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Streambank Erosion

MN Department of Natural Resources Division of Waters • August 1991

...Gaining a Greater Understanding

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Streambank Erosion ...Gaining a Greater Understanding

St. Paul, MN
August 1991

Minnesota
Department of Natural Resources
Division of Waters

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PREFACE

The purpose of this brochure is to provide a basic understanding of streambank erosion as well as actions that can be taken to prevent or limit the impacts of the erosion process. It is intended for use by river/streamfront property owners, and can also be of use to community leaders, local government officials, and other persons involved in erosion control.

The brochure was prepared as a public service by the Minnesota Department of Natural Resources in cooperation with the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota. It was made possible through funding from the Legislative Commission on Minnesota Resources for a project studying river meander and streambank erosion. The goal of the project was to identify effective low cost methods of streambank protection as an alternative to more expensive, traditional means of erosion control. In the past, these methods have been known empirically to be effective, but theoretical or experimental studies on them are sparsely documented. In this project, a theoretical basis for how a streambank can be protected by these methods was investigated.

The brochure will cover:
River mechanics
Bank erosion and failure
Methods of bank protection
Who to contact for assistance

Prepared by:
Cliff Bentley - DNR, Division of Waters
Gary Parker - U. of M., St. Anthony Falls Hydraulic Lab
David Leuthe - DNR, Division of Waters

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INTRODUCTION

Section 1 - **RIVER BEHAVIOR**

Briefly describes the natural processes that affect a stream, and the factors that control its behavior and response to these processes. Specifically, the river mechanics involved in bank erosion and meander formation are presented in order to provide a more clear understanding of streambank erosion problems.

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Section 2 - **BANK EROSION and FAILURE**

Covers several of the most common causes of bank erosion and failure. A bank protection method may be both practical and low-cost, but if it is not specifically designed to address the the underlying erosional process, failure, may result. It is therefore, extremely important that each erosion problem is specifically examined and understood before an effective solution can be selected. An improperly designed or constructed bank protection system can cause an even greater problem to develop.

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Section 3 - **BANK PROTECTION**

Several of the available low cost alternative methods of bank protection are presented. While these methods are termed "low cost", they are not necessarily "cheap", and should be viewed relative to the cost of a standard engineering method. In the case where the proper solution is cost prohibitive, "no-action" or relocation of affected activities should be considered. The benefit of no-action is the saving of money, and avoiding acceleration of the erosion problem caused by the implementation of an improper protection method. Relocation should be considered when the cost of moving to an alternate location is less than the cost of the necessary bank protection.

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Section 4 - **PERMITS and ASSISTANCE**

Before initiating any streambank protection project, all federal, state and local permits should be obtained. Information on where to go and who to contact for further assistance and more in-depth technical information will be given. This brochure provides general information only, and is not intended to serve as a design manual. Knowledgeable professionals should be consulted in order to ensure the successful implementation of a streambank erosion protection project.

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Section One

River Behavior

RIVER BEHAVIOR

Prior to developing an understanding of streambank erosion and failure, we must first understand the nature of a stream and its banks. A stream or river can be considered as a delicately balanced mechanism that is constantly changing. A stream must continually adjust to new impacts, either natural or those caused by human activity, in order to maintain its balance. When the balance is upset, the stream will respond by some compensating action to bring the stream system back into balance. The most common compensating actions are streambank erosion and bed scour or sedimentation.

Streams naturally erode their beds and banks and deposit the resulting sediments. However, over time, natural streams tend to reach an equilibrium state where erosion at one location is roughly balanced by deposition at another. The average channel dimensions of a stable meandering stream are often fairly constant throughout a given reach of stream. But, if events occur which alter the streamflow or sediment supply/characteristics, then accelerated or unexpected erosion may occur as the stream tries to balance itself. Erosion becomes a problem when human activity is endangered by this stream system balancing process. The difficulty in solving an erosion problem comes from the fact that a local solution will likely affect the downstream behavior of the stream as it attempts to regain its lost equilibrium. This can have major impacts on downstream property owners.

EROSION is the removal of soil particles from a bank surface primarily due to water action.

FAILURE is the collapse or slippage of a large mass of bank material into the stream.

Factors affecting streambank/bed erosion:

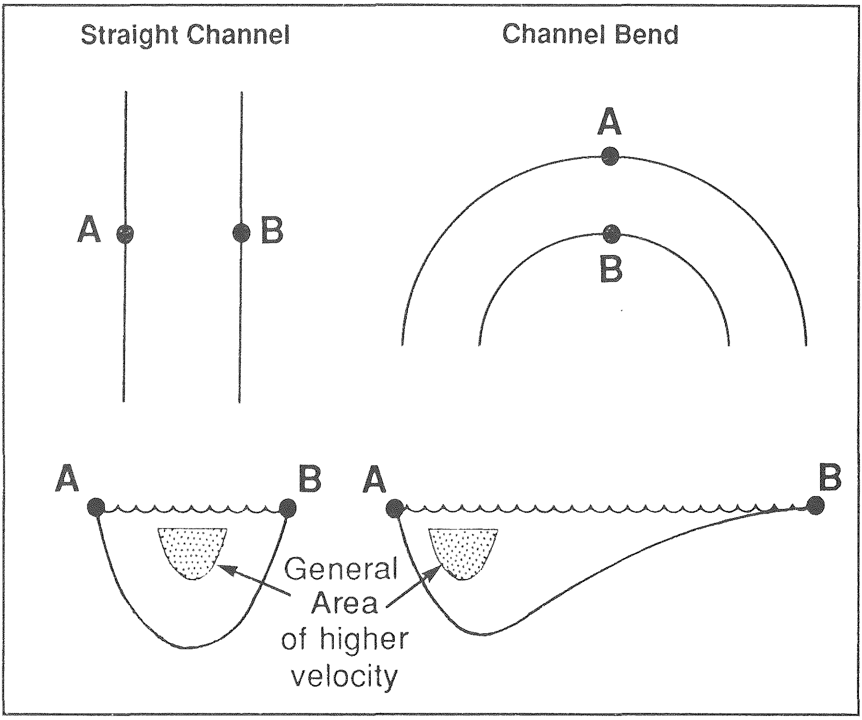
1) *Flow characteristics:*
    - Discharge magnitude (volume of flow)
    - Discharge duration (duration of flow)
    - Velocity (speed of water)
    - Velocity distribution (location)
    - Shear stress (stress on bank)
    - Drag and lift forces (resistance)
    - Momentum forces (water energy)

