Tree Revetments Placement. ***Tree Revetments for Streambank Stabilization***, Missouri Department of Conservation.

The Missouri Department of Conservation gives the following pointers for building a tree revetment:

1. The more limbs and fine branches a tree has, the better it will slow current and trap silt in a tree revetment. For this reason, eastern red cedar is usually the best choice. Cedar trees have the added advantage of good resistance to decay. Hardwood trees with brushy tops (like pin oak) will also work.

2. Trees growing in uncrowded conditions are usually the best choice because their branches are denser. When growing in close competition with other trees, even cedars can have sparse tops.

3. It is best to cut live trees for revetments; trees which have been dead for some time are usually brittle and may break apart as they are moved into place and anchored.

4. Tree size is important. The diameter of the tree's crown should be about two-thirds the height of the eroding bank. A large tree covers more bank than a small one and isn't much more difficult to move into place. Both time and money can be saved by using the biggest trees available. Trees that are more than 20 feet tall are best for most streambanks.

5. After felling trees, it is best to cut off any trunk at the bottom of the tree that is without limbs. The tree limbs are what protects the bank--any excess trunk is simply extra weight that makes it more difficult to move the tree into place.

6. Extreme caution should be used in operating heavy equipment to move the trees. Trees should be well anchored on both ends and the butt ends should be placed upstream. Tree revetments work best on streambanks less than 12' high. There should be no gaps left between revetments.

Wing deflectors help to direct flow away from banks and to the middle of the channel. Table 1. provides good information about where to place instream structures in low to high gradient streams. Dams and weirs provide gradients in otherwise wide, shallow streams, helping to create pools and scour area, which enhance aquatic habitat and attract fish. The turbulence caused by these instream structures also increase dissolved oxygen, important to fish and wildlife. Instream structures are described in ***"Best Management Practices for Improving Water Quality in the West Sandy Watershed,"*** **(Gore, Finley, Hamilton).**

DAMS

The advantages of low-head dam (weir) placement are numerous and include: formation of pool habitat, collecting and holding spawning gravels, encouraging gravel bar/riffle formation, improving flow patterns, trapping suspended sediments, reoxygenating water, allowing organic debris deposition and promoting invertebrate production.

Siting considerations for weirs in general are:

[1] they are most successful in low order streams where maximum discharges generally do not exceed 6 m3/s,

[2] location is best in a straight, narrow reach at the lower end of a steep break in gradient,

[3] banks should be stable and well defined,

[4] it should be possible to anchor both ends of the dam well into the banks (say, 2 m or more),

[5] successive structures should be placed no closer than 5 to 7 channel widths apart,

[6] availability of natural construction materials can make a project much more economically feasible.

There are essentially two types of low-cost construction materials to build weirs for habitat restoration: boulder/rock material and logs, depending upon local availability.

Rock/boulder dams are ideal for very small streams and is less expensive than log dam construction but require a source of quarried rocks and availability of large flat rocks and availability of heavy construction equipment (especially a back-hoe). A seal is provided by packing gravels in between boulders and on the upstream side of the large boulders. If successful, habitat can be enhanced both upstream and in the plunge pool. Of course, this is a natural looking and aesthetically pleasing structure. Problems have been reported with sealing the large flat boulders, the lack of stability during high flow events, and some collapsing into the plunge pool. **[Editors note: We have successfully solved the sealing problem by enhancing the structures with mylar and other synthetic sheeting.]**

Log dams can be designed in a variety of forms to fit the location and desired pool height. Anchoring the logs is of prime consideration and should be considered best when set into the stream at least one third of the channel width. Undercutting is a main cause of failure so the base logs should be imbedded at least 0.2m [6.5']. When the bed is erodible, a mud sill should be added to the upstream face and the downstream plunge pool should be lined with large gravel and small cobbles. To reduce endcutting, the log ends anchored into the substrate should also be riprapped. Life of log dams is enhanced by keeping as much of the logs [as possible] continually wetted. Indeed, a small amount of overflow in addition to that portion going through the "spillway" notch will reduce rot and decay. (See figures 9 and 10, Rock and Log Dams.)

DEFLECTORS

Deflectors are the most commonly used habitat restoration structure in North America as they are relatively inexpensive and can be modified for each location and built with local materials. These appear to be the best generic enhancement structure and the literature is replete with success stories, including a doubling of fish production within a year and significant increases in pool-riffle sequences within three to five years. The hydrologic result of placement of deflectors is the natural formation of scour pools, shelter pools, and riffles while double wings lead to the formation of deep scour pools. In addition, the thalweg [channel] becomes more sinuous resulting in a longer residence time for the water and a greater variety of velocities and depths in any given channel reach.

General siting criteria for deflectors are listed below:

1. Typical placement is in wider, shallow, lower gradient streams lacking pools and cover.

2. Reaches with great variation in water surface elevation should be avoided or construction should be designed to fit low flow conditions.

3. The bank opposite the deflector must be stable or it must be provided with some sort of bank protection such as riprap.

4. Unstable substrates must be avoided; if this is not possible, then upstream sides must have a mudfill and downstream substrate must be armored with gravel and cobble for high flow periods, when undercutting may occur.

5. Alternating deflectors 5 to 7 channel widths will provide a natural sinuosity of the flow.

6. Conditions must be such that deflectors can be anchored at least 2 m [6.5'] into the bank.

7. Use of natural materials enhances low cost considerations.

Rock and boulder low-head dam construction. Adapted from Gore (14).

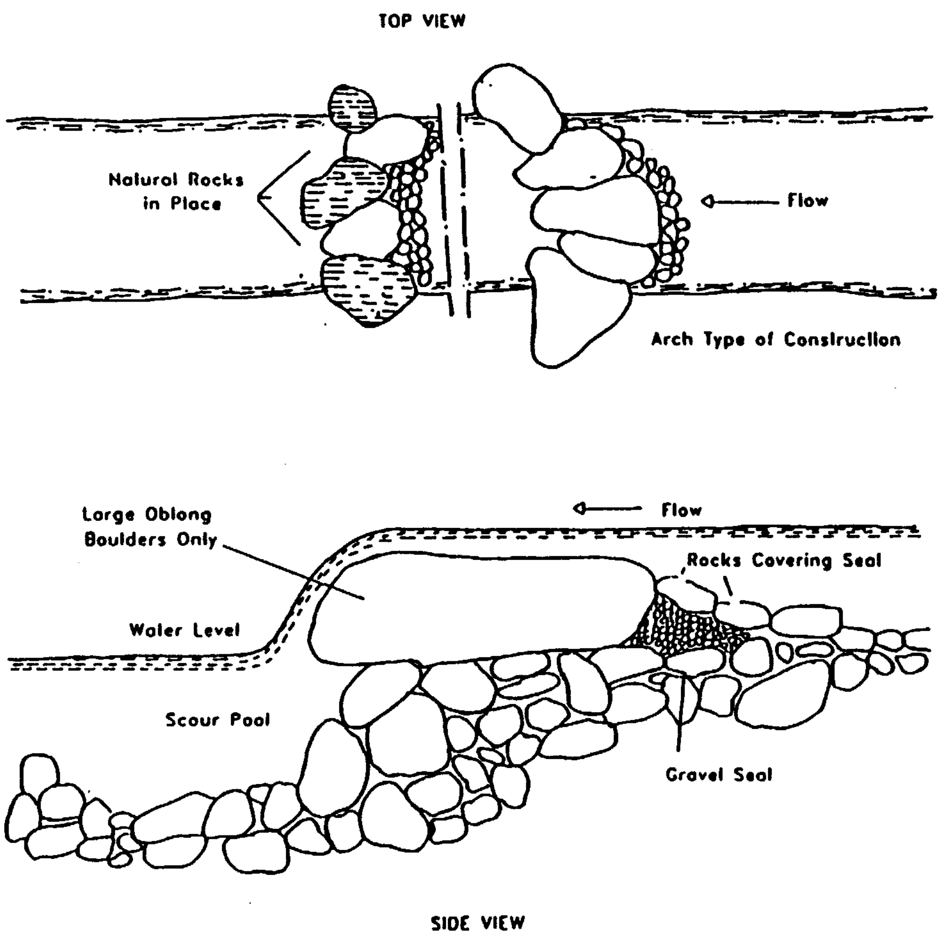


Figure 9. Rock Dam Construction, The Restoration of Rivers and Streams-Theories and Experience, James Gore.

Construction details of most commonly used and most effective low-head log dam (weir) structures. Side views are looking upstream. Support structures on K-dam are on upstream side.

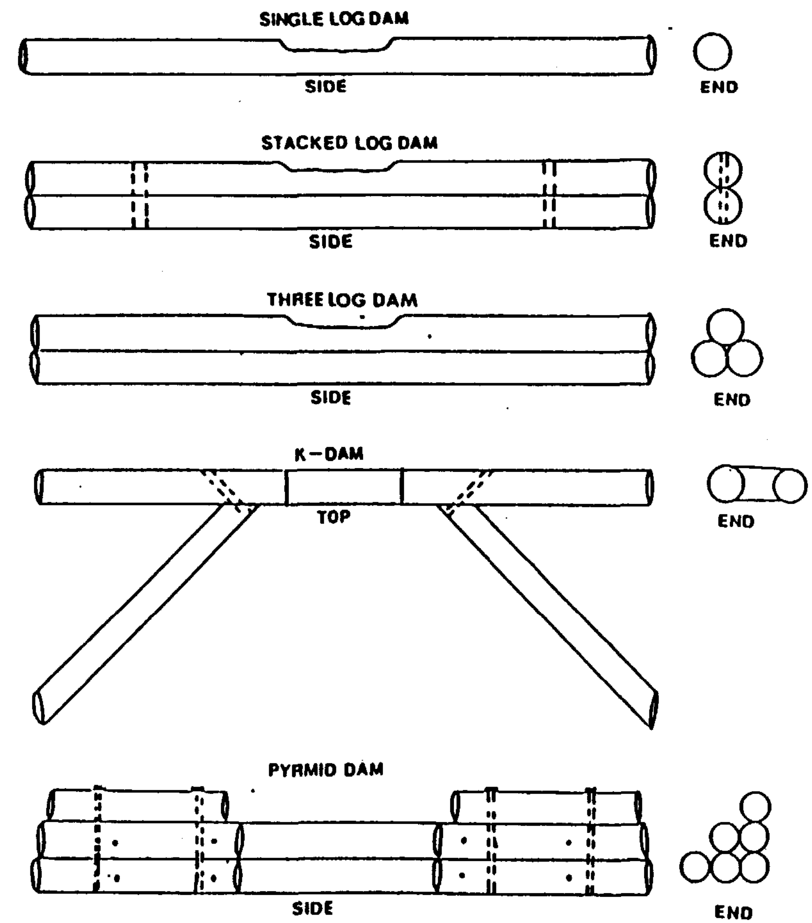


Figure 10. Log Dam Construction, The Restoration of Rivers and Streams-Theories and Experience, James Gore.

> Construction alternatives include log-boulder deflectors, gabion deflectors, and V-deflectors for mid-stream separation of the flow. Typically, the deflector is angled downstream at approximately 45 degrees from the flow while the back brace is set at approximately 90 degrees from the deflector. To avoid damage to the deflector, the maximum elevation should [be] no greater than 0.3 m [1'] above the low flow water surface elevation. V-deflectors can be effectively used in areas where there exists high bank stability. Otherwise, these should be avoided, as they tend to channel flow into areas where energy is dissipated by bank erosion. A typical layout of deflectors would include a series of from 5 to 10 deflectors with the most downstream deflector being a double-wing deflector to channel the thalweg down the center of the unmanaged and unregulated portion of the channel.

Although habitat enhancement has been focused mainly on the restoration of fish communities, these same techniques can be used to enhance benthic macroinvertebrate communities as well. Benthic macroinvertebrates provide the food base for a stable fish population and a dynamic lotic community. According to Gore, from his book, ***The Restoration of Rivers and Streams - Theories and Experience***, benthic cobble beds, which are formed downstream of deflectors and in the pools of low head dams are ideal for benthic macroinvertebrate habitats. The improved water quality, including increased velocity and depth, attract macroinvertebrates to these restored areas. These habitats should be fully colonized in 2-3 weeks under optimum conditions, which include moderate flows. Spring and fall are the best times to establish benthic communities. Under these circumstances the benthic community could become stabilized within 3 months. Optimum conditions include adjacent sources of colonizers from both upstream and downstream unimpacted areas of the same stream. If these conditions are not met, stabilization of communities could take considerably longer. Without downstream or upstream sources of recolonizing fish and invertebrates, recovery has been reported to take five years or longer (Gore and Milner 1990). Part of any restoration or rehabilitation plan should include protection of adjacent areas which serve as nurseries or sources of colonizers. (See Figure 11, Instream structures; and Figure 34, Rock, Gabion or Log-Frame Deflectors.)

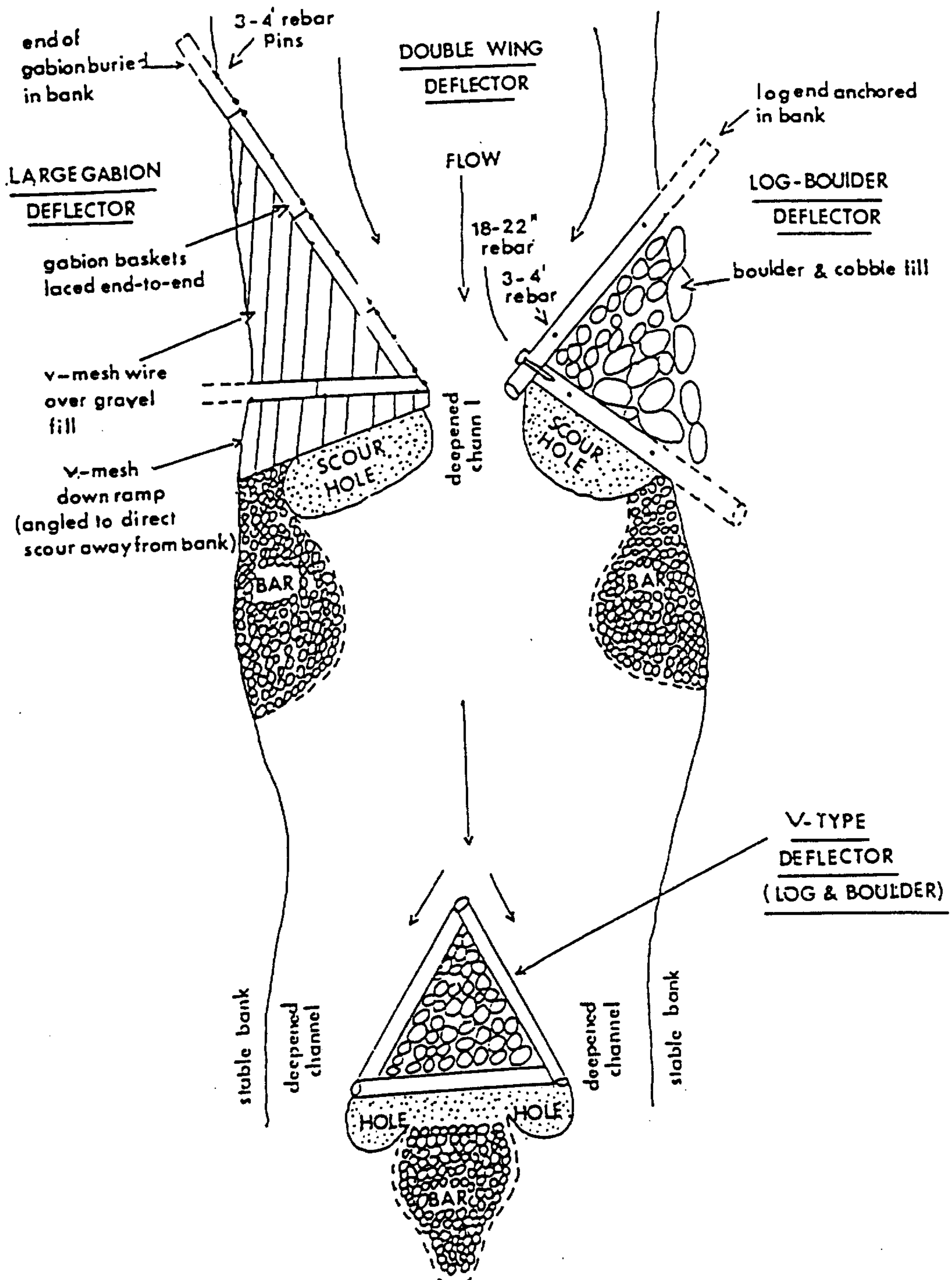


Figure 11. Diagram of Instream Structures Within a Stream Channel, The Restoration of Rivers and Streams-Theories and Experience, James Gore.

LOW GRADIENT STREAMS (SLOPE LESS THAN 1.5%)				
Structure	Stream width in meters(approximate feet)			
	Less than 5.0 (15)	5.0-9.0 (15-30)	9.0-15.0 (30-50)	Over 15.0 (50)
Boulders	3 boulders randomly placed in thalweg (Fig.4) below deflector	6 boulders randomly placed in thalweg deflector	9.12 clumps of 3 boulders randomly placed in thalweg below deflector	12-25 clumps of 3 boulders randomly placed every 30 m (100 ft.)
Deflectors	Single and double wing	Single and double wing	Single and double	---
MEDIUM GRADIENT STREAMS (slope 1.5 - 6.0%)				
Boulders	3 boulders randomly placed in thalweg below deflector	6 boulders randomly placed in thalweg below deflector	9-12 clumps of 3 boulders randomly placed in thalweg below deflector	12-25 clumps of 3 boulders randomly placed every 30 m (100 ft.)
Deflectors	---	Single and double wing	Single and double wing	---
HIGH GRADIENT STREAMS (slope more than 6.0%)				
Boulders	Boulders randomly placed 7.5-15.0 m (25-50ft.) apart	Clumps of 2-3 boulders randomly placed 7.5-15.0 m (25-50 ft.) apart	---	---
Low Water Dam	located 25.0-30.0 m (80-100 ft.) apart	---	---	---

Table 1. Use of Instream Structures in Low to High Gradient Streams. *Riparian Forest Buffers*. U.S. Department of Agriculture Forest Service.

D. CONVENTIONAL VEGETATION

Planting vegetation helps to stabilize banks as root systems help hold soil in place. In addition, roots provide cover for animals and plant matter provides food for these organisms. Shrubs and trees help maintain temperature by shading the water. Plants also help trap sediment as it washes off fields and prevent some of it from entering streams and rivers. Vegetation is important in controlling erosion. A combination of trees, shrubs and grasses and plants should be used to provide variety. Conventional methods involve planting, seeding, sodding and using fabric blankets. Vegetation may need to be combined with bank armoring on steep or severely undercut banks. There should be adequate topsoil to allow root penetration and native, flood-tolerant plants should be used. The type of vegetation depends on the zone it is planted in. The three major zones are the splash zone, the bank zone, and the terrace zone (See Figure 12.) Hollis Allen with the U.S. Army Engineer Waterways Experiment Station describes basic vegetating techniques in the report, ***Streambank Protection With Planted Vegetation***:

> The entire streambank should be treated to furnish a maximum array of plants capable of providing proper ground cover for erosion protection, wildlife habitat, and to be aesthetically appealing. At times, the planting sites or zones may be quite narrow in width or difficult to distinguish. The entire bank in these cases should be treated as a systematic arrangement of plants and treatment practices.
>
> Splash zone. This zone should be planted with primarily reeds, rushes, sedges, and other semi-aquatic plants. This zone cannot be successfully planted by seeding since the zone is inundated most of the year. Transplanting during low water periods is the most practical approach. Three methods of transplanting are recommended: sprigging, sodding, and use of reed rolls.
>
> *Sprigging* is simply just digging, separating, and planting individual plant stems (sprigs) with some roots or rhizomes attached. All species should be planted at a rate of 40 sprigging bushels per acre. Sprigs are placed in holes or narrow trenches so that only aerial sprouts are above the soil (See Figure 13).
>
> *Sodding* is a method in which clumps of grass or herbaceous plants and soil are lifted from existing beds and transplanted to the disturbed sites. Small sections or plugs (2-4 inches in width and 4-6 inches in length) can be dug

and lifted from wild-land sites or nursery or greenhouse grown. The plugs are placed at a depth in the soil which allows the aerial parts of the plant to be exposed. Large rolls of sod also can be lifted and field planted on areas where surface stability is critical. Sections of sod containing reeds, reed grasses, rushes, or sedges can be dug or lifted from native plant communities using large diggers, front-end loaders, backhoes, etc. The sod or root mass is then transferred to the planting site and planted (See Figure 14).

