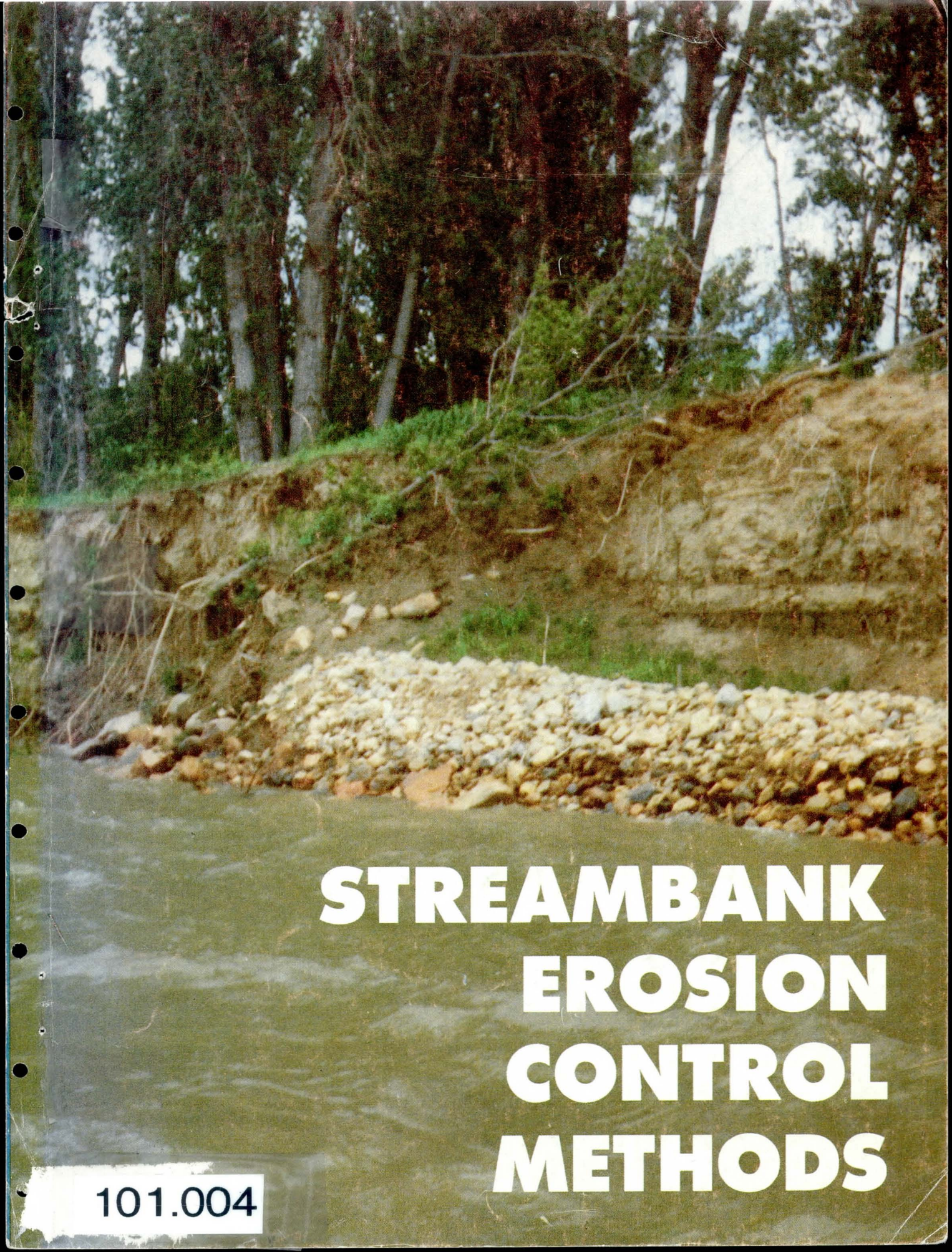

STREAMBANK EROSION CONTROL METHODS

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I. INTRODUCTION

Stabilizing banks of meandering streams and rivers can be a major problem. Where bank cutting may cause severe damage to property or loss of valuable farmland, the problem may require attention.

The Rock Island District recently conducted a study to determine the feasibility of providing bank erosion control measures along the Des Moines River in Iowa and Missouri. This self-help brochure has been prepared as a result of this study to provide technical guidance to local government officials and landowners interested in constructing bank erosion control measures.

Work in the "Waters of the United States" requires a permit from the Corps of Engineers. Each case is reviewed by State and Federal agencies concerned, especially for environmental considerations. Certain bank protection measures may be more suitable than others from an environmental view. Early coordination with the Corps of Engineers may help avoid environmental problems.

II. FEDERAL ASSISTANCE AVAILABLE

In most cases, help from the Corps of Engineers is limited to technical assistance. In cases where bank erosion endangers bridges, essential public facilities, and non-public facilities that provide non-profit public services, Federal participation in the funding of remedial action is possible.

EMERGENCY STREAMBANK PROTECTION

Congress has given direct authority to the Chief of Engineers to authorize and fund certain projects granted in Section 14 of the 1946 Flood Control Act. This direct authority allows a more prompt analysis of local problems. It also provides the basis for Federal participation in the funding of a project.

Each project undertaken under the special authority must be complete in itself. It must be economically justified, which means that the benefits received must exceed the cost of planning, design, and construction.

A Federal limitation cost has been established for projects under this direct authority. The current limitation is $250,000 per project.

When damage or danger of structural damage to essential public facilities, bridges, or non-public facilities that provide non-profit public services occurs, the process for Federal support includes:

* Local entities request help from the Corps of Engineers by writing to the District Engineer at the Rock Island District Office.

* A field inspection by technical personnel evaluates the severity of the problem.

* A reconnaissance report is prepared. This is a letter report addressing the problem, the economic feasibility of a solution, and the environmental impact of any proposed action. If the proposed solution is environmentally acceptable, economically feasible, and sponsored by appropriate local interests, the District Engineer may request Federal support.

* The local sponsor must agree to furnish lands required for the project and participate in the cost-sharing of the design and construction of the project, and provide the maintenance of the completed project.

* Under the special Continuing Authority for Emergency Bank Protection, the Chief of Engineers may assign funds. (Funding of these projects, however, is dependent upon annual budget constraints.)

* If budget conditions are favorable, funds may be assigned for the proposed streambank erosion solution.

* Average time to plan and construct a project is two years; although, in extreme emergency situations the time frame is reduced to six months.

TECHNICAL ASSISTANCE

Even though Federal participation in construction of erosion-control measures may not be economically justified, or the authority not available for private property protection, the Corps of Engineers is available to provide technical assistance. The information presented in this brochure on alternative measures for abating streambank erosion may require additional technical assistance. Rock Island District personnel are available to help explain these measures more fully, but a private engineering consultant firm would be required for the design and construction of the project. Hopefully, in those instances when technical assistance, local initiative, and minimum resources are combined, a solution to bank erosion problems can be found.

III. UNDERSTANDING STREAMBANK EROSION

The control of the interrelated forces causing streambank erosion is very difficult. Over the last century, many of the great rivers in this country have been studied in an attempt to develop them for navigation, power, water supply, and irrigation. But even with this concentrated study of rivers, engineers cannot consistently predict the behavior of a river at any given location from a cursory examination. To reliably determine the specific behavior of a given river reach, it would be necessary to conduct expensive physical model tests. The expense involved in these kinds of tests usually preclude their use in all but the largest projects. However, full scale experimentation and testing on the stream itself is another form of modeling which can be very effective, and this "trial and error" approach is often used to solve bank erosion problems. An experienced engineer can often diagnose and prescribe one or more workable solutions to an erosion problem. But costs generally preclude the use of the "best" solution, and the use of alternate and inferior solutions will reduce the chances of success. However, there are cases where minimal erosion control measures have succeeded but there are also cases where substantial erosion control measures have failed. An individual embarking on a bank erosion control project should be aware of the risks involved, and that even with the best advice, factors and conditions may exist and be overlooked or be created by the construction works which could result in an unsuccessful project.

In attempting to control or modify the nature of a river the environment must be considered. Unfortunately, environmental studies have been quite limited regarding the possible impacts of streambank erosion control measures on the aquatic and terrestrial ecosystems of streams. Future studies may indicate that certain structural measures may be detrimental to the stream environment. If such studies so indicate, it may mean that certain structures will no longer be approved for construction and/or maintenance.