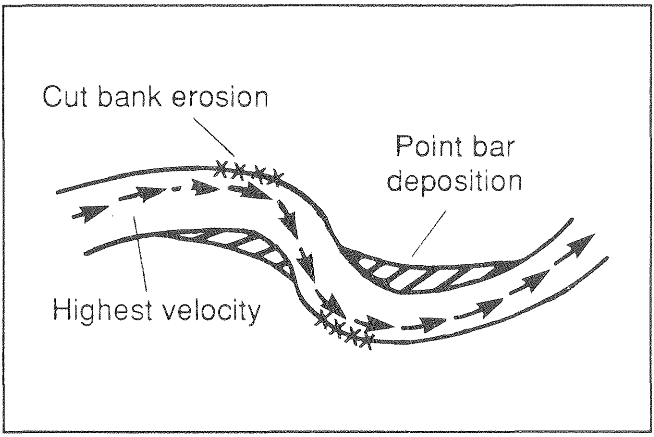
2) *Bed Material:*
    - Size
    - Gradation
    - Shape
    - Specific weight
    - Cohesion

3) *Bank material:*
    - Size
    - Gradation
    - Shape
    - Specific weight
    - Cohesion

4) *Bank vegetation:*
    - Vegetation type
    - Root mat density
    - Propensity to form protective slumps

In a straight section, the stream has a roughly trough-shaped cross-section. The region of highest velocity is near the middle of the cross-section. Natural meandering streams tend to have very few straight reaches, however. Most streams develop bends, which are characterized by scour and erosion on the concave side (outside of bend), and deposition on the convex side (inside of bend). Bends develop in this manner because the region of highest velocity in a bend shifts from the middle to near the outside of the channel. The following is the sequence of events that take place in a natural stream. During periods of high flow, the sediment transport capacity of the stream increases, and erosion occurs. The sediment movement is fairly uniform during this time. As the flow begins to subside, the transport capacity decreases and sedimentation begins to replace erosion. Because the velocity is greater near the concave side of a bend, the sediment usually is deposited along the convex side, forming point bars. As the convex sides receive the sediment eroded from the concave sides, the curvature of the stream increases.





Cut bank erosion and point bar deposition.

The duration of a particular flow condition can have a greater impact on bank stability than the volume of flow. This is because more energy is required to overcome the initial bank resistance, created by bank vegetation and other cohesive forces, than to maintain the erosion process once it has begun. Once the bank is exposed, erosion proceeds much more quickly. Therefore, the longer a bank is exposed to high discharge, the faster the rate of erosion.

Streambank failure is the result of several physical processes working singly or in combination. In general, these processes may be classified as either surface phenomena, such as the removal of soil particles from the bank by streamflow, or as subsurface phenomena, such as the collapse of a saturated bank following a rapid drop in water level. The two phenomena are usually interrelated. For example, erosion of the bank toe (surface phenomena) could steepen the bank which could cause failure of the saturated bank (subsurface phenomena).

Since there are many different types of streambank failure, streambank protection design requires a knowledge of the types of failure at the project site. By understanding the cause of the problem, and matching the problem with a suitable bank protection method, the chances for successfully protecting an eroding bank will be greatly improved.

Streambank erosion is a continuously occuring natural phenomenon that may be accelerated or decelerated by human activity. For most streams the majority of bank erosion occurs during and just after high flows. Erosive forces during high flow may be 10 - 100 times greater than during normal flows.

One of the characteristics of a well balanced stream is that the elevation of its bed remains relatively constant. If an imbalanced condition develops, the stream could respond in one of two ways: by scouring out its bed, or by depositing excess sediment carried by the stream onto the bed. Either condition can lead to problems for the landowner or local government. The streambed acts as a foundation for its banks. If streamflow scours out the bed, and in the process erodes the bank toe, then the upper bank may no longer have any support, and failure can follow. Alternatively, when a stream can no longer carry its sediment load, material will be deposited on the streambed. As a result, the elevation of the bed will rise, reducing the size of the channel. When the next high flow occurs, the stream will try to enlarge itself to its original size in order to carry the increased flow. As the enlargement occurs, not only will the bed be scoured out, but both banks may be eroded as well. The most important consideration here is that if the bed of a stream is rising or falling, the investment of time and money into a streambank protection program is questionable, because the problem may lie with the bed and not the bank. Typical signs that the bed is not in balance include:

* Rushing water in an otherwise tranquil stream
* Waterfalls (headcuts)
* A noticeable increase in channel width caused by caving along both banks
* Continued raising or lowering of the streambed.

This may be observed as a change in bed elevation around bridge piers, docks, pilings, etc. If there is any reason to believe that the streambed in the vicinity of a proposed streambank protection project is not in balance, then professional assistance should be sought before further project planning takes place. If the bed is not in balance, a project should be considered only if the bed elevation can be controlled or if future changes in the bed elevation are anticipated to be minor.