Reed rolls are very good to use in the splash zone. They are constructed by combining sections of sod, rhizomes, and shoots, and enclosing them within a wire net and placing all components in a trench. Various herbaceous plants can be planted in this manner, but the method particularly lends itself to bulrushes and reed grasses such as common reed (Phragmites australis)* and reed canary grass (Phalaris arundinacea). * [**Editor's note: These species can be invasive into natural communities. Please encourage contractors to use varied native species for this process.]**

A trench about 16 inches in width is dug into the bank; wire netting is stretched across the trench; course gravel, sod and reed-clumps are placed in the wire net; and the wire is then drawn around the material and tied with wire. A row of stakes or planks are placed on each side of the roll and attached to the wire for stability. The whole system is then covered just enough to leave aerial stems exposed. The upper edge of the roll should not be more than 2 inches above ground level. A plant roll is an adaptation of this and simply is a cylinder of burlap that encloses planted material by and fastening with hog rings or sewing the edges together.

Bank zone. This zone may be exposed to considerable flooding and wave and current action. If only mild wave and current action is expected, sodding of flood-tolerant grasses like reed canary grass, buffalo grass (Buchloe dactyloides), or switchgrass (Panicum virgatum) can be employed to provide rapid bank stabilization. Usually, the sod must be held in place with wire netting or stakes.

Shrub-like willow, dogwood, and alder transplants or 1-year-old rooted cuttings are effectively used in this zone and can augment the sodding practice. These transplant or cuttings should be planted 1 to 2 feet apart and in rows. Newly planted banks are usually subject to additional erosion and the shrub plantings should have mulch placed over them to serve as temporary protection. Branches of woody plants are best for this and should be the heaviest on outside curves of the stream where the current strikes the bank. The mulch should be tied town with chicken wire or wire laced between stakes since the mulch may float away when flooded.

Where severe erosion is expected, the bank zone should be further protected using a combination of supportive measures. Supportive measures that have been used successfully in Europe and other areas include willow barriers, fascines, wattles, and stone paving with willow slips among the stones.

Willow barriers or mats are interlaced willow switches 2 to 3 years old and 5 to 6 feet long that are placed perpendicular to the bank. The switches are cut from live willow plants and kept moist until planting. The willow switches will sprout after planting, but care must be taken to obtain the switches early in the growing season before the mother stock has started to grow extensively. Switches are only 0.4 to 0.6 inches apart and are placed together in a 6-inch deep excavation that is filled in later. The spread willow switches are held together and in place by wire or by willow hurdling (willow branches used as strapping) fastened to stakes. The whole barrier is lightly covered with earth so that the branches are set in each, but not completely covered.

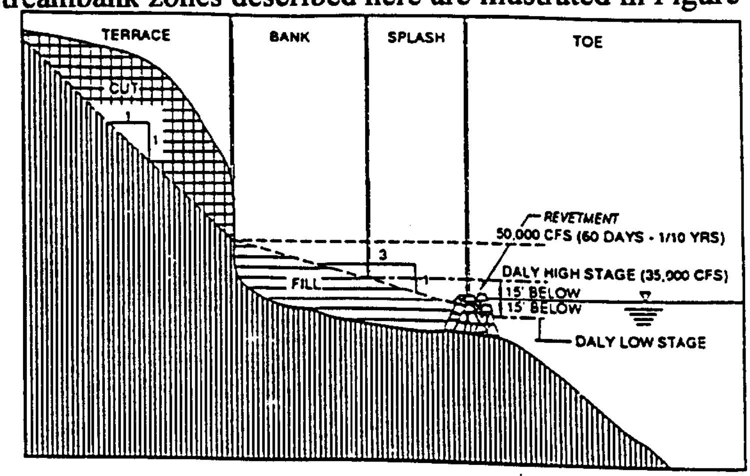
Seeding of grasses can be used in addition to sodding, root pads, and the above supportive measures, but should be used primarily on gentler sloping sites where current and wave actions do not greatly impact.

Terrace zone. The terrace zone can generally be planted by direct seeding and transplanting unless the slopes are greater than 1 V:3 H. Then, they are likely to need surface netting and mulching. Supportive structures such as fascines, wattles, etc., and sodding may be required on slopes of 1 V:1 H.

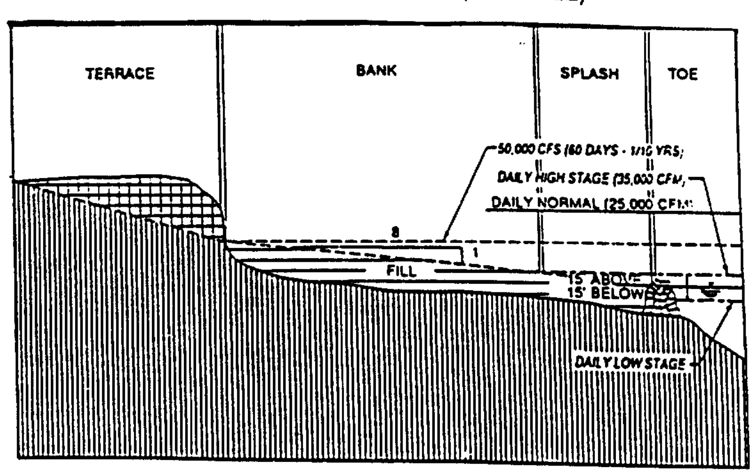
Hydroseeding can be a useful and effective means of direct seeding, particularly on steep slopes. Often barges with hydroseeders mounted on them can be floated on the stream and employed adjacent to the site. Seeds should be blown on first in a water slurry and then mulches applied following seeding to reduce soil moisture loss. The mulch also will tend to tie down and cover the seeds and reduce immediate surface soil erosion by wind and water.

Sometimes surface drainage water intercepts the terrace zone from inland areas and can cause gullying not only in the terrace zone, but in the other zones on the bank. This water should be diverted or controlled with a small furrow or trench at the top of the bank. This trench should be sodded to prevent erosion.

The streambank zones described here are illustrated in Figure 12 below:



1 MAXIMUM SLOPE LIMITS (NO SCALE)



2 MINIMUM SLOPE LIMITS (NO SCALE)

Figure 12., Streambank Zones. "Guidelines for Streambank Erosion Control Along the Banks of the Missouri River from Garrison Dam Downstream to Bismarck, South Dakota", L.D. Logan, U.S.D.A. Forest Service.

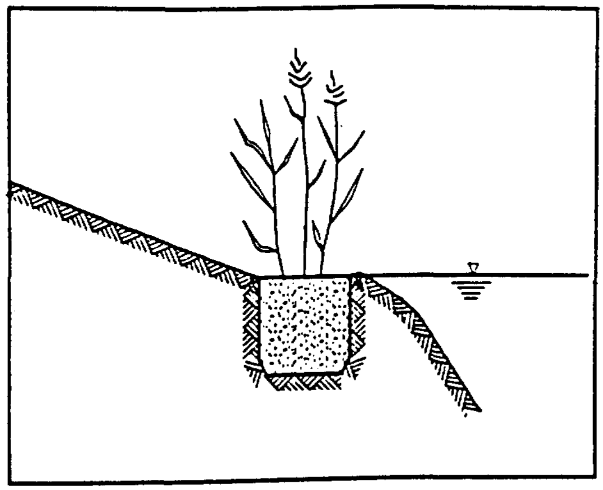


Figure 13. Sprigging, "Guidelines for Streambank Erosion Control Along the Banks of the Missouri River from Garrison Dam Downstream to Bismarck, South Dakota," L.D. Logan, U.S.D.A. Forest Service

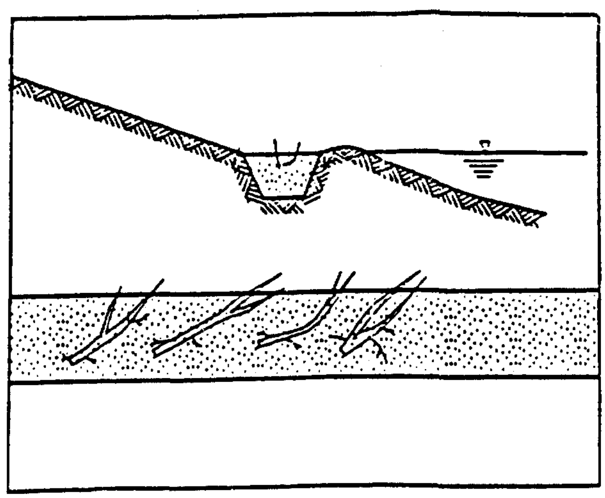


Figure 14, Sodding, "Guidelines for Streambank Erosion Control Along the Banks of the Missouri River from Garrison Dam Downstream to Bismarck, South Dakota," L.D. Logan, U.S.D.A. Forest Service.

E. SOIL BIOENGINEERING

The term, ***soil bioengineering***, describes several methods of establishing vegetation by embedding live plants into streambanks. Soil bioengineering provides all the benefits of vegetation (i.e., streambank stability, habitat, food source for aquatic animals, cover and temperature control) much more quickly than conventional planting. Some involve planting dormant twigs or rolls of live plants, or installing floating islands or breakwaters. These methods can be used separately or in combination. Some work best on shoreline or areas where there is little fluctuation in water levels. Others help to control erosion from streams subject to frequent flooding.

Several bioengineering techniques are described by Hollis Allen in the report, ***"Reservoir Shoreline Revegetation Guidelines"***, below:

> **Wattling bundles.** Wattling bundles are cigar-shaped bundles of live switches of willow or other easy-sprouting woody species that are tied and placed in trenches, staked, and partially covered with soil. Wattling bundles are usually placed on contour, starting at the bottom of a slope and working up.
>
> Wattling bundles have several advantages... energy dissipation, temporary stabilization to allow establishment of other vegetation, sediment entrapment, and lower cost than traditional engineering approaches for bank protection. Disadvantages of wattling bundles are that they are labor intensive, and appropriate woody species are sometimes difficult to locate and acquire in the necessary quantities.
> (See Figure 15.)
>
> **Brush layering.** Brush layering is a technique in which cut, live woody branches (willow, hybrid poplar, etc.) are successively placed in V-like trenches along contours on a slope. The bottom of the trench should be sloped slightly downward so as to catch and retain water. The cut material may vary in length depending on the depth of trench one can dig into the reservoir shoreline but generally will range in length from 0.5 to 1.0 m.[1.5-3']... Branches should be long enough to reach moist soil back in the sloped bank. Cut branches should be laid in a crisscross pattern, and branch ends should not protrude excessively over the lip of the trench. Excessively protruding branches (>15 cm) [or .>3"] could dry the live plant material and kill it.

Brush layering has the same advantages as wattling bundles except that it can be partially installed by machinery when slopes are shallow enough in gradient to support machinery. Graders or bulldozers can cut the trenches with their blades so that field crews can lay the branches of plant material in the trenches by hand. Brush layering has the same disadvantages as wattling bundles. (See Figure 16.)

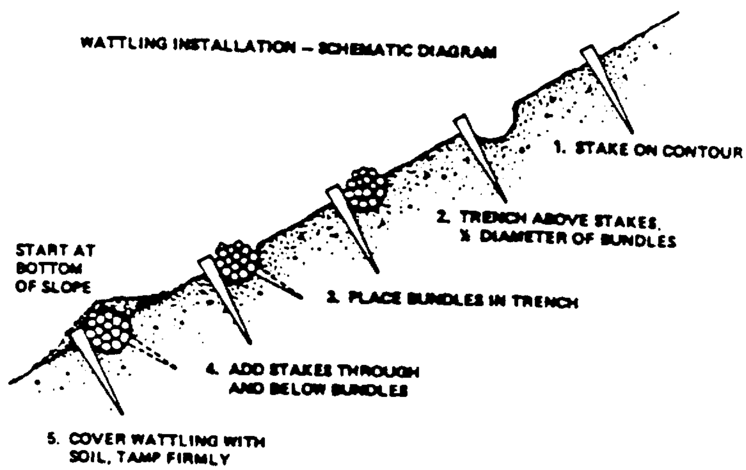


Figure 15. Wattling Installation, "Reservoir Shoreline Revegetation," A.T. Leiser.

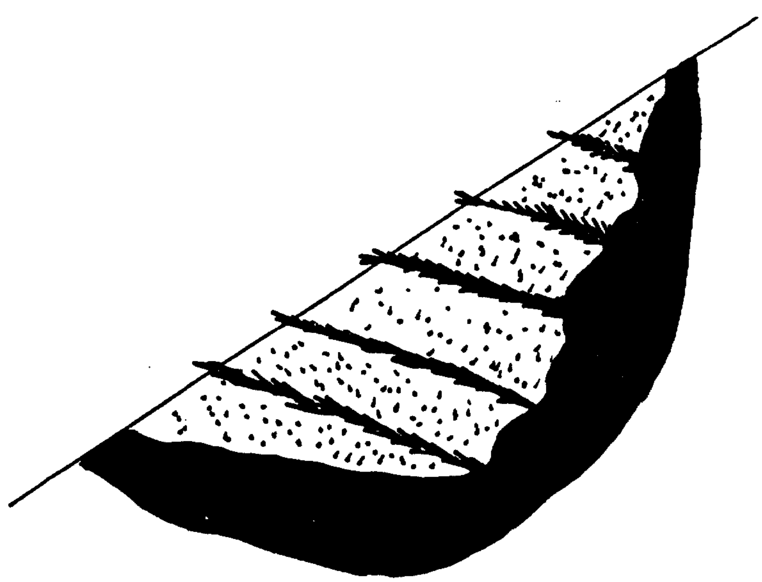


Figure 16. Brush Layering, "Reservoir Shoreline Revegetation," A.T. Leiser.

Brush mattress or matting. This procedure is also commonly used in Europe for streambank protection... It involves digging a slight depression on the bank and creating a mat or mattress from woven wire or single strands of wire and branches from sprouting trees or shrubs. The branches may be placed in the depression with or without woven wire. In either situation, live, freshly cut branches are tied down by a combination of stakes and woven wire or a network of wire or other material to hold them in place. Branches can vary in length but are normally cut 1.0 to 3.0 m long and 1.0 to 2.5 cm in diameter. The branches are crisscrossed and turned alternately so that the butts protrude slightly out of opposite sides of the mattress. This crisscrossing and alternate facing of branches creates a more uniform mattress with few voids. The branches are laid down and covered, staked, and tied with wire; then the structure is partially covered with soil and watered. Covering with soil and watering several times in succession will fill the air pockets with soil and facilitate sprouting. The structure is covered with only enough soil so that some branches are left partially exposed on the surface.

The brush mattress has the advantage of covering a large surface area with live sprouting material in a fairly short period of time. It provides protection from animals digging out the plants because of the wire and soil cover. It is also resistant to waves and currents. Disadvantages of brush mattresses are that: (a) they can be covered with too much sediment if laid flat on a sandy bank, which will smother the vegetative material and prevent sprouting, (b) additional cuttings or transplants are difficult or impossible to later plant through the matting, and (c) [insert] the mattress into an excavation at the toe of the slope and anchor it with wattling bundles at the toe. A light stone bolster at the toe of the mattress also aids in anchoring and preventing undercutting. (See Figure 17.)

Revetment or crib structures. Other more expensive and elaborate structures have been recommended for shoreline protection of streams and reservoirs and may be appropriate where banks are almost vertical.

The "pile and fascine revetment" is a structure in which either timber or metal piles are driven in front of an eroding bank and spaced on about 2-m centers; they are driven below the scour level, with tops extending above the normal pool level of the reservoir. Fascines are bundles of brush or tree branches (similar to wattling bundles) that are placed horizontally between the piles and the bank; then, the brush or branches are weighted down with soil and sandbags. before the plant material is placed, a woven wire fabric is fastened to the back side of the piles and secured to the top cable, interconnecting the piles.

Another type of structure that has been used on streambanks and along waterways is a timber crib wall where sprouting woody branches are layered between the stretchers. Stretchers are placed lakeward [or streamward] of the slope, with headers installed into the slope perpendicular to the cribbing. Successive lifts of live brush with soil placed on top of it are sandwiched between each layer of stretchers. Gray and Leiser (1982) include drawings and specifications for several different kinds of crib walls. Such a structure coupled with vegetation has great potential for controlling erosion on reservoir shorelines, but has not been used extensively for that purpose in the United States. (See Figures 18 and 19.)

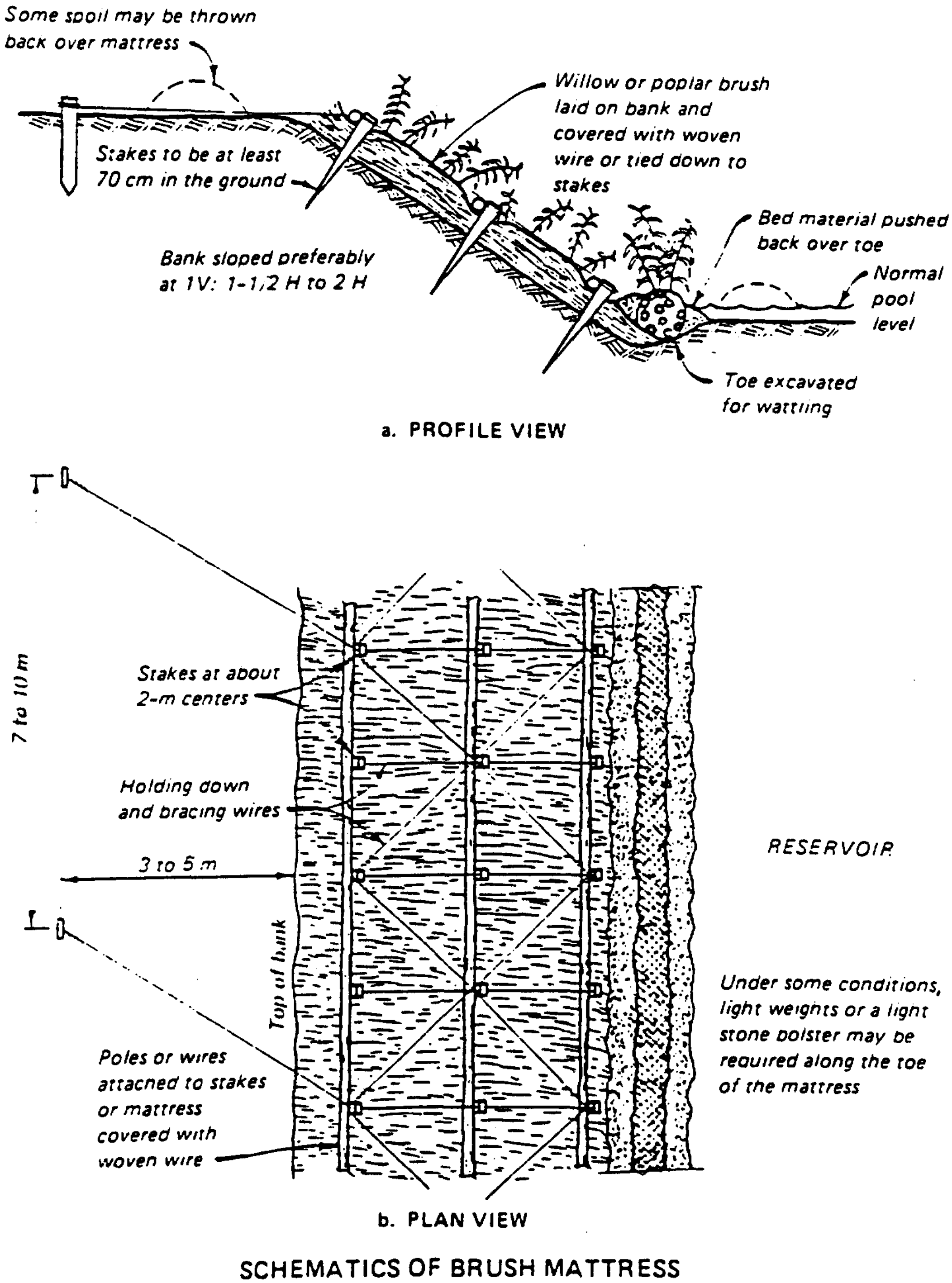


Figure 17. Brush Mattress, "Reservoir Shoreline Revegetation Guidelines," Hollis Allen and C.V. Klimas.

