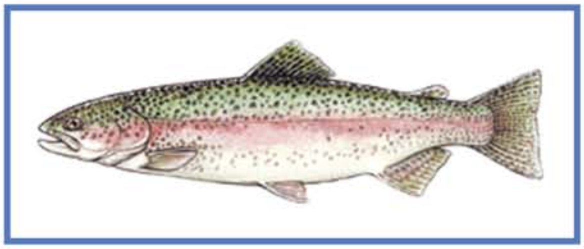
HABITAT IMPROVEMENT

for Trout Streams



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PENNSYLVANIA

Fish & Boat Commission

Habitat Improvement

FOR TROUT STREAMS

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Contents

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Introduction

Fish, like all living organisms, need a certain amount of space in which to live and grow. This space is called their habitat, and it must provide everything that they require for their survival and prosperity. The more diverse this habitat is, the greater potential it has to support a healthy, self-sustaining population. While nature does well on its own, the placement of artificial habitat structures can often enhance stream reaches that lack naturally occurring habitat features. Lack of natural habitat can be the result of many situations, including stream channelization, poor agricultural practices, inadequate stormwater management, and disturbance to the riparian zones bordering the stream.

The Pennsylvania Fish & Boat Commission affirms that fish habitat improvement projects contribute to its mission of providing fishing and boating opportunities through the protection and management of aquatic resources. However, the design and placement of fish habitat improvement structures should not be a haphazard venture. There is a science, and to some extent, an art to this process that should not be ignored. The science comes from very specific criteria that has been developed by the Pennsylvania Fish & Boat Commission from decades of hands-on experience and creating countless successful stream projects. It is also important to understand how flowing water reacts to an improvement structure under normal and, most especially, higher flows. The artistic process comes from developing a personal expertise and philosophy in structure design and placement. And while there are standard designs for all fish habitat improvement structures,there may be a necessity to use some creativity and imagination to modify a device or adjust the placement as the site dictates.

This publication presents some basic understanding of stream ecology and management philosophy as it relates to habitat improvement. It discusses stream habitat assessment to help determine the “limiting factors” that may keep a stream from reaching its potential. It offers some general guidance in determining which habitat structure is appropriate for a situation and how to construct the device. Permit requirements for these designs, which are administered by the Department of Environmental Protection (DEP), are also explained.

The terms “fish habitat improvement” and “habitat restoration,” as discussed in this booklet, involve the enhancement of the existing stream channel. With these methods, there is only minor disturbance to the stream channel and every effort is made to use natural materials that allow fish habitat structures to blend with their surroundings. Stream bank stability is often a secondary benefit, but the primary objective should be resource-based and should seek to provide better aquatic and riparian habitats. While there is certainly some overlap of purpose, other stream restoration methods, including fluvial geomorphology (FGM), or Natural Stream Channel Design (NSCD), have a primary goal of creating stream channel stability, which often involves a reconfiguration of the channel and often with major disturbance. Determining what level of restoration that is actually needed will determine the best approach.

Stream Ecology

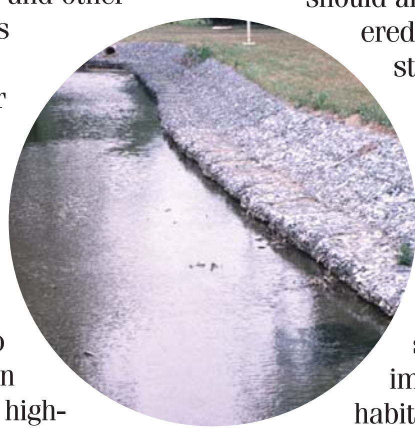
Knowing the mechanics of flowing water, what has good and poor habitat value, and how a stream reacts to change are important elements in understanding and conducting habitat work.

Dynamic nature of streams

Whether a headwaters trout stream or a larger river, all waterways have something in common; they are dynamic systems, which means they are ever-changing and reacting to other processes, both natural and man-made. This is a natural process as the waterway tends to seek equilibrium with a stable pattern, profile and dimension. If a stream is channelized and made wider, shallower and straighter, it will inevitably begin to narrow and deepen itself again and re-establish its natural meandering pattern. As a stream changes, some features like deep pools, remembered as old fishing holes, may temporarily or permanently be lost, but they may appear elsewhere as the stream evolves through years of varying flows. The formation of split channels is also a natural process and often provides beneficial habitat variation for young trout and other wildlife. Even though it is human nature to try to "stabilize" streams, their natural evolution causes their changing and even moving from one place to another across a valley floor. These changes can be subtle, taking decades to occur, or they can happen suddenly during a single high-water event. Successful stream restoration approaches should work with what the stream is trying to do, if possible, instead of working "against the flow."

Stream Bank Stabilization

The use of rip-rap (large stone), gabions (stone-filled wire baskets) and concrete-lined stream banks all provide good bank stabilization when properly used, but with the possible exception of rip-rap, they have little or no habitat value to the aquatic environment. To increase this value and add some variation, a more habitat-friendly approach should always be considered as an option for stream bank stabilization. A variety of more natural techniques discussed later in this publication can provide stream bank stability while improving fish habitat.



Flood Plains, Wetlands and Storm Water

The importance of keeping the stream connected to its flood plain cannot be over-stated. By allowing high flows to escape the channel and spread out across a wider area, the hydraulic energy is released in a more dispersed fashion. In contrast, constructing a barrier between the stream and its flood plain confines all the energy from raging high water to the stream channel, where it scours away existing habitats and can cause extensive stream bank damage as it tries to escape. Evidence of this process can be readily seen in more urban areas, where flood plains have been developed and the destructive energy of high flows is compounded by poor storm-water practices. Developed flood plains coupled with ineffective stormwater management plans allow excess flows to reach the stream more quickly, causing higher-than-normal flows. Since there is less time for water to soak in to the ground, a period of lower-than-normal flows can soon follow. Retention of storm water will go a long way toward helping retain natural aquatic and riparian habitats. Natural flood plains often contain wetland features that are not only valuable for wildlife habitat, but they also act as large sponges, soaking up higher flows and releasing them gradually, thus minimizing high flow damage. Eliminating wetlands not only hurts fish and wildlife habitat, but it also increases the likelihood of storm-water damage to human interests.

Diversity of Habitats for Wild Trout

Initially, when many people think of improving wild trout habitat, they usually picture a large, easily fished hole that will be filled with "lunker" trout. However, the physical makeup of an ideal trout stream will have a diversity of habitat types for all size classes of trout and other aquatic

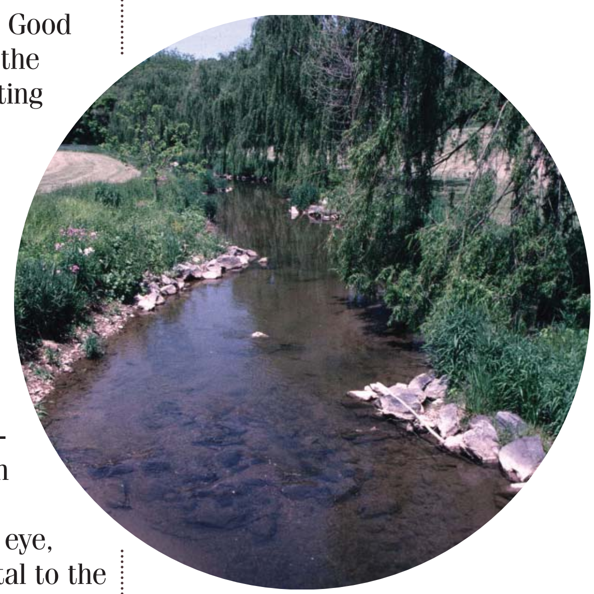
organisms. Good fish habitat serves all the ecological needs of the species, including spawning areas, nursery habitats, and foraging, resting and hiding areas. Therefore, the objective of undertaking a fish habitat improvement project should address all aspects of the life history needs of the designated species.

The objective should not necessarily be to make every linear foot of stream fishable for adult trout. Habitat diversity is the key and will increase the potential for a healthy, self-sustaining ecosystem. It is also important to examine an extended stream stretch beyond the immediate treatment area and any artificial boundaries or property lines. For example, a good riffle stretch on one property may be the only available riffle habitat nearby and should not necessarily be converted to more pool habitat. Good habitat management values the protection of important existing habitats as well as the creation of new habitats.

Woody Debris

To this day, it is often considered an acceptable practice to keep stream channels "clean" by cutting brush from the stream banks and by removing larger woody debris from the channel. Although these efforts seem pleasing to the eye, they usually prove detrimental to the aquatic environment. Large woody debris (fallen trees, roots, log jams) and vegetative matter, such as leaves and twigs, which enter the stream channel, are an important and necessary component of the aquatic ecosystem. This material serves as a primary food source as well as habitat for many organisms throughout the food chain. Larger woody debris helps to form and shape the stream channel and creates variability in habitat types. Woody debris can also provide excellent trout habitat and is not easily duplicated.

Woody debris provides many benefits to the stream ecosystem, but individual debris jams may increase erosion or endanger roadways, bridges and personal property. In these cases, it may be necessary to remove part or all of the jam to alleviate the problem. Removal decisions are subjective and should be made individually, ultimately removing or altering only what is necessary. In more wilderness areas, it can be argued to allow woody debris to continually shape and change a stream channel as a natural process without interference. It should also be noted that good wild trout habitat in this form might not always be "pretty" or easily fished, but it remains a vital component of the stream ecosystem.



Stream Corridor Management

A stream is only as healthy as the land it flows through. In return, the land area adjacent to the stream (known as the riparian zone) derives nourishment from the stream's water. They are connected and depend on each other for their well-being. The waterway and its riparian area are a complete ecosystem and should be managed as a whole. Therefore, when considering aquatic habitat enhancement, managing the riparian area is just as important as placing artificial structures in the stream. Having a vegetated buffer zone between the waterway and other land uses has many benefits. Root systems help to keep stream banks stabilized, reducing the amount of silt that enters the stream. Shading from the tree canopy helps keep water temperatures cooler, which is necessary for the survival of many aquatic organisms. There is a direct increase in food, cover and nesting habitat for a variety of terrestrial wildlife species. Woody debris and leaf litter, which end up in the stream, are a necessary element in a healthy aquatic ecosystem's "food chain." Many aquatic invertebrates use this material as habitat and as a food source. The aquatic invertebrates in turn create an ample forage base for fish. Larger trees absorb excess nutrients through their root systems, changing them into plant tissue, while some nutrients are broken down by organisms in the soil and leaf litter. Sediment can also be filtered out by thick, understory vegetation. A buffer of larger shrubs and trees helps to slow flood waters while deflecting or catching debris, thus protecting fences and other property.