Section Two

Bank Erosion and Bank Failure

CAUSES OF BANK EROSION (1)

Streamflow

As water flows past the banks of the channel, particles of soil comprising the bank may be removed from the bank and carried away by the moving water. This is because the water exerts a "tractive force" on the soil particles. This tractive force is a function of the velocity and the depth of the flow - the higher the velocity and the deeper the flow, the greater the tractive force exerted on the channel bank. Whether or not any soil particles are eroded from the bank depends on the ability of the soil particles to resist the tractive force applied by the flow. Larger particles are more difficult for the flow to lift and carry away, and so are more resistant to the tractive force. Particles with a strong cohesive attraction to one another also offer a greater resistance to erosion. Thus, smaller, loose particles in a deeper, fast moving stream are subject to the greatest amount of erosion. Therefore, erosion is more likely to occur during times of flood flows, than in normal flow periods. Flow velocity is typically greater along the outside curve of a bend than along the inside. This increased velocity tends to erode the streambank, carrying the dislodged particles at least as far as the inside of the next bend, where the sediment may be deposited due to the decrease in streamflow velocity.

Rainfall

The impact of raindrops hitting exposed soil may detach individual soil particles, which after being dislodged, are subject to transport both by the splash of the raindrops and by the flow of rainfall runoff over the surface of the soil. In addition to the direct erosion of the streambank caused by rainfall, the loss of mineral and organic nutrients to the runoff can lead to a loss of vegetative cover on the banks of the stream. Loss of vegetation can accelerate erosion by exposing a greater amount of soil, and also by removing the support provided by the plant root structures.

Seepage

Water that does not run off the surface infiltrates into the soil, eventually reaching the groundwater table. If the groundwater table is higher than the surface of the stream, the difference in elevation will cause the groundwater to flow towards the bank face. The resulting water pressure buildup behind the bank face can cause soil particles to be forced loose. Seepage such as this can be seen as wet soil on the streambank above the surface of the stream, or by water flowing through the bank surface.

Overbank Drainage

Drainage from the land surface above the banks of the stream, while commonly a natural phenomenon, can also be a result of poor land management practices that allow excess runoff. Overbank drainage can lead to severe sheet and rill erosion of the streambanks. Sheet erosion is the term used when the runoff carries away soil particles in thin layers, and rill erosion refers to the process of surface erosion where small channels in the bank material, similar to gullies, are formed by the runoff. The combined effect of sheet and rill erosion produces the same result as discussed in the rainfall erosion section: loss of bank material, as well as mineral and organic nutrients.

Obstacles in Stream

Obstacles in the stream can be either natural or man-made. A natural obstacle could be a tree that has fallen into the stream, or the mass of soil material 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 point bar. 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.

Wave Action

Waves created by the wind, or by boat traffic on larger streams, can detach soil particles from the streambank when they act on unprotected soil material. These dislodged particles are then subject to removal by the flow of the water in the stream. If the loss of soil at the base of the bank is sufficient, the bank may be undercut and the unsupported bank material may then collapse into the stream. This collapse is one of several forms of bank failure to be discussed later in the section on "bank failure".

Freeze - Thaw and Wet - Dry Cycle

When water freezes in the streambank the expanding ice layer pushes soil particles out of their original position. When the ice thaws, these particles settle back into their original location, but in a looser state than they were to begin with.

When wet clay material dries it shrinks and cracks, resulting in a loose, easily erodible surface layer similar to that left after the thaw of a frozen bank.

At the next high-flow condition, when the loosened particles on the bank are exposed to the streamflow, the erosion of the bank will proceed more readily than it would have had the soil material at the bank surface not been loosened by the freeze-thaw or wet-dry cycles.

Ice and Debris

For the most part, rivers with winter ice covers remain dormant, so that the ice causes little or no damage to the banks. The erosion of a streambank by ice is caused when the icepack begins to melt and break up, and is forced along the bank by the flow of water. Generally, this abrasive force on the bank does little damage if the bank itself is still frozen; the erosion is greatest when the bank has begun to thaw, or is already thawed and is at its weakest. Similar erosion of the streambank is caused by non-frozen debris in the water. Any object that comes into contact with the bank can cause erosion if it strikes with sufficient force. The erosion of a bank by ice or debris is caused by either abrasion or by impact.

Changes in Land Use

Any change in land use that increases runoff, removes vegetative cover, increases or decreases sediment load in the stream, etc. can cause a bank that was previously stable to become a problem. Increasing urbanization, particularly (but not exclusively) next to rivers and streams, poses a threat to the stability of the rivers and streams in the area of development. Typically, the construction activities and subsequent changes in the land surface associated with urbanization combine to both increase the amount of soil available for erosion and reduce the infiltration capacity of the soil. The net effect is to increase the amount of surface runoff into the streams and rivers, along with increasing the sediment load carried by the stream. As a result, once stable streambanks now are subject to greater flow velocities and flow volumes, allowing for greater sediment transport. Once high flow conditions subside, the excess sediment that was carried by the stream may be deposited, thereby reducing the capacity of the channel. When the next high flow condition occurs, the channel may then not be able to handle the flow volume due to the decrease in capacity, and even higher flows and more serious erosion may occur. In addition, if the additional sediment is not scoured out either before or during the next flood event, the stream may widen its channel in an attempt to increase its carrying capacity, and in so doing erode the streambanks even further.

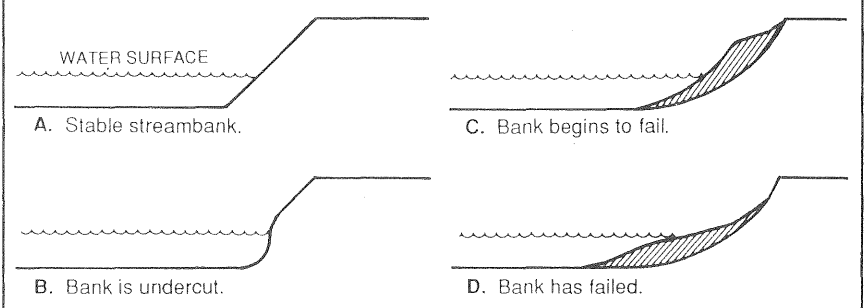
CAUSES OF BANK FAILURE

A streambank is in a stable state when the forces acting on the bank that may cause failure do not exceed the ability of the bank to resist these forces. If the shear strength of the bank is greater than the shear stresses acting on the bank, then the bank may be considered stable.