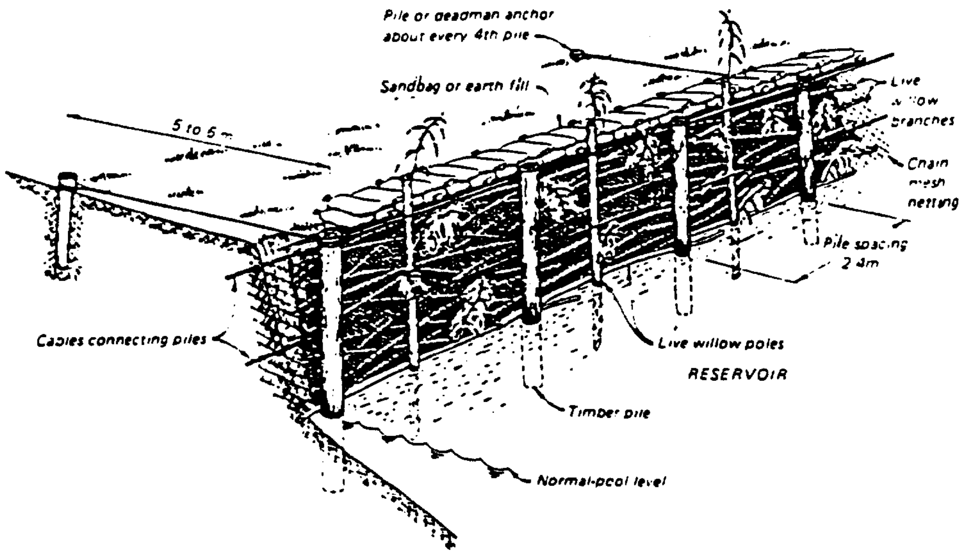


Figure 18. Pile and Fascine Construction, "Reservoir Shoreline Revegetation Guidelines," Hollis Allen and C.V. Klimas.

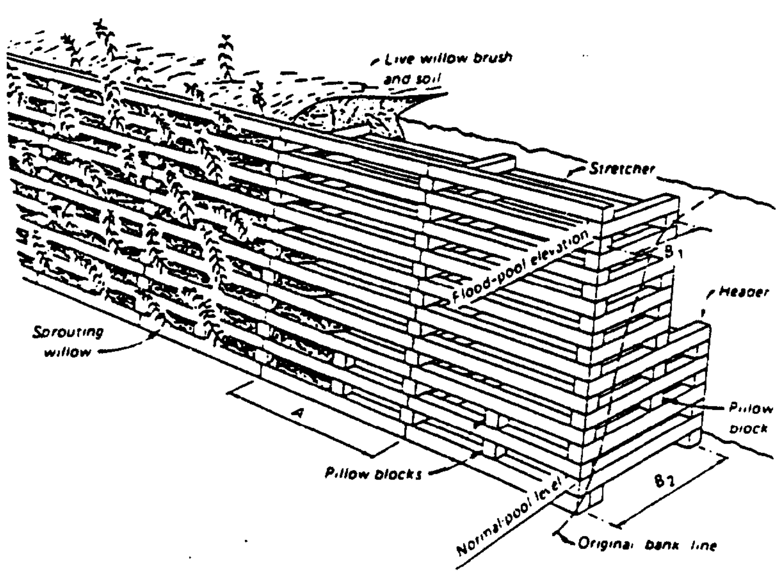


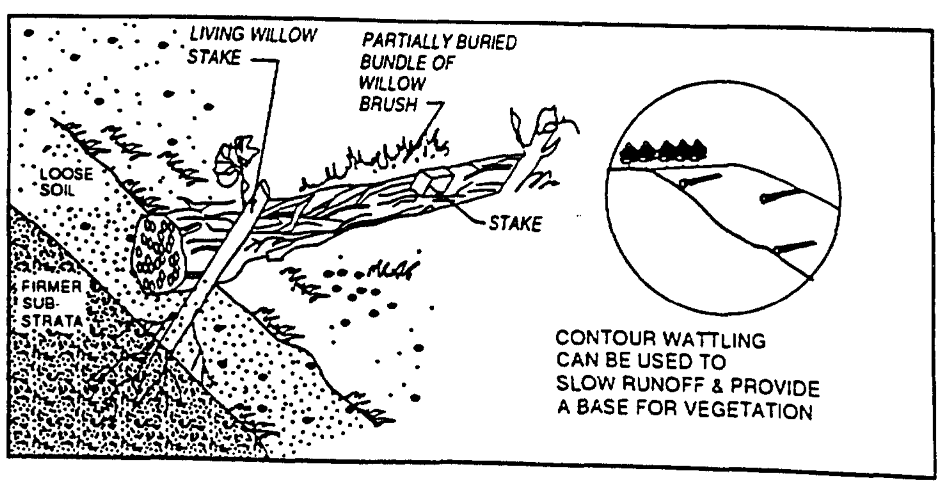
Figure 19. Timber Crib Construction, "Reservoir Shoreline Revegetation Guidelines," Hollis Allen and C.V. Klimas.

The planting of dormant live willow posts is a practice that is being used successfully in many places, including Illinois. Don Roseboom, with the Illinois State Water Survey describes the methods used in willow post planting below in his report, ***Case Studies on Biotechnical Streambank Protection:***

> The willow post method differs from most European bioengineering techniques (Schiechtl, 1980;...) since individual willows are positioned vertically below the depth of channel scour. Most biotechnical bank stabilization techniques have utilized vegetation with a riprap mentality. Layers of horizontally bundled woody vegetation are entrenched in the bed and bank. This type of earth moving and hand labor often doubles installation costs and installation times.
>
> Willows and most woody riparian vegetation do not naturally extend root systems very deeply below the water table. The posts are implanted much deeper than native seedlings would grow. However, lateral root growth rapidly binds adjacent posts together in the bank soil. Lateral branch growth also interlocks adjacent posts to slow flow velocity near the bank.
>
> The willow post method was mentioned by Scheichtl (1980) as a method of ravine stabilization in Germany during the 1800's. Both the Corps of Engineers and the Soil Conservation Service utilized large willow poles in the 1930's... In most cases the posts or poles were laid as a layer along the sloped bank. Placed willow posts in vertical holes ...protect the base of levees in Arizona.
>
> Willow are cut into 10-14 ft. posts when the leaves have fallen and the tree is dormant. At this time growth hormones and carbohydrates are stored in the root system and lower trunk. Dense stands of 4-6 year old willows make the best harvesting areas. These stands are commonly found on the stream deltas in lakes or in old stream channel cutoffs. The willow posts are 4-6 inches in diameter and may be stored up to 1 month if kept wet.
>
> The eroding stream bank is shaped to 1:1 slope with the spoil placed in a 6 inch deep layer along the top of [the] bank. In major erosion sites, post holes are formed in the bed and bank so that the end of the post is 2 ft. below maximum streambed scour. The posts are placed four ft. apart in rows up the stream bank. The posts in one row are offset from the posts in adjacent rows.

While the steel ram and excavator is more efficient at depths of 6 ft. in clay soils, an hydraulic auger and excavator unit forms deeper and longer lasting holes in stoney or sand streambeds. Large stone layers of streambed material cause damage to the excavator when the steel ram is utilized. In fine sand layers, ram holes collapse before the post reaches the bottom of the holes. In highly fluid sands, even auger holes fill but the post can pushed deeper with the bucket or boom. In streams with sand or gravel beds, the hydraulic auger will place posts 9-11 ft. deep.

In larger streams with non-cohesive sand banks, large cedar trees are cabled to the willow posts along the toe of the bank. The cedars not only reduce bank scour while root systems are growing, but retain moisture during drought periods. In larger streams as Illinois' only designated scenic river, the Middle Fork, large rounded boulders were utilized as additional bank protection with the willow posts.



Living willow stakes used in combination with willow fascine.

Figure 20. Living Willow Stakes Used in Combination with Willow Fascines, "The Role of Vegetation in Shoreline Management," Great Lakes Management.

The Illinois State Water Survey gives tips for evaluating bank erosion in the following table:

BANK EROSION SITE ASSESSMENT

1. Does sunlight fall directly on the eroding bank? (Willows must have sun.)

2. Is bedrock close to the surface? (Earth should be 4 feet deep - check with tile probe.)

3. Are lens of fine sand exposed in the eroding bank?

4. Is the stream channel stable upstream of the erosion site? (If the stream cuts behind the upper end of willow posts, the entire bank will erode.)

5. How deep is the stream along the eroding bank? (Willow posts must be 2 ft. deeper than the deepest water or the posts will be undercut below the root zone. The length of the willow posts will depend on the water depth. In sand or cobble streams, hydraulic auger will form a deeper and more stable hole.)

6. How wide is the stream channel at the erosion sites when compared to stable channels upstream and downstream? (If channel is wider at the erosion site, vegetation will not choke the stream channel and cause other erosion problems.)

7. Do you have a source of large willows close to the site? (Your costs are small when the willows are close.)

8. Will the site be wet during dry summers? (Willow posts require a lot of water while the roots are regrowing - willow posts should be only 1-2' above ground in dry sites.)

9. Can you keep cattle away from the posts during the first summer? (Willows produce food for regrowth from leaf photosynthesis.)

10. Have debris jams forced floodwater into the eroding bank? (You must remove large debris jams but follow guidelines established by the American Fisheries Society (1983.)

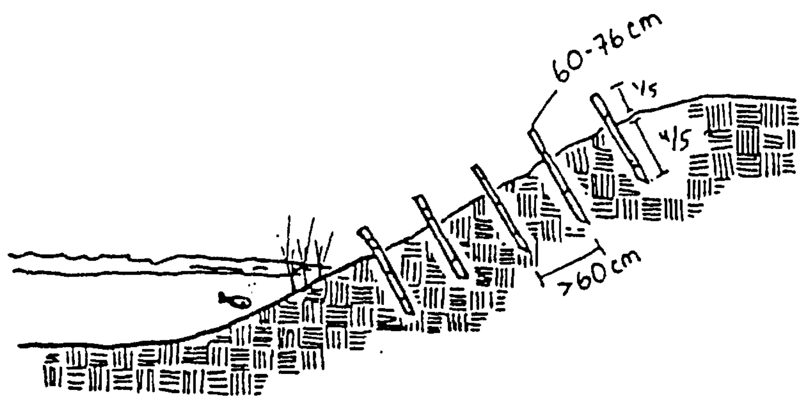
Other species of trees and shrubs may be used in bioengineering. Generally, it is best to use native, water tolerant plants. **The Watershed Restoration Sourcebook**, put out by the **Metropolitan Washington Council of Governments**, describes several methods of bioengineering techniques in the following pages in Figures 21-24.

METHOD	DESCRIPTION	NOTES

LIVE STAKES

Live stakes are living woody plant cuttings that are tamped into the streambank where they take root and grow into mature shrubs that stabilize the streambank. Commonly used plants include willow, alder and dogwood.

1. An effective stabilization method once vegetation is established. Effectiveness is significantly increased if used with other methods.
2. Acts as a strong barrier to siltation from erosion of adjacent land.
3. Effectively increases vegetative cover along a stream where existing vegetation is sparse.
4. An economical method when cuttings are locally available. Can be done with minimum labor.
5. Most useful on streambanks of moderate slope (4:1 or less). Toe of slope should be reinforced with fascines or rock.
6. Applicable only in original bank soil. Should be used more as a preventative measure, before severe erosion problems occur.
7. Applicable on all sizes and types of streams except those with high flow fluctuations.
8. 2-4 cuttings per square yard, 60-76 cm (24-30 in.) long, 1.5-3.8 cm (0.5-1.5 in.) in diameter.



LIVE FASCINES

Live fascines are bundles of live cuttings wired together and secured into the streambank with live or dead stakes. Live fascines are used to protect banks from washout and seepage, particularly at the edge of a stream, and where water levels fluctuate moderately.

1. Applicable on all types and sizes of streams where water level fluctuation is small.
2. This method is quite durable even before the cuttings have rooted.
3. Immediate effectiveness is increased if fascines are used in combination with other methods. For example, placing fascines on a brush layer can reduce water velocity.
4. An economical method where materials are locally available.
5. Breaks the slope into a series of shorter slopes. In dry sections of the slope the fascines are placed parallel to the contour. In wet areas they are placed at an angle.
6. Fascines may be up to 9 m (30 ft.) long.
7. Little soil disruption during construction.
8. Not recommended where surface drainage occurs over the face of the streambank.

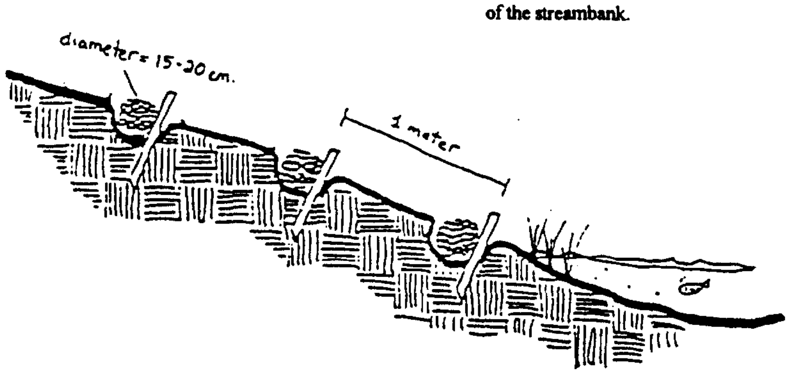
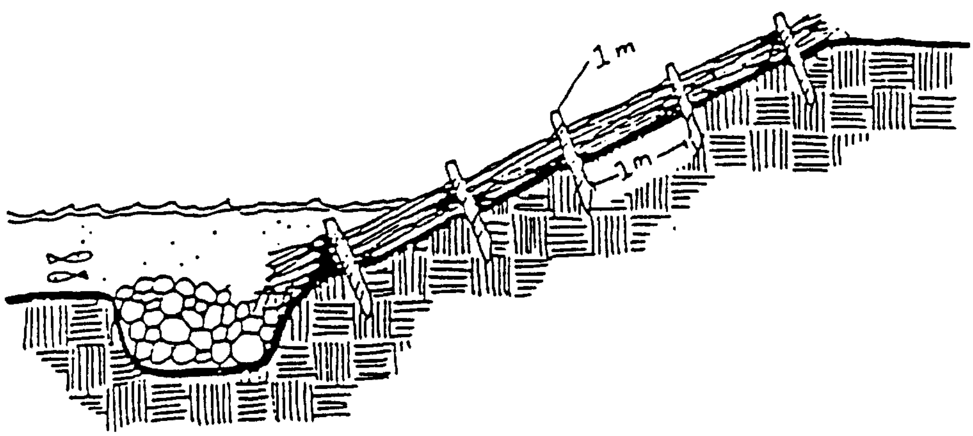


Figure 21. Live Stakes and Live Fascines, Watershed Restoration Sourcebook, Anacostia Society, Metropolitan Washington Council of Governments

METHOD	DESCRIPTION	NOTES
BRUSH MATTRESSES	Six foot willow switches are wired together to form a mat which is then secured to the bank by stakes, fascines, poles or rock fill. The toe of the slope is reinforced with a brushlayer anchored by a live fascine or rip-rap. Mattress should lie perpendicular to the water.	1. The mat establishes a complete cover for the bank. Entire layer must be slightly covered with soil or fill. 2. Captures sediment and rebuilds bank. Plants provide long term durability and erosion control. 3. Establishes dense riparian growth. Allows for invasion of surrounding riparian vegetation. 4. An economical technique which provides protection soon after it is established. 5. Applicable on banks with a uniform gradient not exceeding 2:1. The toe of the slope is reinforced with a brushlayer anchored by a live fascine. 6. Mattress should lie perpendicular to the water. 7. Site should have moderate water level fluctuations.



METHOD	DESCRIPTION	NOTES
BRANCH PACKINGS	Branch packings are alternating layers of live branches and soil used to fill a hole or washed out area in a streambank. Branches are used both underwater and above. The branches above the water will root to provide permanent protection, while those below the water line provide initial stability. Can be packed using fascines to increase effectiveness. Stakes are used for stability and should be 1.5-3.7 m long.	1. This technique provides an immediate barrier, redirecting water away from the washed out area. One of the most effective methods for revegetating holes scoured in a streambank. Produces immediate habitat cover. 2. Can be packed using fascines to increase effectiveness. 3. Cuttings are often available locally, thus an economical method. 4. Slope toe may be secured with rock fill. Soil and gravel mixed and used in between brush layers as fill material. 5. Stakes are used for stability and should be 1.8-2.5 m (6-8 ft.) long. 6. A scoured hole intended for this installation should not be more than 3.7 m (12 ft) long, 1.5 m (5 ft) wide, or 1.2 m (4 ft) deep. 7. A particularly useful method for banks that have had washouts, even where the water is fast and deep.

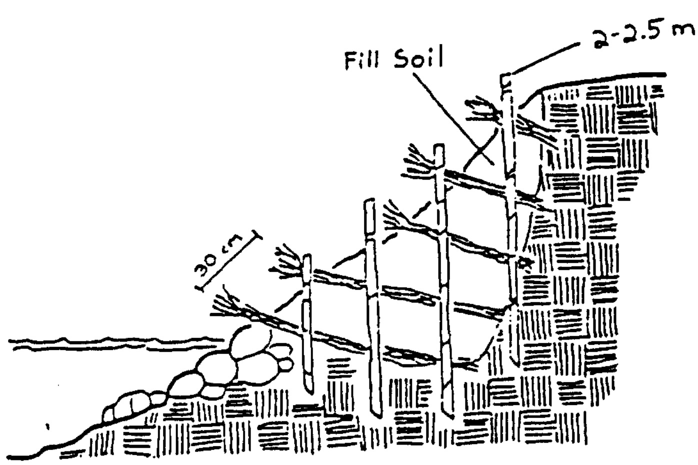
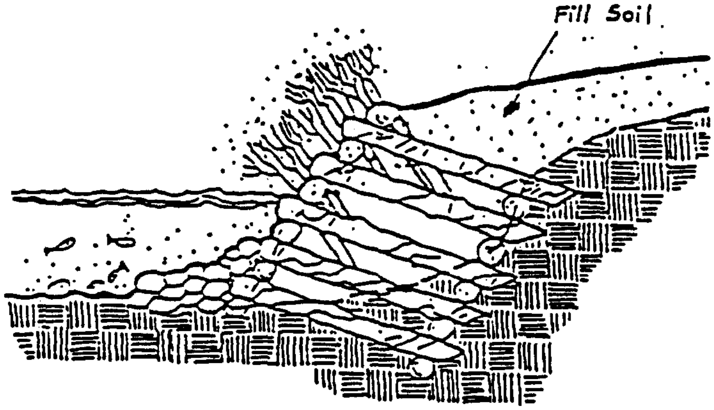


Figure 22. Brush Mattress and Branch Packing, Watershed Restoration Sourcebook, Anacostia Restoration Society, Metropolitan Washington Council of Governments

METHOD	DESCRIPTION	NOTES
LIVE CRIBWALL	The live cribwall is a rectangular framework of logs, rock and woody cuttings. It is used to protect an eroding streambank, especially at outside banks of main channels where strong currents are present and locations where an eroding bank may eventually form a split channel.	1. The log framework provides immediate protection from erosion where the plants provide long term durability. 2. Very effective in controlling bank erosion on all types of streams, including those with rapid flow. Can promote siltation and can retain large amounts of bedload material. 3. The growing plants will eventually take over for the rotting logs. 4. An economical technique, when local materials and unskilled labor are used. 5. Fill is added to regrade very steep slopes. 6. Not applicable where bed is severely eroded as under-cutting occur. Not suitable for rocky terrain or for use in narrow reaches with high banks on both sides. 7. The walk is constructed of logs stripped of their bark or untreated timber, at least 15 cm 6 in) in diameter. 8. Height of cribbing should be 50%-70% of the height of the bank.



METHOD	DESCRIPTION	NOTES
VEGETATED GEOGRID	Geotextile material is used to support fill sections of a streambank. Similar to brush layering. The material used in between the layers of live branches and along the face of the slope.	1. Immediately reinforces the newly constructed bank. Reinforces the fill earth at steep angles. 2. Produces rapid growth for habitat improvement. 3. 100% biodegradable. Lasts 5-10 years, so natural looking bank will be achieved in a short time. 4. Geogrid material costs between $5-$15 per square yd. 5. Fill soil is used in between the brush and is wrapped by geotextile. Must be well compacted. 6. The structure is built during low flow, starting at the waters edge. The first (two) layer(s) is (are) built with cobble.