Summarized below are some important facts an individual property owner should know before beginning a bank erosion control project:

* The river forces contributing to bank erosion and natural meandering of rivers are powerful and persistent forces that are difficult to deter.

* Positive control of these forces generally require substantial structures involving significant investment.

* Other than expensive model testing, the most effective remedial measures can best be determined by the judgment of an engineer who has had experience with bank erosion problems.

* Because individuals generally have limited funds to spend on bank erosion control projects, they are forced to construct minimal projects. These efforts are quite frequently not sufficient to arrest the bank erosion.

* Future environmental studies may dictate that certain structures will not be approved for construction and/or maintenance.

IV. PLANNING CONSIDERATIONS

A. PLANNING PROCESS

Define the problem - The factors affecting streambank erosion are the orientation of the streambank, the velocity and depth of the river, and the soil composition of the streambank. An individual assessment of each particular situation should consider the type of erosion being dealt with, the types of protection that would best remedy the situation, the value of the property in jeopardy, and the cost of the structures needed.

Selecting a Plan of Protection - Many alternative measures have been used with varying degrees of success. Sometimes a "do-nothing" approach may be acceptable. In these cases, minor relocation of the threatened facilities is the apparent solution. Sometimes, a channel relocation is the apparent solution. Generally, however, this causes similar problems elsewhere. Solutions for erosion prevention fall into two categories. One is the physical protection of the bank by use of rock referred to as riprap, snowfence, or various types of mats. The second category involves river works designed to deflect the current and/or produce sediment deposits. These measures include constructing wing dams, jetties, permeable retards, and brush cabled to the bank. The cost of a structure, the risk and consequence of failure, and the materials available will determine the type of structure and its construction details.

The availability of materials will dictate the type of structure and its cost. For example, the lack of stone within economic hauling distance would require the use of some other material.

Some materials are very good, i.e., quarried stone, interlocking steel pile and creosoted wood timbers. Some materials may not be as acceptable such as junk cars, old tires, and thin concrete slabs. Between these extremes is a range of materials that can be used if care, discretion, and ingenuity are applied to produce a more durable structure. Materials can be used in conjunction with other materials, for instance, wire fencing and stones; or quarried stone, cloth bags and grout; or steel sheet piles and quarried stone.

The life of the structure also dictates its type. Obviously, an untreated timber structure should not be installed where a structure is designed to last 50 years. Conversely, a permanent rubble-mound structure would not be required if the need for protection was of an expedient nature. The durability of the structure and its ability to absorb hydraulic forces is also a factor.

The Corps prefers and recommends that permanent protective works be built, but understands that private owners usually cannot afford the large cost. This means there may have to be departures from the standard designs for permanent protective works to provide some degree of protection against erosion. This will tend to decrease the first cost of construction; however, higher maintenance cost and reduced functional life will follow. The danger here is to underdesign the work and risk total failure. Close attention to the construction and maintenance guidelines on this page are needed to minimize losses.

Building Protective Works - Timeliness is the essence of the successful construction of shore protection measures. The best time to build protective work is during low-water periods. Adequate time is needed for an indepth study of the problem.

The final design of protective works can proceed once the general plan of protection has been selected. The final plan should include a layout drawing, construction details, and materials specifications. A complete alignment of the structure should be established as early as possible. Advantage should be taken of adjacent shore protection works if possible. Enough room should be provided for the specified minimum slopes if building a structure to protect the lower slopes of a streambank, known as a revetment. As soon as the alignment is established, quantities can be estimated for establishing equipment and materials requirements.

Access roads and borrow areas should be identified on the plan. Local contractors and local officials can provide information on sources of material and load restrictions on streets and highways. The use of heavy equipment on residential streets can result in severe damage to the pavement.

Another important consideration is the selection of the proper equipment to do the work. Utilize the contractor's experience to establish the best use of equipment and the most efficient operation.

Contracts for shore protection works delineate the responsibilities of both parties, the owner, and the contractor. The contract should be based on plans and specifications and include prices for the estimated quantities of work. It is important that both parties fully understand the scope of work. "Bids" i.e., prices, should be obtained from a number of contractors to help obtain the work at the lowest price.

Contract Plans and Specifications (Typical) - For your protection, contract plans and specifications should be provided to or by your contractor. This should include some, if not all, of the following:

* Location of the work with respect to the highway right-of-way and the streambank.

* A typical cross section indicating dimensions, slopes, arrangement, and connections.

* Quantity of materials (per linear foot, per protection unit, or per job).

* Relation of the foundation treatment with respect to the existing ground.

* Relation of the top of the proposed protection to design high-water and low-water data.

* The limits of excavation and backfill as they may affect measurement and payment.

* Construction details such as weep holes and pervious materials associated with them.

* Location and details of construction joints, cutoff stubs, and end treatment.

* Connections and bracing for framing of timber or steel.

* Anchorage and splicing details, particularly size, type, location, and method of connection.

Safety Considerations - Commonsense safety is necessary to reduce the chance of injury and possible loss of life. Some safety considerations are listed below:

* Safe access and safe working conditions must be provided at all work areas. Unstable bluffs must be graded to a safe slope.

* A first aid kit should be available. Everyone should be physically qualified to perform the work required. No one should expose himself to injury.

* Protective clothing, such as safety shoes, gloves, goggles, and hard hats should be worn by persons engaged in work requiring this protection.

* Construction materials should be stored in an orderly manner on a solid, level surface.

* Waste materials should be removed from the work area daily.

Inspection Considerations - Supervision of construction is very important. Close attention to detail is needed to assure that the final design will perform as anticipated. Prior to and during actual construction make a complete review of the plan. A checklist of the important items are described below.

* Start a pictorial record with pictures of existing conditions. Continue this through all stages of construction.

* Establish elevations of known points, layout line, and grade for construction.

* Note changes in the terrain that may require a change in the plan or the layout of construction.

* Check material sources for compliance with plans.

* Inspect work to insure compliance with plans.

* Record dimensions, limiting heights and depths on as-built plans.

* Maintain a pictorial record throughout the life of the structure particularly after damaging storms.

B. PERMIT REQUIREMENTS

Federal and State permits are required prior to the construction of any work in, under, across, or on the banks of navigable waters of the United States. All modifications of these areas are regulated by Section 10 of the River and Water Act of 1899 and Section 404 of the Clean Water Act. A permit is required to install property protection and/or reclamation devices such as riprap, breakwaters, jetties, etc. Regulatory Functions Branch of the US Army Corps of Engineers, upon request, will furnish application forms, instructions, and other technical assistance needed.

Contact with the Corps of Engineers before commencement of any work in or near navigable waters is strongly advised. This could save considerable time and expense. Persons responsible for willful and direct violation of Section 10 of the River and Harbor Act of 1899 or Section 404 of the Clean Water Act are subject to fines ranging up to $25,000 per day of violation and imprisonment for up to one year, or both.

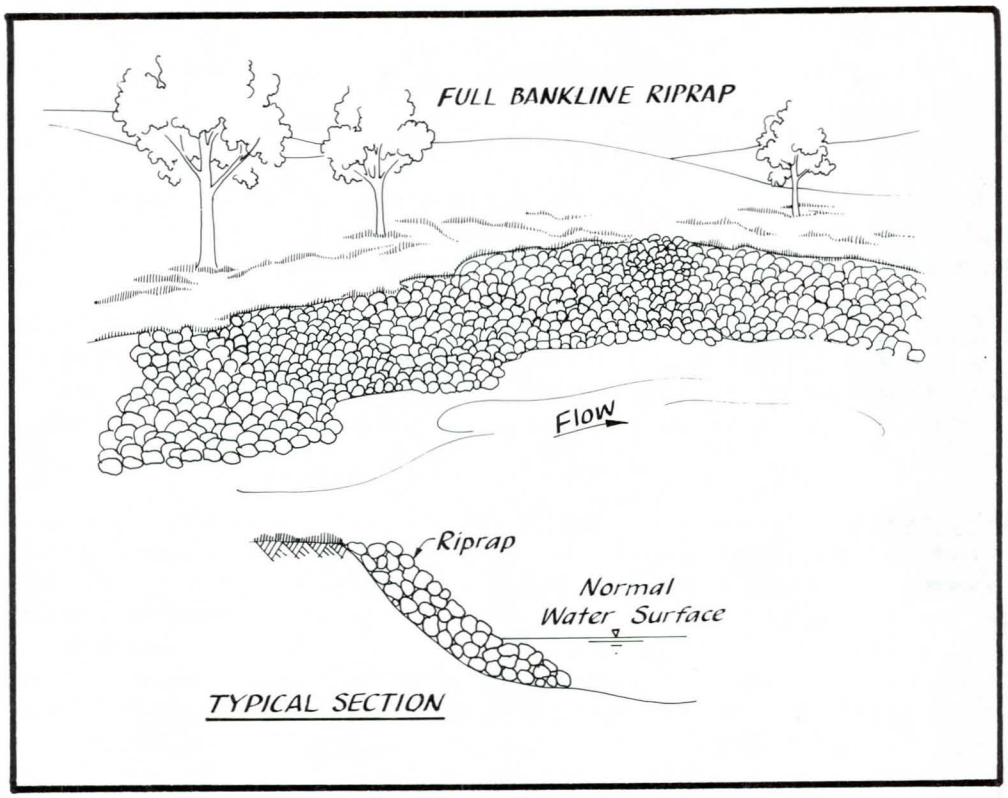
FOR FURTHER PERMIT INFORMATION CONTACT:

The District Engineer
US Army Engineer District, Rock Island
ATTN: Regulatory Functions Branch
Clock Tower Building
Rock Island, Illinois 61201

Telephone: 309/788-6361, extension 209 or 213

V. CONSTRUCTION MEASURES - ADVANTAGES, DISADVANTAGES, COSTS

ROCK RIPRAP PROTECTION - FULL BANK



Rock riprap placed on eroding banks is an effective measure to control erosion. Generally, a 12- to 18-inch thick blanket of stone weighing from 20 to 150 pounds is an acceptable specification. Stone rubble and broken concrete have been successfully used. Prior to placement, the bank is usually graded, if the slope is irregular, and a bed of gravel or porous filter material is laid to allow seepage but which will prevent erosion of the bank material. Varying the rock and rubble size from small to large produces a compact blanket.

ADVANTAGES:

1) Local damage or loss is easily repaired by placement of more rock.

2) Construction is not complicated and only standard construction and practices are necessary.

3) Appearance is natural, hence acceptable in recreational areas.

4) If riprap is exposed to fresh water, vegetation will often grow through the rock adding structural value to the bank material and restoring natural roughness.

5) Riprap is recoverable and may be stockpiled for future use.

DISADVANTAGES: 1) Stability of riprap blanket is hard to accomplish.

2) Materials may be hard to obtain.

3) Heavy equipment required for construction.

4) Difficult to construct where access is limited.

5) Moderately high initial costs.

COSTS:[1/] In-place costs of a riprap blanket including bank preparation, bedding material and transportation of stone are $23/cubic yard.[2/] Assuming 1-1/2 cubic yards per bank-foot, total cost would equate to $35 per bank-foot of protection.

MAINTENANCE REQUIREMENTS: This structure is subject to displacement. The effectiveness of the structure will be impaired by thinning of the protective layer or settling of the structure. Restoration of the rock slope protection to the designed top elevation, equivalent thickness, and reduction of voids in the facing should be accomplished when needed.

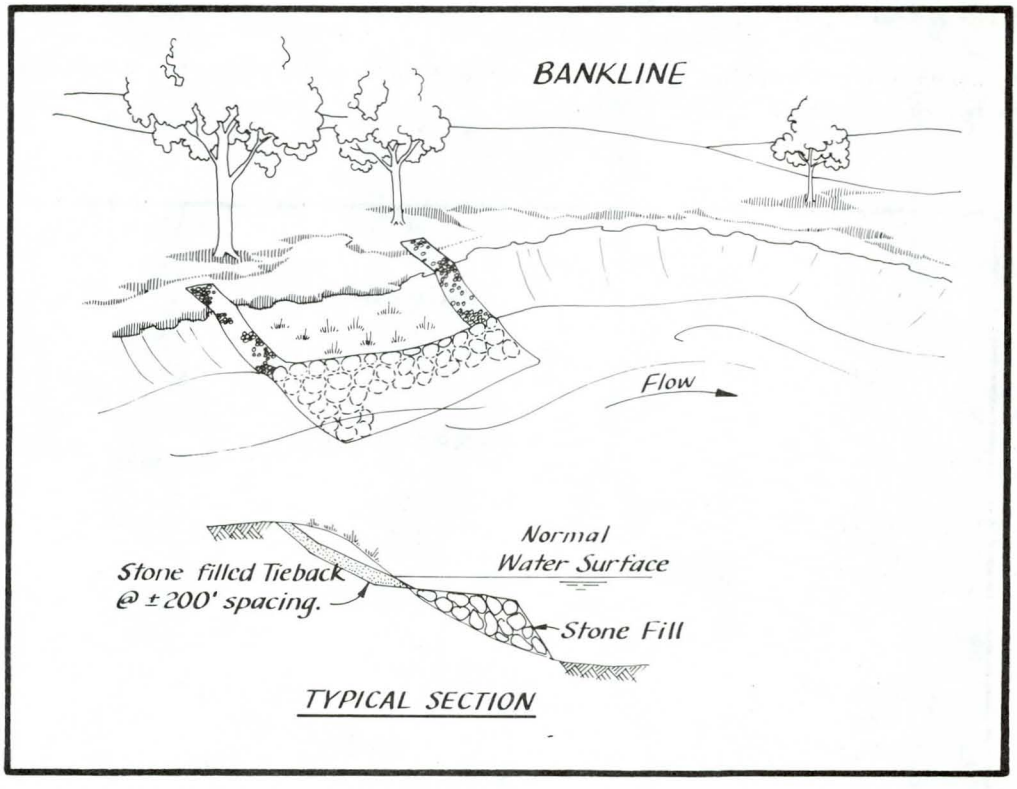
ENVIRONMENTAL ASPECT: No special equipment or construction practices are necessary for riprap protection. This aspect lessens the impacts associated with construction on the riverine ecosystem. The rock structure, although difficult to walk on, takes on a natural appearance, and is acceptable in recreational areas. If riprap is exposed to freshwater, vegetation will often grow through rocks, adding structural value to the bank material and restoring plants which can be used by wildlife. Riprap in an aquatic environment allows for attachment sites for organisms providing a food source and habitat for fish. A negative aspect of riprap is the extensive bank reshaping sometimes associated with its placement. Removal of vegetation in preparation for riprapping can destroy native plants and wildlife habitat and take on a channelized appearance which may not be aesthetically pleasing. Manual placement of riprap may prove to be less environmentally damaging and give the protected area a more natural appearance. Vegetation should be allowed to grow through the riprap. Riprap blankets appear to be the most suitable type of bank structure for most locations from an overall viewpoint that takes cost-effectiveness and environmental impacts, as well as degree of protection, into account.

1/ Estimated costs included in this brochure assume protection of a 12-foot high streambank.

2/ Costs shown are $23 per cubic yard. Depending on construction methods, actual cost may vary by plus or minus 20 percent of values presented in this brochure.

ROCK RIPRAP PROTECTION - BANKLINE AND WINDROW REVETMENTS

Bankline Revetment - This protection method consists of protecting the lower underwater slope with stone fill to prevent undercutting of the banks. This method should be used along shorelines where the lower bank material is very erosive, such as a sandy material. Stone filled tiebacks should be placed intermittently to provide erosion protection to the upper bank and prevent river flows from eroding in behind the lower slope protection.



Windrow Revetment - This erosion control method consists of placing stone along the top of the existing bankline at a predetermined location beyond which additional erosion would not be permitted. Riprap has also been used effectively with a "Trench-Fill Technique." Along with bank grading, a trench is excavated at the base and filled with riprap. Both the surface and trench-fill methods consist of placing (or burying) a sufficient amount of stone fill in a windrow behind the top of the bankline, then permitting the area between the natural riverbank and the windrow to erode through natural processes, until it reaches and undercuts the supply of stone. As the stone is undercut it falls into the eroding area and provides protection against further undercutting. The resulting bankline would remain in a near natural state with an irregular appearance. Portions of the stone fill windrow that are not eroded into the river by the natural process would be available for relocation to severely eroding areas at a later date. The windrow revetment is recommended for use in light forested areas and along stretches of irregular bankline.