Depending on objectives, management of the buffer can either be as simple as letting nature take its course, or it can use a more specific approach. For example, wildflowers or flowering trees can be planted to improve aesthetics. Planting to attract wildlife or to improve water quality may be a priority, or planting fruit trees or managing for timber production to yield a future crop can be a goal.

Planting materials should be native species that tolerate moist soils. Studies have shown that the survival of aquatic invertebrates feeding on native leaf litter was significantly higher than those consuming exotic plant species.

In the year 2000, the Pennsylvania Fish & Boat Commission established a riparian buffer policy to establish and/or preserve, wherever feasible, a stable, vegetated riparian buffer zone between waters of the Commonwealth and other land uses on all Commission property. An excerpt of the Commission's riparian buffer guidelines follows:

Existing riparian buffers will be protected and encouraged to develop naturally with a minimum of disturbance.

Riparian buffers may be established by simply allowing an area to grow naturally, allowing natural succession to determine vegetative composition, or can be accelerated with plantings of native shrubs and/or trees.

Buffer Composition: *A forested buffer provides the most benefits and should be promoted whenever possible. However, a native shrub and/or grass community is also acceptable if it is a more amenable land use. Native vegetation should always be selected while the use of exotics and ornamentals should be avoided.*

Buffer Width: *The width of the buffer area can be very subjective depending upon the use of the site. Forested buffers and areas of limited use should be a* ***minimum*** *of 35 feet wide, measured from the top of the bank or shoreline. On areas that have been routinely mowed for aesthetic reasons, a* ***minimum*** *five-foot strip of denser vegetation should be established along the top of the bank.*

Buffer Maintenance: *Riparian buffer areas should be allowed to grow naturally and with a minimum of disturbance. Any removal of noxious plant species and exotics should be done mechanically whenever possible. If chemicals are to be considered, they should be applied to specific target plants and they need to be approved for use near water. They also need to be used in accordance with label instructions and conform to all Federal, State and Local regulations. Grass buffers in more manicured areas can be maintained by occasional weed eating, but should remain considerably denser and higher than the adjacent mowed lawn.*

Larger woody debris found within the stream channel, on the stream banks or elsewhere in the riparian zone should be left as habitat for aquatic and terrestrial animals, unless it is causing property damage or posing a public health or environmental safety hazard.

Even though the majority of streams in Pennsylvania can benefit from vegetated riparian buffer zones, some select streams without temperature-related problems could actually be enhanced by "daylighting" cuts of the thicker, shrubby vegetation. Typically, the streams that may fit into this category are the spring-fed, meadow limestone streams with a constant water temperature. By maintaining a scattering of larger overstory trees and thicker grassy vegetation for stabilization and overhanging cover, the stream actually can be made more productive by having sunlight reach a portion of the stream channel. This technique should be considered only where water temperatures would not rise above the trout's tolerance.

Addressing stream and riparian-related concerns on agricultural land brings into focus some additional components of stream corridor management. Practices like streamside fencing and the construction of stable livestock access ramps and crossings are important in managing many farm properties.

For more detailed information on these matters and other agricultural-related concerns, see the Pennsylvania Fish & Boat Commission publication, *Corridor Management for Pastureland Stream* (Lalo, J., et al., 1994).

Improving a small stream stretch and its riparian corridor will show many benefits. However, to realize a goal of trout stream restoration, it is often necessary to extend the scope of the project to a watershed scale. By assessing the entire stream and all of its tributaries, problem areas can be identified, priorities can be established, and an organized plan of improvements can be implemented.

Stream Assessment

Conducting pre-project assessments can be beneficial during the initial stages of habitat enhancement planning. Before beginning any design work, it is important to determine the problems, or limiting factors, that keep the stream from reaching its potential. By identifying these limiting factors and developing objectives, creating an effective work plan will be easier. The lack of good habitat is often the limiting factor and can easily be addressed, but sometimes more difficult problems need to be solved, such as water quality, stormwater issues and water temperature.

To evaluate habitat features, the Pennsylvania Fish & Boat Commission uses a habitat assessment procedure that originated in the U.S. Environmental Protection Agency's Rapid Bio Assessment Protocols *(see pages 19–22).* The procedure is quick and simple to complete and is useful in identifying habitat-limiting factors and making planning decisions to improve habitat. The assessment will also provide a numerical score to show justification for project proposals, or the evaluation can be compared with post-project assessments.

Stream stretches to be assessed are first classified as either riffle/run-predominant or glide/pool-predominant. The assessment then rates ten habitat related parameters on a scale of 0 to 20. Parameters examined include fish and aquatic insect cover, channel alteration, sediment deposition, substrate embeddedness, channel flow status, frequency and quality of riffles, pool variability and substrate composition, bank stability, bank vegetation, and riparian zone width. The cumulative score (xxx/200) categorizes the stream stretch as *poor* (0-55), *marginal* (56-105), *sub-optimal* (106-155) or *optimal* (156-200). Each parameter's scoring will also help determine specific limiting factors related to habitat in the stream stretch.

For a more detailed explanation of these protocols, see the following reference: Barbour, M.T.; Gerritsen, J.; Snyder, B.D.; and Stribling, J.B., *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Second Edition. EPA 841-B-99-002.* U.S. Environmental Protection Agency, Office of Water, Washington, D.C., 1999. This reference can be found online at www.epa.gov/owow/monitoring/rbp/ Chapter 5.

The Pennsylvania Fish & Boat Commission also uses fish surveys (electrofishing) and may conduct redd (trout nest sites) count surveys to assess habitat projects. Electrofishing surveys facilitate the calculation of wild trout population estimates and age/size class distributions. The presence or absence of other fish species is also noted during this procedure, because they are good indicators of aquatic diversity. Redd counts are performed during the spawning period to determine where trout are attempting to spawn and to determine any increase in spawning activity as the project proceeds. The pre-project counts will also help determine where or where not to place improvement structures during the design phase, thus protecting preferred spawning sites.

Permit Requirements for Habitat Enhancement Structures

Department of Environmental Protection (DEP)—Chapter 105 & 102 of the Pennsylvania Code

Placement of any device in Commonwealth waters is regulated under Chapter 105 of DEP's regulations. In this chapter, habitat enhancement structures are considered an encroachment and/or water obstruction and require a permit to be constructed.

In cooperation with the Pennsylvania Fish & Boat Commission, DEP has developed *General Permit Authorization-1,* for fish enhancement structures. The permit is free and authorizes the placement of all approved structures used by the Commission's Habitat Management Division. The proposed design work requires pre-approval from the Commission's Division of Habitat Management before DEP will issue an acknowledgement letter to proceed with the project. The acknowledgement letter, in essence, is the authorization and must be on site during construction.

DEP's Chapter 102 addresses the control of accelerated soil erosion, and the resulting sedimentation in Commonwealth waters. All work performed under *General Permit Authorization-1,* mentioned above, must comply with Chapter 102. It also requires that an *Erosion and Sedimentation (E&S) Control Plan* be developed to minimize soil erosion resulting from earth disturbance during the construction of fish habitat enhancement projects. This plan must be pre-approved by the county conservation district and must also be on site as part of the authorization. Review a sample E&S control plan on page 17.

U. S. Army Corps of Engineers (COE)—Section 404 of the Clean Water Act

The U. S. Army Corps of Engineers (COE), under Section 404 of the Clean Water Act, requires a permit to place any material (or structure) in any stream with a flow greater than 5 cubic feet per second. The COE has issued a general permit (SPGP-3) for the construction and maintenance of approved habitat enhancement structures in Commonwealth waters. Essentially, the acknowledgement of and compliance with DEP's *General Permit-1* satisfies the COE's Section 404 regulatory requirements. The exception is if the project length exceeds 250 linear feet, in which case the COE will review the project and will issue its own letter of authorization.

General Construction Guidelines

As mentioned previously, the design and placement of fish habitat enhancement structures should not be a haphazard venture. The Habitat Management Division uses specific criteria for building these structures. The following guidelines include information on habitat structure designs, materials and installation procedures. Actually building these structures is a challenging experience, and varying from these guidelines is often necessary as dictated by the uniqueness of the site.

All fish habitat enhancement structures should be built during normal low-flow conditions, usually early summer through the mid-fall. The completed structure should never be built at an elevation higher than the adjacent stream banks, and it should slope slightly upward from the stream to a point on the stream bank known as "bankfull elevation," the height at which high water leaves the stream channel and enters the flood plain. If both stream banks are equally high, the bankfull elevation will be the top of the bank. If one bank is higher than the other, there will be a line of noticeable change in the slope and/or vegetation on the higher bank, indicating the bankfull elevation. Bankfull water flows have the most effect on natural channel alteration and should therefore be used as a gauge when installing some fish habitat improvement structures.

Stone structures should be keyed into the stream bottom and banks. When using logs, the largest end of the log should be trenched a minimum of 3 feet to 5 feet into the stream bank. Logs are anchored to the stream bottom by drilling and pinning with rebar about every 5 feet along the log, and perhaps closer in the trenches. Driving rebar through logs and into the stream bottom can be made much easier by using a 6-inch-long, 2-inch-diameter soft steel driving head with a ¾-inch-diameter hole drilled 4 inches deep. The driving head slips over the rebar and gives the sledgehammer a larger target to hit. Use slow and steady blows to sink the pin. If the pin hits a rock, keep the same steady pace and the rock may break. Drive the pin until the head meets the log, remove the head, and bend over the last 4 inches parallel and flush with the log, pointing in a downstream direction.

When building structures with flooring, driving nails into submerged boards can be made easier with the use of an "underwater nailer." This tool is made from a ½-inch-diameter heavy gauge water pipe about 2 feet long and a slightly longer length of ⅜-inch rebar. Position the pipe where the nail is to be driven, drop the nail down the tube, insert the length of rebar, and hammer the top of the rebar until the nail is fully seated.

One of the most important things that can be done to reduce future maintenance of structures is to "shingle" the stone fill in place. This technique involves hand-placing stone in an overlapping fashion (like shingles on a roof) by starting downstream and working upstream. Even though it's not always feasible or necessary to hand-place every stone, this procedure should be followed whenever possible.