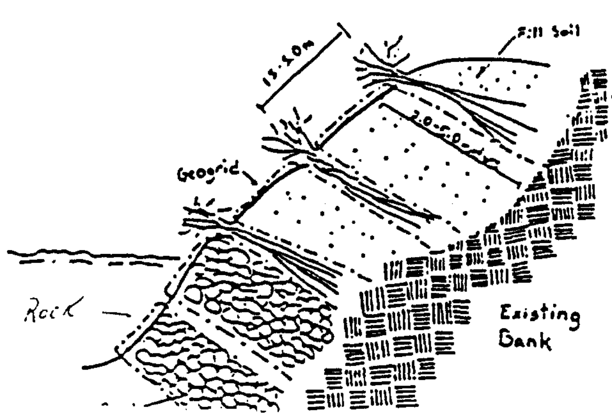
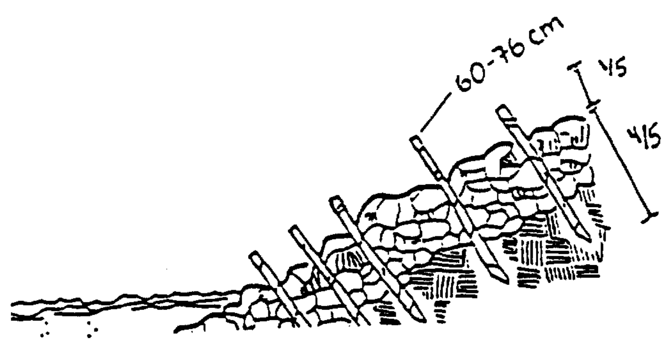


Figure 23. Live Cribwalls and Vegetated Geogrid, Watershed Restoration Sourcebook, Anacostia Restoration Society, Metropolitan Washington Council of Governments

METHOD	DESCRIPTION	NOTES
JOINT PLANTINGS	Willow cuttings or seedlings are placed in the joints of rip-rap or gabions.	1. Enhances the strength and appearance of the hard construction structure. 2. The plantings improve the function of the rip-rap or gabion by reducing water speed near the bank. 3. Mitigates the presence of the hard construction structure by incorporating habitat improving plants. 4. May increase the initial costs of the construction, but will strengthen the structure and reduce maintenance costs in the future. 5. 2-6 cuttings per square yard depending on velocity of flow.



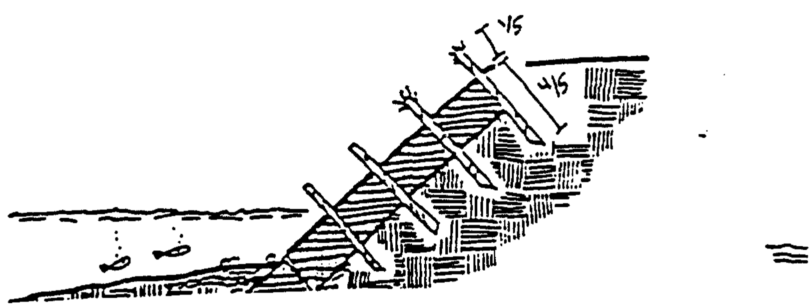


Figure 24. Joint Planting, Watershed Restoration Sourcebook,
Anacostia Restoration Society, Metropolitan Washington Council of Governments

Many bioengineering techniques are limited to stable areas with little fluctuation of water levels, such as shorelines or lake fronts. In these areas, fiber rolls and schwimmkampen islands may be constructed to control erosion from waves and provide fish spawning habitat. These techniques are described and shown in the following by Hollis Allen in the report, ***Reservoir Shoreline Revegetation Guidelines:***

> **Plant Rolls.** Plant rolls are adaptions of "reed rolls"... which have been used extensively in Europe for streambank erosion control. Plant rolls are cylinders of plant clumps in soil that are wrapped by burlap, secured by hog rings or wire, and placed in a trench....(Sources have) described the use of these in marsh establishment for erosion control of a dredged material dike in a moderate wave-energy environment. Such a technique is considered to be applicable to.. . . reservoir shoreline stabilization because plant rolls can withstand considerable wave action (at least 0.3-0.6-m-high waves). Plant rolls can be pregrown in the greenhouse or lathehouse to develop root systems, installed in water with a jet pump or shovel, and treated with fertilizer without excessive leaching of the fertilizer.
>
> Plant rolls are constructed onsite as follows:
>
> 1. A length of burlap (about 1 m wide by 4 m long) is laid on the ground.
>
> 2. Sand or soil is placed on the strip of burlap, and 6-7 clumps of plants are spaced at 0.5-m intervals on the burlap.
>
> 3. About 28 g of 18-6-12 slow-release fertilizer is applied to each plant clump by hand.
>
> 4. The sides of the burlap are brought together around the plants and fastened with hog rings creating a 3-m-long roll of plants and soil.
>
> 5. The plant rolls are positioned at the toe of the bank or upon any existing shallow benches lake ward of the toe and are oriented parallel to the bank.
>
> 6. The rolls are buried in the reservoir substrate by a jet pump or by shovel.

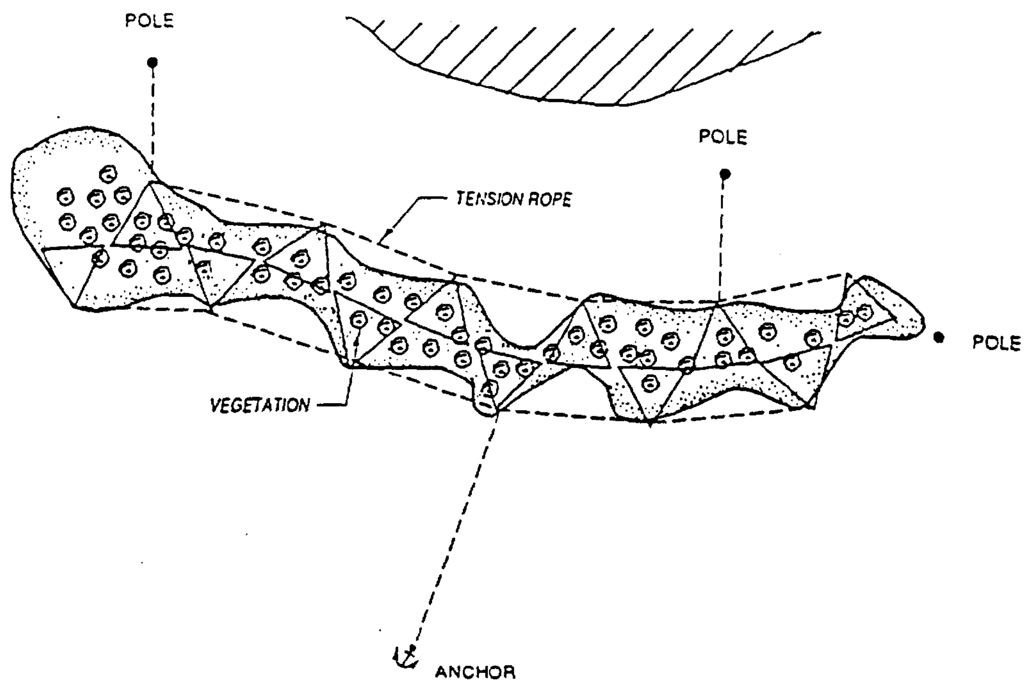


Figure 25. Artificial Floating Islands, Bestmann-Green Systems, Inc. Artificial floating islands follow shoreline for erosion control and habitat development.

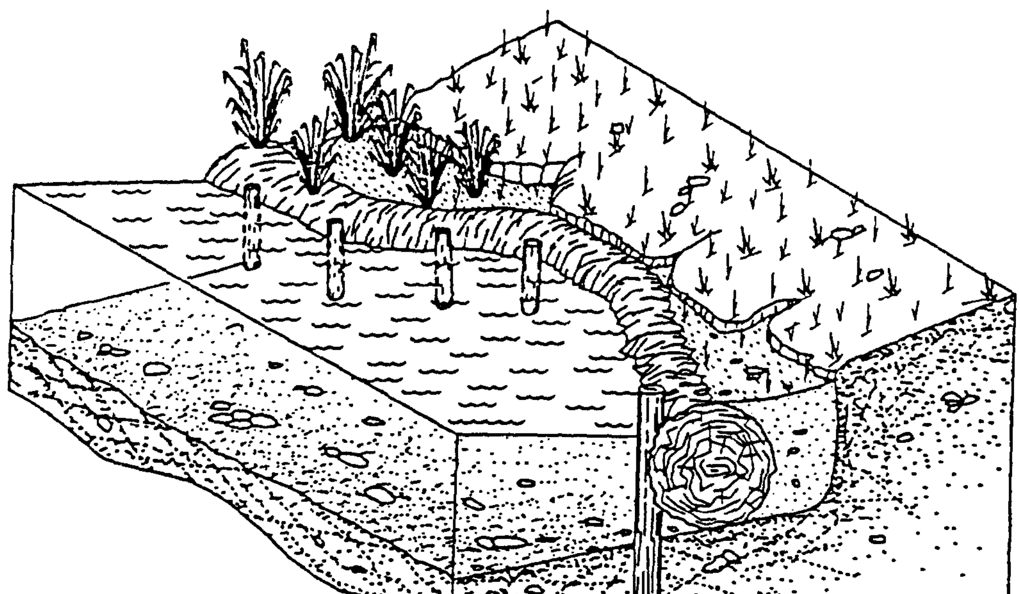


Figure 26. Fiber Rolls, Bestmann-Green Systems, Inc. Fiber rolls stabilize banks and permit establishment of wetland vegetation. The coconut fiber accumulates sediment and biodegrades as plant roots develop and become a stabilizing system.

F. HABITAT RESTORATION

Streambank restoration techniques are important not only for directing flow away from eroding banks, but also for providing pool and riffle areas, which create habitat for fish and benthic macroinvertebrates. In addition to creating pool and riffle areas, habitat can be created by constructing artificial cover. This includes shelves or lunker units. Artificial cover can be created by using a combination of lumber and riprap or by using natural materials such as live trees. Tree revetments, discussed earlier in Section VI-B,6 provide fish habitat in addition to adding streambank stability. Wing deflectors, weirs, dams, and drop structures help (also discussed in Section VI-C) create deeper pool of water to attract larger species. Fish habitat can be created inexpensively using materials that are already present, or near by, such as fallen logs, root wads and boulders.

Bank covers are easy to construct and can be built out of simple materials such as logs, old timber and rocks. The objective for building these structures is to provide a shelter for fish. At the same time, they help protect banks. Brush and debris caught in the shelter also attract insects and other organisms which provide food for fish. When used in combination with vegetating techniques, they help provide bank stability which enables plant growth.

Types of bank covers include bank crib with cover log, log and bank shelters, and lunker structures. Figures 27 and 28 show some examples of bank covers.

BANK COVER

These structures are installed to create an undercut bank effect which provides cover for fish. Bank covers also serve to stabilize eroding banks.

1. Bank covers should be placed at the outside of bends or along straight reaches in conjunction with deflectors to ensure adequate water depth.
2. The bank behind the overhang should be armored with rock.
3. The overhang should be covered with a layer or rocks, followed by soil and sod.
4. Normal stream flow should be roughly even with the bottom of the platform.
5. Not recommended for streams subject to severe flooding, thus, use in urban areas is limited.

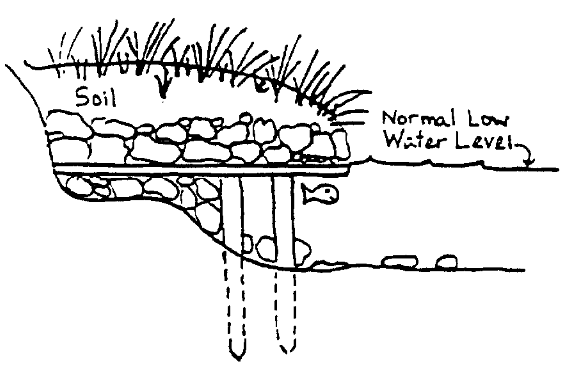
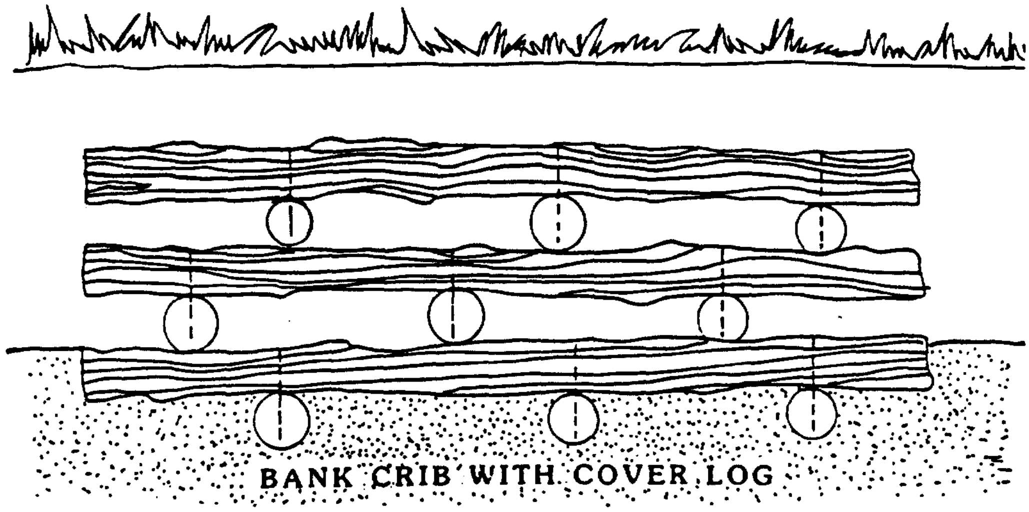
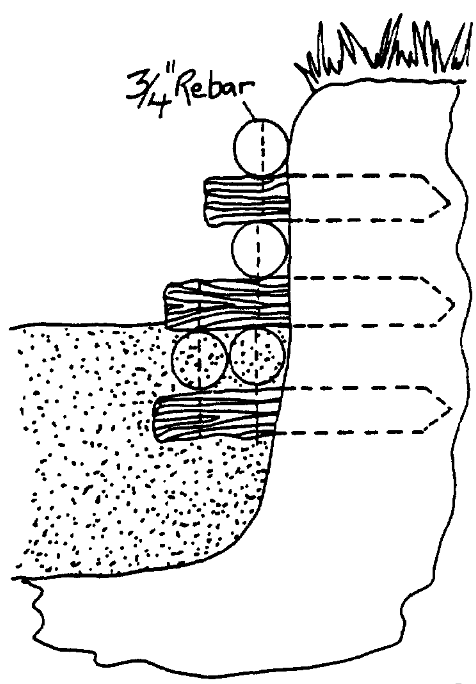


Figure 27. Bank Cover. *Watershed Restoration Sourcebook*, Anacostia Restoration Society, Metropolitan Washington Council of Governments.





BANK CRIB WITH COVER LOG
SIDE VIEW

Figure 28. Bank Crib with Cover Log, adapted by LeAnne Johnson from ***Stream Habitat Improvement Handbook***, Monte Seehorn, U.S.D.A. Forest Service.

A lunker structure is a type of bank cover originally designed to attract salmonid fishes, or trout. Construction of a lunker unit is described in the publication, ***Unit Construction of Trout Habitat Improvement Structures for Use in Coulee Streams:*** by the Wisconsin Department of Natural Resources:

> The LUNKERS unit described here is the culmination of experimentation with different structure designs. This structure is designed to survive and to function well in local coulee streams. [Editor's note: these are medium gradient streams that are cold water.]
>
> Instead of whole logs, brace wire, and steel fence posts, we now use oak planks, oak blocks, and reinforcing rods. Oak blocks, made from short sections of tree trunks, are used as spacers. Oak planks are nailed to the tops and bottoms of the blocks, forming stringers which tie into the stream bank at right angles. Oak planks are then nailed to the top and bottom of the stringer boards. These boards parallel the stream bank. The whole structure forms a crib, which can be constructed on shore and moved by a crawler-loader to the installation site in the stream. The structure is anchored by driving lengths of reinforcing rod through predrilled holes in the structures and then into the streambed (See Figures 29 and 30.)

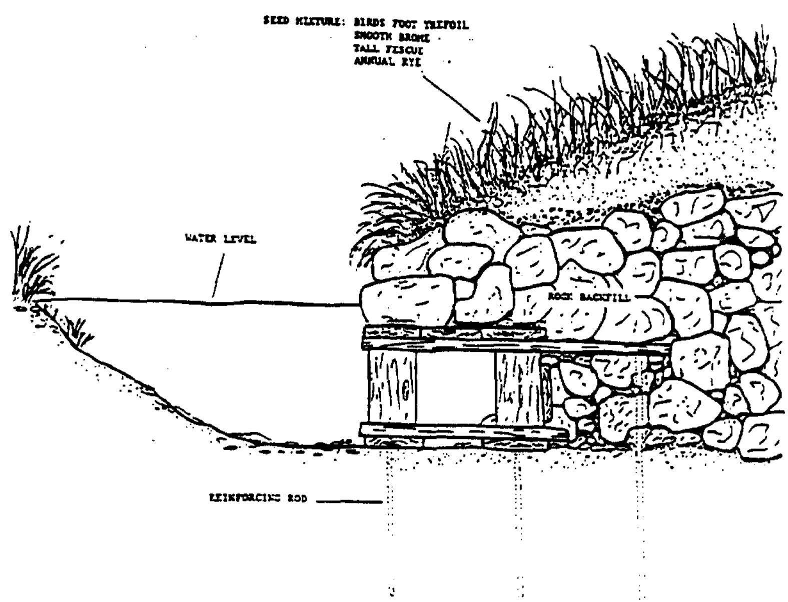
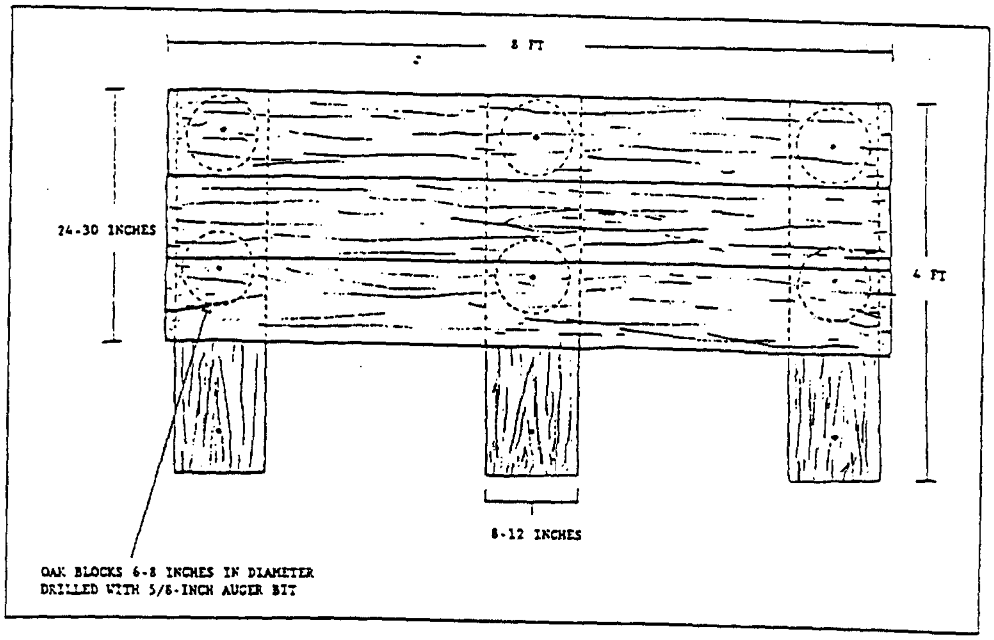
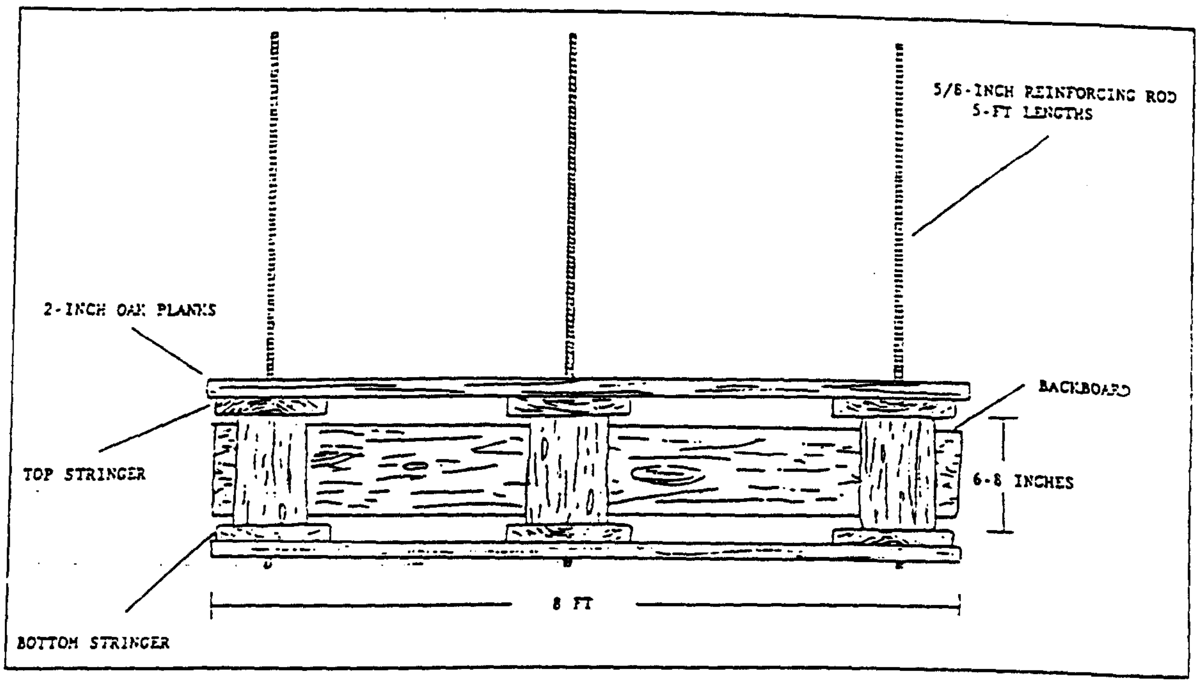


Figure 29., Sideview of lunker structure. ***Construction of Trout Habitat Improvement Structures For Use In Coulee Streams***, Wisconsin Department of Natural Resources.