ADVANTAGES: 1) Can be used in a complex erosion problem area with frequent bends and straight runs in the stream.

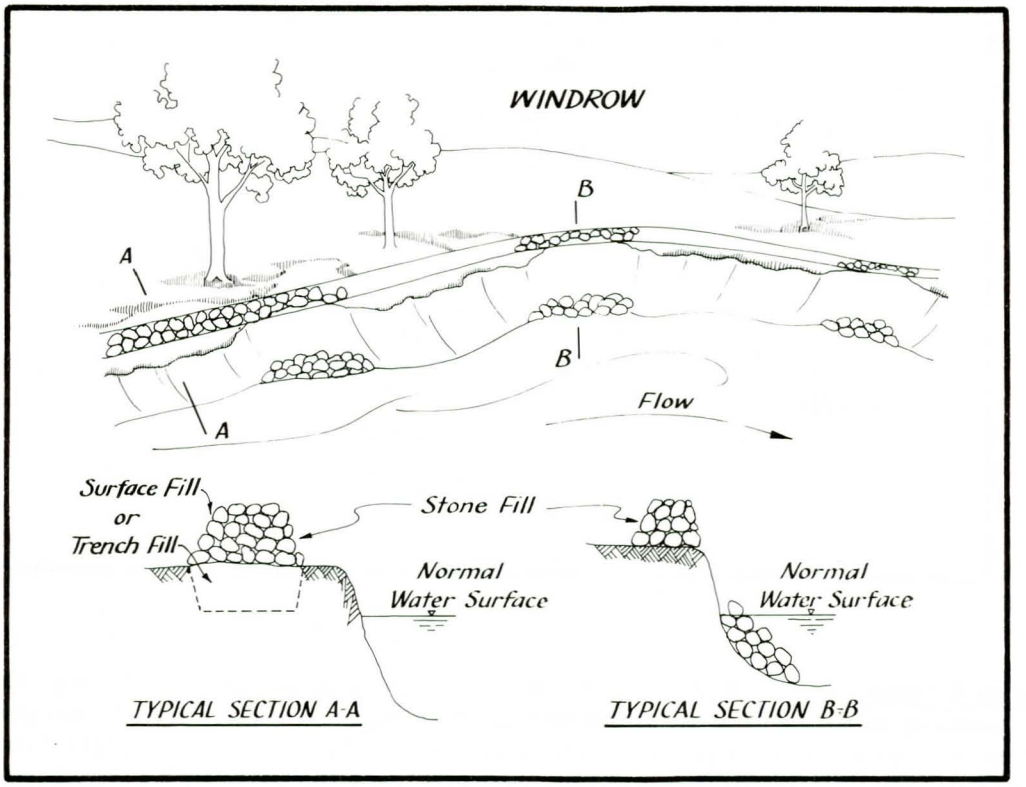
DISADVANTAGES: 1) Moderately high initial cost.

2) Frequent repairs after slump of windrow.

COSTS:

Bankline Revetment - Assuming one cubic yard at $23/cubic yard, the total cost would equate to $23/bank-foot.

Windrow Revetment - Assuming 1-1/4 cubic yards at $23/cubic yard, the total cost would equate to $29/bank-foot.



MAINTENANCE REQUIREMENTS: Continued monitoring and repairing of the riprap blanket required.

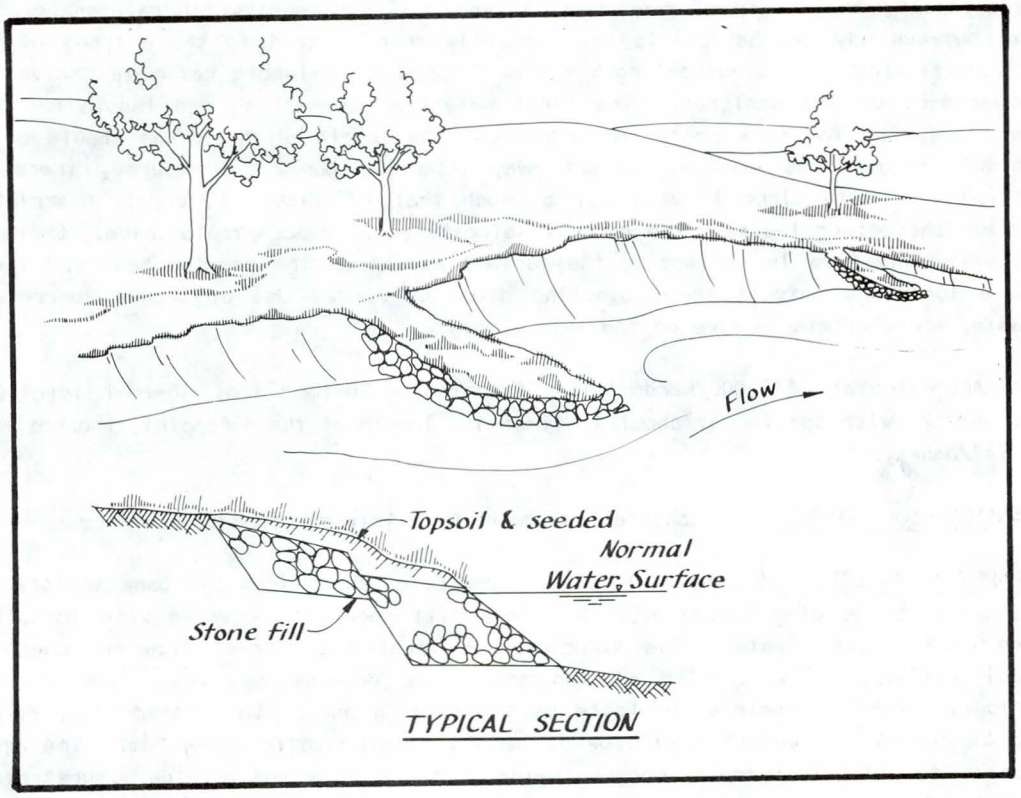
ENVIRONMENTAL ASPECTS:

Bankline Revetment - This technique is used to control undercutting of an eroding bankline, and consists of protecting the lower underwater slope with sufficient materials, such as rock, sandbags, or precast blocks, to prevent further erosive undercutting of the banks. The upper bank receives a lesser treatment. This protection method is a modification of riprap protection in that the portion of the bank underwater receives the primary protection and the portion of the bank above water receives little or no protection. As in riprap, the introduction of the aquatic substrata allows for a

diversity of habitat in which aquatic organisms can establish. This increased habitat may enhance fishing. Another positive for this method is that minimal disturbance to existing vegetation is incurred. Bankline revetments would be desirable in treed areas to prevent their loss as wildlife habitat through erosion. Bankline revetments should be installed during low-flow periods and designed to maintain existing trees.

Windrow Revetment - This technique consists of burying a sufficient supply of erosion resistant material below the existing land surface or placing the material on top of the land surface, then permitting the area between the natural riverbank and the windrow material to erode through natural processes, until it reaches and undercuts the supply of rock. As the rock supply is undercut, it falls into the eroding area and eventually halts further landward erosion. The resulting bankline would take on a "natural" appearance, both aesthetically and environmentally pleasing. The treatment lends itself to the protection of adjacent woodland, or next to long stretches of presently eroding irregular bankline. This method should be designed to preserve existing plants and wildlife. The introduction of the rock substrata into the river would provide habitat for aquatic plants and animals. This method would protect existing recreation, wildlife, and the aesthetics of the area.

SHORT ROCK JETTY HARDPOINTS



Hardpoints are effective in deflecting the current away from the eroding bank. A series of jetties along the bank tends to create back currents between the jetties. This produces a siltation of foreshore between the projecting dikes of rock. Rock should be of sufficient weight to resist the river current.

The hardpoint jetty consists of stone-fill structures placed intermittently along an eroding bankline. The jetty is placed to protrude a short distance into the river channel near the normal water surface level. A root section should be constructed into the bankline to provide protection to prevent stream cutting action behind the hardpoint. For best results a series of hardpoints can be used. Back currents are formed allowing siltation to occur. This will provide added bank protection.

ADVANTAGES:
1) No requirement for sediment deposit in hardpoint field.
2) Impermeability allows reduction of erosion force of stream.