Construction Materials

Logs and Timbers

Logs that average 6 to 12 inches in diameter generally fit most needs, although some situations may call for logs with larger diameters. Most hardwood and some softwood logs, including hemlock, are adequate. Species like aspen, birch and white pine should be avoided because they tend to rot much faster. Raw logs look more natural and blend with the surroundings. The use of treated or creosoted timbers is not necessary or advised.

Flooring

Rough-cut hemlock (1" x 8" x 8') is used for flooring and face boards on water jacks. Eight-inch-wide boards are best because wider boards may bow, and narrower boards are not efficient when spanning a wider stream channel. Rough-cut oak (2" x 6" x 8') is used for flooring in the overhead cover structures. The design work of these structures should allow for this flooring to be submerged at all times to slow rotting. Single oak boards span a distance no greater than 8 feet. Treated lumber is not necessary or advised.

Reinforcement Rods

Rebar rods are used to pin logs together or to secure logs to the stream bottom. Rods having a ⅝-inch diameter, cut in lengths of 2, 3 and 4 feet, should suit most needs for building habitat improvement structures. Two-foot pins are used to attach logs together. Three-foot pins are used to anchor logs to the stream bottom in most cases. However, 4-foot pins can be used for extra holding power in fine substrate. Four-foot pins are also used in the construction of channel blocks to pin the brace logs to the main logs and on through to the stream bottom.

Nails

Whenever a board is to be attached to a log, use two nails equally spaced from the edge of the board. Galvanized nails are not necessary. Use 20d common nails when working with 1-inch flooring and 40d common nails when using 2-inch flooring. Ten-inch spikes can come in handy for attaching smaller-diameter logs.

Stone

Only clean, nonpolluting material should be used to construct fish enhancement structures. Stone size depends on structure design and the stream's scouring ability. Stone used in log frame structures can be smaller (usually 12" to 18") and should be shingled in place. Structures made entirely of stone should use stone large enough so that it cannot be moved by normal high flows (usually 18" to 24"). Rock used for boulder placement (usually 24" to 36") should not be moved by high flows. Construction of some devices (rock vanes, J-hooks, cross vanes) may require very large stone, sometimes as large as 4 to 5 feet in diameter (cube-shaped or rectangular-shape preferred).

Construction of Structures

Boulder Placement

Placing **boulders** *(see page 23)* in uniform stream stretches with little fish cover is probably one of the simplest ways to improve the aquatic habitat. Water flow will scour a deeper pocket around the boulders and fish will use the structures as "side" cover and as places to get out of the main flow. A scattering of boulders may also provide a travel corridor through open areas with minimal cover. Use boulders that are large enough so that they cannot be moved by normal high flows. Generally, they should be placed in the center third or half of the stream channel so that they do not direct flows against the stream bank. They can be placed randomly or in a triangular or diamond pattern. They can also be placed just off the tip of a deflector or positioned to create a small run between the deflector and the boulder. They can also be placed at the downstream tip of a single or multi-log structure as an added brace, which also provides additional cover.

Half-Log and Whole-Log Structures

The **half-log** or **whole-log structures** *(see pages 23 and 24)* are mid-stream cover devices best used in uniform areas that lack fish cover. They are best placed along the edge of a stream's main channel where they don't take the full force of the current, but where there is enough flow to keep the structures clean. These structures are simple to build. They can be assembled on the stream bank before placement.

First, cut two 6" to 8" long sections of log for spacers. Position them under either end of a heavy piece of slab wood or whole log. Drill a hole through the slab wood or log and through the spacers so that the structure can be pinned together with a 4-foot rebar pin. Place the structure in the stream and anchor it by driving the rebar pins into the stream bottom.

Deflectors

Deflectors are triangular structures that serve several purposes. They narrow the existing stream channel, which causes a scouring and deepening effect along the outer face of the device. They will deposit substrate material along the bank below the device, which further narrows the channel. They create some habitat value along the edges of the device, and they provide some stream bank stability where the device is located. Deflectors are often used on overly wide stream sections or to help move the main flow away from the stream bank.

Deflectors can vary in design and construction materials, depending on the specific situation. Whatever the variation, some general guidelines of shape, size and spacing should be followed during construction of these structures *(see page 18)*.

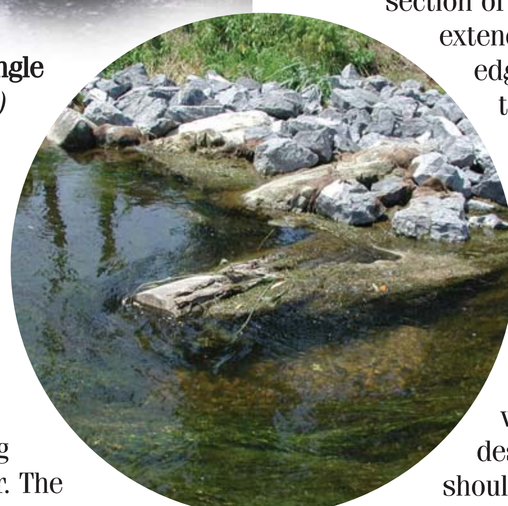
The three angles of the triangle determine the overall shape of the deflector. The most effective design calls for an upstream angle of 30 degrees (to allow scouring to occur along the face of the structure while not causing a damming effect), a downstream angle of 60 degrees (to help deflect higher flows back toward the stream), and a 90-degree angle at the tip of the structure (to provide strength at a critical point).

The deflector size depends on the stream channel's width. Generally, the distance from the stream bank to the tip of the structure should equal a third of the channel width. This measurement can vary depending on the situation, but should never be more than half the channel width. If you know the distance measured from the tip of the device to the stream bank, you can figure out the other dimensions of the deflector *(see page 18)*.

Single deflectors can be used to solve specific problems, but they are more often used in a pattern alternating from one stream bank to the other. This placement helps create a meandering low-flow channel in the existing channel. The spacing of these alternating deflectors varies from stream to stream, but a good place to start is to leave the length of one deflector (measured along the bank) between structures on opposite sides. Adjustments can be made as necessary.

Stone "saw tooth" deflectors *(see page 24)* are basically irregular riprap. They serve not only to stabilize stream banks, but also to create fish habitat in the nooks between the rocks and in the backwater area behind each point. Construction involves grading the bank, where possible, to a 3:1 slope (3 feet of horizontal distance for every foot of vertical drop) and then blanketing the area with large stone up to bankfull height. The stone can be dumped in an irregular pattern, or a backhoe can be used to form the deflector shapes. In most cases, the deflectors should extend only about 5 feet out into the stream.

Larger **stone deflectors** *(see page 25)* can also be constructed. Bigger stone should be used as the frame and keyed into the stream bottom and stream banks. Smaller stone can then be used to fill the frame's interior.



A **stone deflector with single log** *(see page 25)* is a variation of the standard stone deflector that adds a log for some additional fish cover. It is constructed by embedding the large end of a log into the deflector. The log is positioned parallel to the device's downstream edge and allowed to protrude out of the deflector's upstream face for several feet. The log may cause some extra scouring off the tip of the device, and the angle will help direct flows toward the middle of the stream channel.

A **log-faced stone deflector** *(see page 26)* is another variation of the stone deflector that uses logs to add an extra lip of cover along the outer face of the device. It is constructed by embedding two or more sill logs into the deflector, perpendicular to the upstream face of the device. Only a 1-foot or 2-foot section of these logs should extend out from this edge. A face log is then attached to the tips of the sill logs with a short piece of rebar. An additional one or two face logs can be used to increase the width of cover, if desired. Water depth should be close to two log diameters deep.

Log frame deflectors *(see page 26)*, as the name implies, use logs to frame out the device. The log frame allows for the use of smaller stone for construction. The main log (upstream log) is first trenched into the stream bank at a 30-degree angle. The brace log (downstream log) is then trenched into the bank at a 60-degree angle and positioned on top of the main log at a 90-degree angle. The brace log can now be cut to an exact fit, so it can lie behind the main log. The two logs should then be pinned together using a 2-foot rebar pin. The main log can overhang the brace log by a few feet to provide some extra cover and scouring effect. To finish the frame, both logs should be drilled and pinned to the stream bottom with 3-foot or 4-foot rebar pins at 5-foot intervals. Stone can now be shingled into the frame, using larger stone to reinforce the areas where the logs meet the stream bank. Stone should also be placed behind the brace log and taper downstream to prevent a scouring effect in this area.

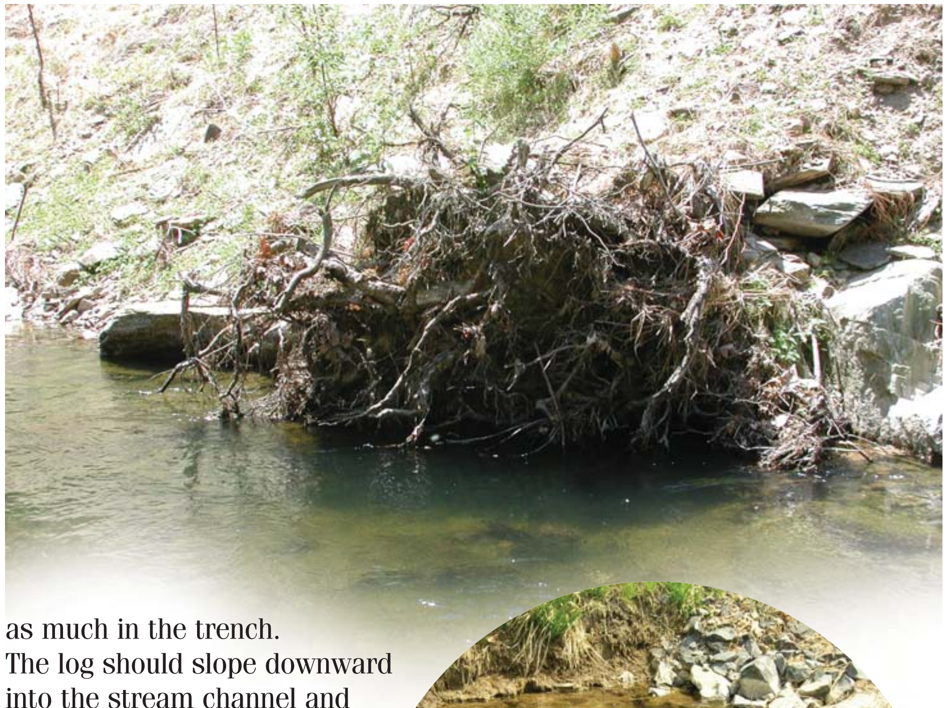
The standard log frame deflector can be modified into an **improved overhead cover deflector** *(see page 27)*, providing overhead cover as flows scour under the face log. This is accomplished simply by nailing 2” x 6” oak flooring onto the main log and angling it down to the stream bed within the deflector frame. Only the outermost third of the main log should be floored and no rebar pins should be located in this area. Another layer of logs should be added, using 2-foot pins, if there is enough water depth.

