CONCEPTUAL DESIGN REPORT

STREAM STABILIZATION PROJECT

WOLF LODGE CREEK
MARIE CREEK
STELLA CREEK

KOOTENAI COUNTY, IDAHO

for

IDAHO DEPARTMENT OF FISH & GAME
REGION 1
2320 GOVERNMENT WAY
COEUR D'ALENE, IDAHO 83814-3683
(208) 765-3111

AUGUST 10, 1990

by

DENNIS D. FINDORFF, LS/EIT
DR. DONALD R. REICHMUTH, PE/LS

GEOMAX, P.C.
PROFESSIONAL ENGINEERS AND SURVEYORS
622 SOUTH 6TH AVENUE
BOZEMAN, MONTANA 59715
(406) 586-0730

Geomax
GEOLEGAL • GEOMECHANICAL • GEODESIGN
PROFESSIONAL ENGINEERS & SURVEYORS

CONCEPTUAL DESIGN REPORT

STREAM STABILIZATION PROJECT

WOLF LODGE CREEK
MARIE CREEK
STELLA CREEK

KOOTENAI COUNTY, IDAHO

for

IDAHO DEPARTMENT OF FISH & GAME
REGION 1
2320 GOVERNMENT WAY
COEUR D'ALENE, IDAHO 83814-3683
(208) 765-3111

AUGUST 10, 1990

by

DENNIS D. FINDORFF, LS/EIT
DR. DONALD R. REICHMUTH, PE/LS

GEOMAX, P.C.
PROFESSIONAL ENGINEERS AND SURVEYORS
622 SOUTH 6TH AVENUE
BOZEMAN, MONTANA 59715
(406) 586-0730 .

Geomax
GEOLEGAL • GEOMECHANICAL • GEODESIGN

PROFESSIONAL ENGINEERS & SURVEYORS

TABLE OF CONTENTS

INTRODUCTION

The Wolf Lodge Creek drainage contains 3 main streams: Wolf Lodge Creek, Marie Creek and Stella Creek. The latter 2 streams drain into Wolf Lodge Creek which eventually empties into Lake Coeur d'Alene. The drainage has been altered by man from its natural condition in many ways. Timber harvest activities, associated road building and past instream debris removal have resulted in stream channel instability due to changes in runoff patterns and bedload sediment displacement. Other adverse impacts have resulted from overgrazing within the floodplain, residential development within the floodplain, removal of riparian vegetation, and the construction of underground petroleum products pipelines. These impacts have led to a decline in the natural trout habitat within the drainage.

PURPOSE

GEOMAX, P.C. was retained by the Idaho Department of Fish and Game to design methods of stream stabilization for the streams in the Wolf Lodge Creek drainage. The implementation of these stabilization techniques will result in improved system stability and stream habitat.

The Conceptual Design Drawings which accompany this report present the proposed stabilization measures in conceptual form. The drawings are based upon Forest Service and GEOMAX aerial photos and site visits performed by GEOMAX personnel. The estimated construction quantities shown on the drawings are approximate. Should the Final Design phase of this project be implemented, field surveys will be performed to derive more accurate quantities, particularly with respect to excavation.

Because the design drawings are only conceptual, they do not necessarily represent the actual stream stabilization work which will be specified by a Final Design. The Conceptual Design presents concepts, which may be employed, to permit review and generate a consensus for the Final Design.

DESIGN PHILOSOPHY

As development along streams and riparian corridors increases, it is evident that these natural resources will be impacted with increasing frequency. Indiscriminate development without regard to minimizing adverse impacts has led to the significant deterioration of many streams in the western United States. GEOMAX, P.C. has been retained to design stream stabilization measures on numerous streams where developments have resulted in riparian degradation. Through experience we have found that understanding the underlying mechanics is the first step to stabilizing a reach of a stream. The GEOMAX design philosophy is based upon a solid understanding of stream mechanics.

A stream and its basin is an interwoven system of rock, soil, water, vegetation and other living things. Pieces of such a system cannot be managed without regard for the effects on the whole. If man is to live in harmony with nature and his neighbors, he must have some understanding of how his actions will affect others. Unfortunately, most discussions of these interrelationships are often obscured in the language of specialized fields such as geology, hydrology and engineering. We prefer to minimize the use of technical terms so that the lay reader may understand the principles that are presented.

In the discussion that follows, the interplay of action and reaction must be kept foremost in the reader's mind. The principal natural functions of a stream system are to remove excess water and erosional debris which the water shed produces. Because the erosional debris is moved primarily by water, there develops an integral relationship between river flows and sediment movement. A change in the amount of either will affect the other, and there will be a general change to accommodate the new conditions. Further, one must be able to trace the movement of both water and sediment through the basin in order to determine whether there is gain or loss of sediment in particular areas.

STREAM CHARACTERISTICS

Figure 1 shows the characteristics of the 4 types of patterns exhibited by streams. The pattern which develops in any stream is a product of 3 factors: water, energy (gradient) and sediment. The 4 stream patterns are named for the vertical behavior which they exhibit: erosional, stable, transitional and depositional.

Erosional streams (Figure 2) cut vertically downward through the strata over which they flow until they reach a resistant layer such as bedrock. The Colorado River flowing within the Grand Canyon is an example of an erosional stream. They are said to be structurally controlled because their horizontal location is dependent on the erosion resistant material underlying the soil. Erosional streams typically display "V" shaped valleys formed by the erosional downcutting action of the flowing water. Because of the confined nature of these valleys, there is little lateral movement or shifting by the stream.

A stable stream shows minimal vertical change. The stream neither erodes or fills its bed appreciably. The Mississippi River depicts a stable stream as it flows through the Midwestern U.S. Stable streams develop a meandering pattern due to slow lateral shifts across flat bottomed valleys. An idealized typical meandering (stable) stream is shown in Figure 3.

Transitional streams oftentimes display both downcutting and filling in portions of the multichannel system which is present.

This occurs because the various channels in transitional sections receive differing amounts of water and sediment. An idealized transitional stream is shown in Figure 4. The stable islands characteristic of these streams bear vegetation of a similar nature and age as the vegetation found along the banks. The simultaneous degradation and aggradation of the double channel system occurs because the top "clean" water is preferentially shunted to the secondary channel while the bedload carrying bottom water remains in the dominant channel. The secondary channel tends to downcut or degrade while the dominant channel fills or aggrades. Over time the two channels will reverse roles when gravel plugs are deposited in the mouths of dominant channel sections. These plugs cause the top and bottom water to switch channels. The transitional pattern typically involves only a short reach of the stream between stable and depositional patterns.

Depositional streams show increasing channel elevations over time due to the deposition of stream transported sediments. Glacial fed streams in Alaska are excellent examples of depositional streams. The tremendous sediment load carried by these streams fills the flat bottomed valleys through which they flow. This causes the streams to braid out into multiple shallow unstable channels in an unpredictable manner. Figure 5 shows a depositional stream resulting from excess transported sediment (bedload). Depositional streams may also result from decreased gradient and decreased flow as shown in Figures 6 and 7.

The 3 figures which illustrate depositional streams also illustrate the effect which the 3 system controlling factors have on stream pattern. As shown in Figure 1, an increase in water and energy and a decrease in sediment will tend to drive the stream pattern "up" the diagram toward a more erosional/less depositional condition. The converse is also true. It is important to note that a change in only one of the 3 factors may trigger a stream pattern shift. For example, a stream having a stable meandering pattern will likely become depositional in response to a gradient decrease induced by the construction of a dam which raises the base level of the stream. This is shown in Figure 6. Likewise "clean" water exiting a dam is sediment deficient and will frequently turn a stable stream erosive immediately downstream from the dam.

It should be noted that in all of the systems with the exception of the erosive system, the stream flows on sediments which the stream has once moved. These sediments are known as alluvium. Clearly, if the stream has moved the material once, it is fully capable of moving it again.

Energy

The system controlling factors of water and sediment are relatively easy to understand because they are tangible. Energy, however, is intangible and, therefore, difficult to comprehend.

Energy in a stream system is closely related to the slope or gradient of the channel. Precipitation falling upon a watershed possesses potential energy due to its elevation with respect to the lowest elevation of the watershed. The potential energy is transformed into kinetic energy as the water droplet (precipitation) travels downhill.

The rate at which the potential energy is transformed into kinetic energy or velocity depends on the vertical fall when there are no dissipating frictional conditions present in the stream channel. Figure 8 shows some of the natural and man-made mechanisms for dissipating energy in streams. The fewer the mechanisms for energy dissipation the greater the rate at which the velocity of the water increases.

We know that energy cannot be destroyed by the basic laws of physics. Energy can only be removed from the flowing water by being transformed into another form of energy. Velocity (energy) is dissipated in streams through friction. The need to decrease velocity in a stream system is evident when one considers the relationship between sediment transport and velocity.

Figure 9 is a diagram showing the sizes of rocks that can be carried by various currents. For example, at a current velocity of 4.5 feet per second, the stream can move two inch rocks, and at currents of 32 feet per second, a river can move boulders weighing about 250 tons. At currents less than 1.5 feet per second, gravels cannot be carried and will be deposited. By viewing the current velocity together with the stream characteristics explained previously, one can clearly see that increasing the velocity of a stream's current will cause the stream to shift toward a more erosive pattern.

Stair-step Profiles

Figure 10 depicts the stair-step profile typically found in high gradient streams. This profile occurs as a natural response to the excess energy possessed by the water in a high gradient setting. Consider a reach of a high gradient stream. Water at the top of the reach possesses potential energy equal to the elevation difference between the top and bottom of the reach. The potential energy must be transferred into kinetic energy through velocity or thermal energy (heat) through friction. Friction can be between the water and the stream bed or in the water alone as turbulence.

When the average slope is excessive, small drops (or waterfalls) form. These drops dissipate large amounts of energy by creating turbulence. The energy dissipated through turbulence heats the water very slightly. The turbulence created by the drops regulates the velocity of the stream and prevents it from becoming excessive.

Pools and Riffles

Moderate gradient streams, develop a balance between velocity and friction through the formation of riffles and pools within the stream. The riffles are areas of steeper gradient where velocity increases as potential energy becomes kinetic energy. A scour hole generally forms at the toe of the riffle as a result of turbulent scouring when the kinetic energy is dissipated. The pool-riffle sequence forms in most systems as some fraction of the available energy is alternately transformed into kinetic energy (velocity) and then dissipated in friction and turbulence. This energy dissipation does considerable work on the channel and creates the pools.

Base Level Control

All streams and rivers shift their pattern in response to changes in gradient and the water-sediment balance. Usually the effect of a local change will be confined between base level controls. "Base level control" is the term used to describe features controlling steam gradient. Examples of these features include erosion resistant bedrock under the channel, lakes, oceans, and channel constrictions such as bridges which artificially raise the upstream water level. It is possible to totally disrupt a stretch of stable river by changing its base level. Figure 6 is an illustration of stream braiding produced by he flattening of the downstream slope. Note in this figure that the new lake has raised the base level of the stream and forced the old stream bed to fill with sediment. This deposition causes the river to pass from a stable meandering pattern to a transitional condition and finally to braiding.

There are a number of ways that the downstream slope can be changed either naturally or by man's influence. As in the example of Figure 6, the construction of a dam creates the new lake thereby raising the base level elevation, which causes the river to alter its slope and pattern.

Effects of Bridges

Another type of manmade obstacle which can change the pattern of a stream is the construction of bridges with openings too narrow to effectively pass bedload. Figure 11 is an illustration of how a bridge constriction causes gravel bars or braided channels to form upstream from the bridge. In this case, the base level has been raised at the bridge just enough to put the river into a depositional state for a short distance upstream.

Meander Cutoffs

Figure 12 is an example of what occurs when the downstream slope is suddenly steepened by a meander cutoff. This type of phenomenon can occur naturally or be man caused. The steepened gradient and resulting velocity increase can cause considerable erosion damage to the banks and stream bed as shown. It is possible, however, to reduce the problem of a newly-steepened channel gradient by placing drop structures in the stream that serve as manmade waterfalls that effectively flatten the gradient and dissipate the excess energy.

Bed Armor

A seemingly stable reach of stream can be substantially disturbed and subject to increased erosion by simply disrupting the protective layer on the bottom of the stream channel, which is called bed armor. This bed armor consists primarily of the largest caliber materials available in the sediment that is being transported by the stream. Oftentimes this armor is only one cobble thick as shown in Figure 13. During low flow, fine silts and clays tend to settle around these large boulders and cement them in place. This layer of larger materials tends to protect the stream bottom from further erosion and also minimizes infiltration. When this armoring layer is disturbed, the stream must go through a process of sorting substantial quantities of gravel to obtain enough of the larger sized materials to replace the cover. This means that substantial amounts of gravel will be eroded from the disturbed area and carried downstream to potentially cause problems at other areas. Any instream channel work can break up previously formed bed armor.

The instability of the areas where the bed armor has been disrupted is easily noted if one attempts to wade along a disturbed channel bottom. With each footstep you can feel gravels washing around your feet and moving downstream. There is no solid bottom and you tend to sink into the gravel, oftentimes above your ankles. This is in sharp contrast to an armored stream bottom where you can walk in the same depth of water and feel a firm, secure bottom underfoot. Areas of disrupted bed armor allow substantial water infiltration, and it usually takes one to two years before the bottom will have a chance to reseal. This resealing process is not much different from that required to seal a stock water pond or irrigation ditch after construction or cleaning. In an active stream channel it usually takes place during low water when the fine silts and sand settle around the large materials, thereby sealing the bottom against excess water penetration.

System Analysis

From the preceding discussion one can clearly see that stream behavior is controlled by water volume, sediment load and stream gradient (energy). The interaction of these three variables is probably the most important key to understanding stream behavior and the ability to foresee what will occur if natural and/or manmade changes occur on a river. It is extremely important, however, to view the overall picture before any action to minimize a particular problem is undertaken, because short-term remedies may well trigger unwanted reactions. One must determine the base level control which bounds the reach in question before implementing any stream alterations. Base level control, whether it be a natural feature such as a lake or bedrock outcrop or an artificial feature such as a dam or bridge, determines the upstream and downstream limits of a particular reach which may be affected by alterations.

IN-CHANNEL STRUCTURES

GEOMAX designs in-channel structures for four primary reasons: to direct flow, control flow velocity, expend energy and hold sediment. The structures proposed in the conceptual design drawings perform one or more of these functions to develop stability within the system.

In-channel structures usually produce two fundamental flow variations. These are illustrated in Figure 14. In the top diagram it is seen that when water overtops a structure located within a channel, the flow will be directed perpendicular to the downstream face. If the flow is directed toward the bank as shown, bank erosion usually occurs. If, however, the orientation is adjusted to some more favorable direction, beneficial results can be obtained. The second phenomenon observed is that obstructions in the channel create turbulence as the flow passes by. In the lower diagram, the turbulence produces localized velocity increases on the bed causing scour to occur. This scour often creates holes and loosens bed materials which can be transported downstream to other locations.

Jetties

There are many structures constructed in streams which protrude from the bank for a fraction of the channel width. These structures are given names such as jetties, groins, deflectors, and wing dikes. Too often these structures create more problems than they cure because the designer fails to predict how the flow and structure will interact. The middle diagram of Figure 15 illustrates some of the problems which can develop if improper configuration and alignment are used when building the structure. The diagram shows where scour and erosion occur and how associated depositions and high energy conditions can develop downstream from the structure. The bottom diagram in Figure 15 illustrates some improved designs. These designs use the downstream face of the structure to direct the water back into the channel rather than turning the water into the bank. Additionally, the structures are designed to minimize end turbulence, thereby reducing be scour in this area.

Riprap

Figure 16 illustrates some of the problems which often develop along riprapped banks. Because riprap is commonly used, it is important to thoroughly understand this behavior. Often the thread (deepest) portion of the stream is drawn near the riprap. This is caused by turbulent scour adjacent to the rock. When this occurs the channel deepens and narrows as shown in the top and middle diagrams. If the riprap is improperly designed, (see middle diagram) failure will occur as the riprap falls into the scour hole. If, however, a rock base is used under the riprap as illustrated, then the riprap can be maintained in a stable configuration. This, however, does not change the fact that the water often speeds up as it passes by the riprap because there is less friction in the system. This occurs because the cross sectional area of the flow is made more compact (hydraulically efficient) by the channel narrowing and deepening.

Bank Barbs

GEOMAX has been successful in minimizing the scour problems along riprap by installing bank barbs as illustrated in the lower diagram of Figure 16. These barbs reduce the velocity along the riprap by impeding flow and also direct flow away from the riprapped bank. Additionally, by decreasing the elevation of the end of the structure with respect to the bank turbulence at the end is minimized. It is our feeling that in many areas where riprap would normally be chosen, use of properly installed bank barbs may be all that is required to stabilize the banks. This reduces the cost of bank stabilization considerably.

Drop Structures

Where more positive control of channel alignment and energy dissipation are required, drop structures as illustrated in Figure 17 are often used. On larger streams the most satisfactory method of building these structures is to use large (2 - 3 foot diameter) rocks. These structures are always keyed into the stream banks to prevent lateral scouring and are aligned to direct flows in the desired direction. It has been our experience that the structures work satisfactorily if they are made sufficiently wide to allow the downstream rocks to scour into the bed, thereby stabilizing the upper portion of the structure. This, in our opinion, is superior to subexcavation during construction of the structure because considerable water quality problems may develop as a result of the increased channel disturbance. When properly designed, these structures tend to self-tighten as scour occurs and stability is attained rather quickly.