Top View, La Crosse LUNKERS unit.



Front View, La Crosse LUNKERS unit. Structures are built using oak planks 2 inches thick by 8-12 inches wide. Structures are nailed together with 20D common spikes.

Figure 30. Top and Front View, LaCrosse LUNKERS Unit, "Unit Construction of Trout Habitat Improvement Structures for Wisconsin Coulee Streams," Minnesota Department of Natural Resources.

The Anacostia Watershed Society provides many examples of habitat improvement techniques in their ***Watershed Restoration Sourcebook***. Many are as simple as using tree revetments (discussed earlier in this handbook) which also help control erosion, or as inexpensive as using boulders from the local area.

AQUATIC HABITAT IMPROVEMENT TECHNIQUES

METHOD	DESCRIPTION	NOTES
BRUSH BUNDLE	Brush is placed along a stream bank to provide overhead cover for fish and reduce erosion.	1. Three or more trees, preferably fresh cut cedar trees should be wired together to form the bundle. 2. Trees should be drilled and attached by cable to a deadman (large concrete slab) on the bank. 3. Trunks are to be placed facing upstream. 4. The brush bundle should be secured by placing large rocks on the downstream branches. 5. Should not be used in extremely flashy streams as frequent high flows may strip branches. 6. Most effective on small streams.

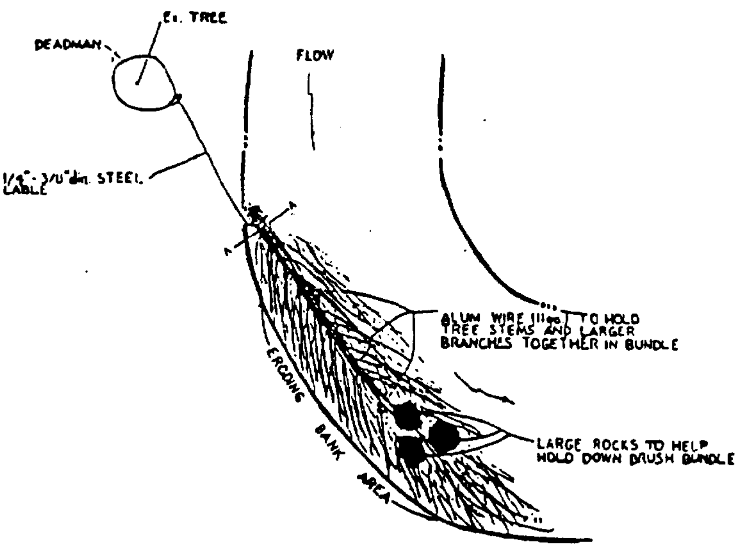


Figure 31, Brush Bundle, Watershed Restoration Sourcebook, Anacostia Restoration Society, Metropolitan Washington Council of Governments.

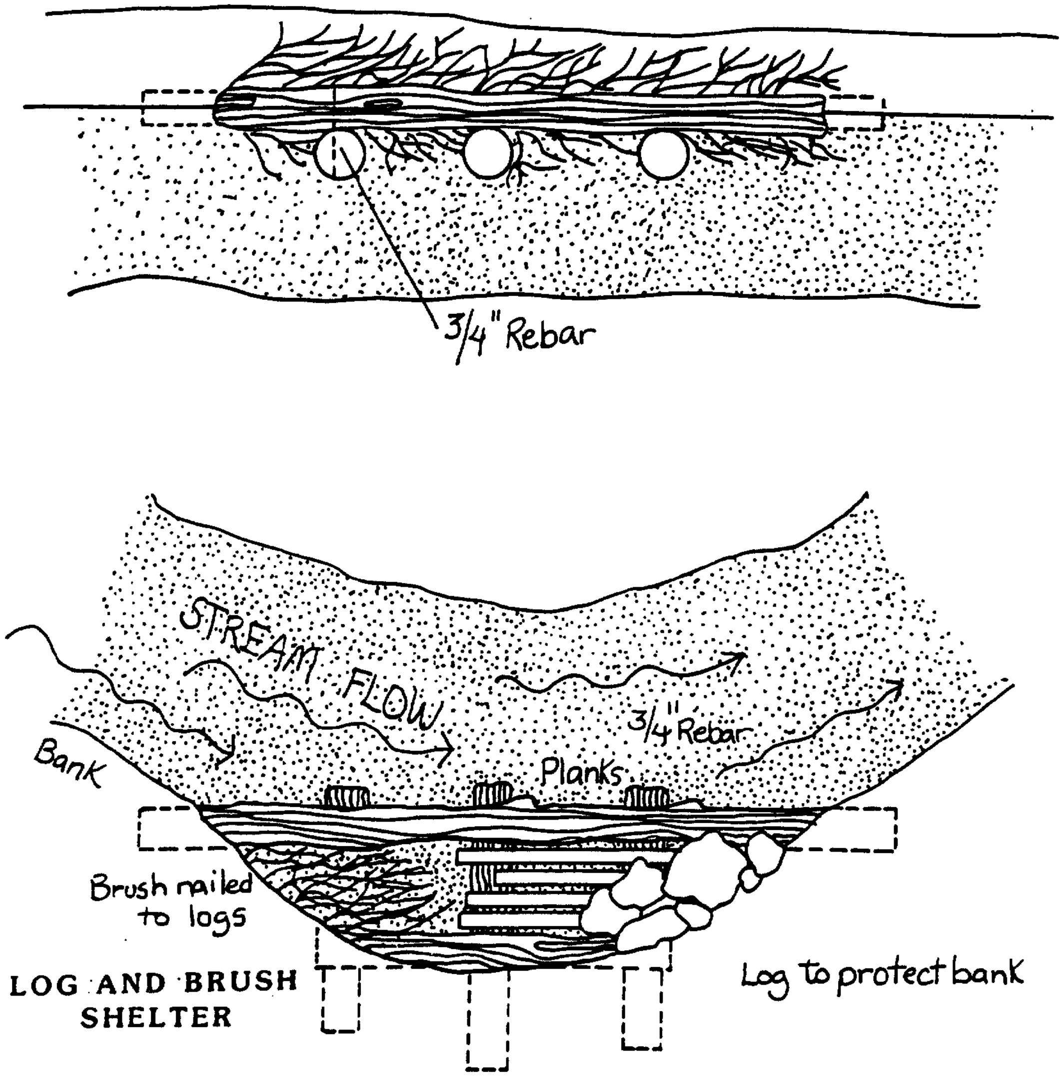


Figure 32. Log and Brush Shelter, adapted by LeAnne Johnson from ***Stream Habitat Improvement Handbook***, Monte Seehorn, U.S.D.A. Forest Service.

METHOD	DESCRIPTION	NOTES
BOULDER CLUSTER	Several large boulders are placed in a riffle to create structural complexity .including eddies and small pools, used as rearing areas by salmonoids and other fish. Boulders may also be placed singly in a random fashion. This method requires minimal maintenance.	1. Clusters are comprised of 3-5 boulders. 2. The clusters should be triangular and placed in the downstream half of a long riffle or glide. 3. Boulders should not be placed in pools. 4. Clusters placed in the same stream section should be at least 1/3 of the stream width apart. 5. Boulders are most effective in wide, shallow, high velocity streams with gravel or rubble bottoms. 6. Clusters can be placed in deeper areas to cause undercutting and increase cover. 7. Height of boulders is determined by the desired habitat effects. 8. Boulders must be heavy enough to resist movement by rapid streamflows.

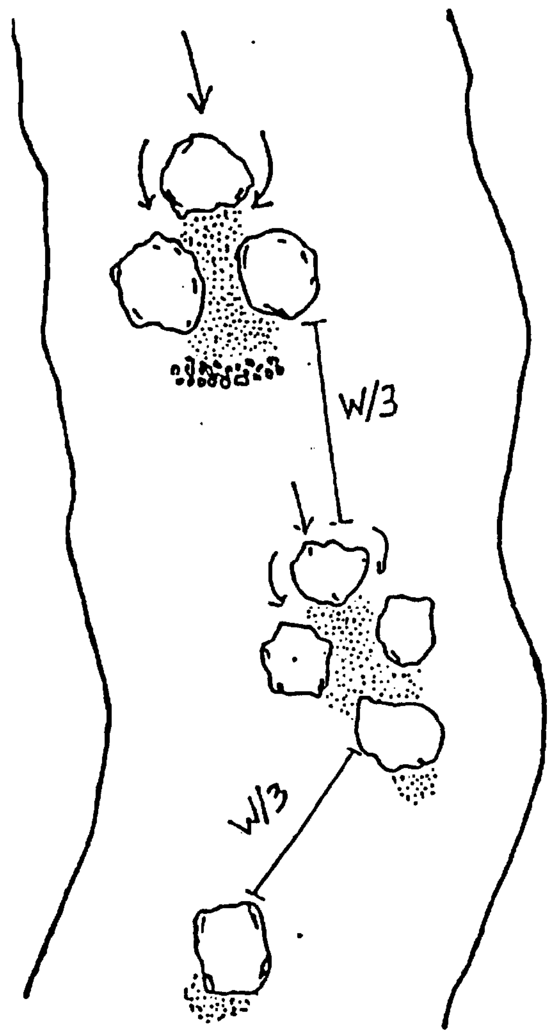


Figure 33. Boulder Cluster, Watershed Restoration Sourcebook,
Anacostia Restoration Society, Metropolitan Washington Council of Governments

METHOD	DESCRIPTION	NOTES
ROCK, GABION LOG-FRAME DEFLECTORS	Deflectors are used to narrow and deepen streams, encourage meandering, form pools, increase cover and protect eroding banks. Deflectors are triangular in shape and may be constructed from rock, gabion or logs. Depending on stream conditions, these structures can be used singly or in series. At least three deflectors should be constructed in a series for best results.	1. Deflectors should not be installed in unstable flood-plains or braided channels and are best suited for low gradient, meandering streams. 2. The structure should be constructed in the lower half of long riffle sections to prevent backwatering upstream. 3. The deflectors should form an angle not greater than 30 to 45 degrees with the streambank conforming with the natural meander of the stream. The greater the velocity of the water, the smaller the angle of deflection. 4. The top level of the deflector should be above the mean low water level, yet low enough to allow passage of debris over it during high flows. 5. Log frame deflectors consist of a triangular log frame filled with tightly placed rock. The logs should be anchored at least 1.8 m (6 ft) into the bank and secured to the stream bottom using 1-1.5 m (3.3-5 ft) rods. 6. The point of connection to the river bank should be armored with rip-rap to prevent washout. 7. The bank opposite the deflector may also need rip-rap to protect it from erosion. 8. Gabion deflectors should be imbedded into the stream bottom at least one-half of their total height. 9. Willow and other riparian species may be inserted into the bed to give a more natural appearance.

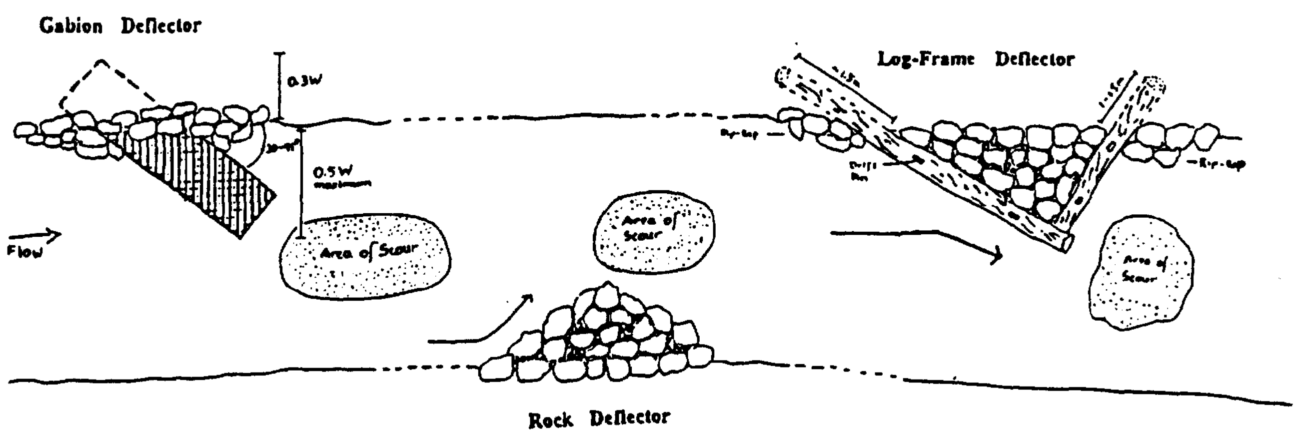


Figure 34. Rock, Gabion, or Log Frame Deflectors, Watershed Restoration Sourcebook, Anacostia Restoration Society, Metropolitan Washington Council of Governments

METHOD	DESCRIPTION	NOTES
CHANNEL CONSTRICTORS (Wing Deflectors)	Channel constrictors are essentially two deflectors on opposite sides of the stream. They are designed to narrow and deepen the channel thereby creating pools to improve fish rearing habitat. Backwater, resulting from the construction, will cause small gravel deposits to form upstream, improving spawning habitat for fish. Constrictors may be constructed of rock, gabions or logs.	1. Design criteria are very similar to those used for 2. Constrictors should reduce stream width by about 25%. 3. At the mid-point of the structure, the constrictor should be roughly the height of expected high flow. 4. If constrictors are installed in series, they should be at least 5 stream widths from each other. 5. The constrictors should be well secured into the streambank and bottom. 6. Banks downstream of the structure should be protected against possible erosion. 7. Opposing deflectors should not constrict the stream more than half the channel width and should only be installed in straight sections.

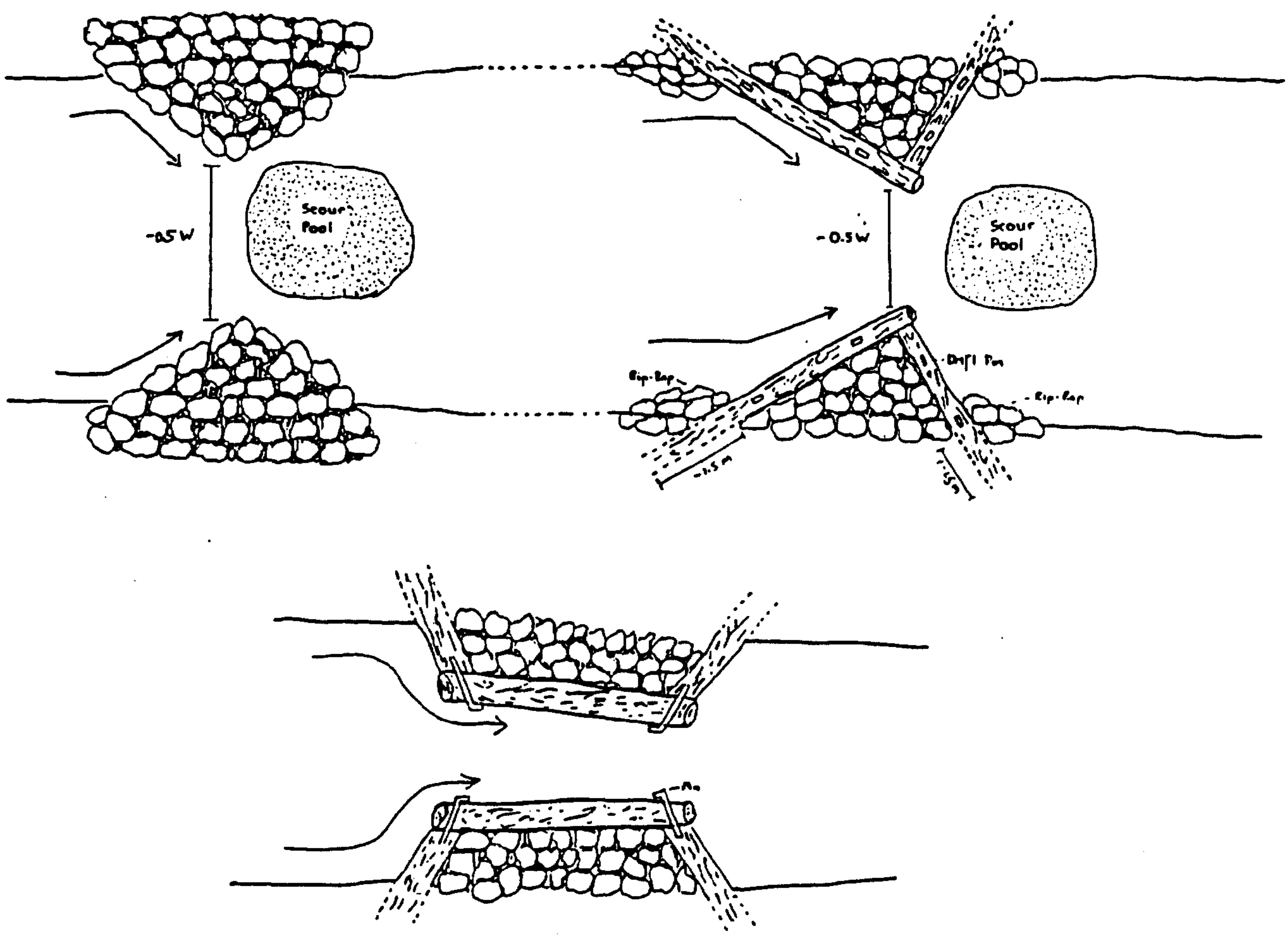


Figure 35. Channel Constrictors, Watershed Restoration Sourcebook,
Anacostia Restoration Society, Metropolitan Washington Council of Governments

METHOD	DESCRIPTION	NOTES
V-NOTCH GABION OR LOG WEDGE	These structures are designed to create and maintain large in-stream pools. They will also cause small gravel deposits to form which are used by fish for spawning purposes.	1. Gabion and log wedges should be installed in long riffle sections which lack pools and spawning areas. 2. The "V" of the gabion structures should point downstream. Each side of the "V" should form an angle of 30-45 degrees with the stream bank. 3. At least one-half of the gabion height should be buried in the streamed. 4. Log wedges should be constructed of logs at least 30 cm (1 ft) in diameter. 5. The "V" of the wedge should point upstream. Each side should form an angle of 45-60 degrees with the streambank. 6. Hardware cloth should be stapled to the upstream edge of the log wedge, extended a distance equal to the stream width and buried at least 30 cm (1 ft). 7. Drift pins are necessary to secure the logs to the stream bottom. 8. The center of the gabion or log wedges should be 15 cm (6 in.) lower than the bank ends. 9. Unstable streambanks around the wedges must be armored to prevent erosion.