DISADVANTAGES:
1) Heavy equipment required for construction.
2) Moderately high first cost.
3) Difficult to construct where access is limited.

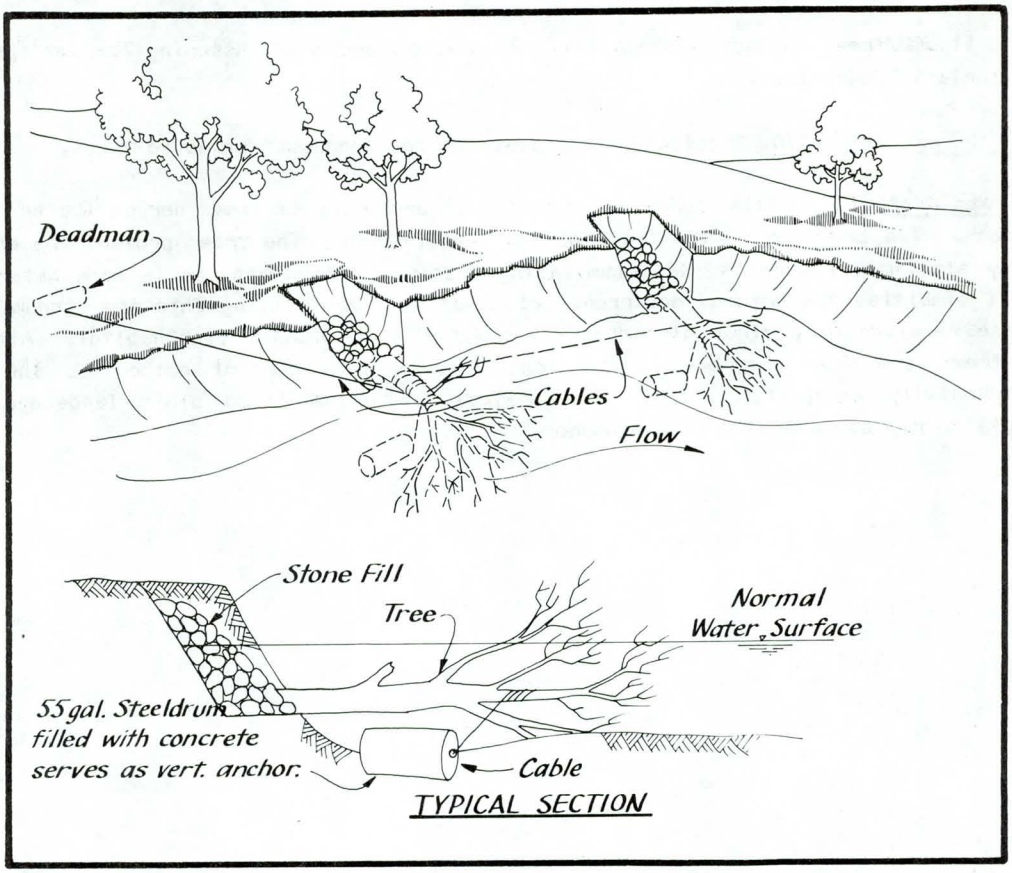
NOTES: Construction materials are usually from quarry-run stone with specified limitations on the maximum size of stone and amount of fines. The hardpoints are built with crowns of various widths up to 10 feet or more depending on the severity of the expected attack, the method of construction, and the requirements for maintenance. The spacing between any two hardpoints has generally been related to the average of their lengths multiplied by a spacing-length ratio. The spacing-length ratio is derived from the experience of the designer. The final selection of spacing and length may be an economic one, but for bank protection purposes, the length of the dikes should be just sufficient to move the eroding current away from the bank. Of course, there is a limitation on length since it must not be such that the dike will unduly restrict the navigation channel or increase the current velocity to an unacceptable value. Short rock jetties are effective in deflecting the current away from the eroding bank and tend to create a foreshore between the projecting dikes of rock. Use of broken concrete, if available, would eliminate some of the initial cost.

COSTS: Approximately $18,000/hardpoint. Assuming a 10-foot top, 46-foot length, and 12-foot height with spacing at about 11 times the length of the hardpoint, the cost would equal $37/bank-foot.

MAINTENANCE REQUIREMENTS: If constructed properly, little maintenance.

ENVIRONMENTAL ASPECT: In this technique, stone is extended from the bank and spaced at points along an eroding bankline. The stone fill should be covered with topsoil and planted with native plants. The structures redirect the current flow and cause some sediment buildup. The spacing of the structures depends on flow rates and river morphology. Short hardpoints should be used over long ones. Long hardpoints, if used, should be notched to permit some flow to maintain the aquatic ecosystem. The aquatic portion of the structure would improve the habitat diversity and provide a substrata for establishment of invertebrates. The above-water portion of the structure, if properly planted, would provide wildlife cover and food. Vegetated hardpoints are not as aesthetically pleasing as some erosion control structures, but may be more visually acceptable than steel jacks, timber jetties, bulkheads, and old tires. Many hardpoints are constructed entirely of stone with no vegetation and would be less likely to blend into the riverine environment.

TREE RETARDS



This erosion control method consists of placing trees horizontally in the river and perpendicular to the riverbank. Approximately 30- to 40-foot trees are placed and anchored at the shoreline with stone fill and concrete or other type of deadmen. The branched portion of the trees will be resting on the bed of the river to protect the banks from direct river attack and to encourage the collection of debris. This type of protection is recommended for use in or near forested areas where a supply of trees would be available. Tree retards are an attempt to reproduce natural conditions that occur when trees along the shoreline are undercut by erosion, fall into the stream, and form a natural barrier against further erosion.

ADVANTAGES:

1) Inexpensive.

2) Good job deflecting flow.

3) Good debris collector with silt depositor.

DISADVANTAGES:

1) Replacements are frequent.

2) Protection is only marginal.

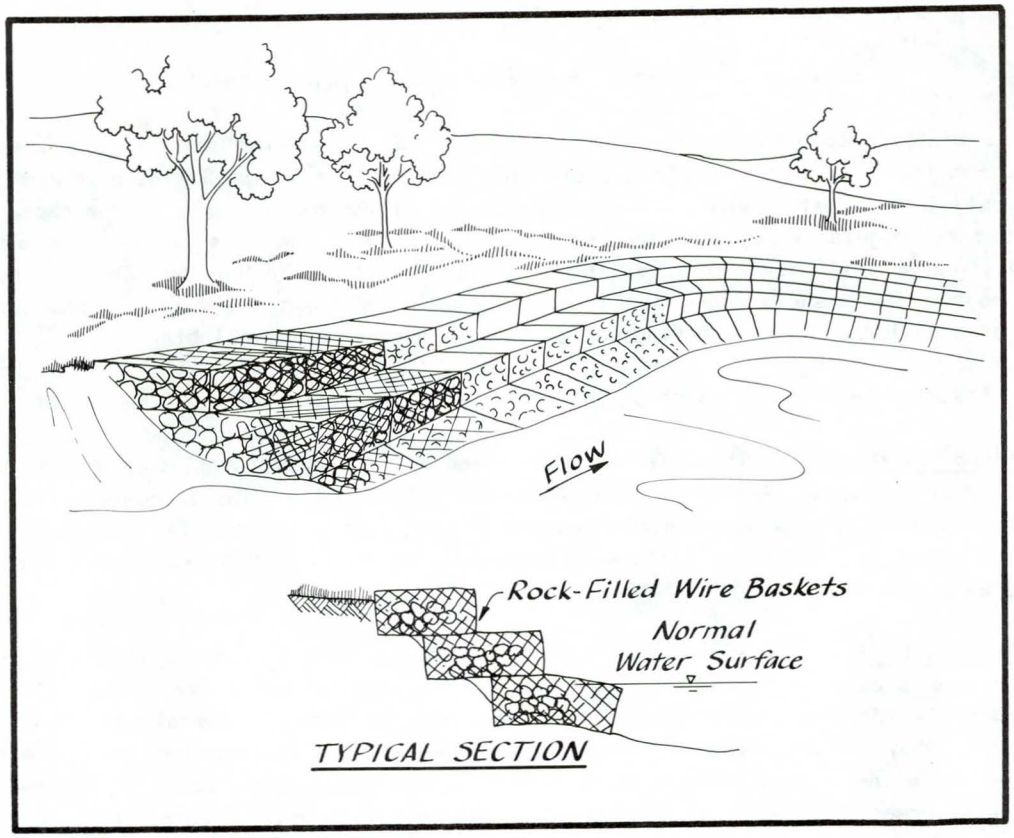
NOTES: Felled trees, found along the adjacent bank, can be laid butt upstream, parallel to and against the toe of eroding bank, and anchored to stumps or trees with used cable. This will tend to build up a foreshore by causing the current to slow down and drop part of its silt load. This is a relatively inexpensive method.