It must be stressed that drop structures are not intended to produce large vertical water level differentials. We limit the vertical water surface elevation differential across the structures to no more than 1-1/2 feet. There have been numerous failures of structures of this type when greater fall heights were used. This is caused by extreme turbulence developing at the base as the water dissipates its energy. When the water surface elevation differential is kept under 1-1/2 feet, downstream standing waves rarely develop in flood flow thereby maintaining streamlined flow. These structures have additional advantages of directing flow, trapping sediments and positively dissipating energy as the water passes over the structure. These benefits are not attained when one uses jetties or riprap. Figure 18 illustrates the effect of structure orientation on flow direction and the creation of scour holes. As can be seen in these diagrams, the flow is directed perpendicular to the downstream faces of the structure and scour occurs in those areas where flow is concentrated or turbulent conditions exist.

It is also important to understand that drop structures are not intended to be dams. It is of minor concern if small holes develop in the structure because the primary function is to create sufficient constriction to maintain a water level differential across the structure and insure that energy is expended under control at the structure. It is usually desirable to make the structure higher at the banks and on the outside of bends as illustrated. This tends to promote better flow characteristics during periods of low flow. This can be a serious consideration where boat or floater passage is critical.

Sill Structures

Sills are similar to drop structures except that the top elevation is essentially at existing grade. There is no vertical elevation difference in water surface across a sill. The purpose of the sill is to prevent erosion or headcutting either within the channel or the floodplain, depending upon where the structure is located. The sill does not impede or prevent flow.

FLOODING AND THE FLOODPLAIN

Flooding is generally perceived as being a totally undesirable event which should be prevented wherever possible. In reality, flooding is a natural phenomenon which is an integral part of riparian systems. We discourage use of the term "flooding" because of the negative image it portrays. High water events, high flows and overbank sheet flows are more descriptive terms which do not carry negative connotations.

Overbank sheet flows are necessary to rejuvenate the fertile soils of the floodplain. Nutrient bearing silts are deposited upon the floodplain as vegetation slows the velocity of the sheet flow, thereby allowing deposition of fine sediments.

The function of the floodplain and riparian vegetation is extremely important in the mitigation of the impacts associated with unusually high flows. The floodplain serves two important functions during these events. First, the floodplain serves as a storage area for excess water. This moderates the peak flow rates experienced downstream. The peak flow is decreased and spread over a longer period of time rather than being extremely high and rapid. This lowers downstream water levels.

The second function of the floodplain is to reduce the in-channel velocities. As discussed previously, higher flow velocities enable the stream to erode and carry larger sediments. The storage function of the floodplain allows sediment laden water to leave the channel, slow down, and deposit its sediment load. If all of the flow were confined to the channel, high velocities with correspondingly high erosion potential would be attained. The vegetation present along the banks and upon the floodplain inhibits flow and, therefore, further decreases the velocity of sheet flows and promotes additional deposition. When the floodplain functions properly, considerable energy is dissipated. This helps control the in-channel erosion which occurs during high water.

The functions of the floodplain are often short-circuited by developments within the floodplain. Construction typically involves destruction of most, if not all, of the riparian vegetation vital to the operation of the floodplain as a mitigation factor in flooding. Structures on the floodplain are encroachments which reduce the conveyance area of the floodplain. Both the lack of vegetation and the diminished conveyance area ensure that more flow will be confined to the channel and that flow velocities in both the channel and on the floodplain will be increased. These conditions obviously increase the likelihood for damage resulting from flooding.

Uses of the floodplain which are compatible with its natural functions include parks and golf courses. These must be planned to provide ample vegetative barriers between grassy open areas to slow overbank flow velocities. The number of buildings must be kept to a minimum and they should be designed to withstand inundation and low velocity flow. Using the floodplain in this manner accommodates the storage and velocity functions of the floodplain while providing desirable recreational areas.

RIPARIAN VEGETATION

The function of riparian vegetation within the stream system is often overlooked. This component is actually an integral part of the system. The diminution of this vegetation results in increased erosion of the stream banks and headcutting within the floodplain. Without vegetation on the floodplain, headcuts would form more readily during periods of overbank flows as there would be no impediment to flow.

Vegetation along the stream banks is extremely important as a means of slowing bank erosion. The root mass of low, dense, woody bank vegetation is vital for binding the bank soil. This root mass slows the rate at which water flowing along the banks erodes the soil. The root mass also allows the banks to be undercut without sloughing. This phenomena produces excellent fish habitat.

Bank vegetation also protects the banks at locations where overbank sheet flows reenter the stream channel. The root mass prevents the formation of headcuts at these areas where the flow is concentrated and moving rapidly. Banks without vegetation will erode under these conditions, triggering a headcut which will migrate upstream to form a new channel.

The development of floodplain areas frequently leads to the loss of much of the native riparian vegetation along the banks of the stream. Lawns and decorative landscaping often replace riparian vegetation. These types of vegetation have minimal root systems with which to resist the forces of flowing water; therefore, erosion of the stream banks increases dramatically. A buffer of suitable riparian vegetation must be maintained along stream banks to minimize bank erosion.

The revegetation of riparian areas, particularly adjacent to residential developments, can be performed in a manner which yields aesthetically pleasing results. A healthy stand of riparian vegetation need not be undesirable from the standpoint of decorative landscaping. Thoughful planning and selection of varieties can produce unique landscaping for river frontage properties. The abundantly watered riparian corridor provides the opportunity to grow more than a typical lawn.

The importance of maintaining healthy riparian vegetation along stream banks and its role in overall stream stability cannot be overemphasized. The destabilization of a stream system can often be traced directly to the destruction of native riparian vegetation, most often associated with human developments. It is imperative that riparian vegetation be reestablished where lacking to develop maximum stability within a stream system. The implementation of structural means of stabilization (drop structures, etc.) must be supplemented with a sound plan of riparian vegetation reestablishment and management. Without such a plan, it is foolish to invest in structural stabilization.

TREE MANAGEMENT

Figure 19 shows the four stages of vegetative cover typically found along streams. The initial stage is undesirable due to the lack of woody vegetation with sufficient root mass to combat erosion. Erosion of the bank soils and the development of headcuts within the floodplain are only slightly inhibited by grassy vegetation.

The second and third stages are most desirable for minimizing erosion of the stream banks and within the floodplain. These stages also provide shading and cover for the stream which is an important factor in fish habitat.

The mature stage, consisting of large trees with little or no underbrush, may result in bank erosion which exceeds the initial stage. Large cottonwood trees are frequently evidence of a mature stage of vegetation. These trees often are undercut by the stream because little or no brushy vegetation is present to resist the erosion. The large lever arm created by the trunk and branches causes the trees to topple after sufficient undercutting has taken place. The fallen tree leaves an exposed raw bank which is easily eroded by the stream.

Proper management of mature trees along the stream banks can minimize the occurrence of tree toppling. Trees threatened by the stream's undercutting should be routinely identified and cut as show in Figure 20. The stump of the tree should be left to stabilize the bank. Managing trees in this manner also decreases the likelihood of debris dam forming in the channel during periods of high water. These dams often form when a newly fallen tree snares floating debris in its branches.

EXISTING CONDITIONS

Classification

The three streams under study in the Wolf Lodge Creek drainage all exhibit horizontal behavior which is consistent with meandering streams. This is due to the natural processes which carved the stream channels prior to the adverse impacts caused by development within the floodplain. The vertical behavior of the streams, however, is not consistent with the stable meandering stream pattern. The vertical behavior has been similar to that exhibited by depositional streams during the past few years. Stream transported sediments from the mountainous upper watersheds have been carried into the flatter valley areas and deposited within the stream channels. The source of these sediments probably results from past land management activities and instream alterations. Clear cutting methods may have also influenced natural erosional processes through changes in runoff patterns.

The streams are rapidly moving down the stream pattern chart presented in Figure 1. Because of the excessive deposition within their channels, some stream reaches have moved from stable meandering patterns to depositional braided patterns in a relatively short time frame. While the streams generally do not display the horizontal behavior characteristic of depositional streams at this time, it is anticipated that this will occur in the near future unless the sediment transport/deposition problem is rectified. Already portions of Stella Creek and Marie Creek have been nearly filled with gravel deposition, thereby reducing their capacity to practically nothing. These portions of the two steams are shown on sheets 4 and 7 of the design drawings.

Floodplain Encroachment

Generally there has not been a significant amount of development within the floodplain of the three creeks studied. The most intensely developed areas are Marie Creek just upstream from Wolf Lodge Road crossing and Wolf Lodge Creek in the vicinity of the Gateway Ranch bridge. Development within the floodplain of the streams decreases the effectiveness of their natural floodplain functions as described previously. We feel that future development within the 100 year floodplain should be prevented to the greatest extent possible.

There are numerous examples of overgrazing within the floodplains of the project streams. This overgrazing destroys both bank vegetation and vegetation upon the floodplain. The loss of this vegetation dramatically increases the likelihood of erosion within the floodplain during periods of high water. New channels can rapidly develop within the floodplain during periods of high flow where vegetation has been denuded.

We were very disturbed to see that topsoil stripping has occurred adjacent to Wolf Lodge Creek approximately 1/2 mile north of Interstate 90. Approximately 18 inches of topsoil was removed over a wide area east of the creek. This practice is very undesirable within the floodplain due to the loss of erosion resistant vegetative matter. The occurrence of overbank flow from Wolf Lodge Creek in this vicinity will increase because channel capacity has been effectively reduced. A narrow strip of top soil was allowed to remain adjacent to the stream along one severely eroding stream bank. This does not provide adequate protection from the erosive force of flowing water.

Channel Modifications

There are two reaches in Wolf Lodge Creek, just upstream and downstream from the Funk residence, where the channel has been straightened artificially. This manipulation appears to have taken place quite a few years ago. Straightening a meandering channel reduces the length of the channel and effectively increases the stream gradient through the straightened reach. This often leads to instability of both the banks and the bed of the channel. Future channel straightening should not be allowed.

Riprap

The presence of riprap within the stream reaches under study is rare. Only two areas of significant riprapping were identified on Wolf Lodge Creek. One area of riprap exists just upstream from the Funk residence along a diked area on the right bank. The other significant riprapped area is just below the Schoolhouse bridge and is comprised of old tires staked along the right bank. The former area of riprap exhibits some of the typical problems associated with riprap. The riprap has drawn the thread of the stream adjacent to it resulting in failure of the riprap.

The bank along which the tire riprap has been placed has revegetated either naturally or with the assistance of the landowner. Regardless of the manner in which the vegetation has been reestablished, it is now flourishing and provides a suitable mechanism for erosion resistance. It is not recommended that either of the riprapped areas be removed. Such removal would likely cause more detrimental effects than beneficial ones.

Pipeline Crossings

The existence of a gasoline pipeline and a natural gas pipeline adjacent to and crossing Wolf Lodge Creek has caused problems in the past and has the potential for future problems. Two areas of interaction between the creek and the pipelines are of immediate concern. The first is located along Wolf Lodge Creek just a short distance downstream from its confluence with Marie Creek. This area is shown in detail on sheet 8 of the Design Drawings. Here the lateral shifting of Wolf Lodge Creek as evidenced by an eroding right bank, threatens to expose the gasoline pipeline.

The other area of concern is detailed on sheet 9 of the Design Drawings where the natural gas pipeline crosses Wolf Lodge Creek. A protective pipe existing above the natural gas pipeline has been exposed by the creek. Exposure of the active pipeline may occur during a highwater event unless protective action is taken soon.

GEOMAX RECOMMENDATIONS

General

Persons living along the stream must realize and accept the uncertainties associated with the dynamic nature of flowing water bodies. There are inherent risks which must be anticipated by those living within the floodplain. Foremost of these is that the stream will overflow its banks. While this is a natural phenomenon, many stream dwellers find it undesirable. It is our belief that unless this can be accepted one should not make his home along a stream.

The designs and recommendations contained within the Conceptual Design Drawings are intended to provide stability to the stream system. They are not intended to prevent those living within the floodplain from being inundated by overbank flows.

There is no practical way to eliminate this from occurring in stream systems.

Sediment Traps

Geomax has chosen locations for two large sediment traps, each being approximately 5000 cubic yards in volume, to trap excessive material transported downstream from the upper watersheds. One trap has been designed each for Stella Creek and Marie Creek. The locations for the sediment traps are on U.S. Forest Service lands. Details for the sediment traps are shown on sheets 4 and 6 of the Design Drawings.

The function and mechanics of a sediment trap are quite simple. Figure 21 shows a plan view and cross section of a typical sediment trap. Water entering a sediment trap carries a large load of sediment which is deposited within the trap when the velocity of the water is decreased to a point where it can no longer transport the sediment load. Water leaving the trap, therefore, is cleaned of the coarse fraction of the sediment. The sediment trap allows the location of sediment deposition to be controlled and localized rather than uncontrolled and extending along a significant reach of stream.

It is anticipated that the material removed from the sediment traps during their initial excavation can be sold to help offset the cost of excavation. Likewise, when the traps are periodically cleaned to remove deposited sediment the material can be sold to help offset the maintenance costs. It is not possible to predict the rate at which the sediment traps will become filled with sediment. This rate is dependent upon soil conditions in the watershed and flow rates within the stream. We advise that a "wait and see" approach be taken whereby the traps are excavated as needed to remove excessive sediments.

A small in-channel sediment trap has been specified for Wolf Lodge Creek immediately upstream from the Schoolhouse bridge. We do not recommend excavation outside the existing channel at this location due to the valuable riparian vegetation which would be destroyed in the process. Furthermore, the deposition of sediment at this particular location should gradually decrease in response to the upstream sediment traps and channel stabilization structures proposed in this Design Package.

Channel Excavation

There are numerous reaches of channel which have been identified as requiring excavation to remove excessive depositions. These locations are shown on the Design Drawings. The channel excavations should only be performed in conjunction with the excavation of the sediment traps and the installation of the stream stabilization structures. This should insure that the channel excavation need to be performed only once rather than routinely. Because excavation within the channel creates adverse impacts with respect to stability and habitat it should be performed minimally, if at all. We generally prefer a "hands off" approach.

Some of the sections of the streams have become so clogged with sediment that there is little recourse except to perform excavation within the channel. Unfortunately, the consequences of gravel removal are very difficult to predict and, as a result, future bank and channel stabilization may be required in response to the channel excavation. The streams must be monitored closely following the channel excavation to detect the presence of instabilities which would require treatment.

Excavation of the sediment traps and within the channel should occur when flow in the streams is minimal. This dictates that the excavation should be performed in late summer or early fall. Timing the excavation in this manner will allow much of it to occur in the "dry" or outside of active flowing stream channels. Flow in portions of Stella Creek and Marie Creek is subsurface during the late summer and early fall months. This is the ideal time to undertake excavation operations.

Gravel Management

The function of streams is to carry water and sediment out of the drainages which they serve. The source of water in a drainage is relatively simple to identify. The water comes from precipitation in the form of rain and snow. Water enters the stream as runoff from the ground surface or as groundwater from subsurface.

The production of sediment in a drainage is more complex and extremely difficult to quantify. Erosion takes place in the form of both mechanical and chemical weathering. Mechanical weathering occurs by flowing water, freeze/thaw cycles, landslides and wind. Chemical weathering occurs when chemical reactions take place in the parent bed rock material which cause the rock to dissolve or decompose into particles of soil. The weathering which occurs in the upper drainages of Wolf Lodge Creek is primarily mechanical in nature. As the elevation decreases and average annual temperatures increase, chemical weathering becomes more significant.

Water running off the steep slopes of the upper drainages collects sediment and carries it into the tributaries feeding the creeks. Clearcut logging practices increase the amount of sediment introduced into the creeks by: 1) disturbing the soil; 2) removing velocity reducing vegetation; 3) killing slope stabilizing root systems; 4) increasing the volume of runoff; and 5) creating higher peak runoff. There is little doubt that the operation of logging equipment and skidding timber across the ground surface loosens the soil and makes it more susceptible to erosion and transport by runoff. This alone will cause a considerable increase in the volume of sediment entering the stream. The damage which occurs to the low ground cover during the logging operation allows for greater runoff velocities which enables larger sizes of sediment to be carried.

Figure 22 illustrates the effect of forest cover on runoff yield and duration. Tree covered slopes yield less total runoff volume because of transpiration and the evaporation of moisture which is held on the branches. The shading provided by the trees also slows the rate at which snow on the ground melts. This lengthens the period of runoff and minimizes peaks in the runoff.

Barren slopes produce greater runoff volumes since the processes of transpiration and evaporation associated with trees are slight. The lack of shade also insures that the snow will melt faster. The absence of vegetation provides no impediment to flow down the slopes of the drainage and minimizes seepage into the soil. These conditions result in a shorter runoff period with higher peaks. These characteristics make the runoff "flashy". Flashy runoff increases undesirable downstream flooding and sediment transport.

Sediment is also introduced into the stream system by erosion along stream banks. The loss or lack of suitable riparian vegetation is probably the most common cause of bank erosion. Dense woody vegetation is an essential component of stable stream banks. The root mass of this vegetation binds the soil of the stream bank together into an erosion resistant network. Loss of this natural defense mechanism translates into unprotected banks which are likely to suffer from excessive erosion.

Gravel management must concentrate on the production of sediment within the drainage. This can only be accomplished by the implementation of logging practices that maintain stream channel stability.. It is our feeling that channel stability in the upper watershed is the key to reducing sediment deposition in the lower valleys.

Rock Structures

The rock structures proposed by Geomax fall under 3 general configurations. These are drop structures, sills and bank barbs. Each individual structure is numbered on the Design Drawings and a brief description of the purpose and estimated rock volume for each structure is located on each sheet where the structures occur.