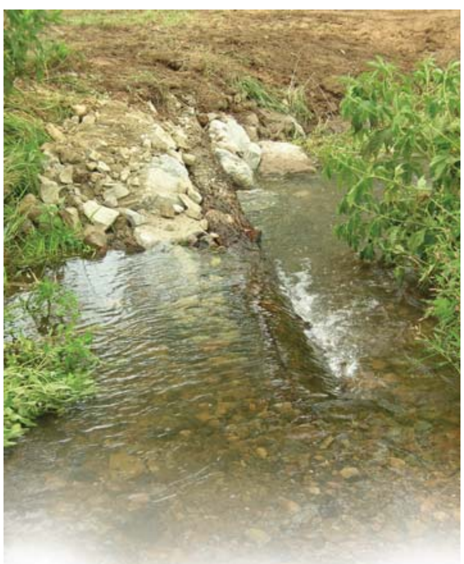
A **stacked deflector** *(see page 27)* is a marriage of the log frame and the improved overhead cover deflectors and again adds overhead cover under the face log. This device is built by “stacking” and pinning the upstream main log on top of the downstream brace log. This provides an immediate undercut along the face of the device. The undercut is maintained by nailing 2” x 6” oak flooring onto the main log and angling it down to the streambed as with the improved overhead cover deflector. An additional log should be pinned on top of the downstream brace log to act as a frame to hold the stone in place. A small diameter framing log can also be pinned on the flooring along the face log to help hold the stone as well. Water depth should be about two log diameters deep.

In low-gradient streams with a high slit load, **brush deflectors** *(see page 28)* can be constructed from old Christmas trees or other dense brush placed in a deflector shape as an alternative to rock. This type of deflector encourages the stream to build a stable stream bank on its own by trapping silt, which will eventually become stable with vegetation growth. The brush should be compacted and secured to stream bottom with wooden stakes and nylon twine forming a webbing over the top.

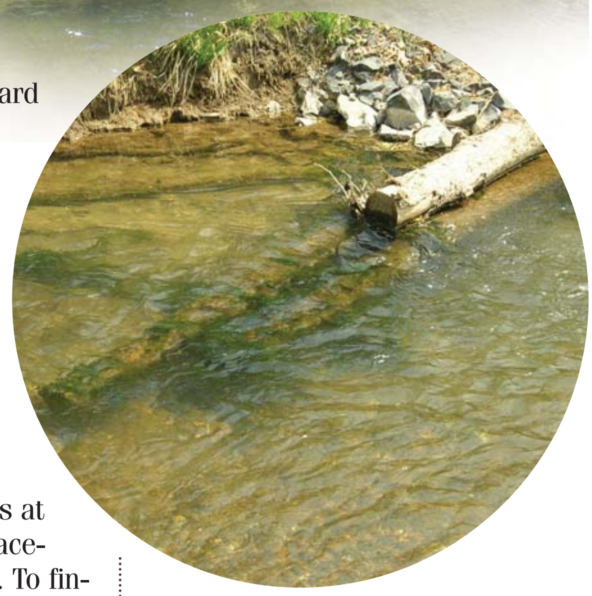
Other deflector variations are not really standard deflectors in the sense that they do not conform to the 30-60-90 degree triangle shape, but they serve their purpose by deflecting water and protecting stream banks all the same.

A **root wad deflector** *(see page 29)* is comprised of a mature tree stem cut to a minimum of 8 feet in length with the root ball still attached. These devices provide excellent habitat and act to stabilize the stream bank as well. They are typically used along higher, eroding stream banks. To install this device, a trench is dug at an upstream angle of 30 degrees. The root wad is placed into the trench with the root ball extending into the stream channel. When laid in the trench, the root ball should rest on the stream bottom or it should be one-third to one-half submerged in deeper water. The upstream side of the root ball should be tight against the stream bank. Large stone should be placed on the stem within the trench and used to backfill the gap between the root ball and the stream bank. Root wads can be installed in an overlapping fashion or can be spaced out over a length of stream bank.





Single log vane deflectors *(see page 28)* are most often used in runs and pools to create and maintain small pockets of habitat and provide some stream bank stabilization. Construction is quite simple, requiring only the digging of a trench in the stream bank for placement of a log. The log should extend out from the stream bank as much as one-third the width of the stream channel, with at least as much in the trench. The log should slope downward into the stream channel and most often be pointed in an upstream direction at a 20-degree to 30-degree angle. This will help direct flows toward the center of the stream. A log angled in a downstream direction will direct flows toward the stream bank, if desired. It should be remembered that water tends to fall off objects at a 90-degree angle, so the placement of the log is important. To finish the structure, large stone should be placed on the log within the trench and in the area where the log enters the stream bank.



A **multi-log vane deflector** *(see page 29)* is a heftier version of the single log structure and is typically used where there is a high stream bank. Construction is the same except that two logs are pinned together side-by-side, or three logs in the form of a pyramid.

Rock vanes and **J-hook vanes** *(see pages 30 and 31)* are linear deflectors constructed entirely from large rock (as large as 4 feet to 5 feet average diameter) and will usually require a trac-hoe with a bucket "thumb" for placement. Rock vanes and J-hook vanes provide stream bank stabilization, help direct flows away from the stream bank and provide some plunge-pool habitat.

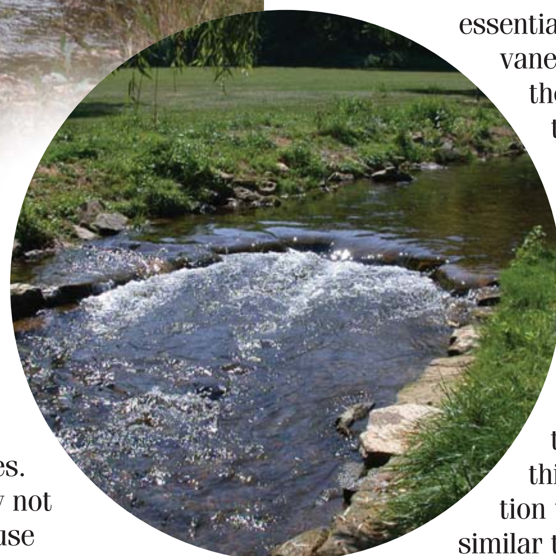
The linear configuration of the rock vane structure runs in an upstream direction at a 20-degree to 30-degree angle to the stream bank. It begins at the bankfull height on the stream

bank, and drops at a 2 percent to 7 percent slope down from the stream bank to just above normal low-flow water levels. A perpendicular measurement from the tip of the device to the stream bank should be one-third of the total bankfull width. To keep the device from falling into it's own scour pool, the first step in construction is to embed a line of footer rocks into stream bottom along the downstream edge of where the surface rocks are to be placed. The tops of these footer rocks should be at the stream bottom level.

A curved "J-hook" pattern can be added to the upstream end of the rock vane to create a centered plunge pool effect. The rocks of this extension can have some space between them, but should also have footer rocks. This extension should reach through only the next one-third of the bankfull width.

These devices work by forcing higher flows to run slightly uphill along the stream bank, thus removing some of its energy. Since flowing water tends to fall off objects at a 90-degree angle, the device will also turn flows toward the center of the stream and away from stream banks and as the water falls, more energy is released into the plunge pool.

While these devices can be used on straight stretches, they are also well suited for the outside of curves. However, it may not be practical to use them on outside bends that exceed a 70-degree radius of curvature. As a general rule these devices should be spaced one device length apart. Placing the uppermost device and observing the water flow can also determine spacing. The device will redirect flows away from the bank, but it will tend to move back toward the bank at some point below. The next device should be placed at the point where flow begins hitting the bank again. In general, these structures will need to be closer together on an outside bend as opposed to a straighter stretch of stream.



Low Flow Channel Structures

Stone cross vane *(see page 31)* structures extend completely across the stream channel and are essentially two linear vanes connected in the middle. The two linear arms should extend to one-third of the bankfull width each, with the middle portion taking up the center one-third. Construction techniques are similar to linear rock vanes. These devices are used for grade control and for centering flows in the channel, but also provide some plunge pool habitat.

A **log cross vane** *(see page 32)* can be constructed using a log trenched into each bank and meeting each other in the middle of the stream

channel. The placement dimensions should be the same as the stone cross vane.

A **water jack** *(see page 32)* is a pool-digging device, best suited for higher gradient streams with little pool habitat. The structure is meant to create and maintain a pool on the downstream side of the device. It is not meant to back up water into a pool above the device where silt will collect and destroy as much habitat as is being created. Water jacks should be located in an area with high stream banks, where the stream channel is narrow and should be situated where a section of high gradient meets a section of lower gradient.

Construction begins with the placement of the main log, perpendicular to stream flow, onto the stream bottom and into trenches in each stream bank. Once the log is level, it is pinned in place on both ends within the trench (not in the middle) with 3-foot or 4-foot rebar. Moving upstream about 3½ to 4 feet, a trench is dug parallel to the main log. This trench should be deep enough so that when the nailer log (6" diameter) is inserted it will sit considerably lower than the main log. When a piece of 8-foot flooring is placed on top of these two logs, it should be at a 20-degree to 30-degree angle with the stream bottom. If the flooring is too level, the trench should be deepened until the board is close to the correct angel and the end catches in the back of the trench. When the nailer log sits deep enough and level, it should be pinned in place like the main log.

Next, take a piece of 1" x 8" x 8' flooring and slide it onto the center of the two logs at a 90-degree angle until the end touches the stream bottom above the nailer log. The flooring should be driven into the stream bottom as far as it will go without lifting off the nailer log. Nail in place, using four nails per board.