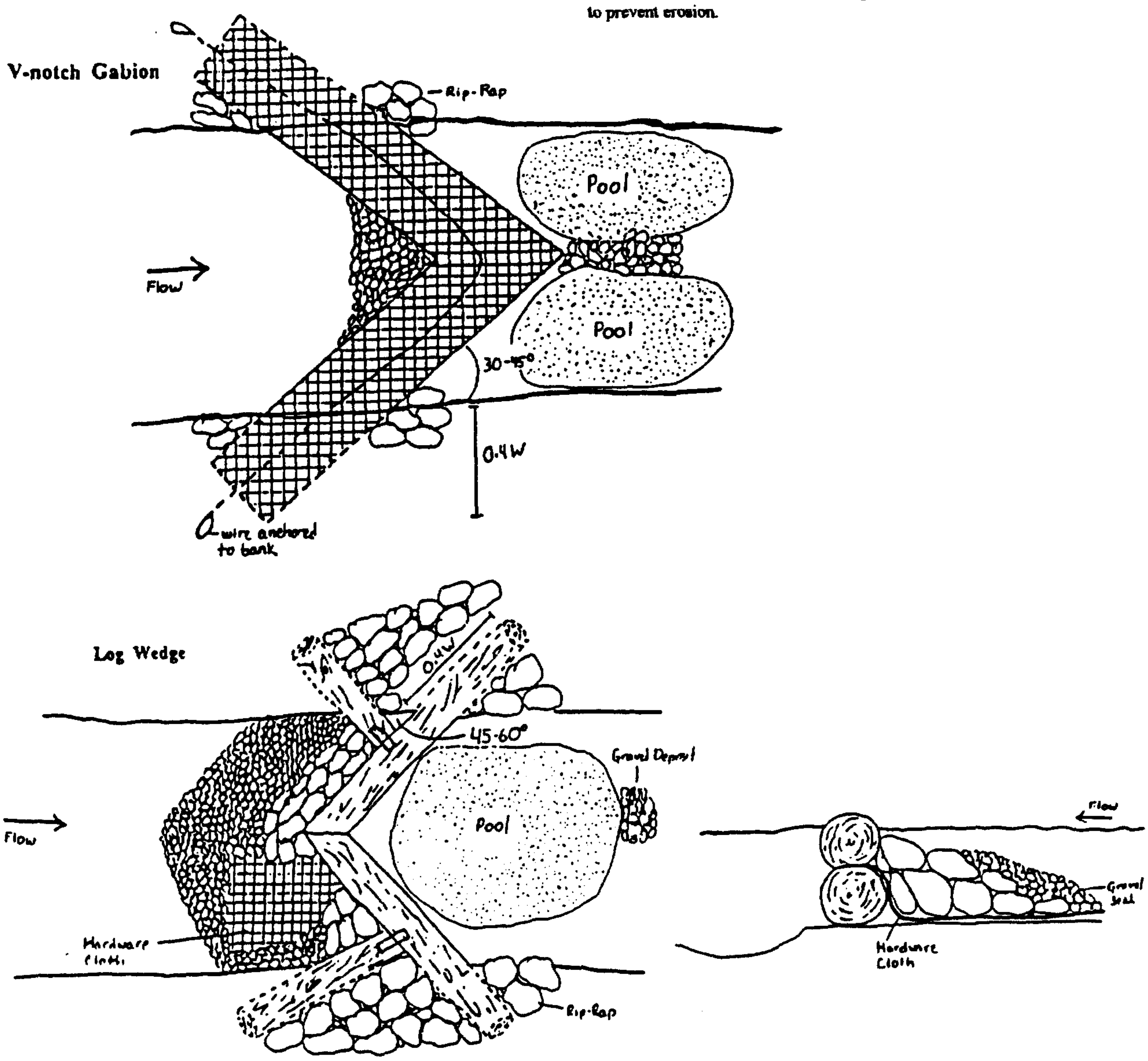


Figure 36. V-Notch Gabion or Log Wedge, Watershed Restoration Sourcebook, Anacostia Restoration Society, Metropolitan Washington Council of Governments

METHOD	DESCRIPTION	NOTES
K-DAMS	K-dams, a type of low stage check dam, create plunge pools downstream of the structure, which are used for shelter and spawning by fish. K-dams consist of a dam log supported by two brace logs which give the structure a letter K shape. Logs, called mudsills, are placed parallel to streamflow, underneath the dam log to provide a base for the construction,.	1. K-dams function best in streams of low flow volume, channel widths and low stream gradients. 2. The ends of the dam log must be placed 2 m (6.5 ft.) or more into the stream bank. 3. The mudsills should be buried at least one-half of their diameter. 4. Hardware mesh should be attached to the upstream side of the dam log and mudsills and extended between 1-1.5 m into the bank. The mesh is covered by a layer of rocks and gravel. 5. K-dams are placed low in the channel, usually less than 1/4 bankfull stage. 6. Avoid placing dams downstream of bends. 7. More costly to build, but stronger than log-drop structure.

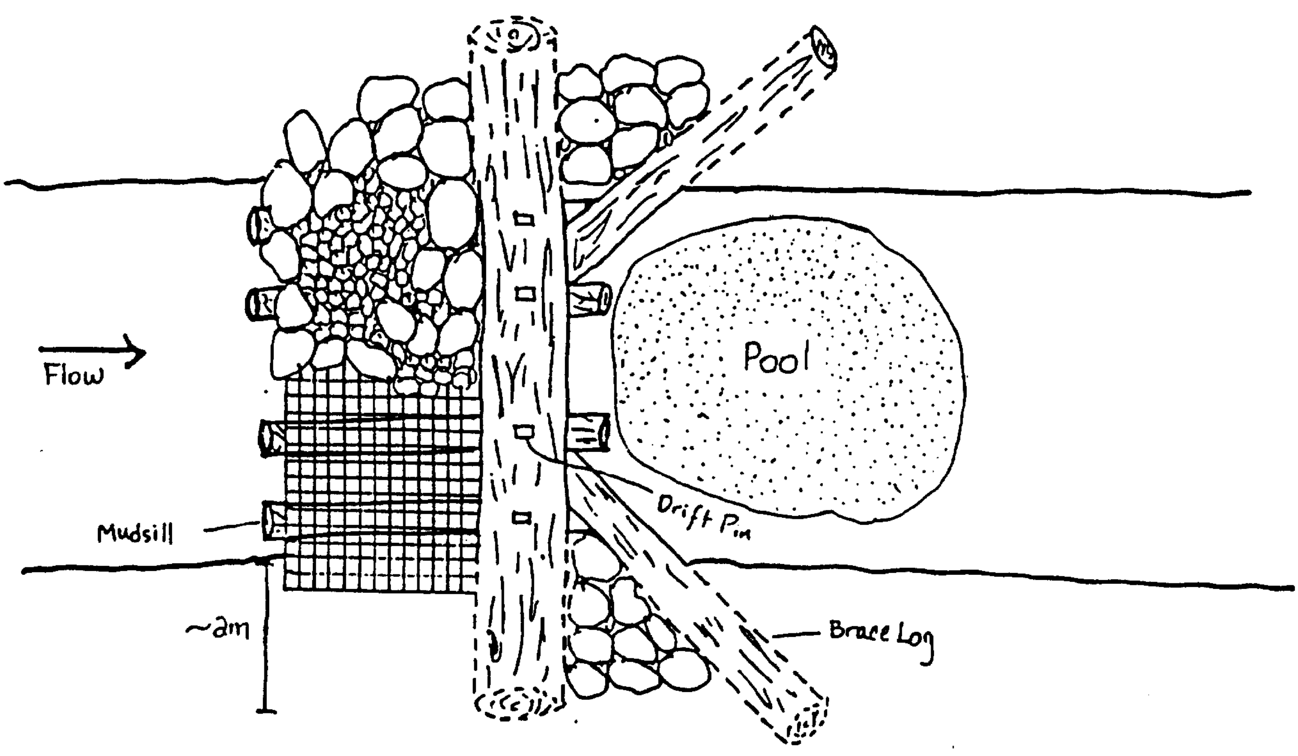


Figure 37, K-Dams, Watershed Restoration Sourcebook,
Anacostia Restoration Society, Metropolitan Washington Council of Governments

METHOD	DESCRIPTION	NOTES
LOG DROP STRUCTURES (Check Dams)	Log drop structures create scour pools downstream of the structure by directing water down into the stream bottom. The scour pools provide cover for fish. Gravel will deposit upstream of the log drop and also downstream of the scour pool. These deposits are often used as spawning areas.	1. If possible, sycamore or other rot resistant log, minimum 30 cm (1 ft) in diameter, should be used for construction. 2. The logs should be anchored at least 0.4 x width into the streambank. If the width is less than 2.4 m (8 ft), each log should be anchored 1-1.5 m (3.3-5 ft) into the bank. 3. The ends should be backfilled with rock and excavated material. The backfill must be armored with appropriately sized rock to prevent erosion. 4. Hardware cloth should be attached to the upstream part of the log and extended upstream a minimum of 10 feet. The cloth should be buried at least 30 cm (1 ft) into the streambed. 5. A notch should be cut into the top center of the log to concentrate low flows. 6. Log drop structures placed in series in the same stream reach should be constructed such that the top of the downstream log is placed at the same level or lower than the bottom of the upstream log. 7. Drop structures are to be located in non-riffle areas where bank height is at least 45 cm in height. 8. Care must be taken to avoid flooding of upstream riffles by backwater. 9. Height of the drop and width of the log must not create a barrier to fish migration.

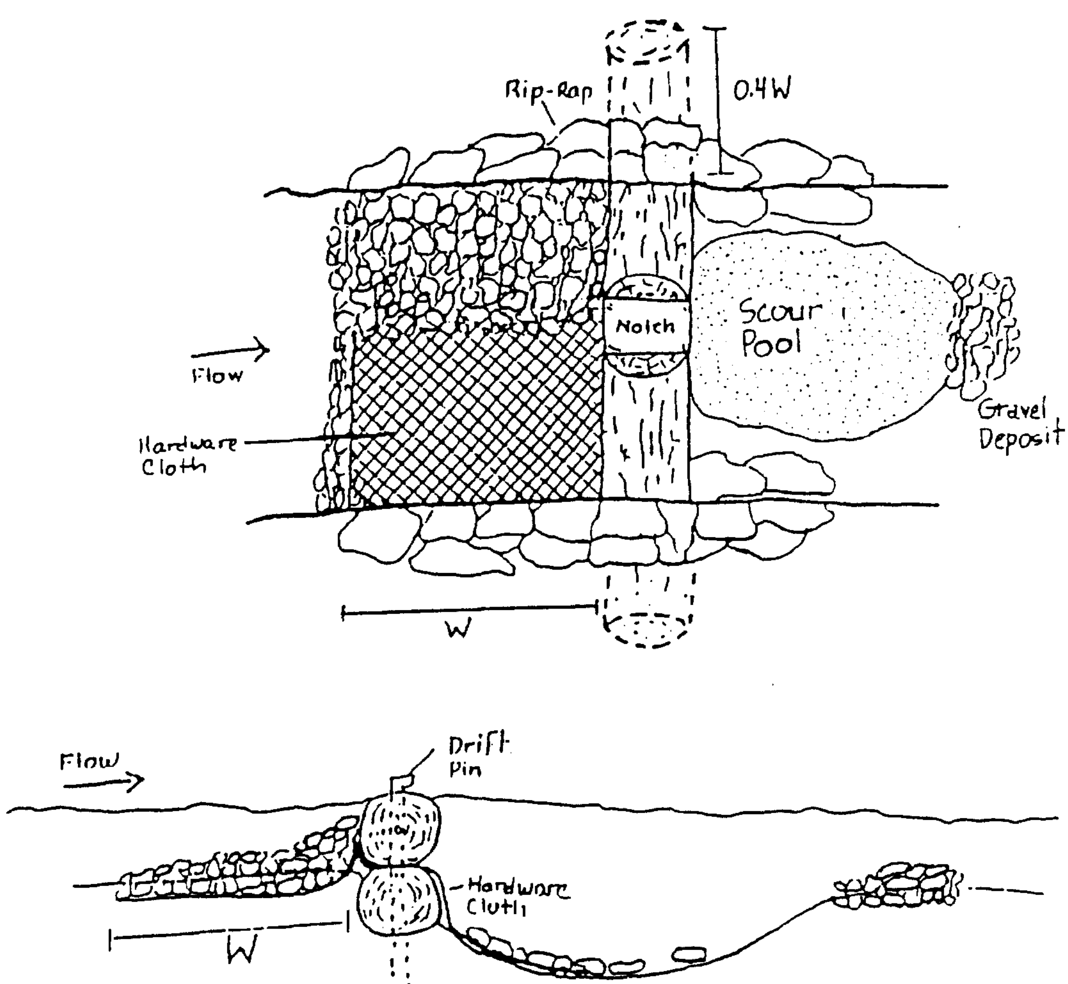


Figure 38. Log Drop Structures, Watershed Restoration Sourcebook, Anacostia Restoration Society, Metropolitan Washington Council of Governments

VIII. CONCLUSION

The streambank stabilization and erosion control methods described in this handbook have been proven to be successful when properly constructed and maintained. The method(s) used will depend upon stream and soil conditions and the severity of the erosion problem.

The cost of streambank stabilization methods will vary greatly. Conventional bank armoring, or the use of riprap may be less expensive where the materials can be found locally. On the other hand, a well constructed spur dike may require less rock, and therefore be less expensive than riprap. Soil bioengineering techniques may be quite expensive. The least expensive techniques will be the ones that involve using local materials, such as logs or boulders.

Besides financial concerns, the type of stream and land surrounding it will influence what types of restoration techniques that are used. For example, jacks and posts will be ineffective in high velocity streams because they are designed to allow large sediment loads to be deposited, thus helping to stabilize streambanks. Understandably, streambanks that have been denuded of vegetation will require replanting. The type of plants used will depend upon soil type, geology, weather conditions of the area, and streambank slope. In areas where vegetation must be established quickly, soil bioengineering techniques may be the desired choice.

A good stream restoration practice for one area may not be good for another. For instance, trees in the stream may create severe obstructions in some areas, but in others they may be placed there purposely to create fish and wildlife habitat. Often, stream restoration techniques serve the double purpose of stabilizing streambanks and creating habitat. In order to find the best solution that will be the least costly in the long run, landowners should seek professional advice about what stream restoration techniques to use.

Landowners seeking to correct erosion problems should contact the Tennessee Department of Environment and Conservation, Division of Water Pollution Control, Natural Resources Section to determine if a permit is required for the activity they plan to undertake. Advice and technical assistance is available from the U.S. Department of Agriculture, Agriculture Stabilization and Conservation Service (ASCS), and the U.S. Department of Agriculture, Soil Conservation Service (SCS). The U.S. Department of Agriculture has approved vegetative filter strips as an acceptable practice in the Conservation Reserve Program (CRP). Information on cost-sharing can be obtained from local U.S.D.A. offices as well as the Tennessee Department of Agriculture (TDA), Agricultural Resources Division. The Army Corps of Engineers may also provide technical assistance on activities involving alteration of stream channels or banks. A contact list of resource agencies is included in this handbook in the appendix.

With a little effort and within a short time, landowners can successfully implement streambank stabilization and riparian restoration techniques. Nature, given a little assistance, can begin to repair the damage caused by manmade and natural events. This leads to a reduction in tons of soil lost from eroded fields and streambanks, increased wildlife habitat, and better understanding of the importance of aquatic resources by landowners.

APPENDIX

IX. LIST OF TABLES AND FIGURES

TABLES:

FIGURES:

LIST OF TABLES AND FIGURES (CONT.)

LIST OF TABLES AND FIGURES (CONT.)

RIPARIAN RESTORATION & STREAMSIDE EROSION CONTROL

SELECTED REFERENCES

American Fisheries Society and the Wildlife Society, 1983, "Stream Obstruction Removal Guidelines".

Allen, Hollis H., 1986 "Streambank Protection With Planted Vegetation", U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 39180.

Allen, H.H, and C.V. Klimas, 1986, "Reservoir Shoreline Revegetation Guidelines", Technical Report E-86-13. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 39180. Phone (601) 634-3845.

Bestmann, Lothar, 1989, Unpublished notes from a notebook describing bioengineering methods used in Germany, Bestmann Ingenieurbiologie, Pinneberg, Germany.

Cairns, John Jr., 1988, Rehabilitation of Damaged Ecosystems. CRC Press, Inc. Boca Raton, Florida. p.24.

Clemens, R.H., (no date), "The Role of Vegetation in Shoreline Management", Great Lakes Basin Commission.

Finley, Mack T., James A. Gore, and Steven W. Hamilton, 1992, "Proposed Best Management Practices For Improving Water Quality In the West Sandy Watershed", Austin Peay State University, Clarksville, Tennessee. Phone (615) 648-7781.

Forest Conservation Manual, 1991, Metropolitan Washington Council of Governments, Maryland Department of Natural Resources, Annapolis, Maryland.

Gore, James A., 1985, The Restoration of Rivers and Streams-Theories and Experience., Butterworth Publishers, Boston, Massachusetts.

Gore, J.A., and A.M. Milner, 1990, Island biogeographical theory: Can It Be Used To Predict Lotic Recovery Rates? Environment Management. 14: 737-753.

Gough, Steve, 1991, "Tree Revetments For Streambank Stabilization", Missouri Department of Conservation, Fisheries Division, Jefferson City, Missouri, 65102. Phone (314) 962-3200.

Gray, D.H. and A.T. Leiser, 1982, Biotechnical Slope Protection and Erosion Control, Van Nostrand Reinhold Co., New York, NY.

SELECTED REFERENCES CONT.

Guide To Forestry Best Management Practices, 1993, Tennessee Department of Agriculture, Division of Forestry, Nashville, Tennessee.

Leiser, A.T., 1983, "Reservoir Shoreline Revegetation," paper presented at U.S. Army Corps of Engineer training course, Wetlands Development and Restoration, Duck, N.C.

Lester, J.E., et al, 1986, "Lake Shore Revegetation Studies at Lake Texoma on the Red River, Texas-Oklahoma", Technical Report E-86-1. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Logan, L.D., 1979, "Guidelines for Streambank Erosion Control Along the Banks of the Missouri River from Garrison Dam Downstream to Bismarck, North Dakota", U.S. Department of Agriculture, Forest Service, State and Private Forestry, Missoula, Montana.

Mikalson, Ted S., 1993 (Draft), *Controlling Streambank Erosion*, Georgia Environmental Protection Division, Atlanta GA. 30334. Phone (404) 656-4988.

Minnesota Department of Natural Resources, Division of Waters, 1991, "Streambank Erosion...Gaining A Greater Understanding." MN-DNR, 500 Lafayette Rd., St. Paul, MN 55155-4031.

Roseboom, Donald, 1993, "Case Studies On Biotechnical Streambank Protection", Illinois State Water Survey, P.O. Box 697, Peoria, Illinois, 61652. Phone (309) 693-5117.

Schiechtl, H., 1980, Bioengineering For Land Reclamation and Conservation, The University of Alberta Press, Edmonton, Alberta, Canada.

Schnelle, Michael A., James R. Feucht, James E. Kleft, 1989, Root Systems of Trees - Facts and Fallacies, Arboriculture: Vol. 15, No. 9.

Streambank Stabilization and Management Guide, 1986, Commonwealth of Pennsylvania, Department of Environmental Resources, Bureau of Land Management and Water Conservation, Harrisburg Pennsylvania, 17105. Phone (717) 787-5267.

Stream Habitat Improvement Handbook, 1992, U.S.D.A. Forest Service, Southern Region, 1720 Peachtree Rd., N.W., Atlanta, Georgia, 30367-9102.

Turner, William, 1993, "Understanding Streams", Missouri Department of Conservation, Sedalia, Missouri, 65301. Phone (816) 530-5500.

SELECTED REFERENCES CONT.

Vetrano, David M., 1988, "Unit Construction of Trout Habitat Improvement Structures for Wisconsin Coulee Streams", Department of Natural Resources, Bureau of Fisheries Management, Madison, Wisconsin.

Watershed Restoration Sourcebook, Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Washington Council of Governments, , 1992. Collected papers presented at the conference, "Restoring Our Home River: Water Quality and Habitat In The Anacostia", held November 6 and 7, 1991 in College Park, Maryland. Metropolitan Information Center, Metropolitan Washington Council of Governments, 777 North Capitol St. NE, Suite 200, Washington, DC, 20002-4201. Phone (202) 962-3200.