The proposed structures shown on the Design Drawings are to be constructed out of large caliber (2-3' diameter) rocks. These rocks are of sufficient size to withstand the velocities present in the streams during high flow periods. A typical materials and construction specification for the rock structures is contained in Appendix B at the end of this report. Details for the rock structures can be found on sheet 6 of the Design Drawings.

The construction of drop, sill and bank barb structures requires that the structures be keyed into the stream banks so that the stream cannot erode around their ends. Properly keying the structures into the banks is an important consideration during construction. The finished top elevations of the structures, particularly drop structures, is quite critical to their proper performance.

Building Envelope Protection — cost of this should be paid by landowner

Building envelope protection involves the protection of structures from high velocity overbank flows. While it is inevitable that structures within the floodplain will be surrounded by water during extremely high flow events activities should be undertaken to prevent destruction by high velocity water. Figures 23 & 24 depict typical building envelope scenarios. The illustrated method of protection consists primarily of constructing a low berm upstream from the building which is to be protected. The upstream alignment of the berm is perpendicular to the direction of flow. The height of the berm is dependent upon historical depths of overbank flow. New vegetation should be established upon the berm and in front of the berm to give the berm erosion resistance and to break up the velocity of sheet flow.

The construction of the berm and associated vegetation is not intended to prevent standing water from existing around home sites. The function of the berm and vegetation is to disrupt the direction and velocity of sheet flow so that it is not detrimental to the building.

While this example of building envelope protection is very general it can be adapted to nearly all situations of structures within the floodplain. Landowners who have experienced serious flooding problems resulting from sheet flow velocities should be identified to GEOMAX for specific recommendations.

Riparian Vegetation Management

The management of riparian vegetation within a stream corridor should emphasize the maintenance of native varieties along the stream bank and the creation of a buffer zone between the stream bank and user areas. Figure 25 depicts a typical stream corridor management plan. The example shows a 50 foot buffer zone containing native riparian vegetation between the stream and an area used for grazing. Where grazing occurs adjacent to a stream, fences should be constructed to prevent access to the buffer zone by livestock. Unrestricted access to the buffer zone by livestock will result in trampling of stream banks and vegetation as well as the vegetation becoming a food source for the livestock. The buffer zone may be used by the livestock under certain circumstances during noncritical times of the year such as late fall and winter when the growing season is over. The stream banks are typically not moist and susceptible to destruction at this time. The buffer may become an ideal location to be used as a wind break during winter months and the calving season.

Oxbow areas should be fenced off as shown in the figure due to their critical nature. Water flowing across the neck of the oxbow during periods of highwater frequently will trigger the formation of a headcut where the water reenters the stream channel. This headcut may migrate upstream and connect with the stream thereby capturing the stream channel and leaving the oxbow channel dry during periods of normal flow. This greatly increases the gradient of the stream and results in increased bed and bank erosion upstream and deposition downstream as shown in Figure 12.

There are numerous areas long the streams under study where the reestablishment of riparian vegetation is required. A riparian buffer zone should be established in these areas to promote long term stability of the stream system. Fences should be constructed where grazing occurs adjacent to the stream.

The areas specified on the Design Drawings should not be considered the only locations where the reestablishment of riparian revegetation is necessary, rather these are the most critical areas. A comprehensive effort for the revegetation of the stream banks within the entire project reach should be undertaken. This plan should involve the intensive revegetation of areas presently lacking any riparian vegetation and more moderate efforts where vegetation now exists but is inadequate. An adequate stand of riparian vegetation would probably by described as one which is difficult to walk through when approaching the river.

SCS

Revegetation should be planned to produce a mixed age stand of vegetation. This will ensure long term stability of the vegetation with no collapse due to mature stages. It is important to maintain and/or supplement existing stands of vegetation to ensure a mixed age state. The practice of cutting brush and preserving mature cottonwoods must be abolished.

Typical riparian vegetation varieties which would be acceptable for use within the Wolf Lodge drainage are willows, alders and dogwood. The precise species of vegetation and the methods for its reestablishment are beyond the expertise of GEOMAX. We recommend that those responsible for the reestablishment of riparian vegetation contact a specialist in the field. Dr. Bruce Lium of the American Water Resources Company in Hailey, Idaho is an expert on riparian vegetation and its reestablishment. We have worked with Dr. Lium on numerous projects and recommend that Dr. Lium or another expert be consulted prior to undertaking revegetation efforts.

There are numerous examples of healthy riparian vegetation existing within the project area. These areas are typified by dense vegetation combined with beaver dams and ponds. This is typical of what the stream corridor looked like before man's impact and development. While a return to this condition would be desirable from a stability and habitat standpoint it is not practical for the recreational enjoyment of the stream. However, some sort of riparian buffer zone should be established along the entire length of the streams involved in the project.

COST ESTIMATE

A cost estimate for the construction of the Conceptual Design shown in the Design Drawings is contained in Appendix C. The total construction cost estimate is $210,000.

SUMMARY

The largest factor destabilizing the streams within the Wolf Lodge drainage is the presence of excessive sediment. Modification of timber harvesting practices along with the construction of the sediment traps proposed by the Conceptual Design should mitigate the adverse effects of the sediment deposition. Cleaning the channels of deposited sediment should be a one-time activity which will regain channel capacity and decrease the occurrence of overbank sheet flows. The proposed rock structures will stabilize the stream system in the lower watershed, thereby controlling the production of sediment through bank and channel erosion. The stability regained through the implementation of the Conceptual Design should facilitate the improvement of trout habitat within the streams of the Wolf Lodge drainage.

APPENDIX A

FIGURES

CHARACTERISTICS OF STREAMS

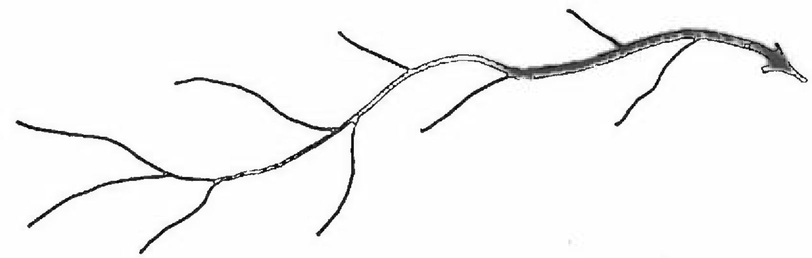
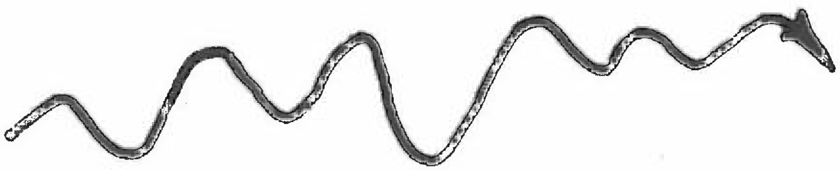
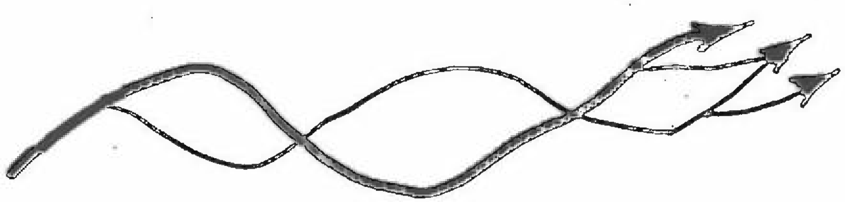
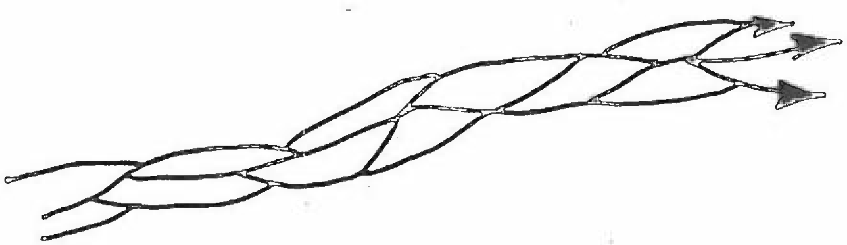
STREAM PATTERN	VERTICAL BEHAVIOR	HORIZONTAL BEHAVIOR	SYSTEM CONTROLLING FACTORS
	EROSIONAL	STRUCTURALLY CONTROLLED "U" SHAPED VALLEY MINOR SHIFTING	INCREASE WATER INCREASE ENERGY DECREASE SEDIMENT
	STABLE	MEANDERING FLAT BOTTOMED VALLEY SLOWLY SHIFTING	
	TRANSITIONAL	DOUBLE CHANNELS SHORT REACH STABLE ISLANDS	
	DEPOSITIONAL	BRAIDED FLAT BOTTOMED VALLEY SHALLOW UNSTABLE CHANNELS	

Figure 1 - Stream classification system.

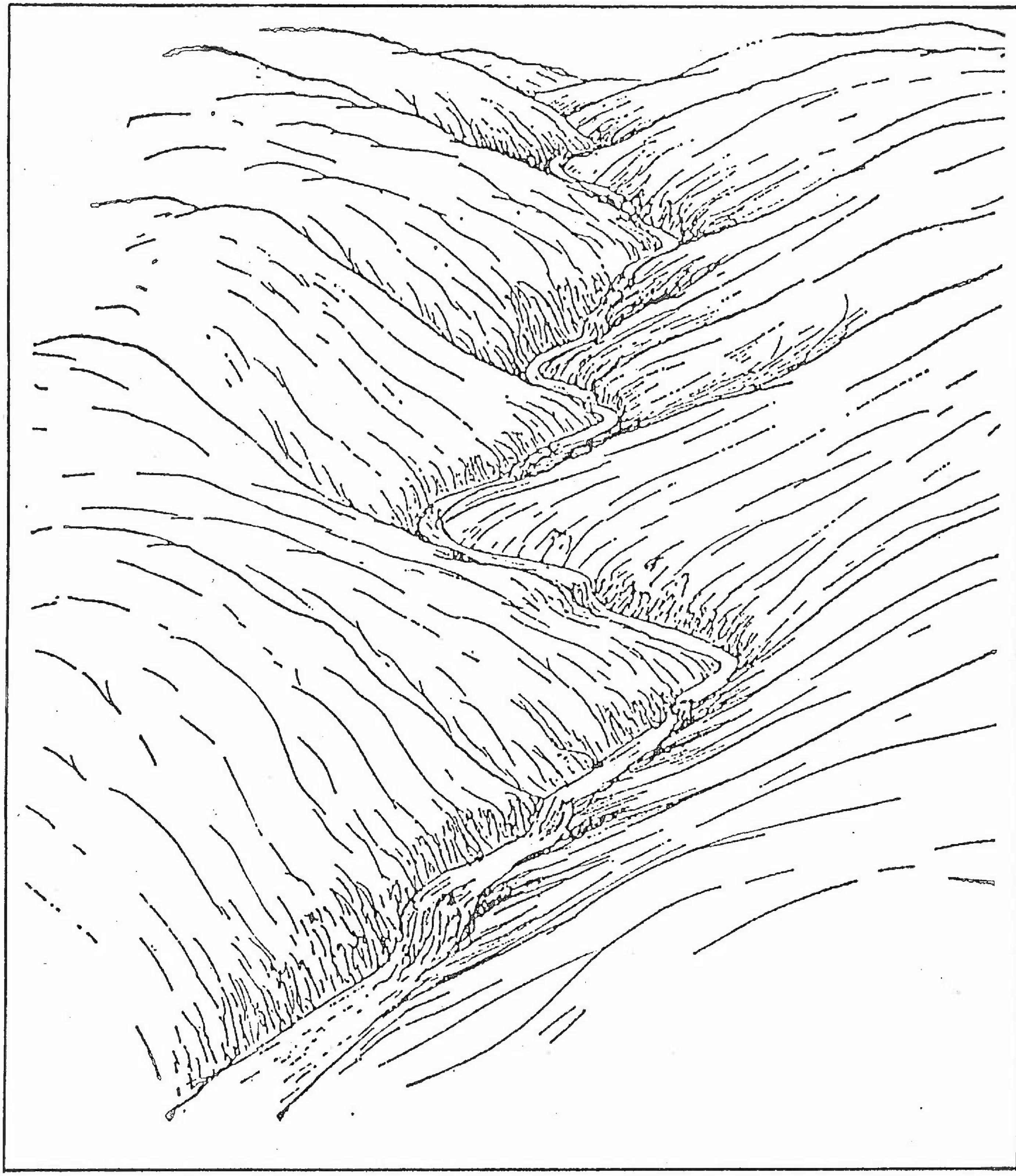


Figure 2 - Idealized erosional stream.

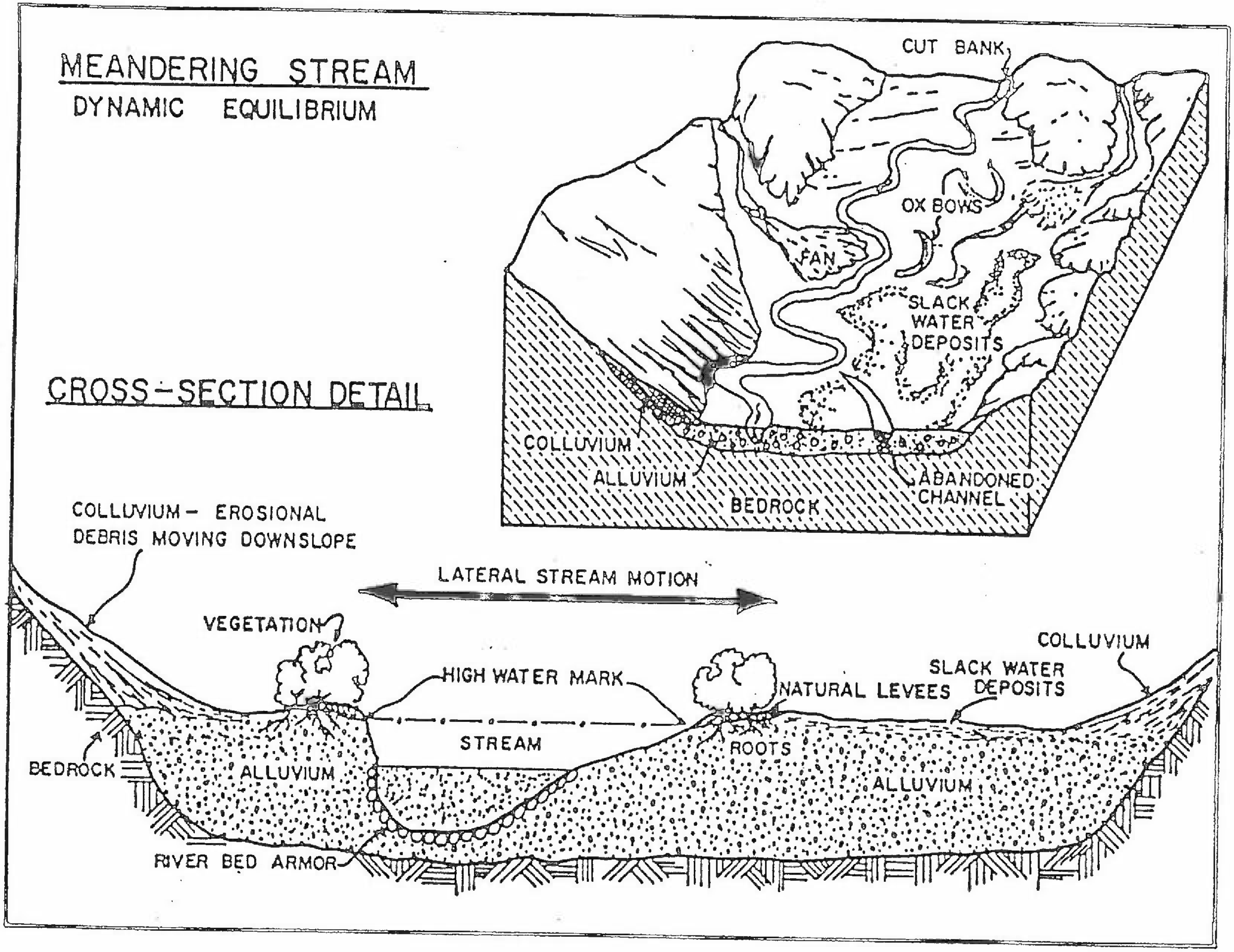


Figure 3 - Idealized stable (meandering) stream.