Continue this procedure in both directions until there is a single layer of flooring spanning the entire stream channel. Use stone and gravel to fill any gaps while creating a smooth transition between the flooring and the banks. The overhanging ends of these boards can be trimmed off, but don't cut them too short at this point.

To obtain an immediate seal, a layer of clear, 4-mil plastic, in a 12-foot width, is laid over this first layer of flooring. Cut this sheeting so that it extends at least 5 feet onto both stream banks. Several pairs of hands will be needed to help spread the plastic out and hold it above the structure and over the water surface. When everybody is in position, lay the upstream edge down onto the stream bottom and secure the edge with stone and gravel. Hold on to the downstream edge until the water pressure slowly pulls the sheeting tight over the flooring. Water should now be flowing over the structure, creating a small waterfall.

Apply a second layer of flooring by sliding boards down over the plastic (only until they touch the bottom—do not drive them through the plastic), making sure they overlap the cracks of the first layer. Nail these boards in place, following the nail line on the first layer, which can be seen through the clear plastic (see information on underwater nailers in the Construction Guidelines section). Trim both layers of flooring so that only a few inches overhang the main log.

Before attaching the wings, the size of the opening must be determined. It should be wide enough to take normal flows, yet narrow enough to concentrate the hydraulic force of the water to dig the desired hole. The small end of the wing logs should be pinned through the flooring and into the main log with a 2-foot pin on either side of the desired opening. The other end of this log should be pinned in a trench dug at a 30-degree angle to the bank and should slope slightly upward. Complete the wings by installing brace logs on both sides, attached by 2-foot pins through the flooring and into the main log. Face boards can be nailed to the inside or outside of the wing logs to minimize leaking though this area. To complete the water jack, stone should be shingled into each wing and any place a log enters the bank should be reinforced with large stone.

Adding Downstream Wings to a Water Jack

After a water jack structure has been given time to scour a deep plunge pool (a year or so), the addition of downstream wings is usually recommended and can help stabilize and greatly enhance this pool area. The wings can be made of stone only, or with logs and flooring if additional cover is desired *(see page 32).* When completed, the downstream wings should somewhat mirror the existing upstream wings.

The following describes the construction of the log and flooring version. Start by digging a trench 3 feet to 4 feet into the stream bank on the downstream side of the main log. The trench should be deep enough that when a sill log is laid in place, it will be covered by 2 inches of water. Counter-balance the sill log by placing large stone within the trench. Attach the small end of the wing log to the end of the sill log with a 2-foot rebar pin. The other end of this log should be trenched into the stream bank and pinned in place with 3-foot or 4-foot rebar. Once secure 2” x 6” x 8’ oak flooring positioned perpendicular to the stream bank, is nailed to the top of this wing log. Overhanging boards can be trimmed off before pinning a top log in place with 2-foot pins, sandwiching the flooring between the two logs. The final step is to shingle stone over the flooring and reinforce the area where the logs enter the bank.

A **“brookie” water jack** *(see page 33)* is an abbreviated version of the full-sized water jack. It is meant for small brook trout type streams with the same physical characteristics as required for the standard water jack. Construction is very similar with the main exception being there is no upstream nailer log. Instead, the flooring is placed at a 45-degree angle to the main log and driven into the stream bottom before being nailed to the main log. Two layers of flooring are still used with or without plastic being sandwiched between the layers. Generally, stone wings suffice for both the upstream and downstream sides of the device.

Mud Sill Cribbing

Mud sill cribbing *(see page 33)* is an excellent overhead cover device that is best suited for lower gradient streams with steep, eroded banks found next to a deep main channel. They provide stream bank stability and create a stable undercut bank effect for fish cover. They can be constructed on a straight stretch of stream or they can follow the contour of an outside curve. In most situations, a backhoe is very helpful, if not necessary, to construct a mudsill.

To begin construction, it’s often desirable to grade any steep banks back to a 3:1 slope. The next step is to set the sill logs, usually 8 to 10 feet in length, into a series of trenches dug perpendicular to the stream flow. A properly dug trench should allow a sill log to sit in a level position with about two 2 to 4 inches of water over the log. If using an 8-foot sill log, 5 feet should be in the bank and 3 feet should extend out into the stream (a 6-foot and 4-foot split, if using a 10-foot sill log). Once the sill log is in proper position, hand place the stone on the back end until it is stable. Now the backhoe can dump additional stone into the trench and can be topped off with soil. The first and last trench should contain only one sill log, while the ones in between should be doubled. The widest point between sill logs should be 8 feet or less.

After all the sill logs are in position, attach face logs running from the tip of one sill to the next using 2-foot pins. Drive these pins only to the point where they are flush with the bottom of the sill log so no debris catches underneath.

Next, nail 2” x 6” x 8’ oak flooring

from sill to sill, running from the face log to the stream bank, to create an overhanging or "front porch" effect. If the sills are set properly, this flooring should remain slightly underwater.

To complete the framework, a wing log should be added to each end of the structure, running from the tip of the last sill to the bank. This log should slope slightly upward and enter a bank trench at a 30-degree angle. To provide some extra cover, oak flooring can be nailed to the wing logs, running at a downward angle toward the stream bank.

To finish, single stone over the flooring, fill the wings with stone and place stone on the stream bank up to bankfull height. As always, reinforce the wing logs where they enter the bank.

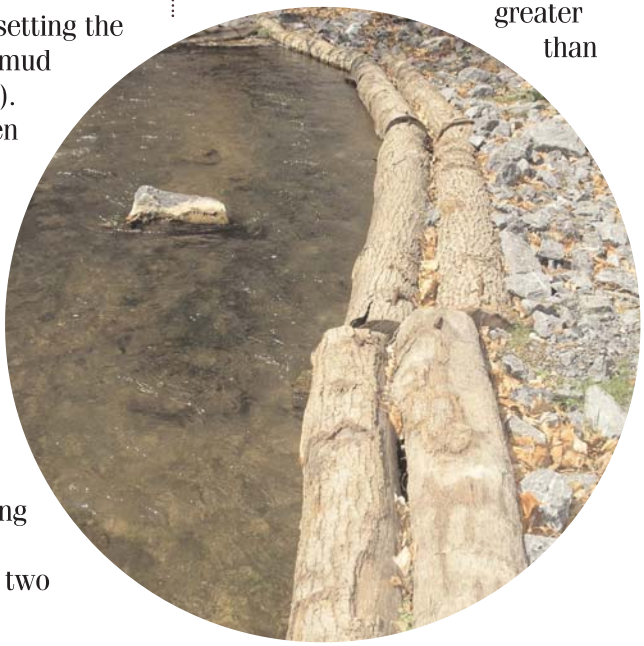
The **modified mud sill crib** *(see page 34)* is a simplified version of the full mud sill crib. It is used in the same situations as the full mud sill, but does not use the oak board flooring. This allows the spacing of the sill logs to vary up to 15 feet apart. This is useful if trenches need to be dug around trees or other obstructions along the stream bank. Two face logs are used to form the undercut instead of the flooring.

Construction begins by setting the sill logs as with the full mud sill structure (see above). Double-face logs are then pinned to the tips of the sill logs with 2-foot rebar pins. Stone fill is placed from the face logs back to the bankfull point on the stream bank. Larger stone can be propped up along the face log by hand to maintain the undercut when back filling with stone. Water depth should be no more than two log diameters deep.

The **bank cover crib** *(see page 34)* is a simplified variation of the mudsill cribbing and provides similar benefits of stream bank stability and overhead cover. It is most suited to span an outside bend of an eroded stream bank, but can work on a straight stretch as well.

Begin by digging a trench on both sides of an outside turn. Insert a single log into these trenches so that it spans the bend, sits level and is submerged by 2 inches of water. Pin the log in the trenches with 3-foot or 4-foot rebar pins.

Oak flooring (2" x 6") is now nailed perpendicular to the log, sloping downward toward the stream bank at an angle no greater than 45 degrees. Attach a top log by using 2-foot pins driven through the flooring and into the bottom log. To avoid catching debris, do not allow these pins to extend out of the bottom log.



The final steps are to grade the bank to a 3:1 slope, if necessary, fill the frame with stone, and reinforce the logs where they enter the bank. Sill logs can be used under a splice of the main log or to modify the structure for straight stretches. A face log should not span more than 15-feet without the addition of a sill log.

Channel Blocks

Channel block structures are designed to do just what the name implies—block off the flow of one channel and divert all the flow into another channel. It should be noted that every split channel does not necessarily need to be blocked. In fact, many side channels add to the variety of habits in the stream's ecosystem and are often used as nursery waters for young trout. They might be best used to direct normal flows away from a road, building or other property. However, remember that the blocked channel will still fill with water during higher flows.

When deciding to modify a split channel with this structure, it is critical to choose the best channel to block off. Though many factors come into play, generally it is best to work with what the stream may be trying to do. It is important to construct these structures at a lower elevation than the surrounding stream banks, as to allow higher flows to pass over the device, releasing pressure on the main channel.

A **log frame channel block** (see page 35), best for smaller streams, is started by placing two parallel logs into slight depressions across the stream bottom and into trenches in each stream bank. The logs should be about 4 feet apart with the back log a little smaller or sit slightly lower than the front log. Pin these two logs in the trenches using 3-foot or 4-foot rebar pins.

Next, cut brace logs long enough to span the distance across the two lower logs. Spaced about 4 feet to 5 feet apart, pin the brace logs in place by driving a 4-foot pin through both logs and into the stream bottom.

Fill this frame and the trenches with stone, making sure that the overall height of the structure is lower than the surrounding stream banks. To complete the structure, place stone behind the back log, tapering downstream, to prevent scouring in this area.

In some situations, especially larger streams with higher flows, it may be more feasible to build a **stone channel block** (see page 35). Use stone large enough so they are not moved by normal high flows. Key them in

the width of the channel bottom and slightly into the stream banks. Larger stone should be used as a frame to hold the smaller stone in the middle and behind the structure. As with the log frame structure, make sure the overall height of the stone structure is lower than the surrounding stream bank.

Closing

The first version of this publication was printed in the 1950s, and the Pennsylvania Fish & Boat Commission has been conducting fish habitat improvement since the 1930s. At first, work was done with Commission staff and equipment. Later, the work developed into a cooperative program using conservation-minded volunteers from all over the Commonwealth. Over the years, the designs and techniques have changed, but the mission remains the same—providing fishing and boating opportunities through the protection and management of aquatic resources.