Wingate, P.J., et al, 1979, "Guidelines for Mountain Stream Relocations in North Carolina", North Carolina Wildlife Resources Commission, Division of Inland Fisheries, Raleigh, North Carolina., 27611. Phone (919) 733-3633.

On the following pages are copies of regulations for aquatic alteration activities such as gravel dredging, constructing road crossings, and installing utility lines.

RULES
OF
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
WATER QUALITY CONTROL BOARD
DIVISION OF WATER POLLUTION CONTROL

CHAPTER 1200—4—7
AQUATIC RESOURCE ALTERATION

TABLE OF CONTENTS

1200—4—7—.01 DEFINITIONS. As used in this chapter, unless the context requires otherwise:

(1) "In the dry" means in such a manner that no equipment or dredged material is in contact with flowing water and that the soil-water interface is not touched by equipment and that infiltration to the dredging site is not pumped to the stream;

(2) Berm means an area of natural undisturbed material from the site that is left between the dredging area and the stream;

(3) Channelization means alterations of stream channels including but not limited to straightening, widening or enlarging stream channels;

(4) Dredging and "sand and gravel dredging" mean the removal of sand, gravel and similar deposits from a stream bed by any means;

(5) Individual permit means a permit issued by the Division of Water Pollution Control to a person to conduct specified activities at a specified location for a specific time period; and

(6) Stream means waters of the State on the surface of the ground including but not limited to creeks, rivers, and tributaries.

Authority: T.C.A. §§69—3—105 and 69—3—101 through 69—3—121. Administrative History: Original rule filed February 26, 1987; effective April 12, 1987. Amendment filed October 8, 1991; effective November 22, 1991.

1200—4—7—.02 through 1200—4—7—.04 RESERVED.

1200—4—7—.05 GENERAL PERMIT FOR LAUNCHING RAMPS.

(1) Construction of launching ramps is permitted by this rule provided the activity is done in accordance with the terms and conditions of this rule and provided:

(a) an individual permit is not required;

(b) no portion of the activity is located in wetlands;

(Rule 1200—4—7—.05, continued)

(c) no portion of the activity is located in a component of the National Wild and Scenic River System or a State Scenic River, or streams within the property boundaries of public lands administered by the National Park Service, the National Forest Service, the Tennessee Department of Environment and Conservation and the Tennessee Wildlife Resources Agency;

(d) no portion of the activity is located in any waterway which is identified by the Department as having contaminated sediments;

(e) the activity will not permanently disrupt the movement of aquatic life; and

(f) no portion of the activity is located in a known habitat of State or Federally listed treatened or endangered species.

(2) This general permit will expire August 1, 1996.

(3) Terms and Conditions.

(a) Persons proposing to construct a launching ramp in waters of State shall notify the Department by submission of an application which includes the following minimum information:

1. a map showing the exact location of the proposed construction site; and

2. a single copy of construction plans which includes specifications for proposed stream channel alterations and pollution control methods or structures.

(b) Construction shall not commence until the Commissioner issues written notification that the proposal may proceed in accordance with the terms of this rule or issues an individual permit.

(c) The width of the proposed ramp shall not exceed 20 feet.

(d) The ramp shall be constructed in the dry to the maximum extent practicable during winter drawdown periods of lakes/reservoirs or during low flow periods of free flowing streams. If wet construction is necessary, cofferdams shall be utilized.

(e) The excavation and fill activities associated with the ramp construction shall be kept to a minimum and all excess material shall be hauled to an upland site and properly stabilized to prevent reentry to the waterway.

(f) Clearing, grubbing and other disturbance to riparian vegetation shall be limited to the minimum necessary for slope construction and equipment operations. Unnecessary vegetation removal is prohibited. All disturbed areas shall be properly stabilized as soon as possible.

(g) The use of the ramp must not interfere with the public's right to free navigation on all navigable waters of the United States.

(h) Ramps constructed on fill shall have the side slopes stabilized with riprap.

(i) Material may not be placed in such location or manner so as to impair surface water flow into or out of any wetland area.

(j) The material to be discharged shall be free of contaminants, including toxic pollutants, hazardous substances, waste metal, construction debris, organic material, etc.

(Rule 1200—4—7—.05, continued)

(k) Erosion and sedimentation control measurers to protect water quality must be maintained throughout the construction period and repaired, if necessary, after rainfall. Straw or hay bales and/or silt fence must be installed along the base of all fills and cuts, on the downhill side of stock piled soil, and along stream banks in cleared areas to prevent erosion into streams. They must be installed parallel to the stream channel, entrenched and staked, and extend the width of the area to be cleared. The bales and/or silt fence may be removed at the beginning of the work day, but must be replaced at the end of the work day.

(l) Upon achievement of final grade, all disturbed areas must be stabilized and re-vegetated within 30 days by sodding or seeding and mulching. Seed to be utilized shall include a combination of annual grains and grasses, legumes, and perennial grasses. Lime and fertilizer shall be applied as needed to achieve a vegetative cover.

Authority: T.C.A. §§69—3—105(b) and 4—5—201 et seq. Administrative History: Original rule filed October 8, 1991; effective November 22, 1991.

1200—4—7—.06 GENERAL PERMIT FOR THE ALTERATION OF WET WEATHER CONVEYANCES.

Wet weather conveyances are defined in rule 1200—4—3—.04 of the Rules of Tennessee Department of Environment and Conservation. Rule 1200—4—3—.02(7) requires that waters designated as wet weather conveyances shall be protective of wildlife and humans that may come in contact with them and maintain standards applicable to all downstream waters. No other use classification or criteria apply to these waters. Activities which result in the alteration of wet weather conveyances are permitted by this rule provided the activity does not result in the discharge of waste or other substances which may be harmful to humans or wildlife, and that erosion and sedimentation and other pollution control mechanisms are employed to maintain the quality of downstream waters. This general permit will expire August 1, 1996.

Authority: T.C.A. §§69—3—105(b) and 4—5—201 et seq. Administrative History: Original rule filed October 8, 1991; effective November 22, 1991.

1200—4—7—.07 GENERAL PERMIT FOR MINOR ROAD CROSSINGS.

(1) Construction of minor road crossings is permitted by this rule provided the activtity is done in accordance with the terms and conditions of this rule and provided:

(a) an individual permit is not required;

(b) no portion of the activity is located in wetlands;

(c) no portion of the activity is located in a component of the National Wild and Scenic River System or a State Scenic River, or streams within the property boundaries of public lands administered by the National Park Service, the National Forest Service, the Tennessee Department of Environment and Conservation and the Tennessee Wildlife Resources Agency;

(d) no portion of the activity is located in any waterway which has been identified by the Department as having contaminated sediments;

(e) no portion of the activity is located in a known habitat of State or Federally listed treatened or endangered species.

(2) This general permit will expire August 1, 1996.

(Rule 1200—4—7—.07, continued)

(3) Terms and Conditions.

(a) Persons proposing to construct a minor road crossing in waters of State shall notify the Department by submission of an application which includes the following minimum information:

1. a map showing the exact location of the proposed construction site; and

2. a single copy of construction plans which includes specifications for proposed stream channel alterations and pollution control methods or structures.

(b) Stream alteration activities shall not commence until the Commissioner issues written notification that the proposal may proceed in accordance with the terms of this Rule or issues an individual permit.

(c) The crossing shall be culverted, bridged or otherwise designed to prevent the impairment of flow.

(d) The crossing shall be designed and constructed so as not to disrupt the movement of aquatic life.

(e) The width of the fill associated with the crossing shall be limited to the minimum necessary for the actual crossing.

(f) Stream alteration activities shall be limited to a 50 linear foot transition within the stream channel on either side of the road crossing and shall be limited to bank stabilization activities.

(g) Temporary erosion control measures must be in place before earthmoving operations begin, maintained throughout the construction period and repaired, if necessary, after rainfall. Straw or hay bales and/or silt fences must be installed along the base of all fills and cuts, on the downhill side of stock piled soil, and along stream banks in cleared areas to prevent erosion into streams. They must be installed parallel to the stream channel, entrenched and staked, and extend the width of the area to be cleared. The bales and/or silt fence may be removed at the beginning of the work day, but must be replaced at the end of the work day.

(h) Excavation and fill activities shall be separated from flowing waters. All surface water flowing toward excavation or fill work shall be diverted through utilization of cofferdams, berms, or temporary channels. Temperary diversion channels must be protected by non-erodable material and lined to the expected high water level. Cofferdams must be constructed of sand bags, clean rock, steel sheeting or other non-erodable material.

(i) Slurry water pumped from work areas and excavations must be held in settling basins or treated by filtration prior to its discharge into surface waters. Water must be held in sediment basins until at least as clear as the receiving waters. Sedimentation basins shall not be located closer than 20 feet from the top bank of a stream. Sediment basins and traps shall be properly designed according to the size of the drainage areas or volume of water to be treated.

(j) Checkdams shall be utilized where runoff is concentrated. Clean rock, log, sandbag, or straw bale checkdams shall be properly constructed to detain runoff and trap sediment.

(k) Clearing, grubbing and other disturbance to riparian vegetation shall be limited to the minimum necessary for slope construction and equipment operations. Unnecessary vegetation removal is prohibited. All disturbed areas shall be properly stabilized as soon as practicable.

(l) Streams shall not be used as transporation routes for heavy equipment. Crossings must be limited to one point and erosion control measures must be utilized where the stream banks are disturbed. Where the stream bed is not composed of rock, a pad of clean rock must be used at the crossing point. All temporary fill must be completely removed after the work is completed.

(Rule 1200—4—7—.07, *continued*)

(m) Construction debris must be kept from entering the stream channel.

(p) All spills of petroleum products or other chemical pollutants must be reported to the appropriate emergency management agency and measures shall be taken immediately to prevent the pollution of waters of the State, including groundwater.

(o) Upon achievement of final grade, all disturbed areas must be stabilized and re-vegetated within 30 days by sodding or seeding and mulching. Seed to be utilized shall include a combination of annual grains and grasses, legumes, and perennial grasses. Lime and fertilizer shall be applied as needed to achieve a vegetative cover.

Authority: T.C.A. §§69—3—105(b) and 4—5—201 et seq. Administrative History: Original rule filed October 8, 1991; effective November 22, 1991.

1200—4—7—.08 GENERAL PERMIT FOR UTILITY LINE CROSSINGS OF STREAMS.

(1) Construction of utility line crossing of streams is permitted by this rule provided the activity is done in accordance with the terms and conditions of this rule and provided:

(a) an individual permit is not required;

(b) no portion of the activity is located in wetlands;

(c) no portion of the activity is located in a component of the National Wild and Scenic River System or a State Scenic River, or streams within the property boundaries of public lands administered by the National Park Service, the National Forest Service, the Tennessee Department of Environment and Conservation and the Tennessee Wildlife Resources Agency;

(d) no portion of the activity is located in any waterway which is indentified by the Department as having contaminated sediments;

(e) the activitiy will not permanently disrupt the movement of aquatic life;

(f) no portion of the activity is located in a known habitat of State or Federally listed threatened or endangered species; and

(g) the utility lines are not proposed to convey hazardous materials as recognized by State and Federal regulations.

(2) This general permit will expire August 1, 1996.

(3) For the purpose of this rule, bodies of water defined as navigable pursuant to Section 10 of the Rivers and Harbors Act of 1899 are subject to different restrictions than all other waters regarding the specific construction methodologies to be employed under this general permit.

(a) When the activity is located in waters which are not navigable pursuant to Section 10, excavation and fill activities shall be separated from flowing waters. All surface water flowing toward the excavation or fill work shall be diverted, piped or flumed to the downstream side of the work. This can be accomplished through utilization of cofferdams or constructed berms in conjunction with a pipe or flume. Cofferdams must be constructed of sand bags, clean rock, steel sheeting or other non-erodable material.

(b) Where the activity is located in waters defined as navigable pursuant to Section 10 of the Rivers and Harbors Act of 1989, excavation and fill work may be accomplished within the water column.

(Rule 1200—4—7—.08, continued)

(4) Terms and Conditions.

(a) New utility line crossings shall be located such as to avoid permanent alteration or damage to the integrity of the stream channel. Large trees, steep banks, rock outcroppings, etc. should be avoided.

(b) In the case of proposed gravity sewer lines and other utility lines which follow the stream gradient or otherwise parallel the stream channel, the number of crossing shall be minimized. Where cumulative impacts are likely because of numerous crossing, an individual permit may be required.

(c) The alignment of new utility line crossings shall intersect the stream channel as close to 90 degrees or as perpendicular as possible, and in no case less than 45 degrees angle from the center line of the stream.

(d) In the case of small streams with a bedrock stream bed which must be blasted to form a trench, provisision shall be made to prevent the loss of stream flow to fracturing of the bedrock. Where loss of surface flow is likely to occur, an individual permit may be required.

(e) Temporary erosion control measures must be in place before earthmoving operations begin, maintained throughout the construction period and repaired, if necessary, after rainfall. Straw or hay bales and/or cuts fence must be installed along the base of all fills and suts, on the downhill side of stock piled soil, and along stream banks in cleared areas to prevent erosion into streams. They must be installed parallel to the stream channel, entrenched and staked, and extend the width of the area to be cleared. The bales and/or silt fence may be removed at the beginning of the work day, but must be replaced at the end of the workday.

(f) Backfill activities must be accomplished in a manner which stabilizes the stream bed and banks to prevent erosion. Backfill materials shall consist of suitable materials free of contaminants. All contours must be returned to pre-project conditions. The completed work may not disrupt or impound stream flow.

(g) Slurry water pumped from work areas and excavations must be held in settling basins or treated by filtration prior to its discharge into surface waters. Water must be held in sediment basins until at least as clear as the receiving waters. Sedimentation basins shall not be located closer than 20 feet from the top bank of a stream. Sediment basins and traps shall be properly designed according to the size of the drainage areas or volume of water to be treated.

(h) Checkdams shall be utilized where runoff is concentrated. Clean rock, log, sandbag, or straw bale checkdams shall be properly constructed to detain runoff and trap sediment.

(i) Clearing, grubbing and other disturbance to riparian vegetation shall be limited to the minimum necessary for slope contruction and equipment operations. Unnecessary vegetation removal is prohibited. All disturbed areas shall be properly stabilized as soon as practicable.

(j) Streams shall not be used as transportation routes for heavy equipment. Crossings must be limited to one point and erosion control measures must be utilized where the stream banks are disturbed. Where the stream bed is not composed of rock, a pad of clean rock must be used at the crossing point. All temporary fill must be completely removed after the work is completed.

(k) Construction debris must be kept from entering the stream channel.

(Rule 1200—4—7—.08, continued)

(l) All spills of petroleum products or other chemical pollutants must be reported to the appropriate emergency management agency and measures shall be taken immediately to prevent the pollution of waters of the State, including groundwater.

(m) Upon achievement of final grade, the disturbed streambank shall be stabilized with riprap or other suitable material. All other disturbed soils must be stabilized and re-vegetated within 30 days by sodding or seeding and mulching. Seed to be utilized shall include combination of annual grains and grasses, legumes, and perennial grasses. Lime and fertilizer shall be applied as needed to achieve a vegetative color.

(n) Upon completion of construction, the stream shall be returned as nearly as possible to its original, natural conditions.

Authority: T.C.A. §§69—3—105(b) and 4—5—201 et seq. Administrative History: Original rule filed October 8, 1991; effective November 22, 1991.

1200—4—7—.09 GENERAL PERMIT FOR BANK STABILIZATION ACTIVITIES.

(1) Bank stabilization activities are permitted by this rule provided the activity is done in accordance with the terms and conditions of this rule and provided:

(a) an individual permit is not required;

(b) the activity is necessary to repair or prevent bank erosion;

(c) no portion of the activity is located in wetlands;

(d) no portion of the activity is located in a component of the National Wild and Scenic River System or a State Scenic River, or streams within the property boundaries of public lands administered by the National Park Service, the National Forest Service, the Tennessee Department of Environment and Conservation and the Tennessee Wildlife Resources Agency;

(e) no portion of the activity is located in any waterway which is identified by the Department as having contaminated sediments;

(f) the activity will not permanently disrupt the movement of aquatic life; and

(g) no portion of the activity is located in a known habitat of State or Federally listed threatened or endangered species.

(2) This general permit will expire August 1, 1996.

(3) Terms and Conditions.

(a) Persons proposing to conduct streambank stabilization activities in waters of the State shall notify the Department by submission of an application which includes the following minimum information:

1. a map showing the exact location of the proposed construction site; and

2. a single copy of construction plans which includes specifications for proposed stream channel alterations and pollution control methods or structures.

(b) Stream alteration activities shall not commence until the Commissioner issues written notification that the proposal may proceed in accordance with the terms of this rule or issues an individual permit.

(Rule 1200—4—7—.09, continued)

(c) Stream bank disturbance associated with stabilization shall be limited to the minimum needed for abatement and prevention of stream bank erosion.

(d) Material may not be placed in such location or manner so as to impair surface water flow into or out of any wetland area.

(e) Materials used in stabilization shall include clean shot rock, rip rap or anchored trees or other non-erodable materials found in the natural environment. Stabilization materials shall not include gravel, sand, sediments, chert, soil, or other unconsolidated materials. Materials to be discharged shall be free of contaminants, including toxic pollutants, hazardous substances, waste metal, construction debris, organic materials, etc.

(f) Streams shall not be used as transportation routes for heavy equipment. Crossings must be limited to one point and erosion control measures must be utilized where the stream banks are disturbed, Where the stream bed is not composed of rock, a pad of clean rock must be used at the crossing point. All temporary fill must be completely removed after the work is completed.

(g) Vegetation and debris disturbed by activity at the construction site shall be removed from the site to such a location so as to prevent reentry into the waterway.

(h) Clearing, grubbing and other disturbance to riparian vegetation shall be limited to the minimum necessary for slope construction and equipment operations. Unnecessary vegetation removal is prohibited. All disturbed areas shall be properly stabilized as soon as practicable.

(i) Upon achievement of final grade, all disturbed areas must be stabilized and re-vegetated within 30 days by sodding or seeding and mulching. Seed to be utilized shall include a combination of annual grains and grasses, legumes, and perennial grasses. Lime and fertilizer shall be applied as needed to achieve a vegetative cover.

(3) For the purpose of this rule, bodies of water defined as navigable pursuant to Section 10 of the Rivers and Harbors Act of 1989 are subject to different restrictions than all other waters regarding the scope and type of bank stabilization activities authorized under this general permit. Where the activity is located in waters which are not navigable pursuant to Section 10, the following special conditions apply:

(a) Removal of living trees and other riparian vegetation which help comprise the integrity of the stream bank or which help provide canopy or shade to the waters or the placement of fill which would otherwise injure or damage stream side vegetation is not authorized by this rule.

(b) Grading, sloping, dredging or reshaping of the steam banks or bed is not authorized by this rule.

(c) The discharge of stabilization materials is limited to 200 linear feet of stream bank.

(4) Where the activity is located in waters defined as navigable pursuant to Section 10 of the Rivers and Habors Act of 1989, the following special conditions apply:

(a) the discharge of materials is limited to less than an average of one cubic yard per running foot placed along the bank;

(b) the activity may be up to 500 feet in length.

Authority: T.C.A. §§69—3—105(b) and 4—5—201 et seq. Administrative History: Original rule filed October 8, 1991; effective November 22, 1991.

1200—4—7—.10 GENERAL PERMIT FOR SAND AND GRAVEL DREDGING.

(1) Dredging of sand or gravel in any waters of the State is permitted by this rule provided it is done in accordance with all terms and conditions of this rule and provided:

(a) an individual permit is not required;

(b) no portion of the activity is located in wetlands;

(c) no portion of the activity is located in a component of the National Wild and Scenic River System or a State Scenic River, or streams within the property boundaries of public lands administered by the U.S. Fish and Wildlife Service, the National Park Service, the National Forest Service, the Tennessee Department of Environment and Conservation or the Tennessee Wildlife Resources Agency;

(d) no portion of the activity is located in any waterway which is identified by the Department as having contaminated sediments;

(e) the activitiy will not permanently disrupt the movement of aquatic life; and

(f) no portion of the activity is located in a known habitat of State or Federally listed threatened or endangered species.

(2) This general permit will expire August 1, 1996.

(3) This rule does not authorize the discharge of any substance into waters of the State, for any purpose, including dredged or fill material.

(4) Authorization by this rule does not relieve the applicant from requirements of other applicable federal, state, and local law.

(5) This rule does not authorize the removal of material from streams for the purpose of flood control or channelization.