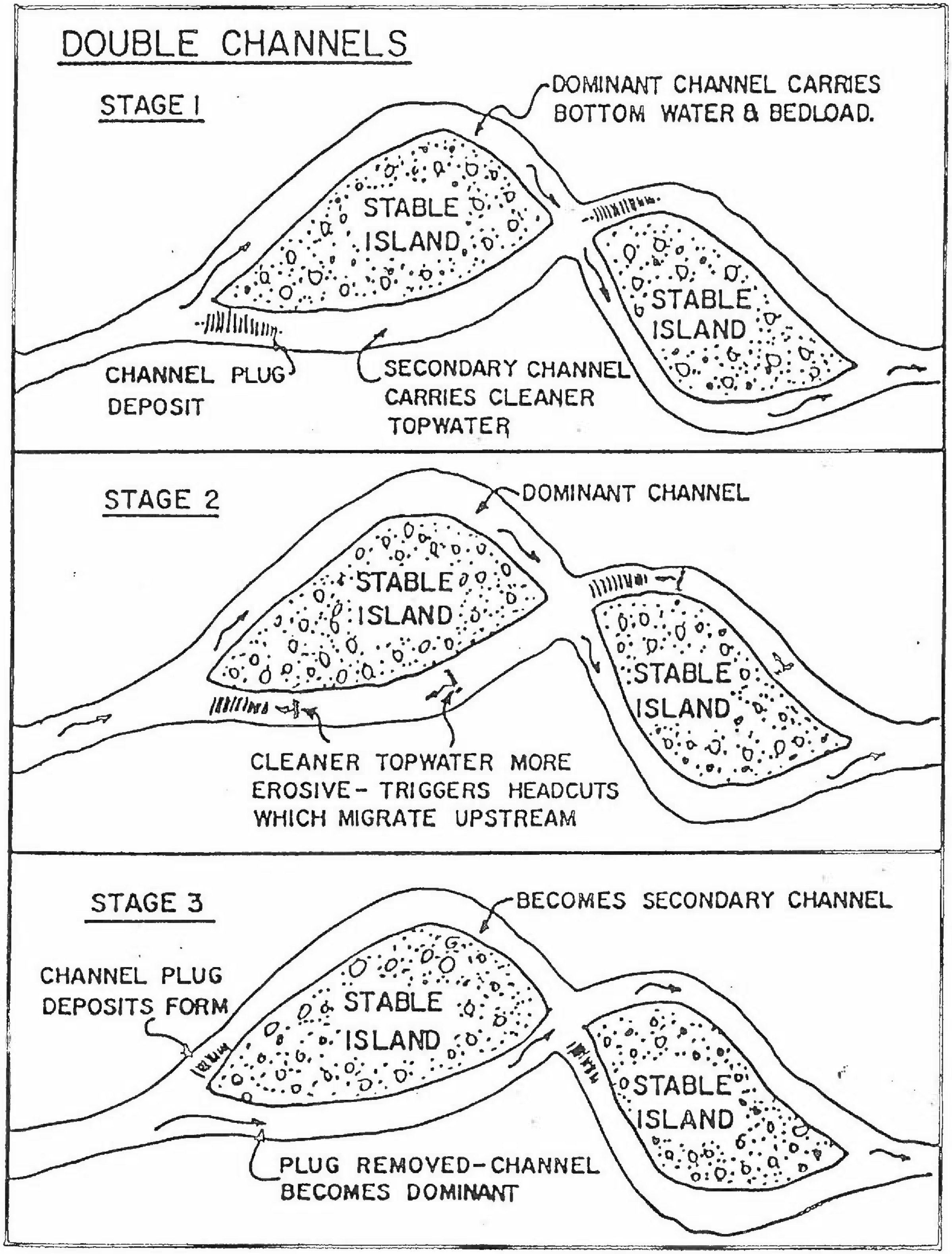


Figure 4 - Idealized transitional stream with double channels.

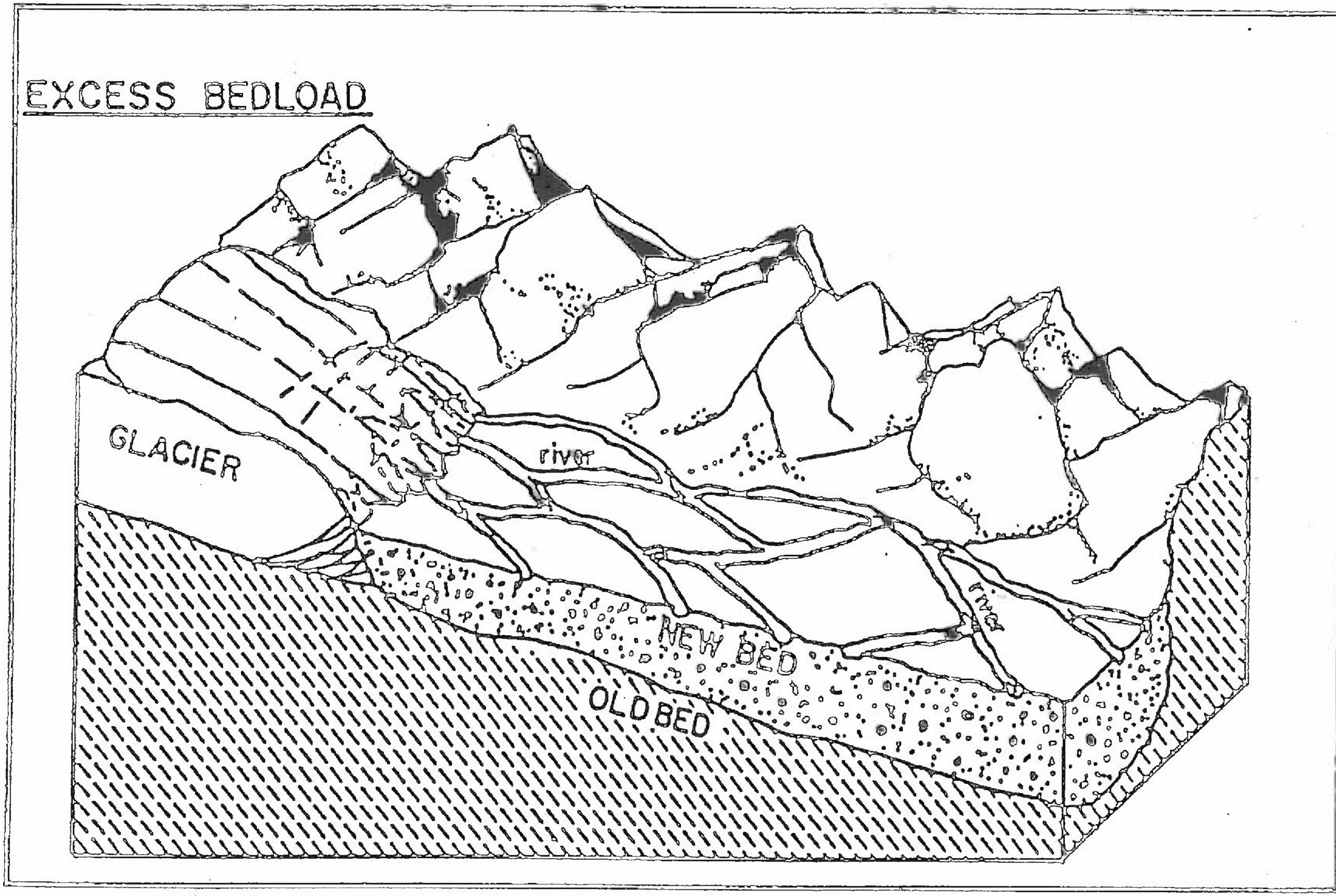


Figure 5 - Depositional stream caused by excessive bedload.

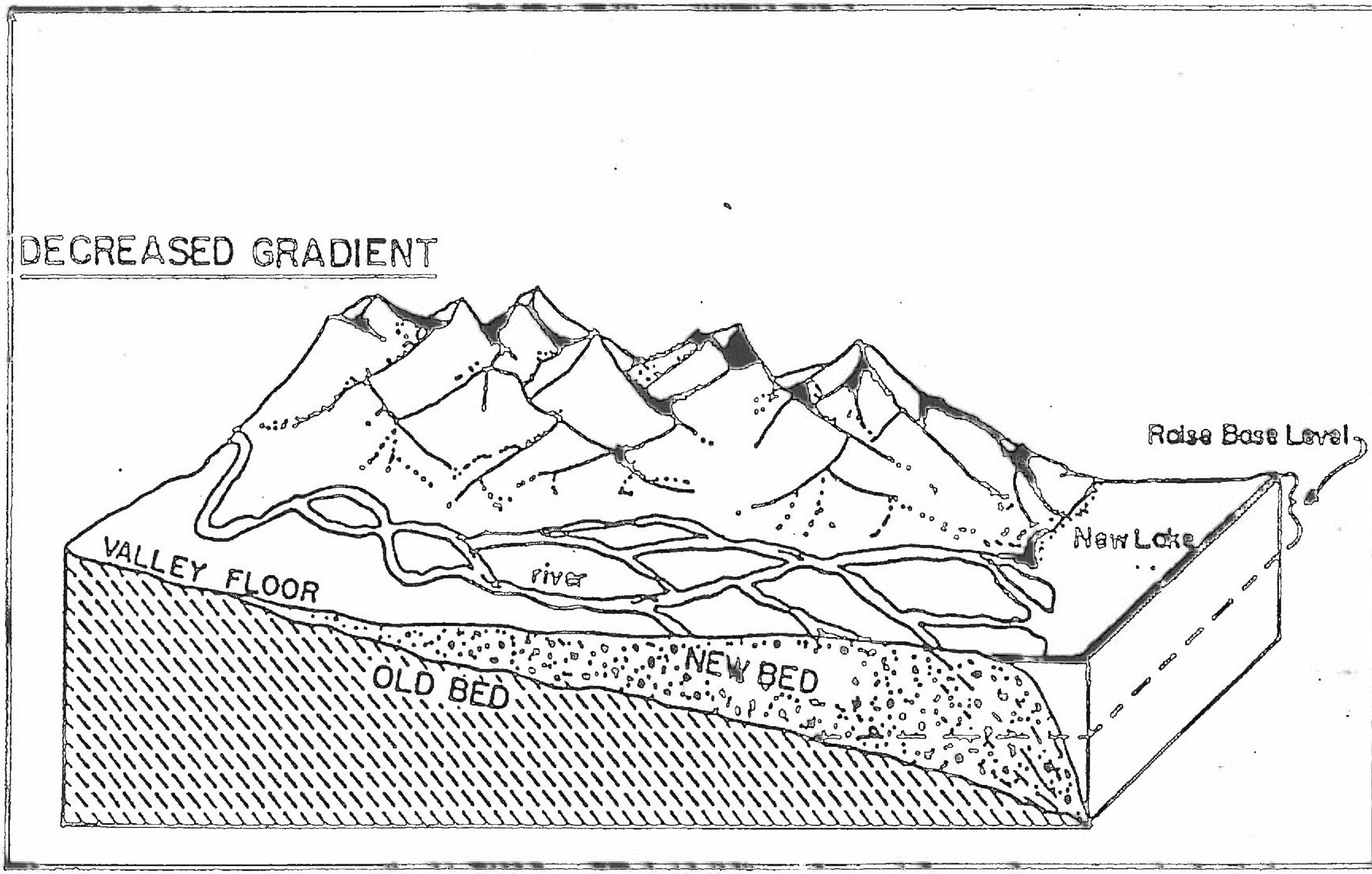


Figure 6 - Depositional stream caused by decreased gradient.

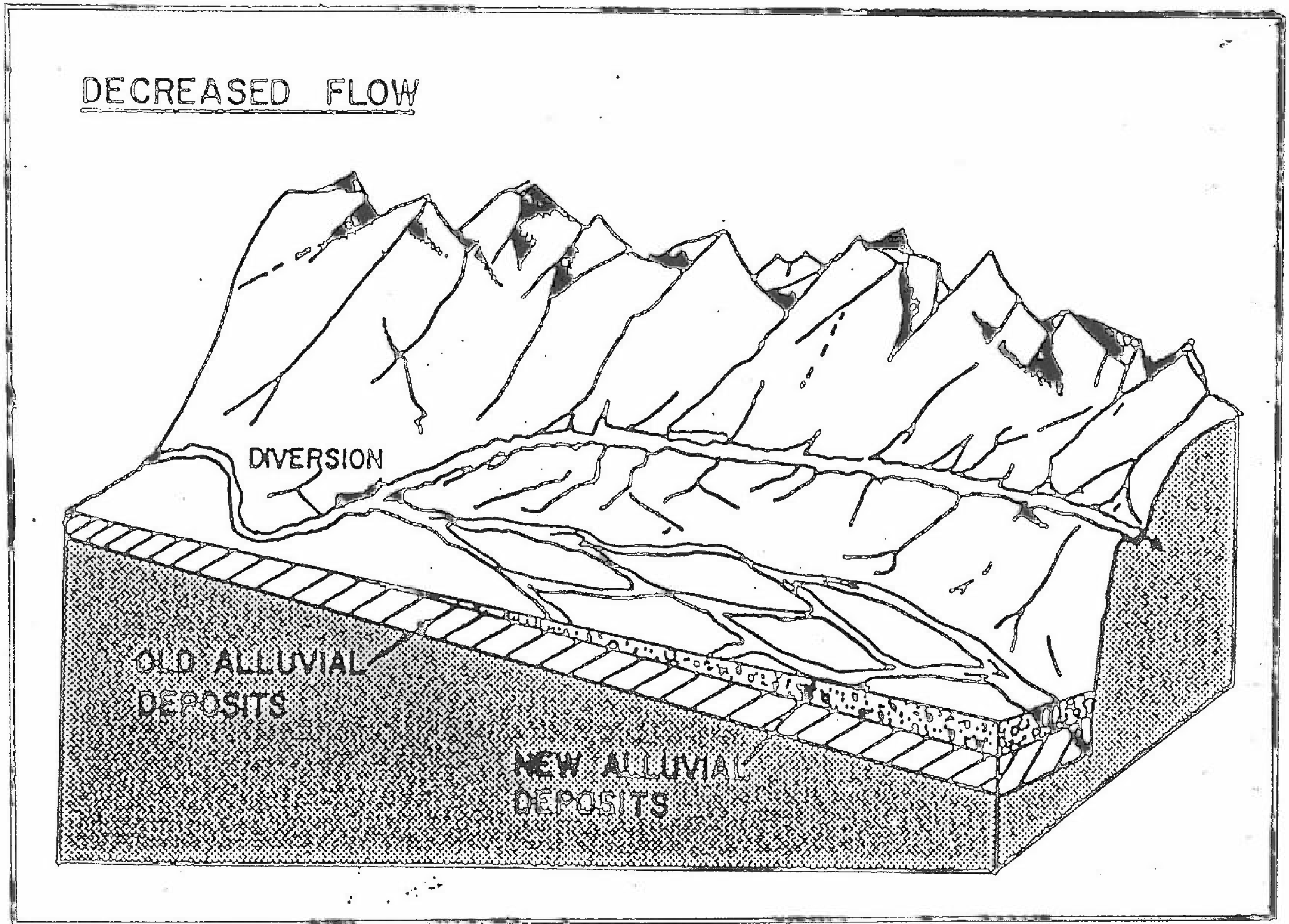
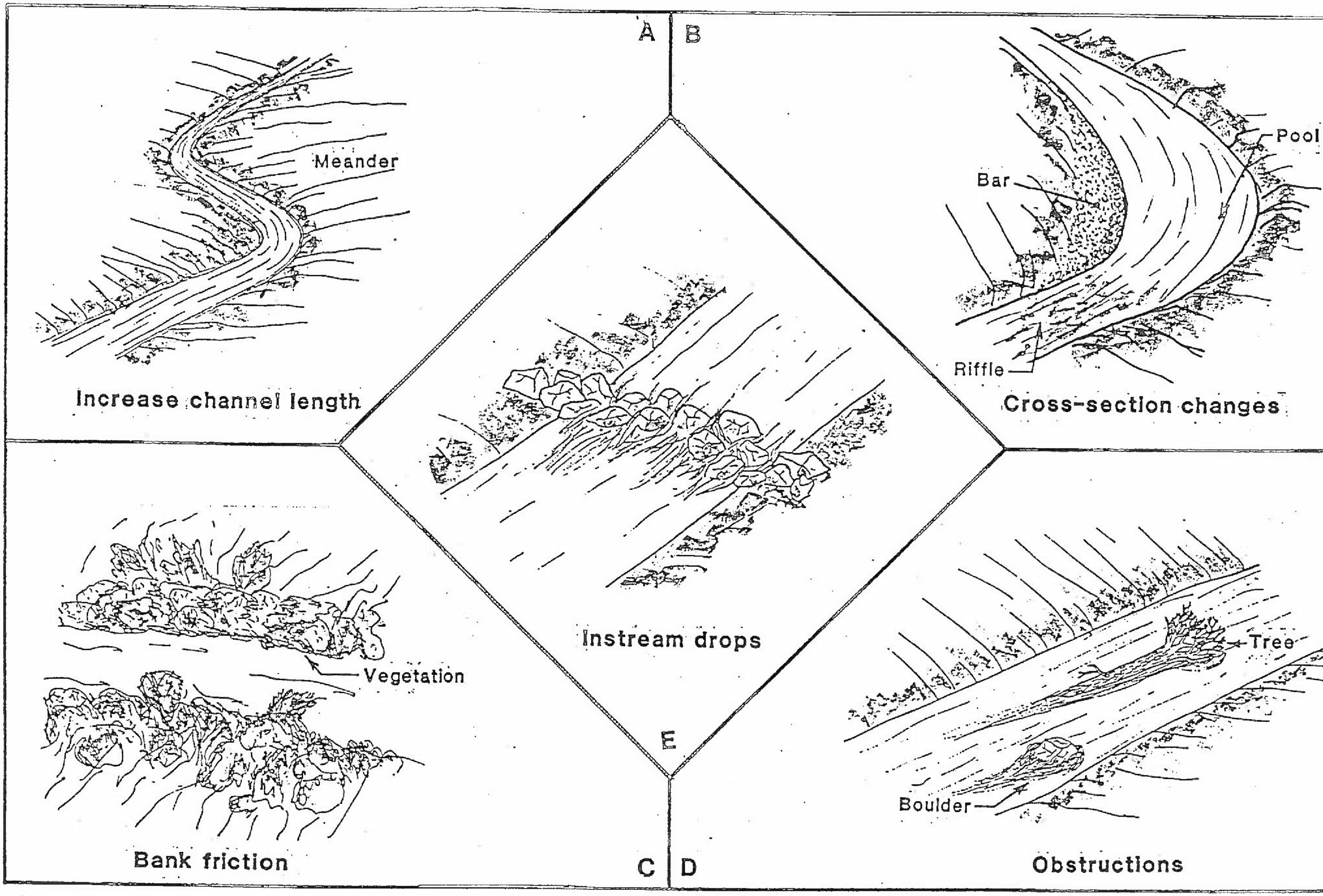


Figure 7 - Depositional stream caused by decreased flow.