When a bank fails, it "sloughs off", either in a thin layer or as a large mass of soil material sliding down the bank. The cause of failure can be either a reduction in the shear strength of the bank, an increase in the shear stress acting on the bank or a combination of both.

Decrease in shear strength	**Increase in shear stress**
Common causes: * Swelling of clays due to absorption of water. * Increased internal pressure due to groundwater within the bank. * Movement of the soil ("soilcreep").	*Common causes:* * Changes in channel shape. * Increased loading on the top of the bank (buildings, roads, etc.) * Rapid drawdown (quick drop in the water surface elevation) of water at the face of the bank.

Changes in channel shape can influence failure by increasing the height of the bank, steepening the slope, or undercutting the base of the bank. Groundwater higher in the bank than the water surface elevation of the stream and rapid drawdown of the stream both serve to create a pressure imbalance at the bank face. When the water surface elevation of the stream is high for a sufficient length of time, water will tend to seep into the bank. If the water level in the stream then drops quickly, the water in the bank face will increase the outward pressure on the soil in the bank. Similarly, if the groundwater table elevation at the face of the bank is higher than the water surface elevation of the stream, the same increase in outward pressure on the soil material of the bank will occur.



A. Stable streambank.

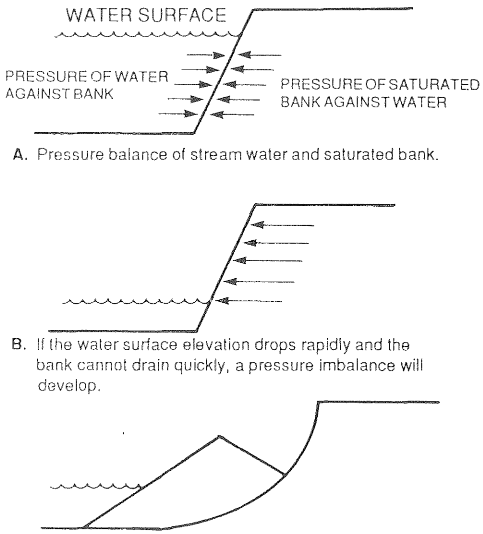
C. Bank begins to fail.

B. Bank is undercut.

D. Bank has failed.

Failure of streambank due to undercutting at the toe.

Bank failure due to the water against a saturated bank being lowered faster than the bank can drain. (rapid drawdown)



A. Pressure balance of stream water and saturated bank.

B. If the water surface elevation drops rapidly and the bank cannot drain quickly, a pressure imbalance will develop.

C. Bank may fail because of pressure imbalance.

Bank failure due to the water against a saturated bank being lowered faster than the bank can drain (rapid drawdown).

Section Three

Principles and Methods of Bank Protection

PRINCIPLES OF BANK PROTECTION

When facing a streambank erosion or failure situation, the first step that should be taken is to obtain any available technical assistance. The names, locations, and phone numbers of agencies that may be able to provide technical information, assistance, or project review for erosion control structures are given at the end of this brochure.

While there is no guarantee on the success of any erosion control project, an organized, well planned approach to the problem, such as the following example step-by-step approach, can help improve the chances for success. Technical assistance and project review will also help reduce the possibility of wasting time and money on a project that will not be effective.

1. Determine the cause of the bank erosion/ failure.
2. Decide if the bank is worth protecting.
3. Gather information on the resources available for undertaking the project (money, material, technical assistance, etc.).
4. Consider the resulting impacts of localized protection on the future or downstream behavior of the stream.
5. Choose a bank protection method.
6. Obtain a permit.
7. Construct the erosion control structure.
8. Maintain the project.

All work on a stream involving more than one project or land owner should be planned so that the flow relationships between projects can be established, and so that the project of one owner does not adversely affect another owner. Cooperative agreements between landowners may be necessary before an effective project can be constructed.

Thought should be given to the need for watershed management. Sound management practices can reduce the runoff and soil loss from a watershed, and can make streambank erosion problems less severe. These practices include the maintenance of vegetated buffer strips between stream banks and land use activities.

Continued inspection and maintenance of a completed bank protection structure is essential to prevent failure and future streambank damage. Erosion control measures are, by nature, not necessarily permanent. Changes in the stream dynamics as it adjusts to future conditions may alter the effect of the protection structure. Also, because it is difficult to completely predict the amount and intensity of treatment needed at the beginning of a project, careful inspection of projects during the first few years following installation can disclose points of weakness where the project needs improvement.

As far as improving the success of the project goes, the most crucial steps in a project plan involve identifying the cause of the problem and choosing a proper bank protection method. The chosen method should correctly remedy the underlying cause, and not accelerate the erosion process.