COSTS: $1,500/tree, including stone fill and deadman anchors. Assuming 75-foot spacing, cost equals $20/bank-foot.

MAINTENANCE REQUIREMENTS: Replacement of trees or rearrangement of moved trees.

ENVIRONMENTAL ASPECT: This technique consists of anchoring of trees perpendicular to the riverbank. The branches of the tree rest on the riverbed. The trees protect the eroding bank by slowing the current and accumulating debris. This technique is more natural in that it simulates the natural occurrence of undercut trees falling into the stream. The bankline receives only minor disturbances, and the trees provide fish habitat. Although some trees are lost for bank protection, this erosion control method is the most environmentally acceptable as it is harmonious with the flood plain landscape, and attempts to reproduce a natural phenomenon.

ROCK-FILLED WIRE BASKETS



Variable sized wire cages filled with low grade stone can be used for streambank erosion protection. These filled baskets are used as building blocks to form the protective structure along the streambank. Prior to the placement of the cages, a support apron should be laid on the bank extending at least 6 feet past the toe of the basket works. The apron, constructed of baskets, should have a minimum height of 1.5 to 2 times the depth of the scour predicted at the toe of the bank. Following this procedure layers of baskets are placed on top of this apron and all are wired together.

ADVANTAGES:

1) Cages are somewhat flexible and are, therefore, able to accommodate minor changes in bank geometry and ease of repair.

2) The voids between stones allow bank drainage, which aids in the elimination of failures due to excessive hydrostatic pressure.

3) Reduced first cost if you fabricate baskets yourself.

4) Inexpensive ungraded rock can be used.

5) Moderate to low maintenance costs.

DISADVANTAGES: 1) Baskets subject to rust and deterioration if not coated against corrosion.

2) Limits use of riverfront.

3) Basket cost high if purchased already constructed.

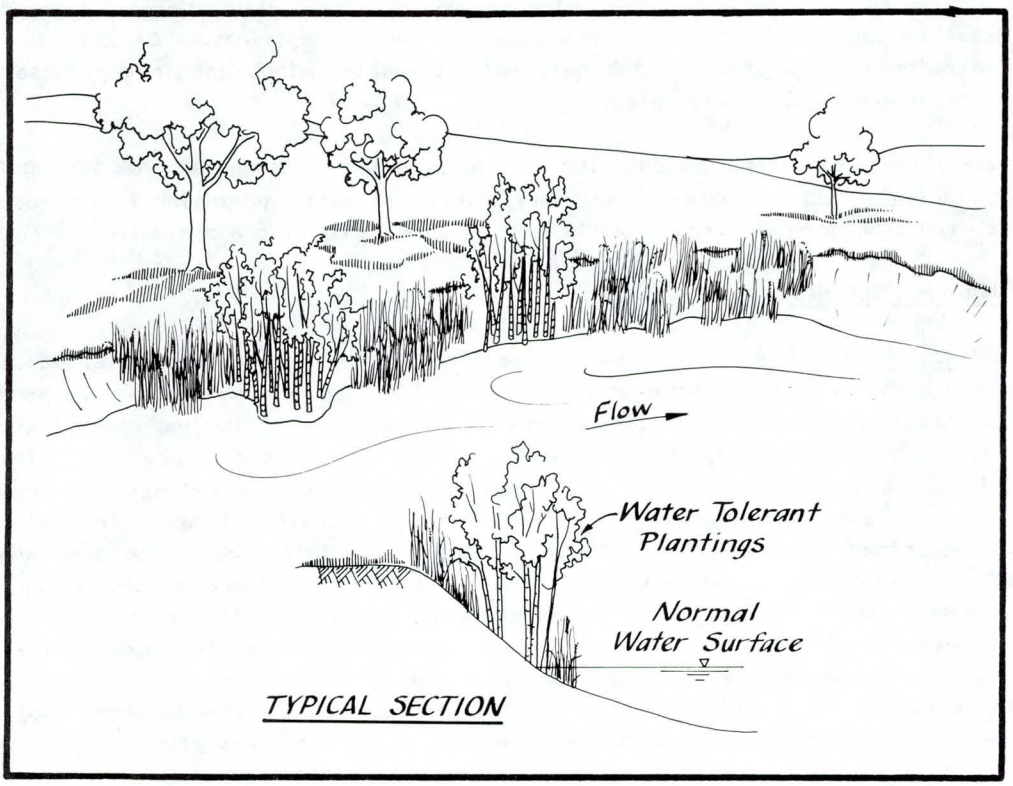
NOTES: Prefabricated baskets have been marketed in Europe for many years; however, baskets for the construction of bank protection works in the United States have been used widely only in the past 15 years. The basic element of the basket works is the cage. The cage is a rectangular wire-mesh structure divided by diaphragms into cells. The mesh is generally galvanized steel wire, which is coated if it is to be used in a corrosive environment. The baskets can also be of homemade variety and the total project can be done over a period of time depending on the funds and man-hours available.

COSTS: Assuming 1-1/2 cubic yards at $47/cubic yard, the cost equals $70/bank-foot.

MAINTENANCE REQUIREMENTS: The life of rock-filled wire basket protection depends on the durability of the wire. Replace broken wires with galvanized or plastic coated wire. The baskets occasionally are moved during severe storms, but can often be replaced. Such movement indicates foundation failure or scour at the toe. Repair all storm damage as quickly as possible.

ENVIRONMENTAL ASPECT: The major advantage of rock-filled wire baskets is that they can be designed and placed in forms that are physically and visually compatible with the surroundings. Another advantage is that because the rock is contained within wire inclosures, they can be placed at steep angles, requiring disturbance of only a minimum width of shoreline. This feature is particularly beneficial where space is limited such as in urban areas, recreational developments, and sensitive environmental areas. A third advantage is that soil and other debris accumulate in the openings between the rocks which form the cages. Vegetation will become established in the soil and further help them blend into the environment. Vegetation growing on the baskets provides some wildlife habitat, and where they extend underwater the rocks provide attachment sites for benthic organisms. These benthic organisms in turn provide food for fish.

VEGETATION



Vegetation is an economical method of limited streambank erosion protection. The principal functions of vegetation are to keep fast-moving water and transported coarse materials away from the surface of a streambank slope and improve the structural integrity of the bank. The topsoil of the bank to be protected is generally stripped for weed control. Grass can be planted by sodding, sprigging, or by spreading of mulches consisting of seed, fertilizer, and other organic mixtures. In addition, various hydrophytic plants, e.g., willows may be used. Woody plants have a greater initial cost and longer time to become established than grass, but are more effective for long-term protection. For sections of a streambank where scour is a problem, woody plants established at the toe of the slope and grass above the toe have proven to be good protection. Trees raised in nurseries are preferred over local plants because they are usually healthier, bushier, and have better developed root systems at maturity.

ADVANTAGES:

1) Low cost.

2) Little maintenance.

3) Environmentally acceptable.

DISADVANTAGES:

1) Limited protection for serious erosion problems.