Energy Dissipation Methods

Figure 8 - Energy dissipation methods.

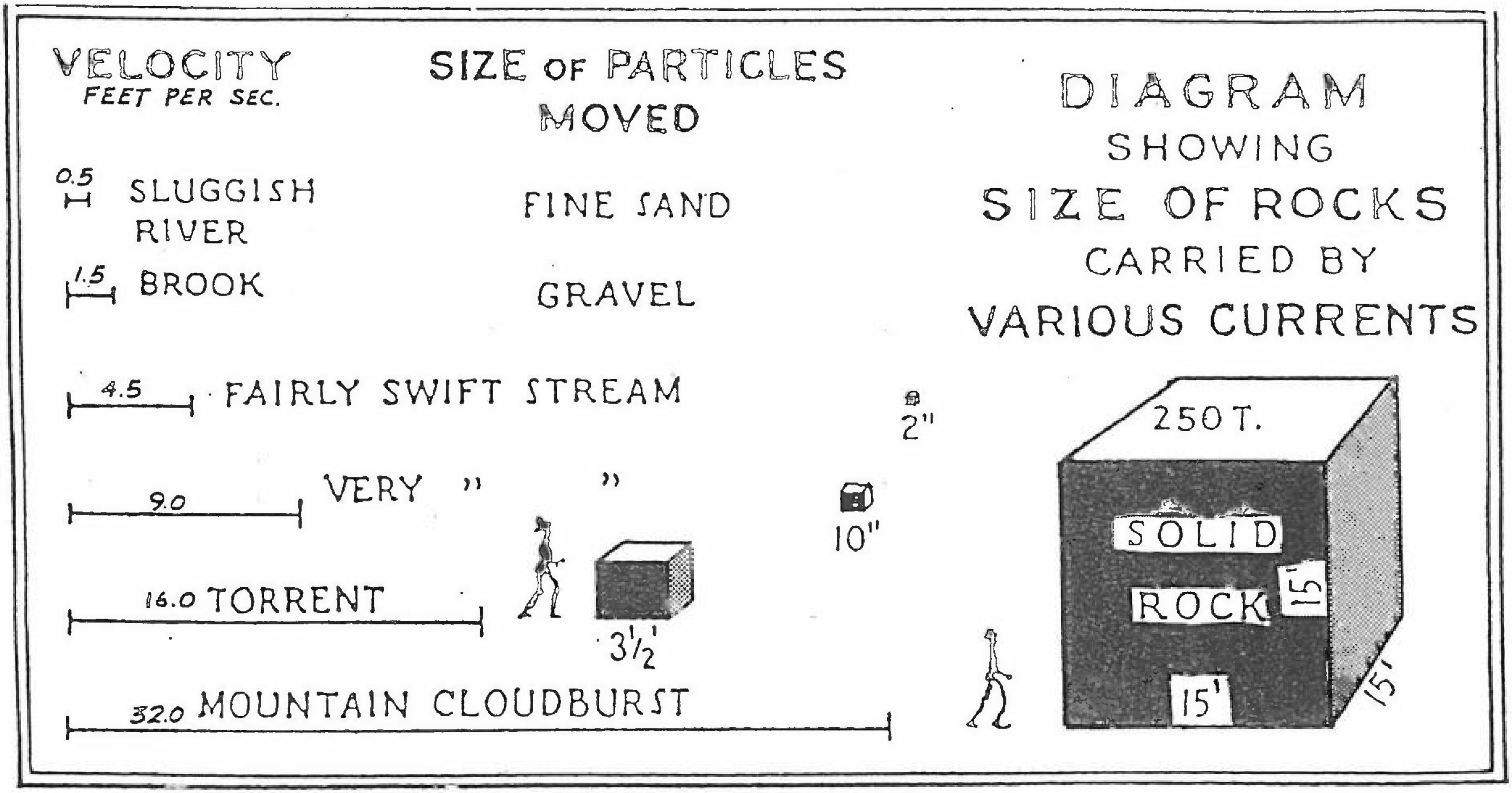


Figure 9 - Relationship between stream velocity and bedload size.

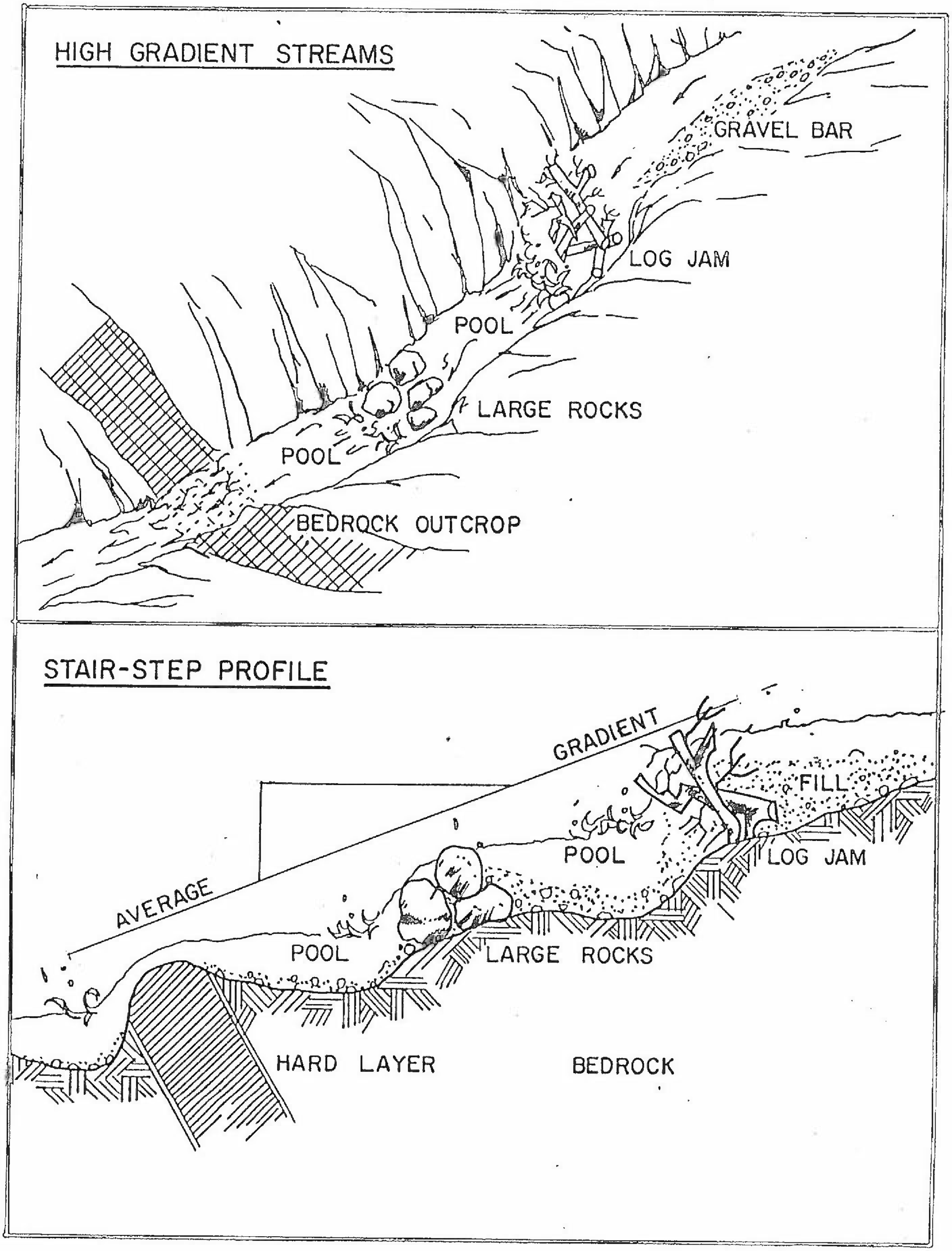


Figure 10 - Stair-step profile in high gradient streams.

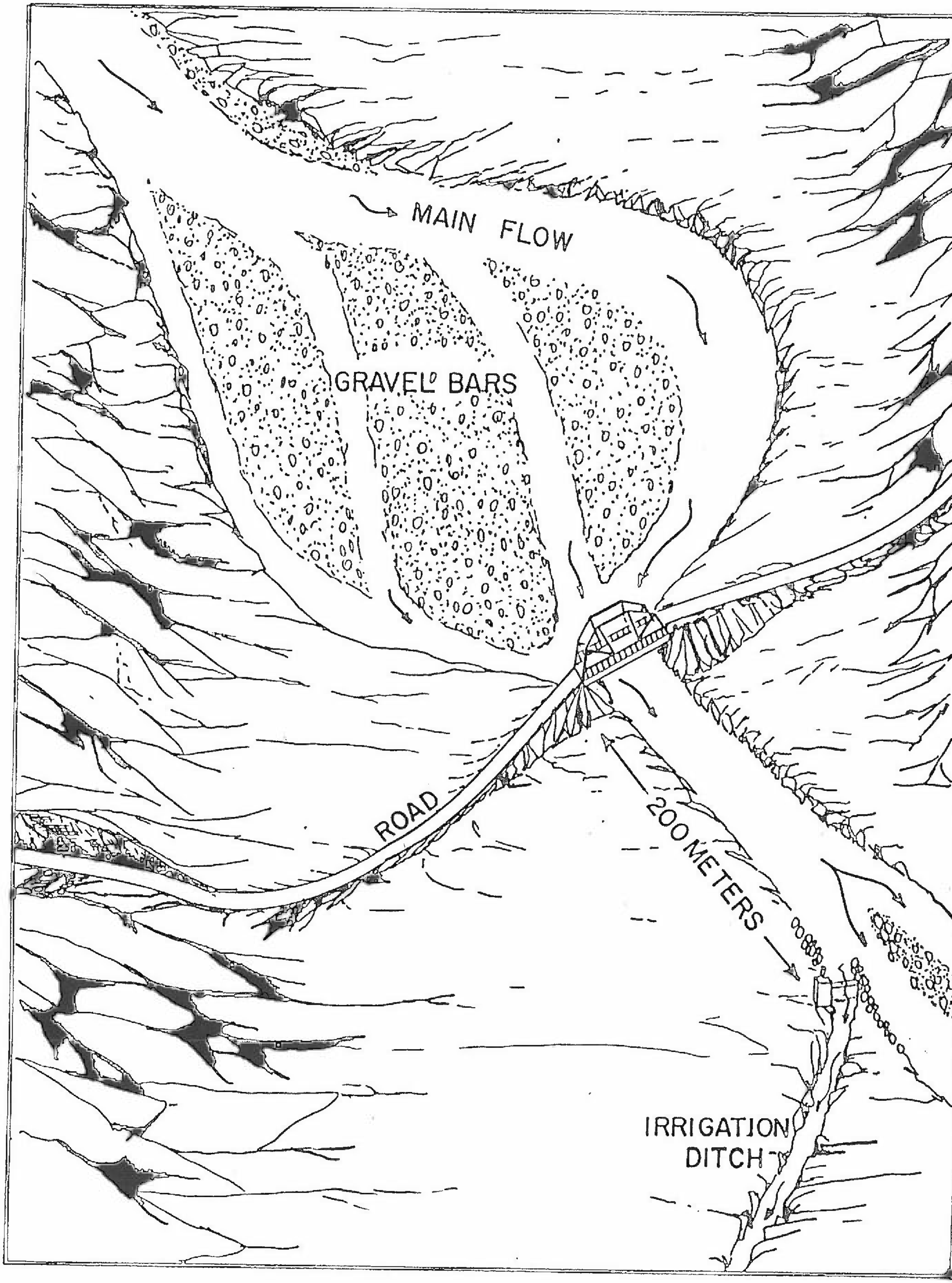


Figure 11 - Effects of bridges when flow is constricted.

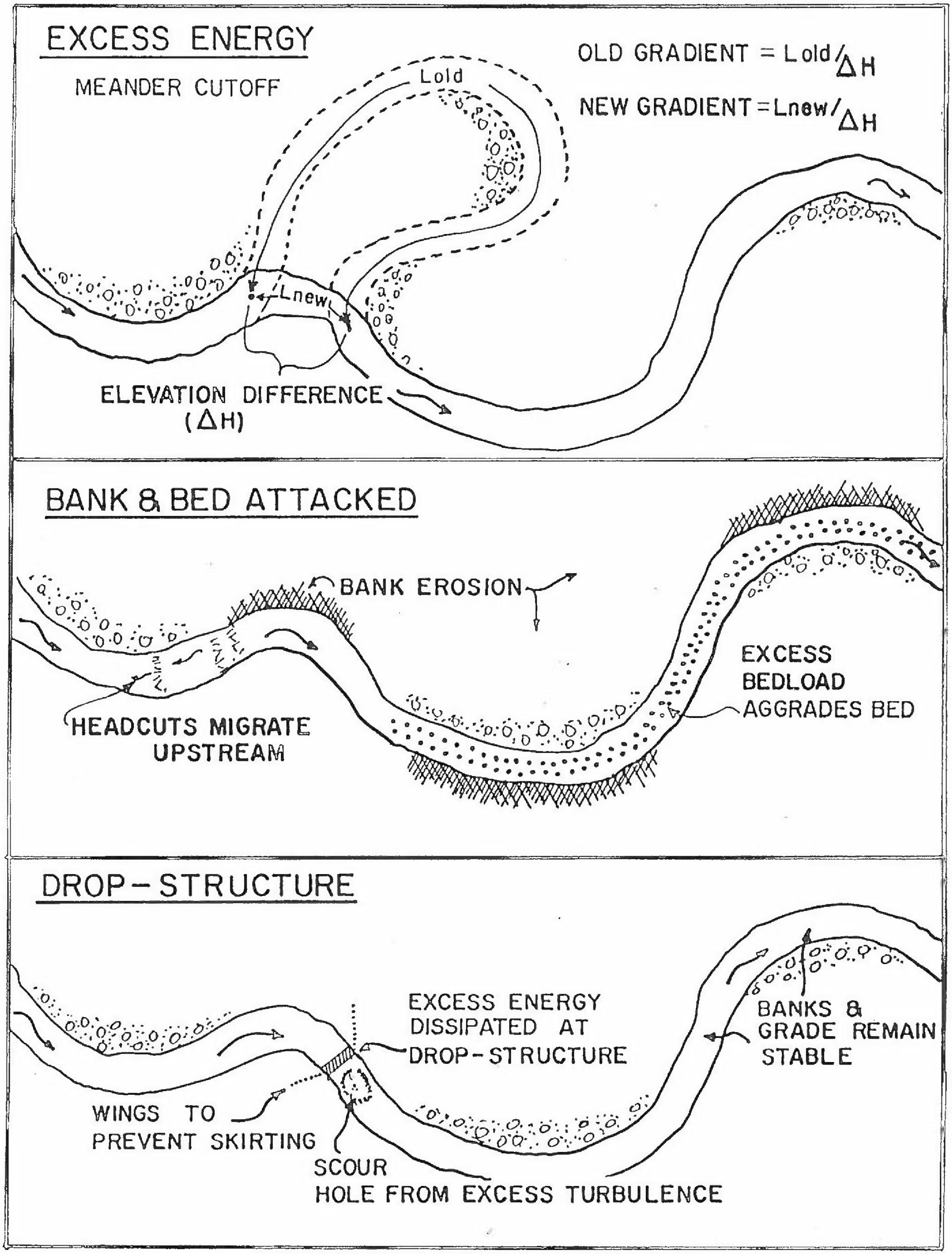


Figure 12 - Effects of meander cutoffs.