Choosing a proper protection method requires the assistance of qualified technical professionals. To help identify the causes of bank erosion, or indicate where a problem may develop, the following warning signs should be looked for (1):

* Exposed soil
* Loss of vegetation
* Sheet or rill erosion
* Cracks in the bank or the area near the top of the bank
* Overhanging banks
* Undermined trees with exposed roots
* Scour along the base of the bank
* Changes in the elevation of the bed of the channel
* Excessive wave action
* Rapid drawdown
* Increased load at the top of the bank
* Higher flood levels than in previous years
* Appearance of objects in the stream

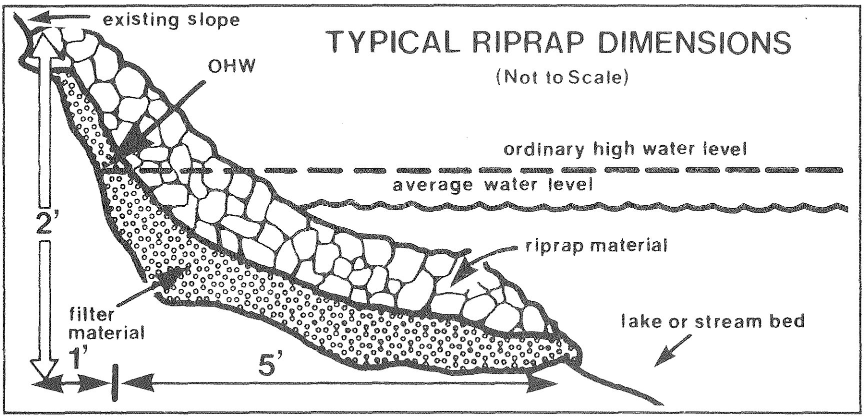
Erosion of the streambanks basically depends on the velocity of flow in the stream, as well as the strength of the bank material to resist the tractive erosion forces exerted by the flow. The ways to protect a bank from eroding consist of reducing the flow velocity near the bank, increasing the strength of the bank material, diverting the flow away from the problem area, or a combination of these.

METHODS OF BANK PROTECTION

The following is a list of possible methods of bank protection. Individual circumstances, design considerations and permit constraints all must be evaluated in the process of selecting a method.

ROCK RIPRAP

Properly placed rock riprap is one of the most effective methods of bank protection. Riprap consists of rock material placed on the bank surface at the location of the erosion problem, and serves to protect the bank from erosion by protecting it from the erosive forces of the stream. In all cases the riprap should extend far enough up on the bank to where natural vegetation can provide adequate protection.

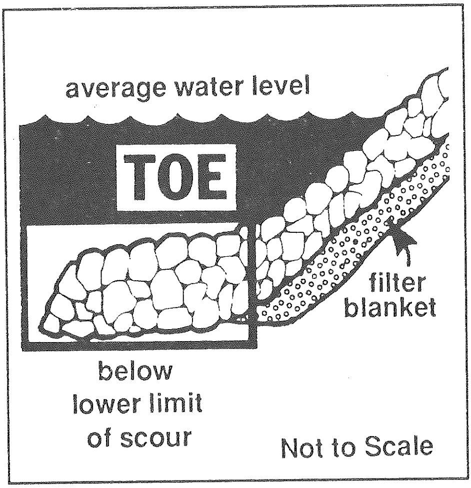


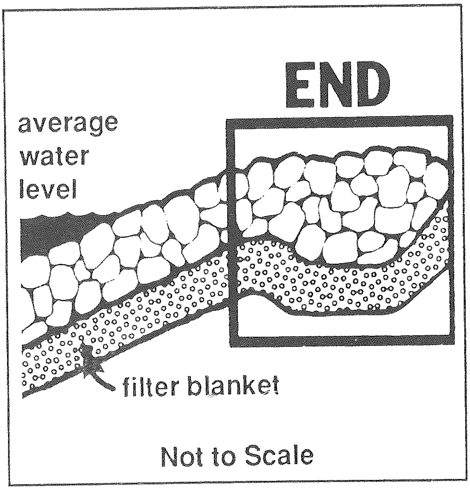
The most common method of riprap placement is dumping the rock material onto the streambank. There may be cases, however, that require more careful placement of the rock material to avoid separation of the large and small stones, or grading. The finished surface should not have pockets of finer material that will wash out and weaken the revetment.

Riprap is typically a more costly method of bank protection due to the cost of quarrying, transporting and placing the rock material. However, if suitable material is located within a reasonable distance, the cost of the project may not be prohibitive.

A filter layer consisting of material coarse enough that it will not be washed out from under the riprap layer thereby eroding the bank beneath the riprap, is essential to ensure the success of a riprap project. If sufficiently coarse material is not available, a filter blanket will be required. The filter layer should be about six inches thick.

An important element of riprap design is toe protection, or protecting the base of the bank from scour. Toe protection will help prevent the riprap from being undercut, and falling into the scour hole.

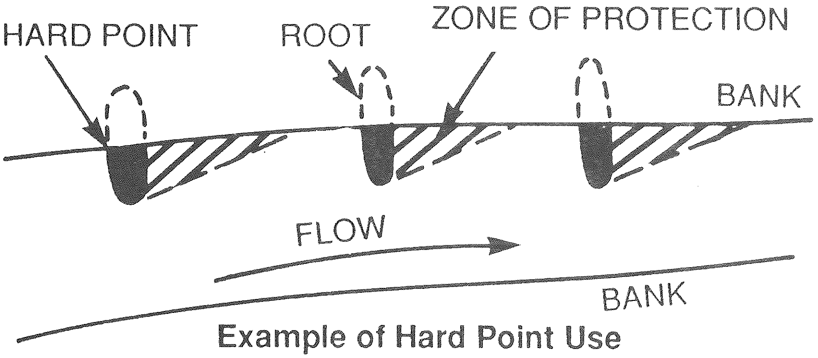




Another important element of riprap design is end protection. End protection helps anchor the riprap, and keeps the riprap from being eroded out at the top.

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.



Example of Hard Point Use

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.