(6) Terms and Conditions.

(a) Persons proposing to dredge sand and gravel in waters of State shall submit a notifcation form to the Department which includes a work plan with the following minimum information:

1. a map (or copy) showing the exact location of the proposed dredging site; and

2. a sketch or drawing of the gravel deposit in relation to the stream, including the access point.

(b) Dredging shall not commence until the Commissioner issues written notification that the proposal may proceed in accordance with the terms of this rule or issues an individual permit.

(c) The operation shall be conducted in the dry. A berm of at least five feet in width shall be left between the work area and the stream flow, or of such width as necessary to separate the excavation from the water in the stream. Berm is defined here as natural undisturbed material that is left between the dredging area and the stream.

(d) Access to the work area shall be made at one point only, limiting disruption of trees and other stream cover to an area less than 20 feet wide.

(e) Stream crossing shall be limited to a single right angle crossing directly adjacent to the gravel bar.

(Rule 1200—4—7—.10, continued)

(f) Measures shall be taken to prevent erosion and sedimentation. When work is completed in an area, normal physical characteristic of the work area shall be recreated to the extent that machinery can do so without causing additional disturbance. This shall be accomplished by grading the site to smooth contours without disturbing the berm or its bank.

(g) Vegetation and debris disturbed during dredging or dredge site preparation shall be removed to an upland location and placed in such a manner as to prevent re-entry into the stream.

(h) Dredged material shall not be stored or stockpiled in the stream bed.

Authority: T.C.A. §§69—3—105(b) and 4—5—201 et seq. Administrative History: Original rule filed October 8, 1991; effective November 22, 1991.

1200—4—7—.11 GENERAL PERMIT FOR DEBRIS REMOVAL.

(1) Removal of debris from streams is permitted by this rule provided it is done in accordance with all terms and conditions of this rule, and provided the Department does not require an individual permit.

(2) This general permit will expire August 1, 1996.

(3) Terms and Conditions.

(a) Sediment removal is not authorized under this rule except in accordance with the requirements of (3)(b), which is for the removal of unconsolidated sediments from around bridges and culverts.

(b) Unconsolidated sediments, such as sand and gravel may be removed from the vicinity of bridges, culverts and low water crossings provided that the following requirements are adhered to:

1. All work must be performed within one hundred feet of the bridge culvert or low water crossing.

2. There shall be no disruption of the stream banks except at the access point.

3. All disturbed material shall be removed from the stream channel.

(c) This rule does not authorize the removal of any living streambank vegetation except when the vegetation is causing a direct blockage of flow, or when removal is needed to allow access to the debris accumulation. Trees in proximity to the stream (alive or dead) which, because of undermining or mortality, are likely to cause a problem in the near future may be removed. However, where the roots help provide stability to the streambank, the roots should be left intact.

(d) Equipment that will cause the least damage to the enviroment shall be selected for performing the debris removal. First consideration shall be given to the use of hand operated equipment such as axes, chain saws, and winches to remove accumulations of debris. Major accumulations of debris may be removed by small tractors, backhoes, small trackholes, small bulldozers, and log skidders. However, no work by larger equipment is authorized.

(e) Access to the work area shall be made at one point only, limiting disruption of trees and other stream cover to an area less than twenty feet wide and measures shall be taken to prevent erosion.

(f) Debris removed from the stream shall be moved to an upland location and secured in such a manner as to prevent its reentry into the stream channel.

(g) No removal of material shall result in draining or alteration of any wetland.

(Rule 1200—4—7—.11, continued)

(h) No material removed from the stream shall be deposited in wetlands.

Authority: T.C.A. §§69—3—105(b) and 4—5—201 et seq. Administrative History: Original rule filed October 8, 1991; effective November 22, 1991.

U. S. Army Corps of Engineers

List of Navigable Waters of the United States pursuant to the Rivers and Harbors Act of 1899

Navigable Waters Within the Memphis District

I. Forked Deer River - Mouth to Mile 25 (confluence with North and South Forks).

A. North Fork Forked Deer River (FDRM 25) - Mouth to Mile 6 (Dyersburg, TN).

B. South Fork Forked Deer River (FDRM 25) - Mouth to Mile 94 (Jackson, TN).

II. Hatchie River - Mouth to Mile 140 (Bolivar, TN).

III. Obion River - Mouth to Mile 69.1 (Obion, TN).

IV. Wolf River - Mouth to Mile 15 (Raleigh, TN).

Navigable Waters Within the Nashville District

CUMBERLAND RIVER AND TRIBUTARIES

I. Cumberland River (CR) - Mouth to Mile 694.2 (Head of River, Confluence of Poor Fork and Clover Fork, at Harlan, Kentucky).

A. Little River (CRM 59.0) - Mouth to Mile 60.9 (Confluence of the North and South Forks).

B. Red River (CRM 125.3) - Mouth to Mile 76.5 (Prices Mill Dam).

1. West Fork Red River (Red River Mile 1.2) - Mouth to Mile 7.4 (Head of Slackwaters of Barkley Lake).

2. Sulphur Fork Red River (Red River Mile 25.5) - Mouth to Mile 26.6 (Road Bridge 1.5 Miles Northeast of Springfield, Tennessee).

3. Elk Fork Red River (Red River Mile 33.8) - Mouth to Mile 8.7 (Road Bridge Near Darnell, Kentucky).

4. Whippoorwill Creek (Red River Mile 54.9)- Mouth to Mile 11 (Head of Slackwaters of Lickskillet Mill Dam).

5. South Fork Red River (Red River Mile 56.9) - Mouth to Mile 7.9 (Tennessee-Kentucky State Line).

C. Harpeth River (CRM 152.9) - Mouth to Mile 114.5 (US Highway 41A Bridge).

1. Jones Creek (Harpeth River Mile 10.6) Mouth to Mile 14.4, (Tennessee Highway 47 Bridge).

2. Turnbull Creek (Harpeth River Mile 35.1) Mouth to Mile 13.1, (Tennessee Highway 96 Bridge).

3. South Harpeth River (Harpeth River Mile 43.4) Mouth to Mile 8.4, (Old Harding Pike Bridge).

4. West Harpeth River (Harpeth River Mile 78.7) Mouth to Mile 8.6 (Confluence with Leipers Fork).

D. Stones River (CRM 205.6) - Mouth to Mile 38.6 (Confluence of East and West Forks, Stones River).

East Fork, Stones River - Mouth to Mile 38.2 (Confluence of Carson Fork).

2. West Fork, Stones River - Mouth to Mile 21.8 (Confluence of Middle Fork Stones River).

E. Caney Fork River (CRM 309.2) - Mouth to Mile 134.2 (Cumberland County Highway Bridge).

1. Smith Fork Creek (Caney Fork Mile 15.9) Mouth to Mile 30.5 (DeKalb County Highway Bride near Cottage Home, Tennessee).

2. Falling Water River (Caney Fork Mile 53.4) Mouth to Mile 10.2 (Head of Slackwaters of Center Hill Lake).

3. Collins River (Caney Fork Mile 91.2) Mouth to Mile 55.2 (Confluence with Big Creek).

a. Barren Fork (Collins River Mile 21.5) Mouth to Mile 23.1 (Warren County Highway Bridge near Trousdale, Tennessee).

M. <u>Flint River</u> (TRM 339.1) - Mouth to Mile 51.2 (Madison County Highway Bridge Due East of Fisk, Alabama).

N. <u>Paint Rock River</u> (TRM 343.2) - Mouth to Mile 60.0 (Confluence of Estill Fork and Hurricane Creek).

1. <u>Estill Fork</u> (Paint Rock River Mile 60.0) - Mouth to Mile 10.0 (Confluence of Keller and Dry Creeks).

2. <u>Hurricane Creek</u> (Paint Rock River Mile 60.0) - Mouth to Mile 7.4 (John Gifford Hollow).

O. <u>Town Creek</u> (TRM 360.8) - Mouth to Mile 14.0 (High Falls).

P. <u>Short Creek</u> (TRM 360.8) - Mouth to Mile 6.5 (Short Creek Falls).

Q. <u>Crow Creek</u> (TRM 401.1) - Mouth to Mile 33.7 (Confluence with Dry Creek).

R. <u>Sequatchie River</u> (TRM 422.7) - Mouth to Mile 86.3 (Site of Cooper Mill Dam).

1. <u>Little Sequatchie River</u> (Sequatchie River Mile 8.0) Mouth to Mile 8.0 (One Mile North of Coppinger Chapel).

S. <u>South Chickamauga Creek</u> (TRM 468.2) - Mouth to Mile 17.3) (Tennessee-Georgia State Line).

1. <u>West Chickamauga Creek</u> (South Chickamauga Creek Mile 13.2) Mouth to Mile 3.2 (Tennessee-Georgia State Line).

T. <u>North Chickamauga Creek</u> (TRM 470.9) - Mouth to Mile 17.4 (U.S. Highway 27 Bridge).

U. <u>Hiwassee River</u> (TRM 500.3) - Mouth to Mile 65.8 (Tennessee-North Carolina State Line).

1. <u>Ocoee River</u> (Hiwassee River Mile 34.4) - Mouth to Mile 38.8 (Tennessee-Georgia State Line).

V. <u>Piney River</u> (TRM 532.5) - Mouth to Mile 8.9 (Confluence with Soak Creek).

W. <u>Clinch River</u> (TRM 567.7) - Mouth to Mile 202.1 (Tennessee-Virginia State Line).

1. <u>Emory River</u> (Clinch River Mile 4.4) - Mouth to Mile 45.3 (Site of Macedonia Church).

2. <u>Obed River</u> (Emory River Mile 28.4) - Mouth to Mile 34.5 (U.S. Highway 127 Bridge).

C. Big Sandy River (TRM 67.0) - Mouth to Mile 52.6 (Carroll County Highway Bridge near Wildersville, Tennessee).

1. West Fork Big Sandy River (Big Sandy River Mile 8.8) - Mouth to Mile 8.2 (Tennessee Highway 69 Bridge).

D. Duck River (TRM 110.8) - Mouth to Mile 262.8 (Head of Slackwaters of Normandy Lake).

1. Buffalo River (Duck River Mile 15.4) - Mouth to Mile 116.7 (Lawrence County Highway Bridge at Henryville, Tennessee).

E. Beech River (TRM 135.7) - Mouth to Mile 21.6 (Henderson County, Highway Bridge near Chesterfield, Tennessee).

F. Yellow Creek (TRM 215.1) - Mouth to Mile 32.1 (Head, Tennessee Valley Divide).

G. Bear Creek (TRM 224.7) - Mouth to Mile 130.0 (Head of Slackwaters of Upper Bear Creek Lake).

1. Cedar Creek (Bear Creek Mile 27.7) - Mouth to Mile 38.3 (Head of Slackwaters of Cedar Creek Lake).

a. Little Bear Creek (Cedar Creek Mile 14.9) - Mouth to Mile 23.1 (Head of Slackwaters of Little Bear Creek Lake).

H. Cypress Creek (TRM 255.0) - Mouth to Mile 17.6 (Lauderdale County Highway Bridge).

1. Little Cypress Creek (Cypress Creek Mile 10.2) - Mouth to Mile 8.0 (Head of Slackwaters of Sharps Mill Lake).

I. Shoal Creek (TRM 264.3) - Mouth to Mile 56.0 (Confluence with Little Shoal Creek).

1. Factory Creek (Shoal Creek Mile 28.6) - Mouth to Mile 9.7 (Wayne County Highway Bridge 0.1 Mile Upstream of Couch Branch).

J. Elk River (TRM 284.3) - Mouth to Mile 194.1 (US Highway 41 Bridge).

1. Richland Creek (Elk River Mile 42.6) - Mouth to Mile 48.6 (Confluence with Clear Creek).

K. Flint Creek (TRM 308.4) - Mouth to Mile 28.2 (Huckaba Bridge).

L. Limestone Creek (TRM 310.7) - Mouth to Mile 32.0 (Confluence with Little Limestone Creek).

I. Buck Creek (CRM 533.8) - Mouth to Mile 45.0 (Kentucky Highway 70 Bridge).

J. Rockcastle River (CRM 546.4) - Mouth to Mile 53.2 (Confluence of Middle and South Forks).

1. South Fork Rockcastle River - Mouth to Mile 8.5, (Confluence with Pond Creek).

2. Middle Fork Rockcastle River - Mouth to Mile 7.8, (Confluence of Indian Creek and Laurel Fork).

3. Roundstone Creek (Rockcastle River Mile 43.1) - Mouth to Mile 13.4, (Confluence with Renfro Creek).

K. Laurel River (CRM 552.1) - Mouth to Mile 30.5 (Head of Slackwaters of Dorethea Lake).

L. Clear Fork of Cumberland River (CRM 592.3) - Mouth to Mile 33.0 (Confluence with Tackett Creek).

1. Hickory Creek (Clear Fork of Cumberland River Mile 28.2) - Mouth to Mile 9.8 (Confluence with Stinking Creek).

M. Poor Fork of Cumberland River (CRM 694.2) - Mouth to Mile 39.9 (Confluence with Franks Creek).

N. Clover Fork of Cumberland River (CRM 694.2) - Mouth to Mile 11.0 (Mouth of Bailey Creek).

1. Martins Fork of Cumberland River (Clover Fork of Cumberland River Mile 1.6) - Mouth to Mile 19.5. (Head of Slackwaters of Martins Fork Lake).

TENNESSEE RIVER AND TRIBUTARIES

II. Tennessee River (TR) - Mouth to Mile 652.1 (Head, Confluence of French Broad and Holston Rivers).

A. Clarks River (TRM 4.3) - Mouth to Mile 20.2 (ELVA Bridge).

1. West Fork Clarks River (Clarks River Mile 12.7) - Mouth to Mile 11.9 (Kahler Bridge).

B. Blood River (TRM 50.7) - Mouth to Mile 9.7 (Kentucky Highway 121 Bridge).

(1) <u>Hickory Creek</u> (Barren Fork Mile 10.5) Mouth to Mile 12.6, (Confluence with West Fork).

4. <u>Rocky River</u> (Caney Fork Mile 92.6) Mouth to Mile 9.6, (Head of Slackwaters of Great Falls Lake).

5. <u>Calfkiller River</u> (Caney Fork Mile 104.6) Mouth to Mile 23.3, (Confluence with Cherry Creek).

6. <u>Cane Creek</u> (Caney Fork Mile 108.8) Mouth to Mile 10.8, (Confluence with Indian Camp Branch).

F. <u>Roaring River</u> (CRM 357.8) Mouth to Mile 22.3 (Site of Johnson Falls).

1. <u>Spring Creek</u> (Roaring River Mile 12.0) Mouth to Mile 8.6, (Site of Waterloo Falls).

2. <u>Blackburn Fork</u> (Roaring River Mile 8.0) Mouth to Mile 14.3, (Site of Cummins Falls).

G. <u>Obey River</u> (CRM 380.9) - Mouth to Mile 58.2 (Confluence of East Fork and West Fork Obey River).

1. <u>East Fork Obey River</u> - Mouth to Mile 29.6 (Confluence with Hurricane Creek).

2. <u>West Fork Obey River</u> - Mouth to Mile 20.0 (Confluence with Dry Hollow Branch).

3. <u>Wolf River</u> (Obey River Mile 31.1) - Mouth to Mile 35.6 (Confluence with Rotten Fork).

H. <u>Big South Fork Cumberland River</u> (CRM 516.0) - Mouth to Mile 77.0 (Confluence of Clear Fork River and New River).

1. <u>Little South Fork</u> (BSF River Mile 26.1) - Mouth to Mile 31.5 (at Parmleysville, Kentucky).

2. <u>Rock Creek</u> (BSF River Mile 40.9) - Mouth to Mile 3.6 (at White Oak Junction, Kentucky).

3. <u>North Whiteoak Creek</u> (BSF River Mile 71.5) - Mouth to Mile 6.5 (at Zenith, Tennessee).

4. <u>New River</u> - Mouth to Mile 36.0 (Confluence with Smoky Creek).

5. <u>Clear Fork River</u> - Mouth to Mile 25.8 (at Gatewood's Bridge).

a. <u>Whiteoak Creek</u> (Clear Fork River Mile 9.4) - Mouth to Mile 5.6 (Tennessee Highway 52 Bridge).

a. West Prong, Little Pigeon River (Little Pigeon River Mile 4.7) Mouth to Mile 12.3, (Champmans Highway Bridge).

b. East Fork Little Pigeon River (Little Pigeon River Mile 9.6) Mouth to Mile 11.0 (Confluence of Long Branch and Dunn Creek).

2. Nolichucky River (French Broad River Mile 69.1) - Mouth to Mile 100.8 (Tennessee-North Carolina State Line).

a. Lick Creek (Nolichucky River Mile 16.0) - Mouth to Mile 49.8 (Lick Creek Mill).

3. Pigeon River (French Broad River Mile 73.8) - Mouth to Mile 25.9 (Tennessee-North Carolina State Line).

In addition, embayments and tributary streams of all impounded reservoirs of navigable waters of the United States are also considered navigable waters of the United States to the extent of slackwaters, and jurisdiction will be exercised accordingly.

(1) Clear Creek (Obed River Mile 4.4) - Mouth to Mile 29 (U.S. Highway 127 Bridge).

(a) White Creek (Clear Creek Mile 8.8) - Mouth to Mile 6.9 (Twin Bridges).

(2) Daddys Creek (Obed River Mile 9.1) - Mouth to Mile 33.9 (Tennessee Highway 28 Bridge).

2. Poplar Creek (Clinch River Mile 12.0) - Mouth to Mile 18.3 (Tennessee Highway 61 Bridge).

3. Powell River (Clinch River Mile 88.8) - Mouth to Mile 115.7 (Tennessee-Virginia State Line).

X. Little Tennessee River (TRM 601.3) - Mouth to Mile 49.4 (Tennessee-North Carolina State Line).

1. Tellico River (Little Tennessee River Mile 19.2) - Mouth to Mile 37.0 (One mile downstream of Bald River Falls).

Y. Little River (TRM 635.6) - Mouth to Mile 50.5 (At Elkmont, Tennessee).

Z. Holston River (TRM 652.1) - Mouth to Mile 142.2 (Head, Confluence of North and South Fork Holston River).

1. North Fork Holston River (Holston River Mile 142.2) - Mouth to Mile 5.0 (Tennessee-Virginia State Line).

2. South Fork Holston River (Holston River Mile 142.2) - Mouth to Mile 73.7 (Head of Slackwaters of South Holston Lake).

a. Watauga River (South Fork Holston River Mile 19.9) - Mouth to Mile 55.1 (Tennessee-North Carolina State Line).

(1) Doe River (Watauga River Mile 26.4) Mouth to Mile 22.7, (1.[illegible] miles SSW of Roan Mountain).

(2) Elk River (Watauga River Mile 46.8) Mouth to Mile 14.5 (Tennessee-North Carolina State Line).

b. Middle Fork Holston River (South Fork Holston River Mile 72.3) - Mouth to Mile 1.3 (Head of Slackwaters of South Holston Lake).

AA. French Broad River (TRM 652.1) - Mouth to Mile 102.6 (Tennessee-North Carolina State Line).

1. Little Pigeon River (French Broad River Mile 27.4) - Mouth to Mile 25.5 (Highway 73 Bridge).

CONTACT LIST

Please contact these agencies for assistance with aquatic alteration activities:

U.S Department of Agriculture (Check your local listing for an office near you)

Agriculture Resources Division
Tennessee Dept. of Agriculture
Ellington Agriculture Center
P.O. Box 40627
Nashville, Tennessee 37204
(615)360-1008

Forestry Water Quality Management Program
Tennessee Div. of Forestry
Ellington Agriculture Center
P.O. Box 40627
Nashville, Tennessee 37204
(615)360-0756

Tennessee Department of Environment and Conservation, Division of Water Pollution Control Offices:

Natural Resources Section
7th Floor, L&C Annex
401 Church Street
Nashville, Tennessee 37243
(615)532-0625

Nonpoint Source Section
7th Floor, L&C Annex
401 Church Street
Nashville, Tennessee 37243
(615)532-0625

Check Aquatic and Permits and Regulations, Section III for Water Pollution Control field office addresses and phone numbers.

Ray D. Hedrick
U.S. Army Corps. of Engineers
Room A - 452 U.S. Courthouse
Nashville, Tennessee 37202
(615)736-5026

Wayne Pollack
Tennessee Wildlife Resources Agency
P.O. Box 40747
Nashville Tn. 37204
(615)781-6500

9-95