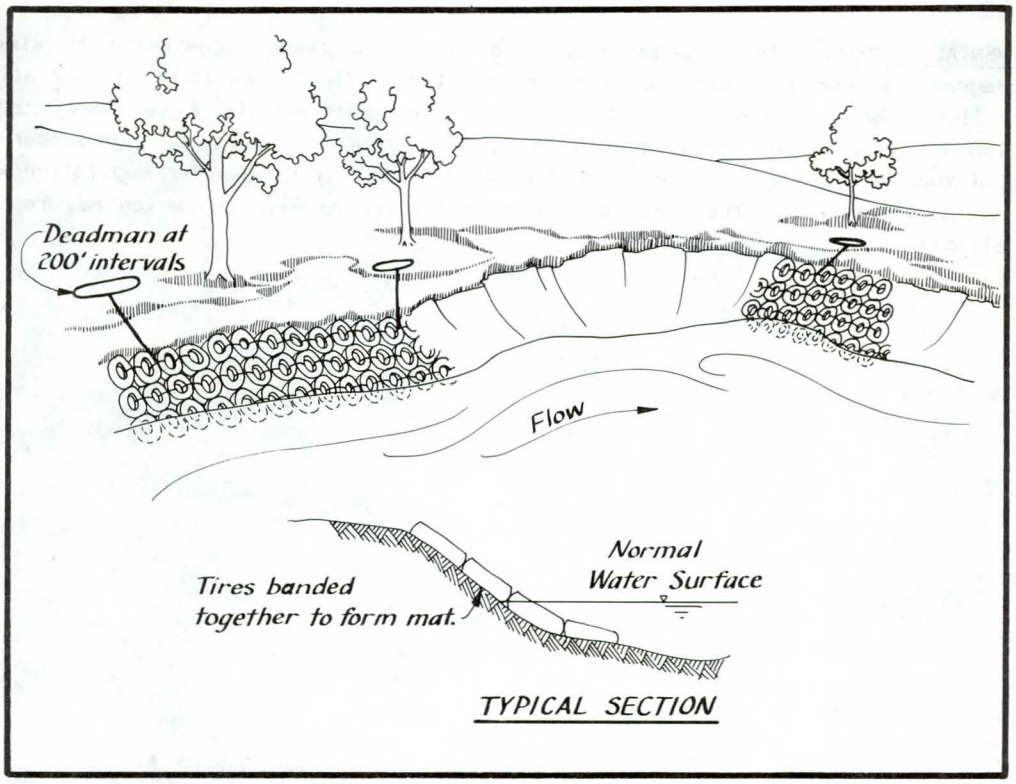
NOTES: Above the mean high waterline of bank slopes and in backwater areas, the major soil erosive action results from the mechanical disintegration of soil masses by alternate wetting and drying (periods of precipitation and sunshine) and wind. Grasses have proven to be excellent deterrents to soil erosion under these conditions. Of all the bank protection methods, vegetation is the only self-renewable method and in many cases the most economical and aesthetically pleasing.

COSTS: $5-7/bank-foot of protection. The cost of planting grass ranges from $500 to $650 per acre, including soil preparation and fertilizer. If woody vegetation is planted with the grass, the average cost is approximately three times that of grass alone.

MAINTENANCE REQUIREMENTS: Little.

ENVIRONMENTAL ASPECT: Probably the least expensive, most visually attractive, and least complex method of combatting bank erosion is to establish and maintain a deep-rooted vegetative cover along the river. Trees provide the greatest protection against erosion because of the massive root systems. Grasses and herbaceous species are also valuable, but provide less protection because their root systems are less extensive. Grasses, however, can be established more quickly and at less cost than trees. Tree planting programs, and other efforts to establish a protective vegetative cover can also provide expanded wildlife habitat, enhanced recreation opportunities, improved aesthetics, and improved water quality. Used alone, vegetation is a very positive method of erosion control. Revegetation should also be used to supplement and improve the impacts of all of the erosion control methods which have been discussed in this section. Thought should be given to selection of plant species which will provide maximum erosion protection, the most benefits to wildlife, and have the least impact on existing vegetation.

OLD TIRE MATS



Old automobile tires have been used to form mats or panels to protect streambanks. This is another relatively inexpensive method of bank protection. This protection method consists of mattresses constructed by banding used automobile tires together. The used tires should be put in place as a mat. The mat can be constructed in place or built in sections in an adjacent area and then banded together after the sections are placed on the bankline. The mat is held in place on the slope by deadman anchors to prevent it from sliding down the bank or floating. Holes may be drilled in the sidewalls of the tires to allow trapped air to escape and prevent mat flotation. The mat stability becomes less of a problem after vegetation becomes established and sediment builds up in the tires.

ADVANTAGES: 1) Low initial cost.

2) Allows natural vegetation which aids in protection.

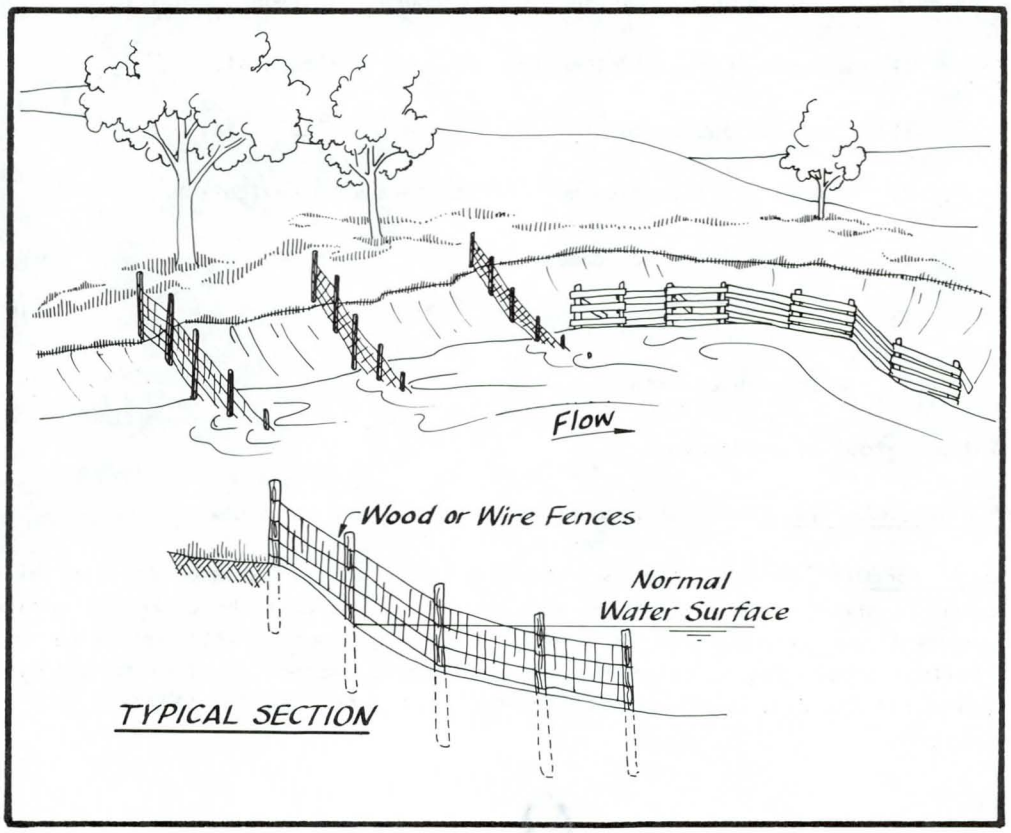
DISADVANTAGES: 1) Stabilization of mats is a problem. Not initially aesthetically pleasing.

COSTS: $30/bank-foot of protection. Tires are available in quantities at little or no cost from tire centers and recapping services. Used oil field cable can be used to further reduce costs.

MAINTENANCE REQUIREMENTS: Securing of mats after high water is about the only required maintenance.

ENVIRONMENTAL ASPECT: In this technique old tires are lashed together with wire or non-biodegradable rope and placed as a mat on the bank. Vegetation is planted or allowed to establish over the tires. Initially, the tire mattress is an eyesore, but as vegetation is established, the area develops a more natural appearance. The underwater portion of the tires may provide some aquatic habitat and the above water vegetation would become wildlife habitat. The tires may prove difficult to walk on, which may restrict access slightly.

FENCE JETTIES (WOOD AND WIRE)



Fence jetties are used to solve a variety of bank protection problems. They can be constructed parallel to the bank as well as transverse to the streamflow. Materials for construction can vary. Types often used are treated or untreated wood, used rails, pipe, and steel or concrete beams. The fencing material is usually wood or wire. If wire fencing is used, the required tensile strength depends on the design loading by the water and debris.

Fencing is not one of the most effective means of bank protection, but is commonly used because no special techniques for construction are required and materials are readily available.