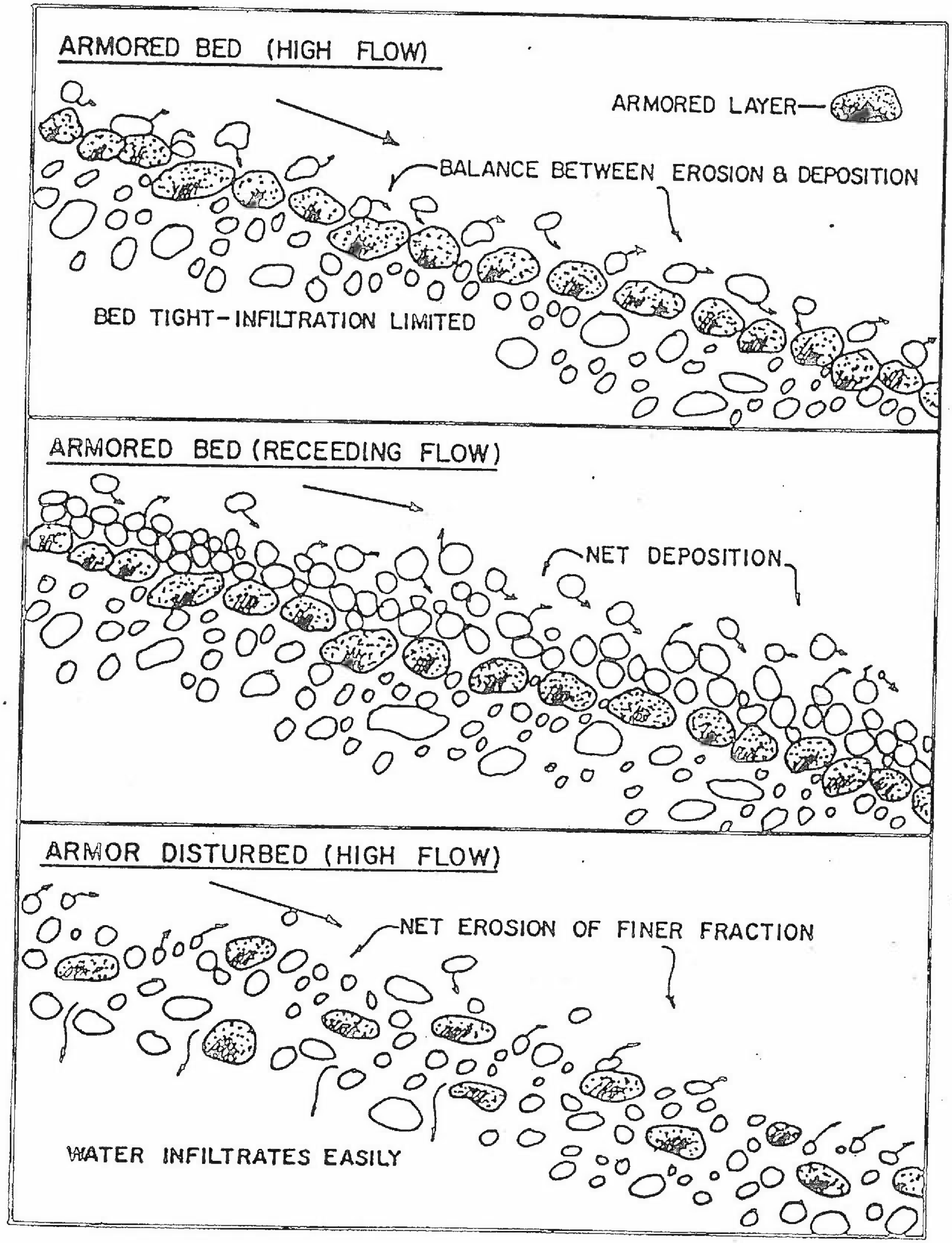


Figure 13 - Effect of bed armor disturbance on erosion and infiltration.

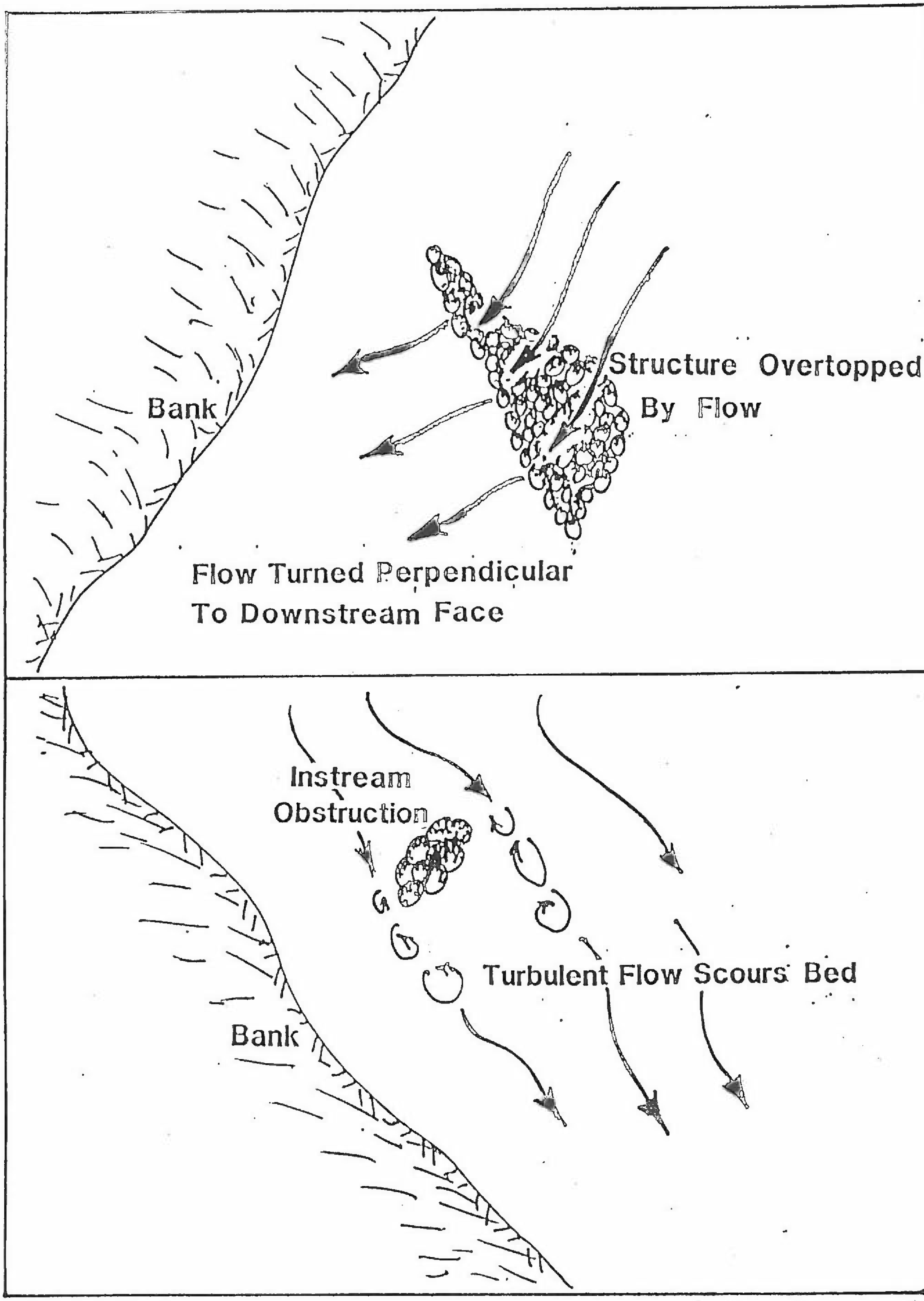


Figure 14 - Flow behavior near in-channel structures.

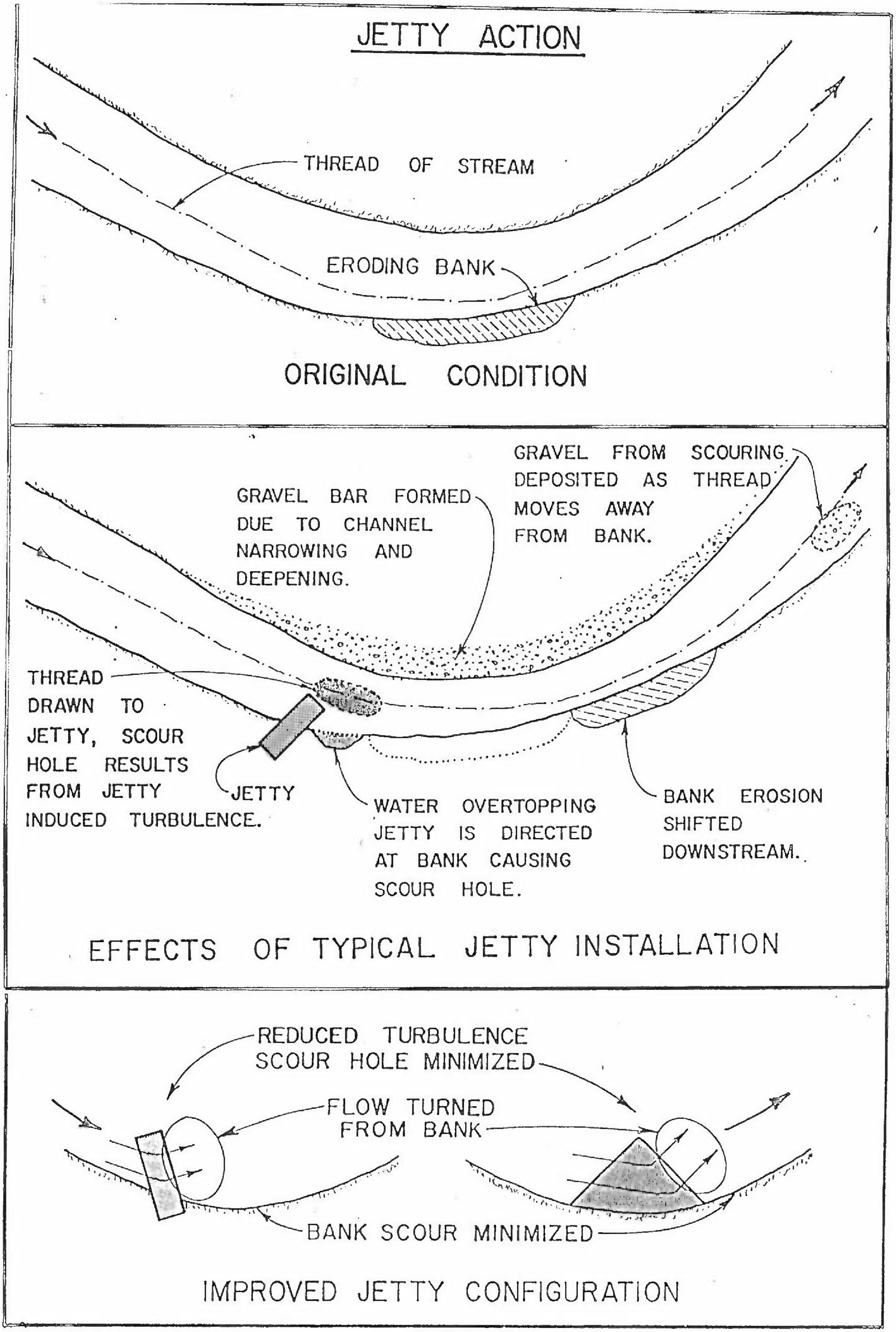


Figure 15 - Effects of jetties on stream behavior.

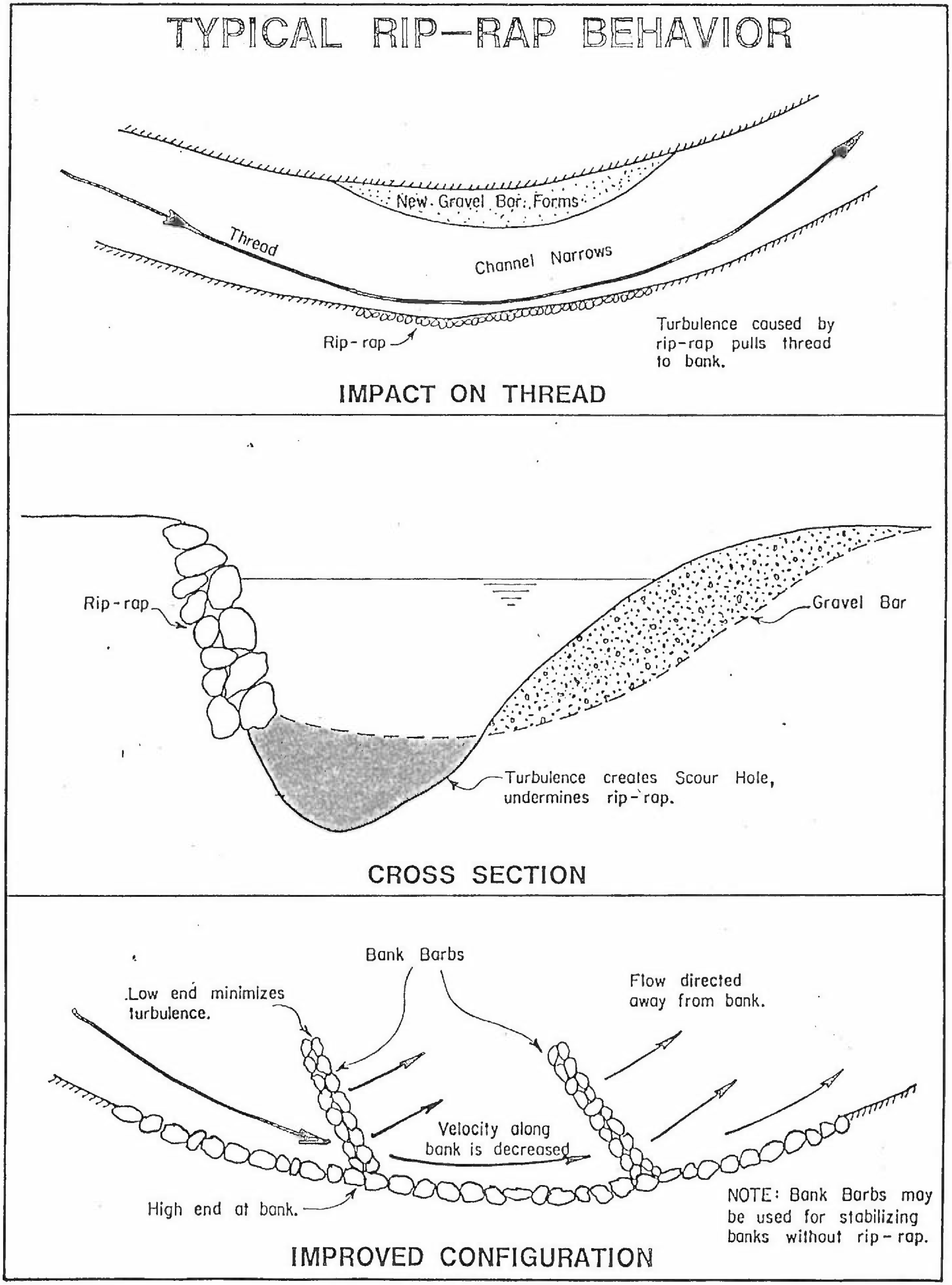


Figure 16 - Effects of riprap installation on stream behavior.

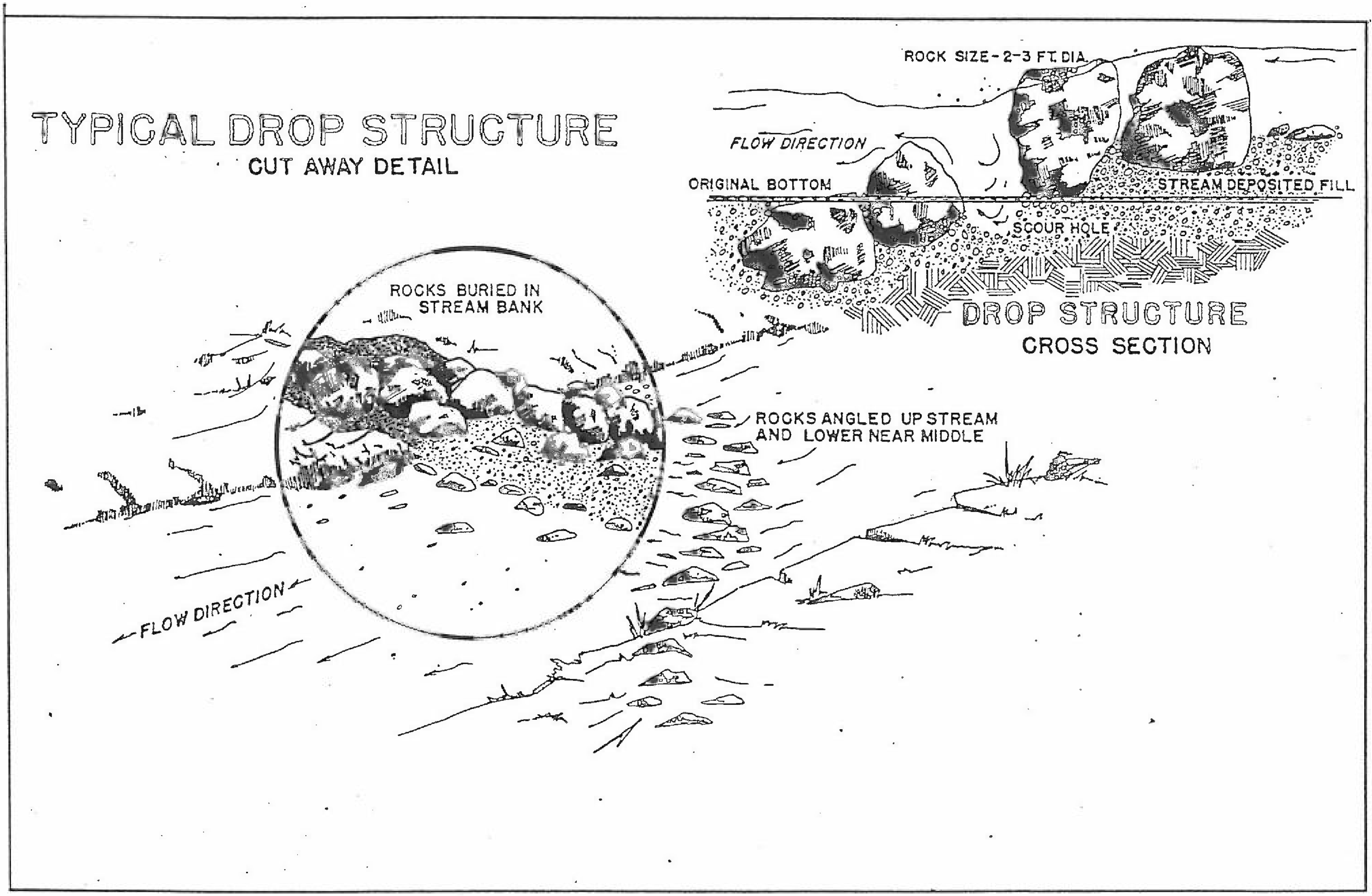


Figure 17 - Typical rock drop structure.