In 2006, the Commission elevated its commitment to restoring and improving aquatic habitats by creating the Division of Habitat Management under the Bureau of Fisheries. This new division will build on decades of successful habitat work by providing more expertise in the field, bringing more funding to the table, and extending its outreach to those interested in improving the aquatic resource. Continuing and expanding the existing partnerships with individuals, organizations and other agencies will be a vital part of completing the high-quality habitat work that will keep Pennsylvania a national leader in fish habitat initiatives.

References

Barbour, M.T.; Gerritsen, J.; Snyder, B.D.; and Stribling, J.B. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Second Edition. EPA 841-B-99-002,* U.S. Environmental Protection Agency, Office of Water. Washington, D.C., 1999.

Lalo, J. and Lutz, K.J. *Corridor Management for Pastureland Streams.* Pennsylvania Fish & Boat Commission, 1994.

Sample Erosion and Sedimentation Plan

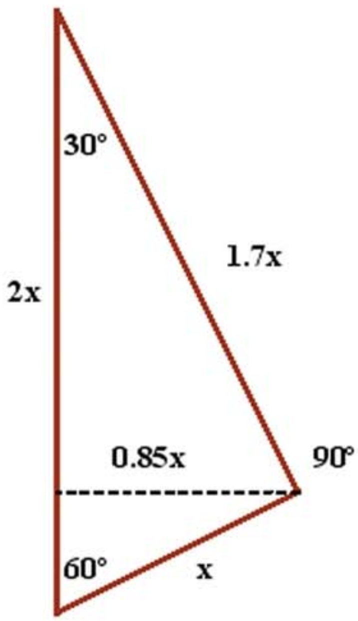
Pennsylvania Fish & Boat Commission
Division of Environmental Services
Habitat Management Section
450 Robinson Lane
Bellefonte, PA 16823-9620

Erosion & Sedimentation Control Plan
for the Construction of
Fish Enhancement Structures

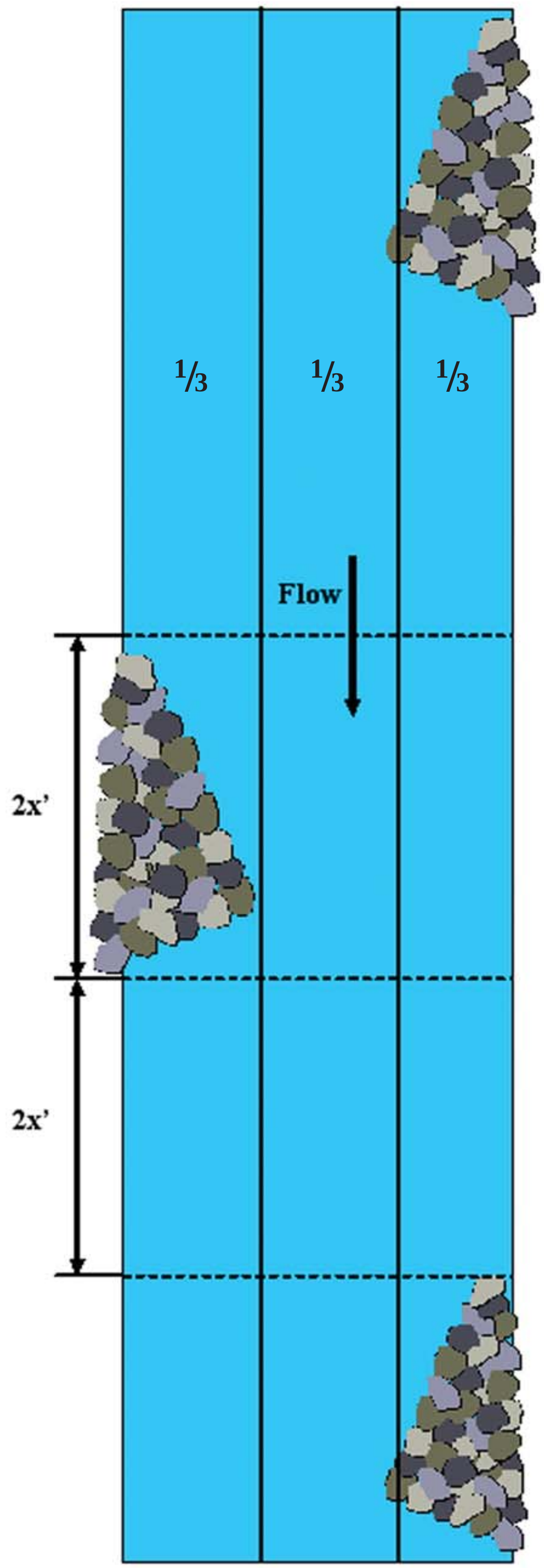
1. Maps and Plans:
   - Maps should show the location of the project with respect to municipalities, access roads, existing structures or other landmarks.
   - Work plans should show a detailed drawing of the specific work site including device dimensions, stream width and other on-site features (including seed mixtures and rates of seeding and mulching).
2. All work will be done during low-flow conditions, avoiding periods during or immediately following heavy precipitation.
3. Any and all equipment work will be done from the stream bank. Equipment should be inspected to ensure that there is no leaking of lubricants, fuel, hydraulic fluids, etc.
4. Excavation of stream banks and/or stream bottom for the purpose of keying in stone and/or timbers, will be restricted to work that can be completed in one day.
5. All disturbed areas will be immediately stabilized with rock, seeding, and mulching, or other suitable material, during the one-day construction limit. Newly vegetated areas will be inspected and repaired (as needed) until grass is well established.
6. Grass seed mixtures used in stabilization will be either a shade, conservation or slope variety depending upon the site requirements. Hand broadcasting of seed will average six pounds per 1,000 sq. ft.
7. Straw or hay mulch will be placed by hand to produce a loose layer three-fourths to one inch deep. (2.5 Tons/Acre)
8. Only clean, nonpolluting materials shall be used as fill, which should be shingled or keyed into the structures for longevity. Minimum stone size should be R-4, as rated by the National Stone Association.
9. Any material excavated during the installation of the structures should be deposited in a suitable site away from areas affected by flood waters or wetlands, and stabilized within 24 hours of initial excavation.
10. All enhancement structures shall be constructed according to approved Pennsylvania Fish & Boat Commission specifications. Other designs may be reviewed on a case-by-case basis.
11. Enhancement structures shall be maintained in a safe and functional condition, including necessary debris removal by the owner.

Revised 6/11/98

Deflector Dimensions and Spacing



0.85x	x	1.7x
5'	6'	10'
7'	8'	14'
9'	11'	18'
11'	13'	22'
13'	15'	26'
15'	18'	30'
17'	20'	34'
19'	22'	38'
21'	25'	42'
23'	27'	46'
25'	29'	50'
27'	32'	54'
29'	34'	58'
31'	36'	62'
33'	39'	66'
35'	41'	70'



Habitat Assessment Forms

Habitat Assessment Field Data Sheet – Low Gradient Streams (side 1)

Stream Name:	Location:	
Station #: Rivermile:	Basin/Sub-basin:	Agency:
Lat: Long:	Date: Time: am pm	Reason for Survey:
Investigators:	**TOTAL SCORE:**	

Habitat Parameter	**Condition Category**			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization & fish cover; mix of snags submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (logs/snags that are not new fall and not transient	30-50% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale.	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Pool Variability Note: Deep = > 18”	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and < 20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills > 75% of the available channel; or < 25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Low Gradient Streams (side 2)

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization i.e., dredging (greater than past 20 years) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note: channel braiding is considered normal in coastal plains and other low-lying areas. This is not easily rated in these areas).	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability Note: Determine left & Right by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. < 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5 – 30 % of bank in reach has areas of erosion.	Moderately unstable; 30 – 60 % of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; raw areas frequent along straight sections and bends; obvious bank sloughing; 60 – 100 % of bank has erosional scars.
Score (LB):	10 9	8 7 6	5 4 3	2 1 0
Score (RB):	10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection	More than 90% of the stream bank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70 – 90% of the stream bank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50 – 70% of the stream bank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the stream bank surfaces covered by vegetation; disruption of stream bank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
Score (LB):	10 9	8 7 6	5 4 3	2 1 0
Score (RB):	10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width	Width of riparian zone > 18 meters (58"); human activities (parking lots, roadbeds, clearcuts, lawns or crops) have not impacted zone.	Width of riparian zone 12 – 18 meters (39'-58'); human activities have impacted zone only minimally.	Width of riparian zone 6 – 12 meters (20'-39'); human activities have impacted zone a great deal.	Width of riparian zone < 6 meters (20'); little or no riparian vegetation due to human activities.
Score (LB):	10 9	8 7 6	5 4 3	2 1 0
Score (RB):	10 9	8 7 6	5 4 3	2 1 0

Habitat Assessment Field Data Sheet – High Gradient Streams (side 1)

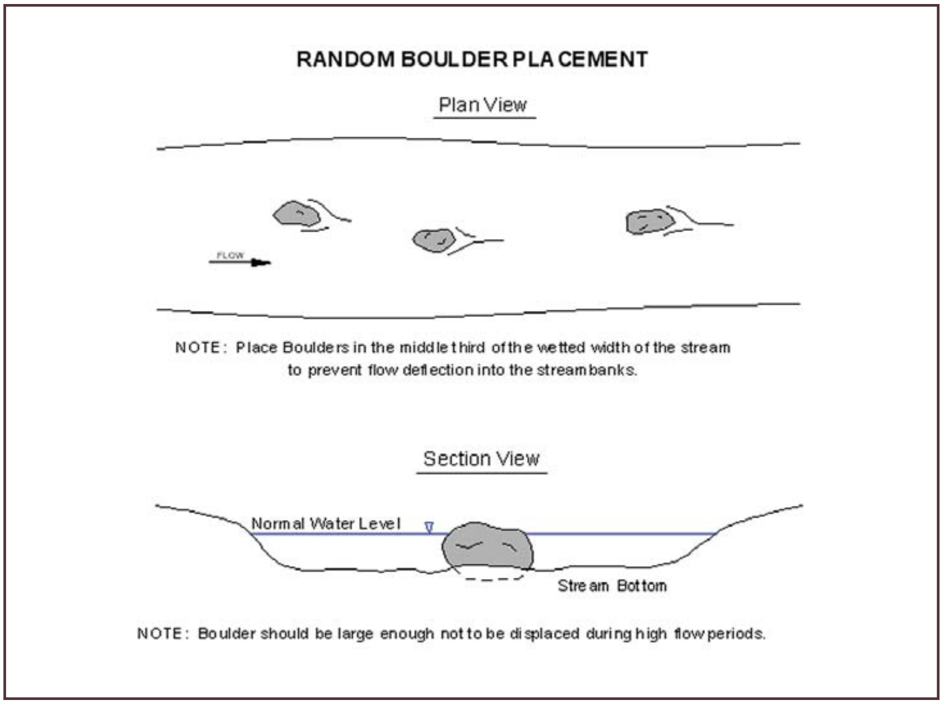
Stream Name:	Location:	
Station #: Rivermile:	Basin/Sub-basin:	Agency:
Lat: Long:	Date: Time: am pm	Reason for Survey:
Investigators:	**TOTAL SCORE:**	