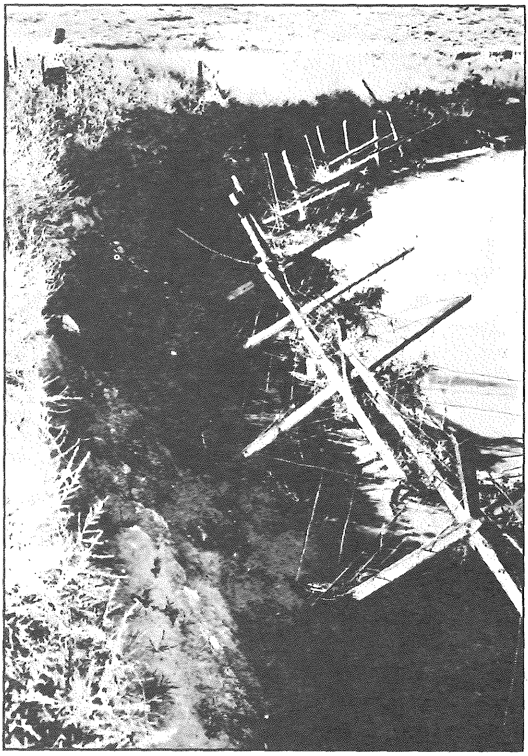
JACKS and POSTS

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 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.



Example use of jacks (2)

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.

SPUR DIKES

Rock spur dikes are similar to hard points, except that they extend farther 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 farthest 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.

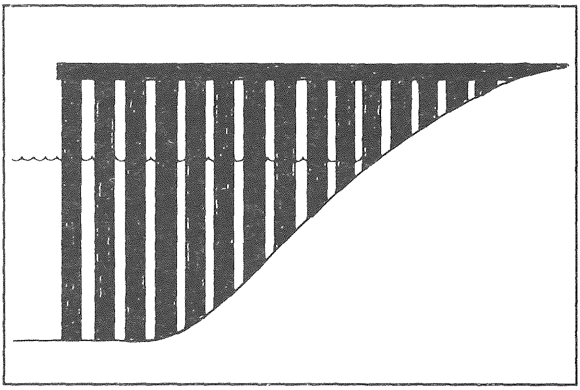
Rock spur dikes are typically constructed by end dumping from trucks. A properly designed dike field can require less rock, and be less expensive, than riprap. On the other hand, the tip of each rock dike usually needs to be supplied with an extra stockpile of stone in order to counter severe local scour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

CRIBS

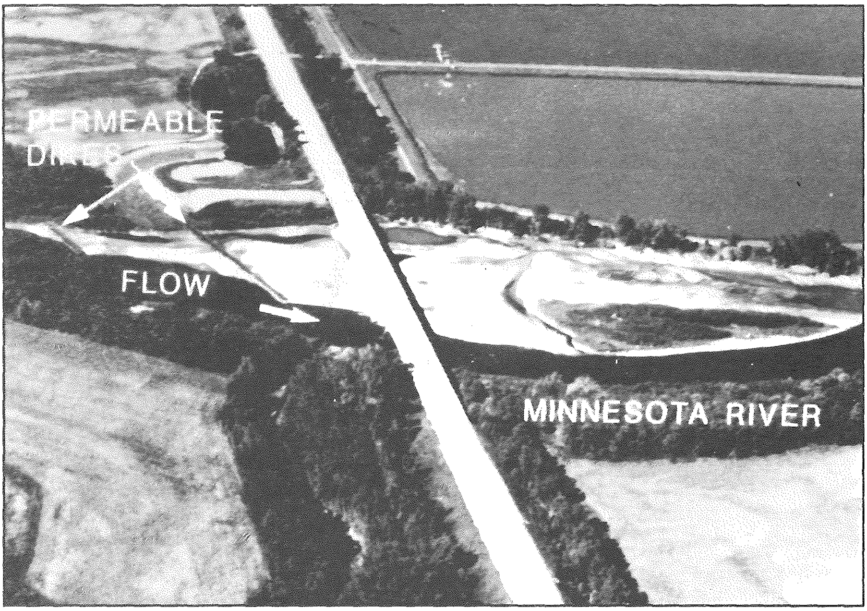
Cribs are timber boxes built outward from the river bank. The boxes are filled with sand and gravel. Such boxes, built in series, can have a protective effect similar to hard points or rock spur dikes. They are preferred where timber is cheap and plentiful, or where rock riprap is not easily available.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

PILE DIKES

Pile dikes are a permeable dike 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.



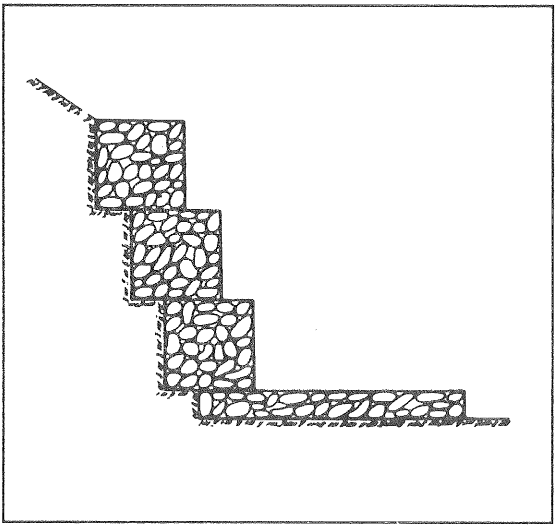
Example of pile dike



Example of deposition caused by effective permeable dike (3)

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.



Example of gabions

DROP STRUCTURES

Drop structures are local structures placed along a river channel that act like small waterfalls. The effect of the drop structures is to dissipate the energy of the flow, which reduces the flow velocity. This reduction in velocity decreases the tendency for erosion farther downstream. They are commonly used in series along streams which have been subject to bed lowering. If the lowering of the bed can be stopped, the erosive stress on the banks can often be significantly reduced (see section on bank failure).

BIOENGINEERING

Bioengineering refers to the design of an erosion control system that consists primarily of living plant materials. Often a combination of plants and other material, rocks for example, are used to form a protective structure. The plants serve to provide support to the eroding bank by means of the root structure, while also encouraging deposition of sediment. Bioengineering can control erosion on a long term basis, while preserving the natural environment.