Another way to use fences is to construct two fences parallel to the bank 3 to 10 feet apart. Brush, hay, or rock is stacked between the fences, providing an extra measure of protection against the erosive action of the water currents. If the fences are constructed parallel to the bank and the bank is steep enough, a second fence is not required for holding the brush backfill. Fences constructed parallel to the bank generally serve as an erosion stopgap measure to allow sufficient time for the establishment of vegetation or to prevent sloughing of the bank. Fences constructed across part of the stream section promote sediment deposition. A transverse fence can be positioned to deflect debris downstream or to trap it. By constructing the fence so that it is oriented downstream at an oblique angle to the current flow, debris will be

deflected into the main channel. This technique is useful if the stream has a heavy debris load and the designer desires to keep the banks clear. Conversely, the fence can be constructed so that it is oriented upstream at an oblique angle to the current flow. Debris is then trapped behind the fence. This construction method is effective for clearing the main channel of debris and serves to encourage sediment deposition.

ADVANTAGES:

1) Directs energy of river from bank to open channel.

2) Collects debris to slow current and promotes siltation.

DISADVANTAGES:

1) Length is limited so not to interfere with navigation.

2) Susceptible to ice damage.

3) Costs are high.

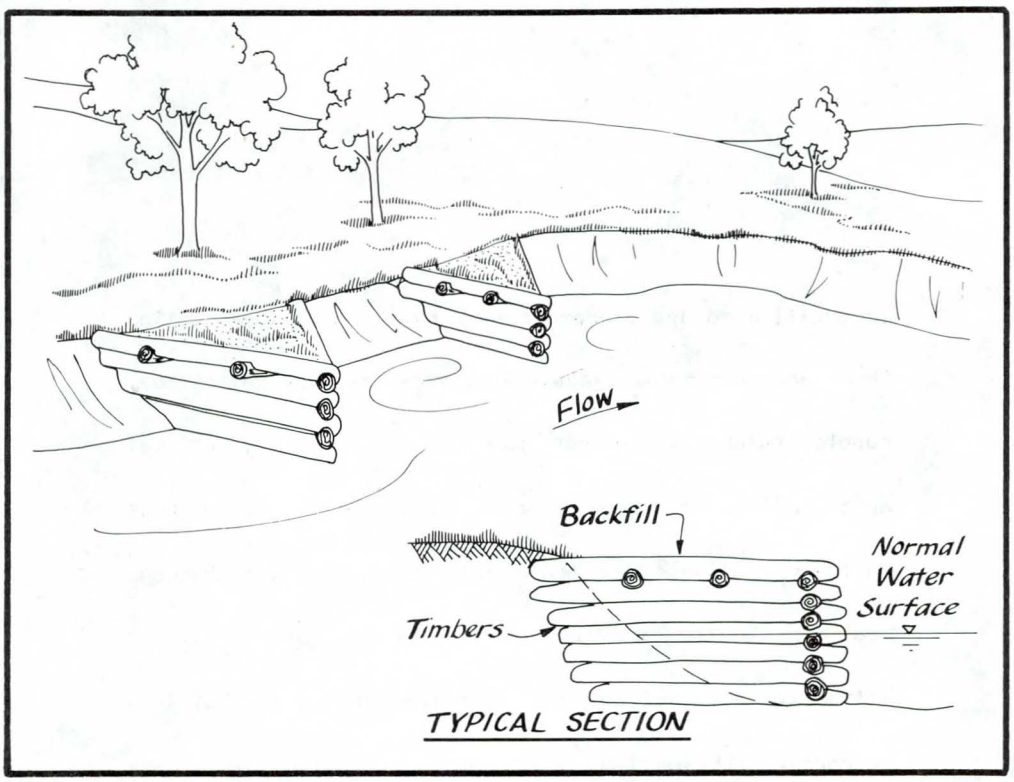
4) Maintenance costs high.

COSTS: $54/bank-foot of protection.

MAINTENANCE REQUIREMENTS: Periodic repairs of damaged fence sections.

ENVIRONMENTAL ASPECT: Fence jetties are constructed of wood and spaced in parallel rows perpendicular to the bank. The jetties are designed to deflect the current flow and to collect sediment and debris. After a long period, vegetation will establish in the sediment buildup area. The value of this erosion control method to wildlife and fish is limited. The structure is visually unappealing. The impact on the existing vegetation would be minimal.

TIMBER CRIBS



Streambanks can be protected directly with timbers or railway ties cabled to deadmen and earth or stone-filled. The cribs then will be aligned away from the streambank. This method has been used primarily on small streams and is now being used on a limited basis in the western United States.

ADVANTAGES:

1) Lends itself to protecting short reaches.

2) Can be constructed of materials that are readily available.

3) Structure is easily repaired.

DISADVANTAGES:

1) Structural integrity depends upon adequate toe protection. Vertical walls induce severe scour at their base.

2) Limits use and access to river.

COSTS: $200/bank-foot of protection.

MAINTENANCE REQUIREMENTS: Repair of pilings after high water and storms.

ENVIRONMENTAL ASPECT: This protection method has the least aesthetic value in presenting a natural landscape. The method would protect existing wildlife habitat and might provide attachment sites for aquatic organisms. This method is used in urban areas due to the shortage of installation space, intense wave action from boats, and a need for recreational access.

In addition to the aforementioned types of bank protection there are many more. Vane dikes, rock and wire mattresses, rubble, bulkheads, Kellner jack fields, synthetic matting, auto bodies, cellular blocks, soil cement, bituminous mattresses, timber and brush mattresses, and tetrahedrons are only a few of these methods which may not be as attractive a method as those described in the text of this brochure. If you have any questions about these or any method of streambank protection you may contact the US Army Corps of Engineers.

VI. GLOSSARY

Bank Protection. Placement of revetment or other armor to stabilize a streambank against erosion or use of a river training structure designed to deflect the hydraulic erosive forces away from a streambank.

Bulkhead. A vertical or nearly vertical structure supporting a natural or artificial embankment.

Crib. An open-frame structure filled with earth or stone ballast designed to absorb energy and to deflect hydraulic currents away from a streambank.

Cross Section. A vertical section (profile) of the surface, the ground, and/or underlying material, which provides a side view of the structure.

Cut Bank. The concave wall of a meandering stream that is maintained as a steep or overhanging cliff by the impinging streamflow against its base.

Dike (sill, groin, spur, jetty). A river training aid constructed of earth, wood, or stone, designed to deflect erosive currents away from a bank and to control movement of bed material.

Erosion. The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or wind.

Fence. A river training structure normally consisting of mesh attached to a series of posts often in double rows; the interstitial space between the rows may be filled with rock, brush, or other locally available materials.

Filter. Layer of sand, evenly graded rock, or cloth, placed between the bank armor and soil for one or more of three purposes: to prevent the soil from coming through the armor by extrusion or erosion, to prevent the armor from sinking into the soil, and to permit natural seepage from the streambank to occur and thus prevent buildup of excessive hydrostatic pressure.

Impermeable. Not permitting passage of water.

Lower Bank. That portion of a streambank having an elevation less than the mean water level of the stream.

Organic Mixtures and Mulches. Any of a number of organic agents (e.g., petrochemicals or vegetative matter) used to stabilize a streambank against erosion by affording permanent protection or temporary protection and nutrients for the establishment of vegetation. These agents, which may be in the form of liquids, emulsions, or slurries, are normally applied by means of mechanical broadcasters.

Permit. A document issued by the Department of the Army expressing the assent of the Federal Government, so far as concerned the public rights of navigation and the

general public interest, for the accomplishment of certain works on or adjacent to navigable waters of the United States.

Pile. An elongated member, usually made of timber, concrete, or steel, that serves as a structural component of a river training structure.

Revetment. Armor of erosion-resistant material designed to protect a streambank.

River Training Structure. Any configuration constructed in a stream or placed on, adjacent to, or in the vicinity of a streambank, which is intended to deflect currents, induce sediment deposition, induce scour, or in some other way alter the velocity regimen of the stream.

Specifications. A detailed description of particulars, such as size of stone, quality of materials, contractor performance, terms, quality control, etc.

Stone Riprap. Natural cobbles, boulders, or broken stones dumped or placed on a streambank or filter as armor against erosion.

Toe. That portion of a stream cross-section where the lower bank terminates and the channel bottom or the opposite lower bank begins.

Trench-Fill Revetment. Stone, concrete, or ceramic material placed in a trench dug behind and parallel to an eroding streambank. When the erosive action of the stream reaches the trench, the material placed in the trench retards further erosion.

Upper Bank. That portion of a streambank having an elevation greater than the mean water level of the stream.

Vegetation. Woody or nonwoody plants used to stabilize a streambank and retard erosion.