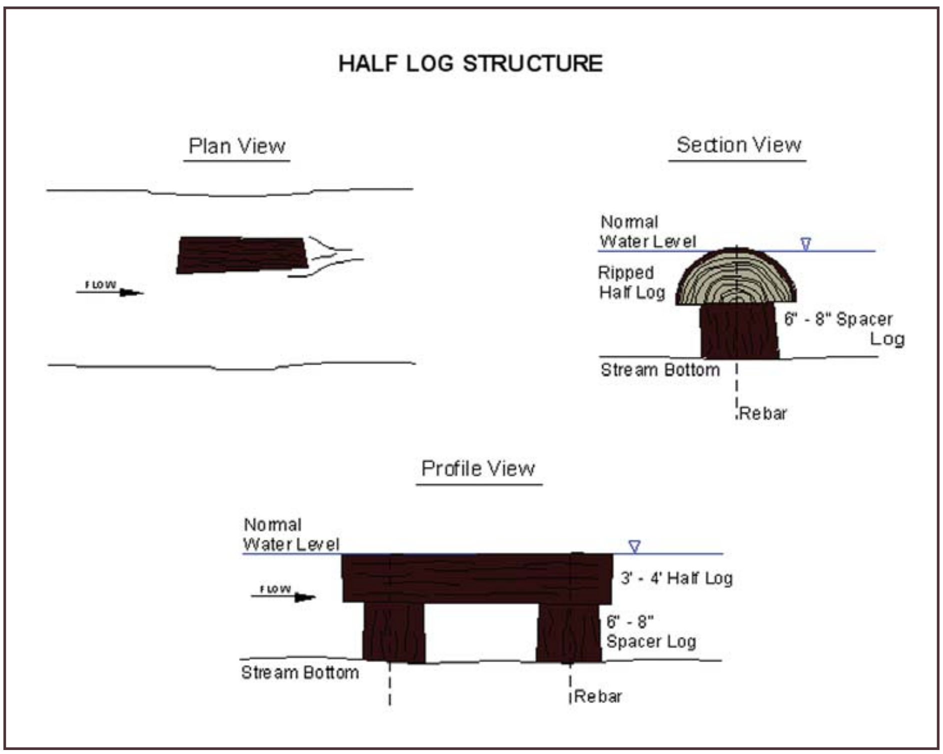
Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization & fish cover; mix of snags submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (logs/snags that are not new fall and not transient	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale.	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble and boulder particles are more than 75% surrounded by fine sediment.
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime Note: Deep = > 18”	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow) (Slow is <0.3 m/s, deep is > 0.5 m).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and < 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills > 75% of the available channel; or < 25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

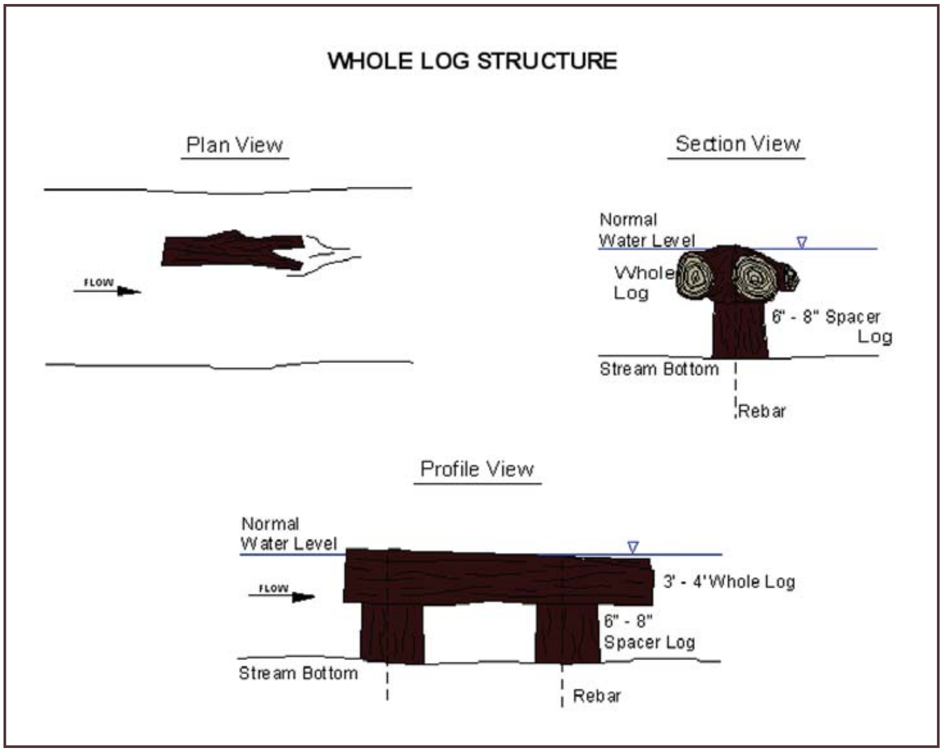
High Gradient Streams (side 2)

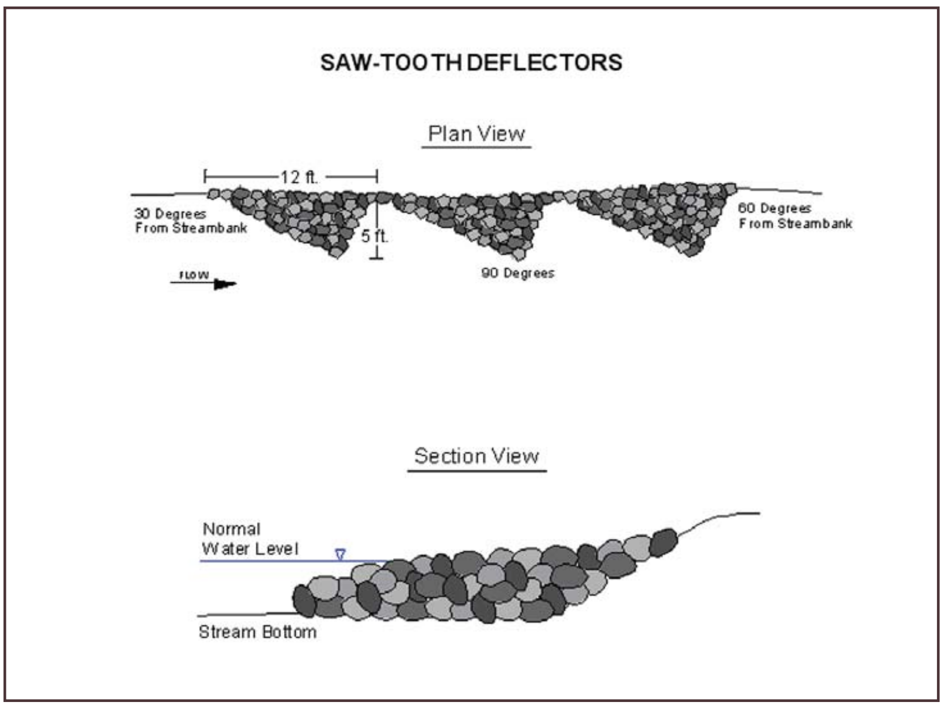
Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization i.e., dredging (greater than past 20 years) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream < 7:1 (generally 5 to 7); variety of habitat is key in streams where riffles are continuous, placement of boulders or other large natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of > 25.
SCORE:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability Note: Determine left & right banks by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. < 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5 – 30 % of bank in reach has areas of erosion.	Moderately unstable; 30 – 60 % of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; raw areas frequent along straight sections and bends; obvious bank sloughing; 60 – 100 % of bank has erosional scars.
Score (LB):	10 9	8 7 6	5 4 3	2 1 0
Score (RB):	10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection	More than 90% of the stream bank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70 – 90% of the stream bank surfaces covered by native vegetation, but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50 – 70% of the stream bank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the stream bank surfaces covered by vegetation; disruption of stream bank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
Score (LB):	10 9	8 7 6	5 4 3	2 1 0
Score (RB):	10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width	Width of riparian zone > 18 meters (58”); human activities (parking lots, roadbeds, clearcuts, lawns or crops) have not impacted zone.	Width of riparian zone 12 – 18 meters (39’-58’); human activities have impacted zone only minimally.	Width of riparian zone 6 – 12 meters (20’-39’); human activities have impacted zone a great deal.	Width of riparian zone < 6 meters (20’); little or no riparian vegetation due to human activities.
Score (LB):	10 9	8 7 6	5 4 3	2 1 0
Score (RB):	10 9	8 7 6	5 4 3	2 1 0