SHEET PILINGS or WALLS

Sheet pilings or walls can be driven or placed vertically at a point of severe bank erosion. The abruptness of the wall often causes severe local scour near the base, so care must be taken to place the wall at sufficent depth, so that the scour does not reach the base of the piling. Sheet piling is neither cheap, nor easy to install. Installed correctly, however, it can halt bank erosion completely. For these reasons, it is typically used only at critical points, where no bank erosion can be tolerated, or where the lateral space required for other forms of bank protection is not available.

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.

PALMITER METHOD

The Palmiter method (4) is more of a river management technique than an actual erosion control structure. The method is used to naturally alter the flow patterns of a stream to eliminate the cause of the erosion problem, rather than simply protect the bank from erosion.

PALMITER METHOD

1. Remove log jams
2. Protect eroded bank
3. Remove sand & gravel bars
4. Revegetate
5. Remove potential obstructions
6. Maintain

The six steps involved in the Palmiter method are shown above. Although the steps are listed in order, they do not necessarily need to be conducted in this sequence. Generally, the worst problem should be taken care of first. An understanding of the site-specific physical and biological characteristics of a stream will help to organize the proper sequence of steps.

Remove log jams

Log jams can cause deposition to occur, which reduces the sediment load of the stream. A reduced sediment load increases the transport capacity, which in turn allows more erosion. Additionally, the log jam can divert the current into a streambank, causing erosion. Removal of the log jam allows the current to erode the sand bar created by the log jam rather than the streambank. The removed material can also be used for protection of the eroded bank.

Protect eroded bank

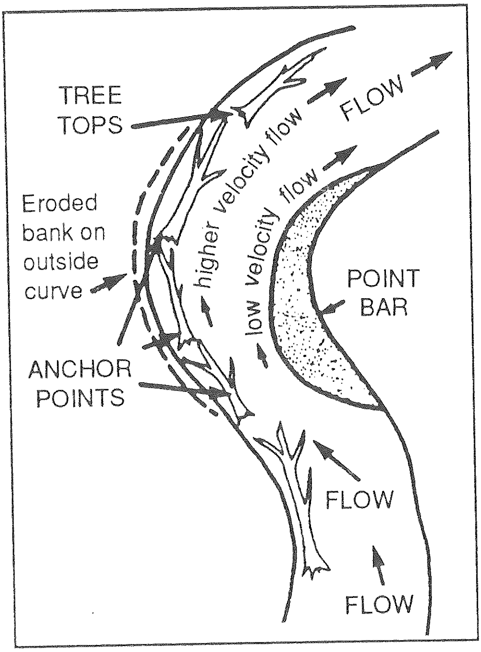
If an obstruction is causing the erosion of the bank, then removal of the obstruction should be the first step. If the erosion is caused by something else, then perhaps protecting the bank should be the first step. Again, it depends on the dynamics of the specific site which step comes first. The Palmiter method of bank protection consists of anchoring trees or brush material along the bank to be protected.

The trees serve to divert the erosive flow away from the eroded bank, while at the same time reducing the flow velocity within the trees, causing suspended sediments to be deposited. The deposited sediments build back the eroded bank.

The trees are anchored with cable to fixed points on shore such that the "butts" of the tree trunk faces upstream.

Remove sand and gravel bars

A sand or gravel bar that was formed as a result of an obstruction or log jam can cause a diversion of the flow against a



Example use of trees

streambank. The bank may then erode, where it would not have eroded had the sand or gravel bar not been there. Many times, removal of the obstruction that caused the bar to form will allow the stream to naturally erode the bar. Other times, the bar will need to be removed by other means.

Revegetate

Revegetation of the channel bank and in the newly deposited sediments can serve to both stabilize the bank, and induce further deposition. The bank becomes more stable as a result of the root structure of the plants, which hold the soil particles together. Vegetation in the deposited sediment will further slow the velocity of the flow, which allows more sedimentation to build back the eroded bank.

Remove potential obstacles

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 occuring 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.

Maintenance

Periodic inspection of the stream management area after the implementation of the project will be necessary to determine if additional work is needed. These inspections are needed to ensure that the restoration was sufficient, and the erosion problem was solved. A good time to check the project is after a period of high flow.

Section Four

Permits and Assistance

PERMITS and ASSISTANCE

Permits or approvals will be necessary for streambank stabilization or protection measures. Federal, state and local units of government have rules or ordinances which address projects involving work in or near rivers and streams. It is very important that you obtain all necessary permits or approvals before you commence any work.

Simple projects that meet established design criteria, such as a natural rock riprap, may not need an engineered design or extensive technical review. More complex projects however, may require you to retain professional technical assistance. Federal, state and local governments have staff that may be involved in technical review of this type of project but the responsibility for obtaining technical design assistance, where necessary, will rest with the landowner.

Those landowners who have a streambank erosion problem and wish to look into stabilization and/or protection measures should make an initial contact with their local Soil and Water Conservation District (SWCD)(see the following map). If a project appears to be practicable and feasible, then the appropriate governmental units should be contacted for a review of permit requirements and such technical assistance that may be available.

The federal permit authority would be the U.S. Army Corps of Engineers and can be contacted at (612) 220-0375. The state permit authority is the Department of Natural Resources, Division of Waters. Attached is a map and list of Area Hydrologists for the state. Counties and cities have zoning ordinances which may have additional requirements. The local planning or zoning office should be contacted. Watershed districts or water management organizations may also have permit authority and should be contacted. The SWCD office may be able to direct people to the appropriate local contacts.