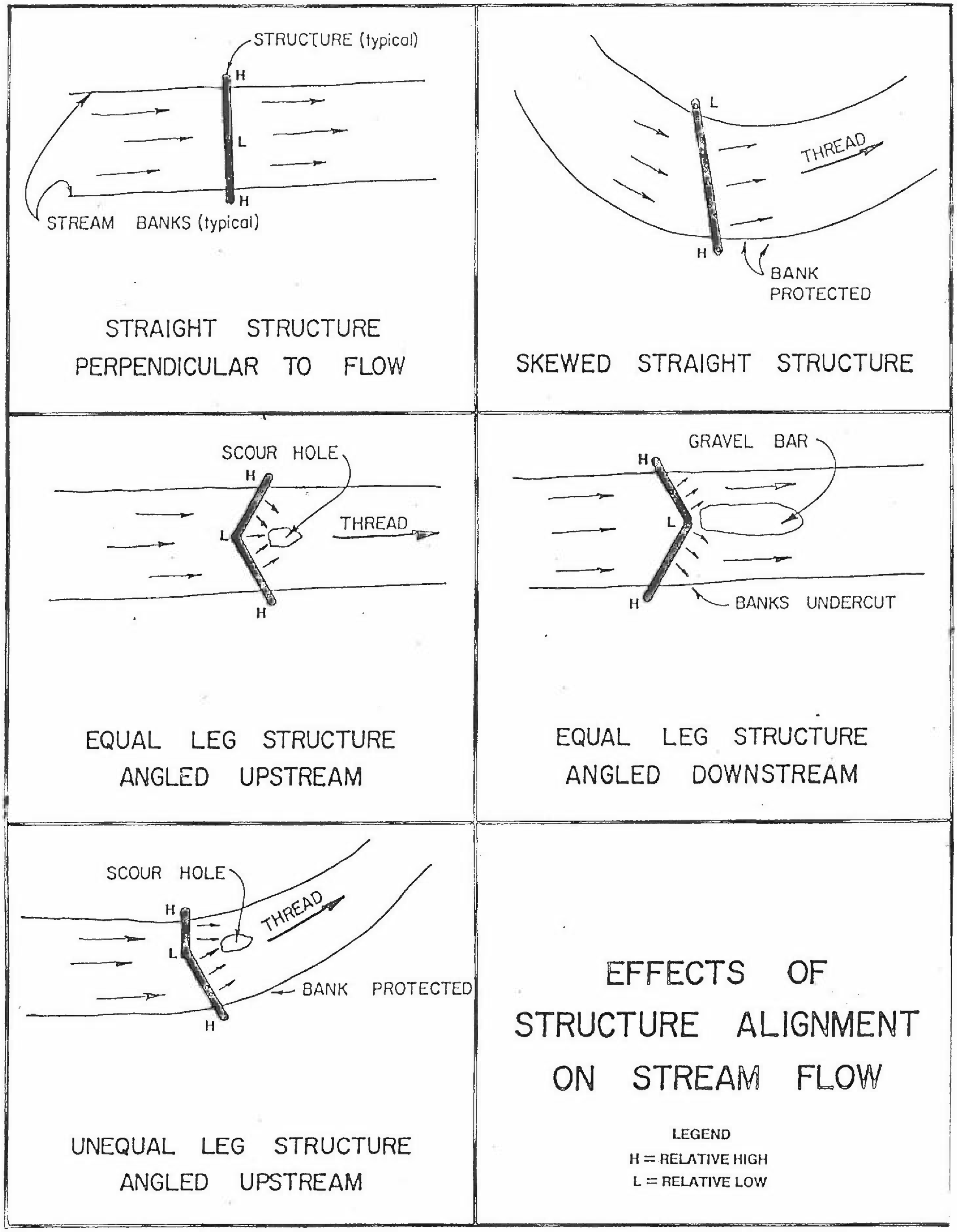


Figure 18 - Effect of structure alignment on downstream stream flow.

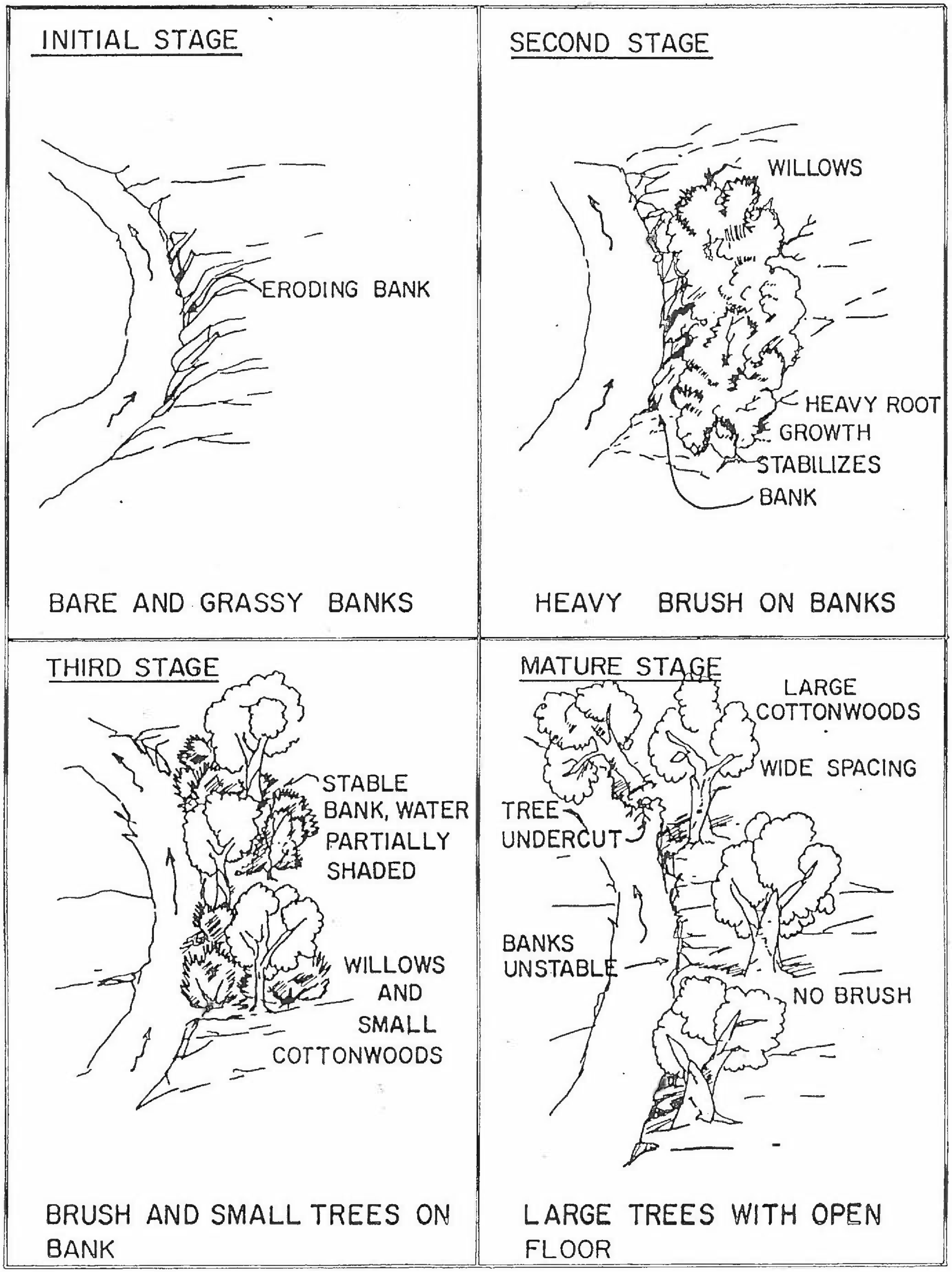


Figure 19 - Effect of riparian vegetation on stream bank erosion.

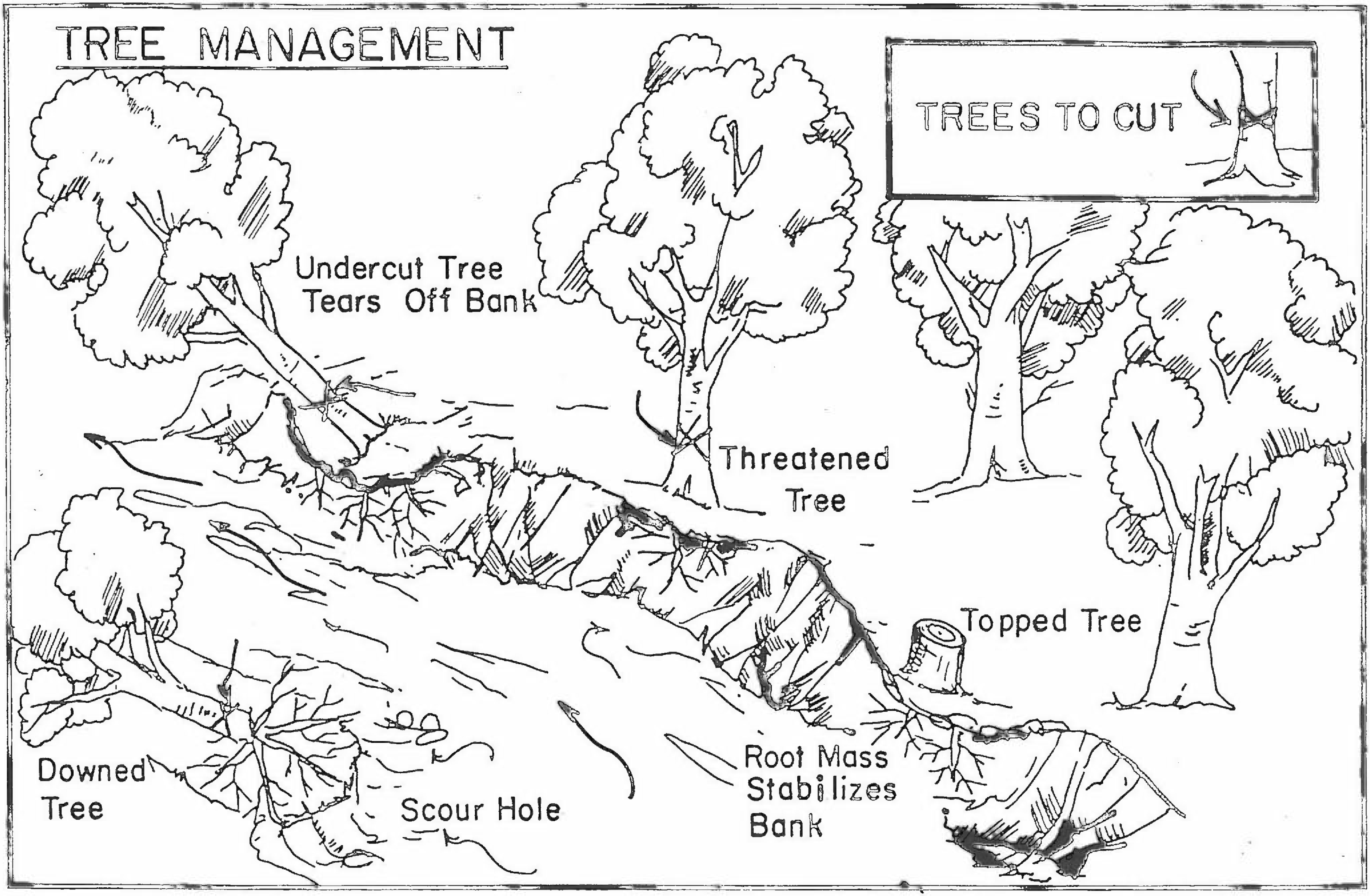


Figure 20 - Tree management along streams.

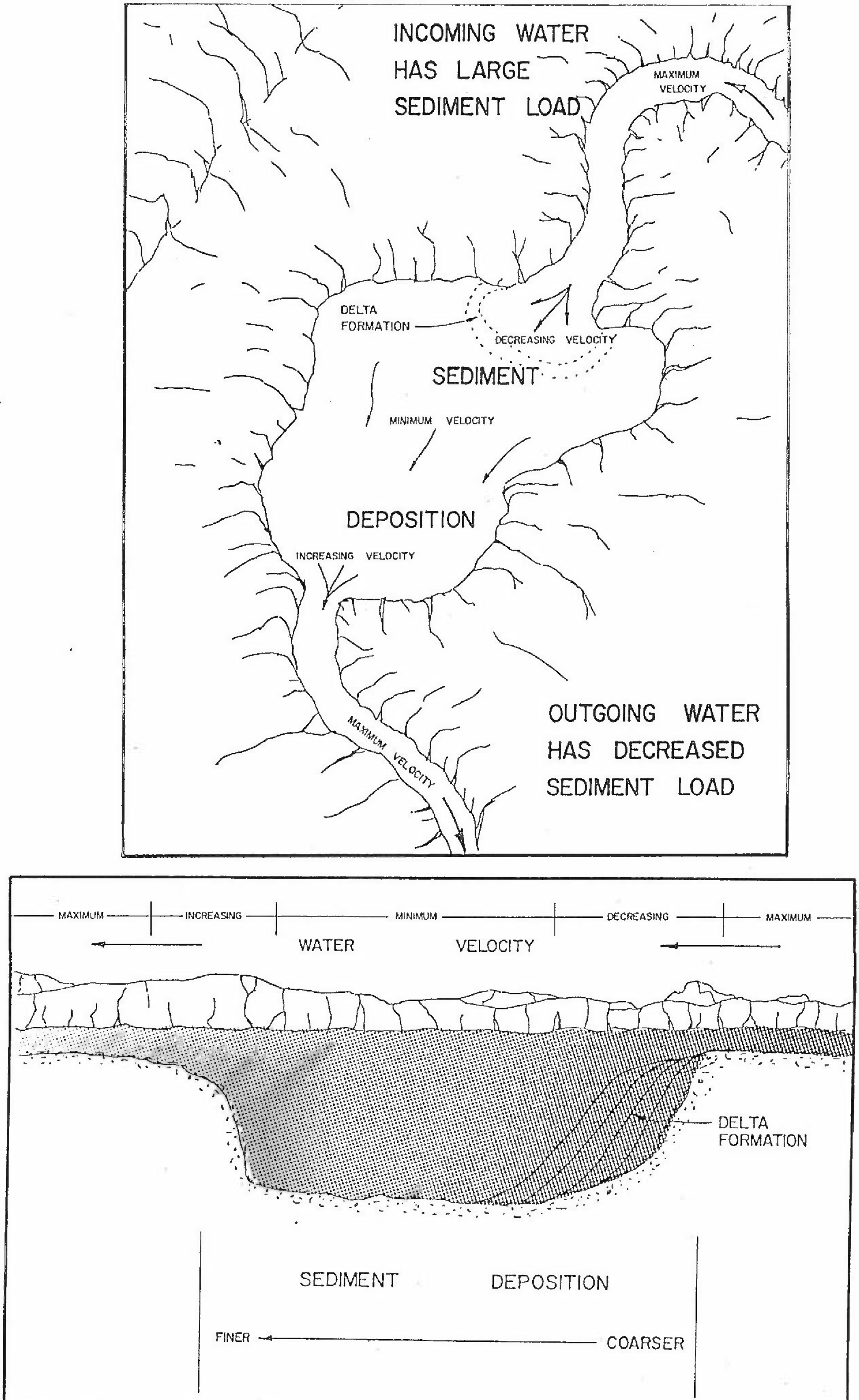


Figure 21 - Theoretical sediment trap operation.

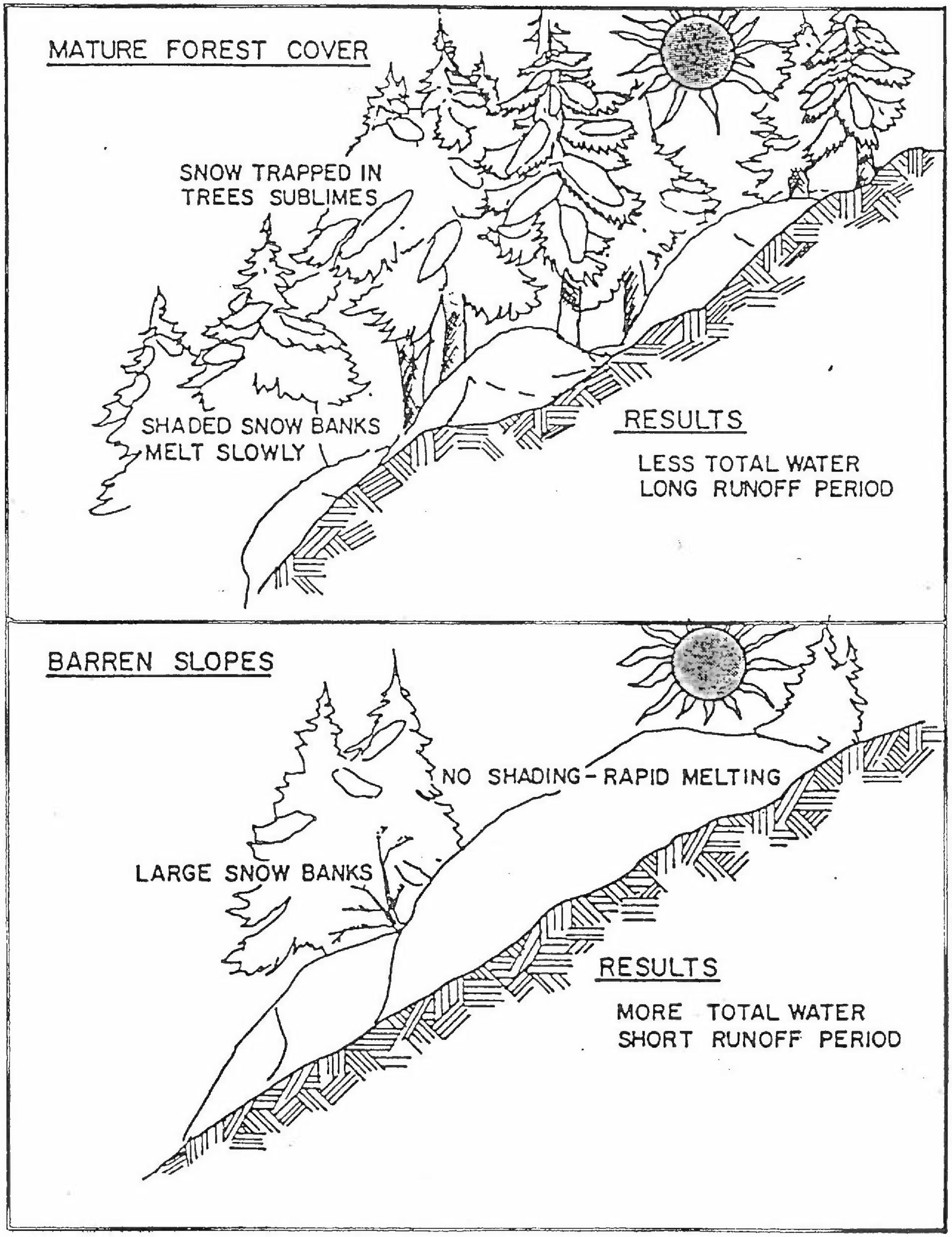


Figure 22 - Effect of vegetative cover on runoff.

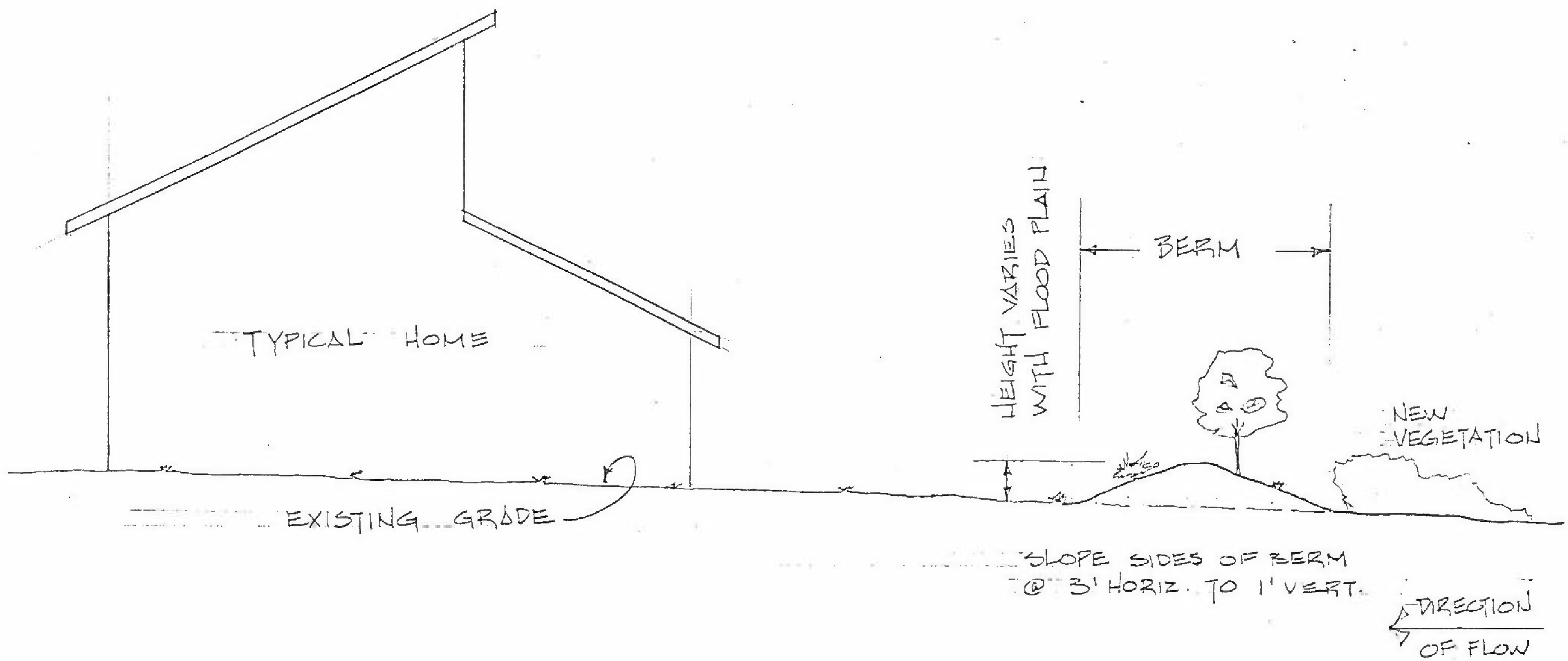


Figure 23 - Typical building envelope protection, elevation view.

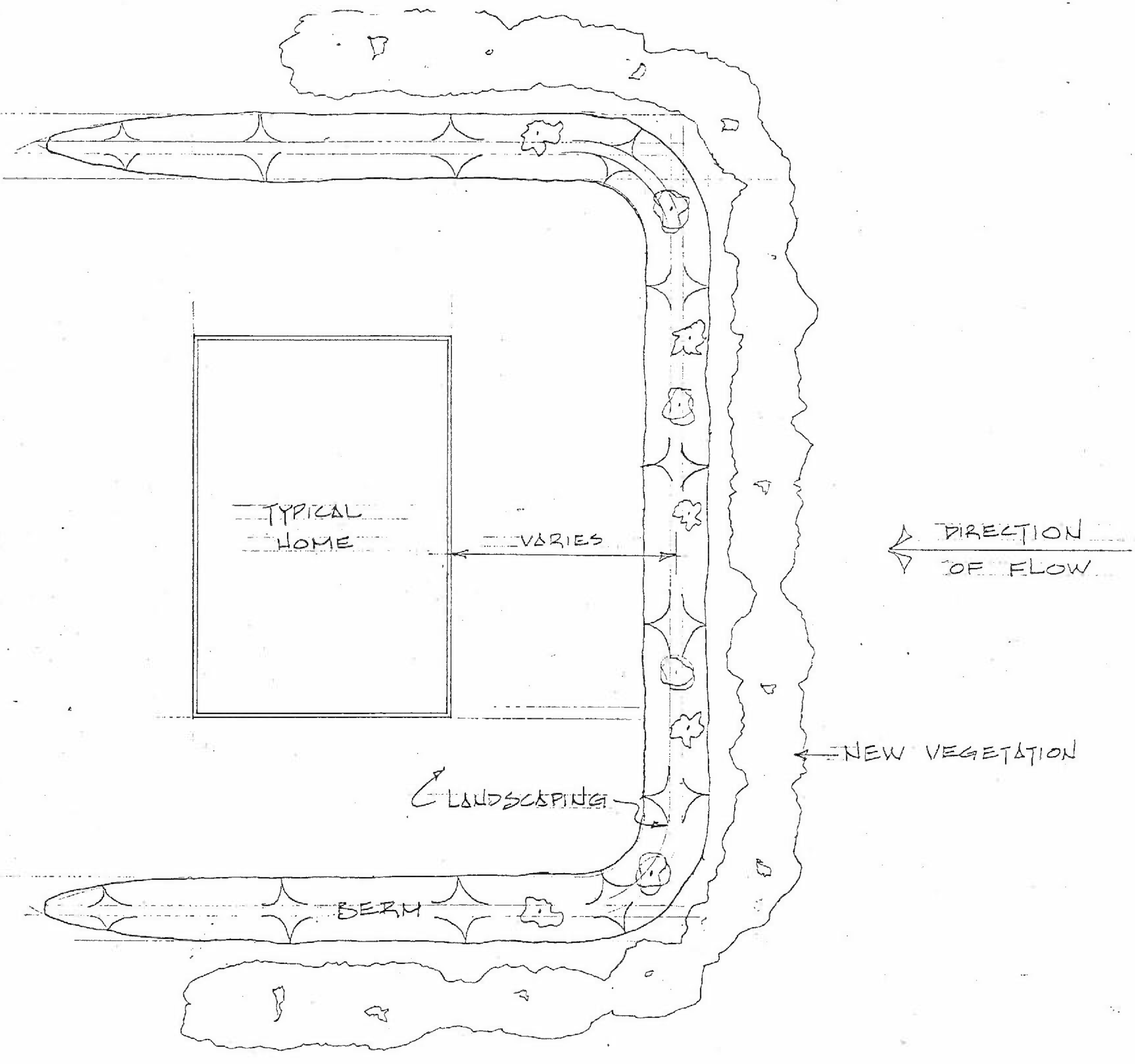
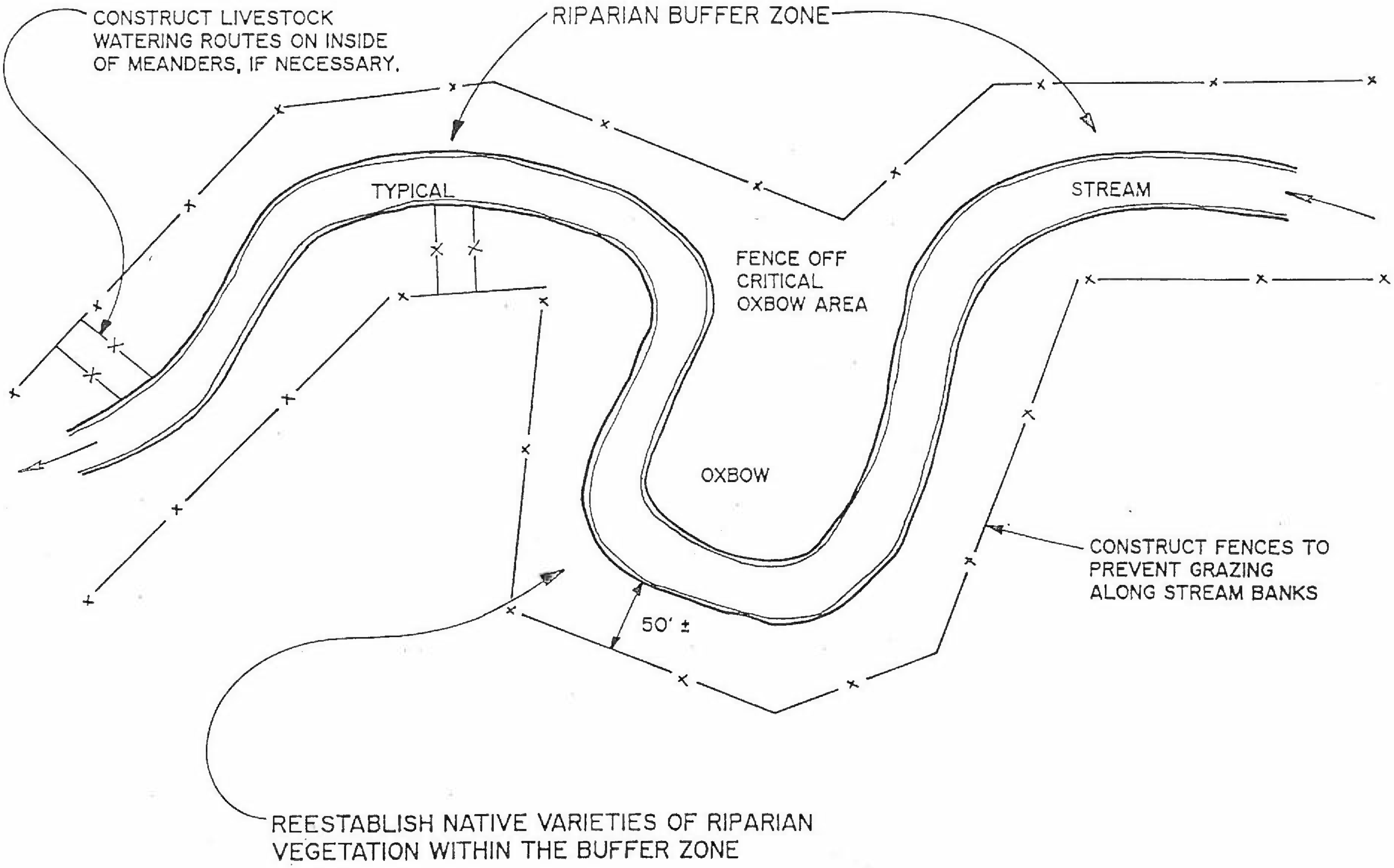


Figure 24 - Typical building envelope protection, plan view.



STREAM CORRIDOR MANAGEMENT

Figure 25 - Typical stream corridor management plan.

APPENDIX B

ROCK STRUCTURE MATERIAL

AND CONSTRUCTION SPECIFICATIONS

MATERIAL AND CONSTRUCTION SPECIFICATIONS

ROCK DROP, SILL AND BARB STRUCTURES

MATERIALS

Structural Rock - Quarry stone shall be used which is sound and durable against disintegration under conditions to be encountered during handling and placement. Rock shall be hard and tenacious and otherwise of a suitable quality to ensure permanency. Rock showing signs of deterioration, cracks, entrapped air or other defects shall not be used in the construction.

All stone shall be angular, each piece having its greatest dimension not greater than three times its least dimension, free from thin slabby pieces, and shall conform to the following test requirements of the American Society for Testing Materials Standards:

	Requirement	ASTM Standard
Apparent specific gravity, minimum	2.60	C-127-59
Abrasion, maximum percent	45	C-535-65
Freeze thaw loss, maximum percent after 12 cycles	10	AASHTO 103 Procedure A

Concrete masonry or concrete pavement may not be used for structural rock. The gradation requirements for ordinary structural rock shall be as follows (approximate weight assumes a spherical shape which most closely approximates the size of the individual stone):

CLASSIFICATION AND GRADATION OF ORDINARY STRUCTURAL ROCK

% Smaller Than Given Size By Weight	Intermediate Rock Dimension (Inches)	Approximate Min-Rock Weight (Pounds)
100	42	3642
40 - 60	33	1767
10 - 30	24	680
2 - 5	9	36

Based on Specific Gravity = 2.60

CONSTRUCTION

Rock Structures - Stone shall be individually placed. Each stone shall be set in place at essentially the final position by the use of a grapple device or other suitable equipment for handling material and, if necessary, the stone shall be picked up and repositioned. Excavation for placement of rock shall be limited by the size of stone being placed. The excavated hole shall be only large and deep enough to accept the stone and maintain surface grade. Where little excavation is required to place the stone, excavated material shall be sprinkled over the structure to form an interlocking network with the placed stones or gently cast upstream from the structure alignment, as directed by the GEOMAX Field Engineer. Where significant excavation is required (as in the construction of sills), all excavated material in excess of that which can be integrated with the structure shall be removed from the floodplain. Placing equipment shall always work on the upstream side of structure alignment. Dragline buckets and skips shall not be used for placement of structural rock.

Placement of rock in an active stream shall follow the construction sequence as follows:

1. Excavate keyway in bank farthest away from rock stockpile as shown on the design drawings.
2. Place structural rock in far key and backfill with suitable material that will promote vegetative growth.
3. Place rock along specified alignment beginning at far key and extend into stream no more than three-quarters of the stream width.
4. Excavate keyway in near bank as shown on the design drawings.
5. Place structural rock in near key and backfill with suitable material that will promote vegetative growth.
6. Place rock along specified alignment beginning at near key and extend across stream and integrate with previously placed rock in 3 above.

The elevation of drop structures shall be decreased 0.5 foot below the top elevation shown on the design plans as directed by the GEOMAX Field Engineer for approximately 10 feet along both the left and right legs adjoining the angle point of the structure. Sill structures shall match the existing grade unless otherwise directed by the GEOMAX Field Engineer.

Moving stone by drifting or manipulation down the slope will not be permitted. Stone shall not be dropped from a height of greater than one foot. Stones in their final position shall be oriented such that their maximum dimension is perpendicular to the stream flow with the flatter side located at the bottom. The largest stones to be used in the construction of the structure shall be placed along the downstream face of the structure. Adjacent stones shall be set in contact with each other so that the vacancies between adjacent stones shall be as small as the character of the stone will permit. It should be anticipated that rehandling of individual stones after initial placement may be required to achieve required slopes, grade, elevations, position and water surface profile. A tolerance of plus or minus 0.5 foot from the indicated top elevation shown on the design drawings will be allowed in the finished surface. After the stones have been placed and approved by the Field Engineer, additional smaller stones shall be placed in the voids between the larger stones.

Rock barb structures shall be constructed at the locations shown on the drawings or as directed by the GEOMAX Field Engineer. Barbs shall be keyed into the bank in a manner similar to that described in the preceding section for Rock Drop and Sill Structures. Barbs shall be constructed to the top elevation at the bank as shown on the drawings and shall uniformly taper down two feet vertically to the in-stream end over the specified structure length.

APPENDIX C

COST ESTIMATE

CONCEPTUAL DESIGN CONSTRUCTION COST ESTIMATE

WOLF LODGE CREEK DRAINAGE

AUGUST 10, 1990

STRUCTURAL ROCK	2905 CY @ $25/CY	72,625
SEDIMENT TRAP EXCAVATION	11,800 CY @ $ 5/CY	59,000
CHANNEL EXCAVATION	11,400 CY @ $ 5/CY	57,000
		$188,625
CONTINGENCIES (± 11%)		21,375
CONCEPTUAL DESIGN CONSTRUCTION COST ESTIMATE		**$210,000**