SOIL and WATER CONSERVATION DISTRICTS

REGIONAL OFFICES

Northwest Region
Board Representative (218) 755-3963
Field Hydrologist, Local Water Planning
(218) 755-4176
1106 Paul Bunyan Drive NE
Bemidji, MN 56601

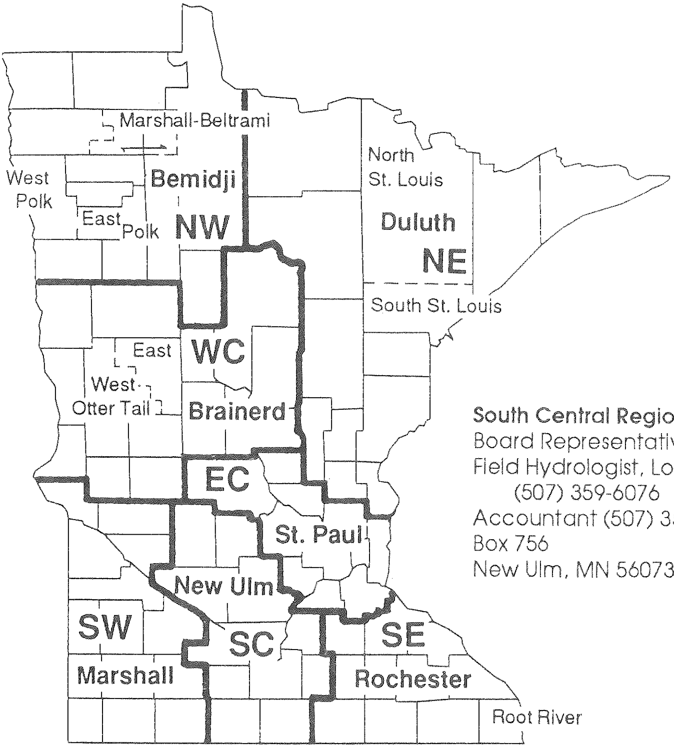
West Central Region
Board Representative (218) 828-2604
Field Hydrologist, Local Water Planning
(218) 828-2598

Southwest Region
Board Representative (Vacancy)
(507) 537-7260
Area II Staff Engineer (507) 537-6125
Box 111 - 1400 E. Lyon Street
Marshall, MN 56258

Northeast Region
Board Representative (218) 755-3963
(218) 723-4923
394 South Lake Avenue , Room 403
Duluth, MN 55802

East Central Region
Board Representative
155 S. Wabasha Street, Suite 104
St. Paul, MN 55107
(612) 297-1894

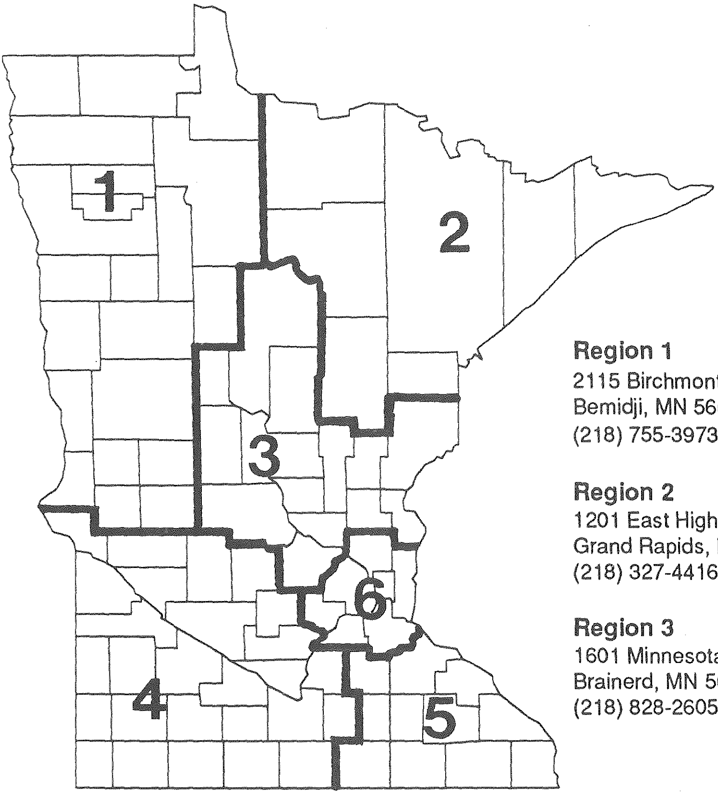
Southeast Region
Board Representative
1200 S. Broadway
100 Friedel Building
Rochester, MN 55904
(507) 285-7458



South Central Region
Board Representative (507) 359-6075
Field Hydrologist, Local Water Planning
(507) 359-6076
Accountant (507) 359-6077
Box 756
New Ulm, MN 56073

DNR REGIONAL HYDROLOGISTS

For additional information and assistance, please contact the appropriate Regional Office or the Division of Waters in St. Paul.



Region 1
2115 Birchmont Beach Road N.E.
Bemidji, MN 56601
(218) 755-3973

Region 2
1201 East Highway 2
Grand Rapids, MN 55744
(218) 327-4416

Region 3
1601 Minnesota Drive
Brainerd, MN 56401
(218) 828-2605

Region 4
Box 756, Highway 15 South
New Ulm, MN 56073
(507) 359-6053

Region 5
P.O. Box 6247
Rochester, MN 55903
(507) 285-7430

Region 6
1200 Warner Road
St. Paul, MN 55106
(612) 772-7910

Central Office
DNR Building
500 Lafayette Road
St. Paul, MN 55155-4032
(612) 296-4800

ACKNOWLEDGEMENTS

1. Significant content and ideas for this brochure were based on information and drawings from: Streambank Protection Guidelines ... For Landowners and Local Governments. By Malcolm P. Keown, Environmental Lab., October 1983. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

2. Photos from: "Stabilization of Frenchman River using steel jacks", by Richard R. Frogge.; Journal of Waterways and Harbors Division Proceedings of the ASCE. August 1967.

3. Photo courtesy of St. Anthony Falls Hydraulic Lab.

4. A Guide to the George Palmiter River Restoration Techniques., C. Neil Herbkersman, Miami University, Institute of Environmental Sciences, Oxford, Ohio.

5. A special thanks to Jim Zicopula for his diligent layout effort and quality graphics work.