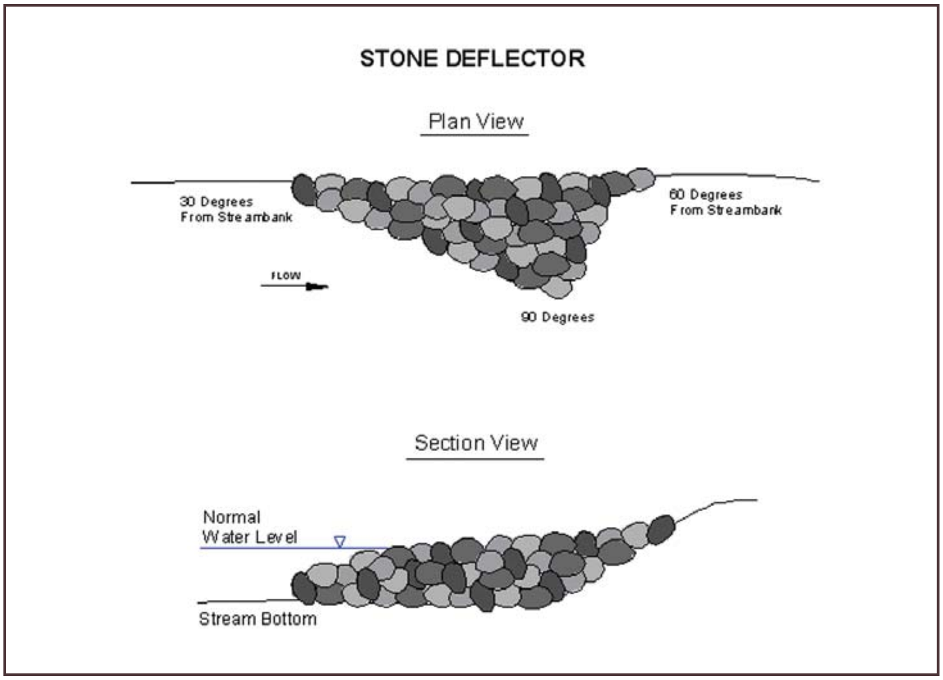
Structure Drawings

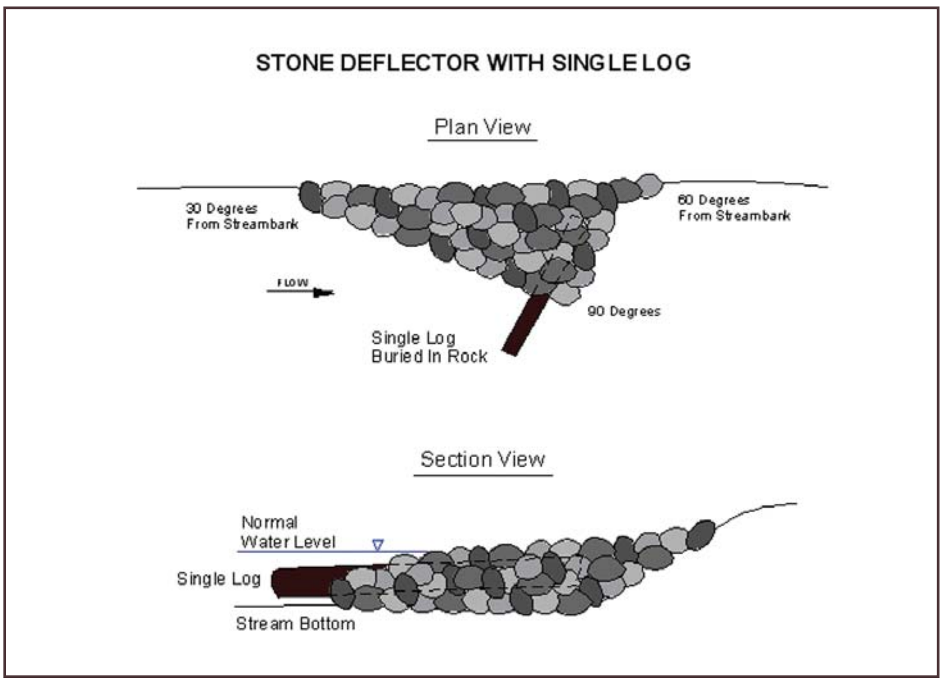


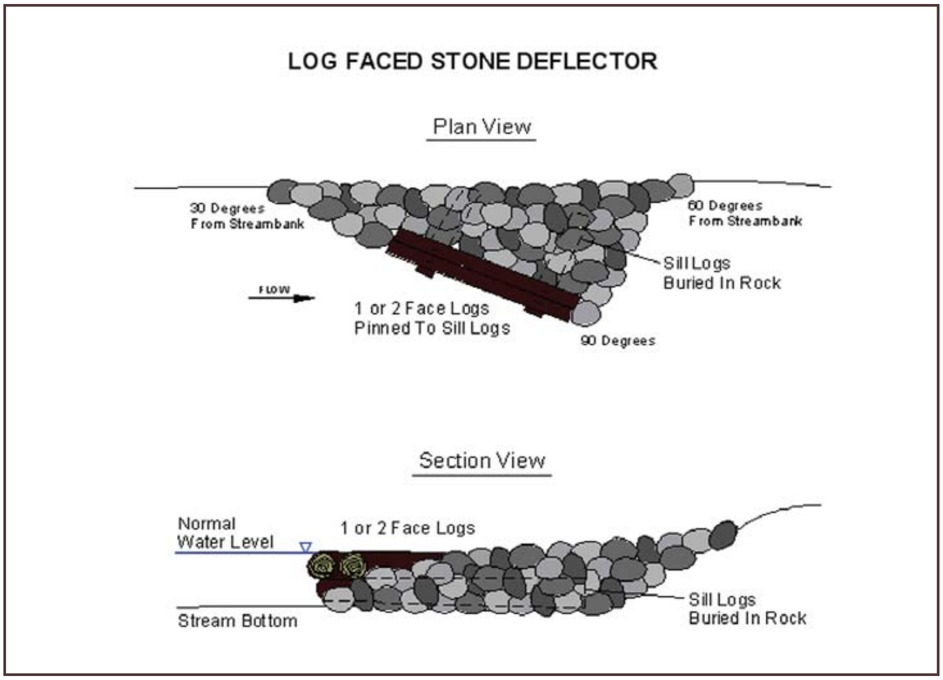


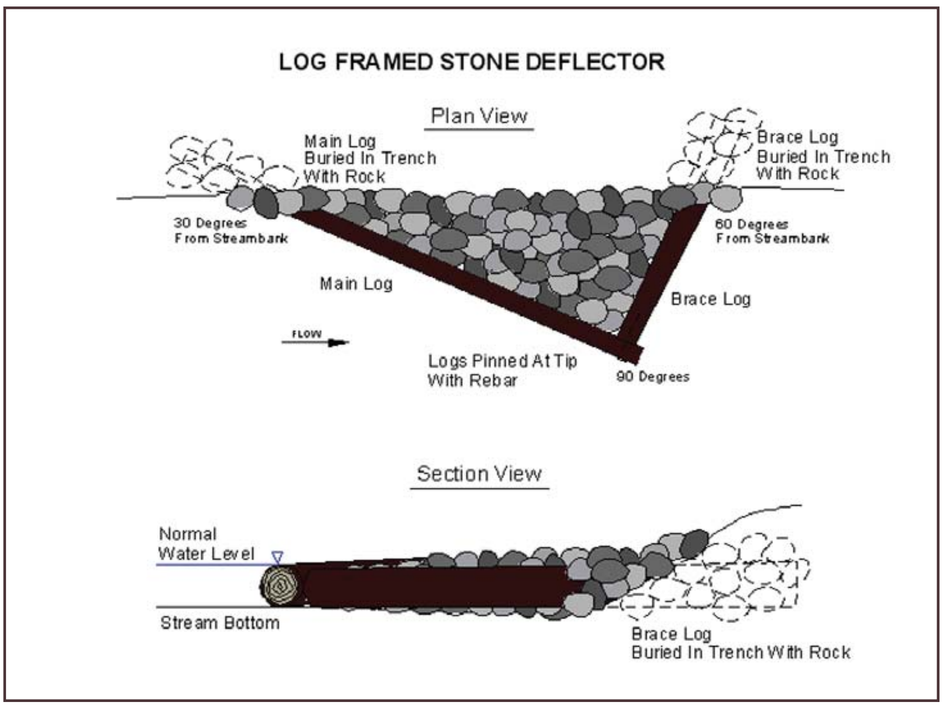

WHOLE LOG STRUCTURE
Plan View
FLOW
Section View
Normal
Water Level
Whole
Log
6" - 8" Spacer
Log
Stream Bottom
Rebar
Profile View
Normal
Water Level
FLOW
3' - 4' Whole Log
6" - 8"
Spacer Log
Stream Bottom
Rebar

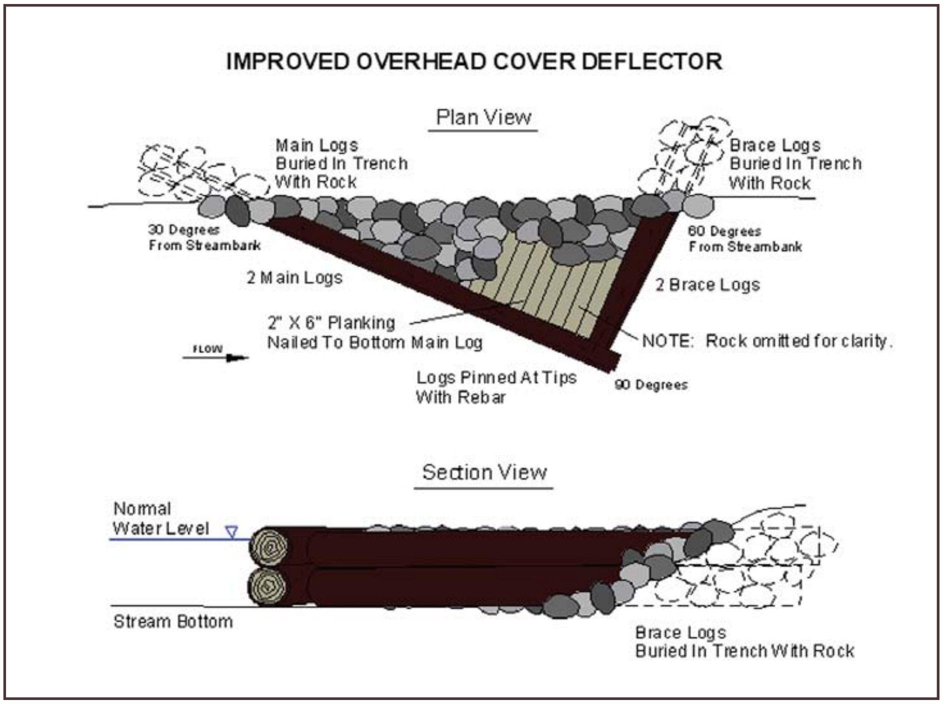

SAW-TOOTH DEFLECTORS
Plan View
12 ft.
30 Degrees
From Streambank
5 ft.
90 Degrees
60 Degrees
From Streambank
FLOW
Section View
Normal
Water Level
Stream Bottom

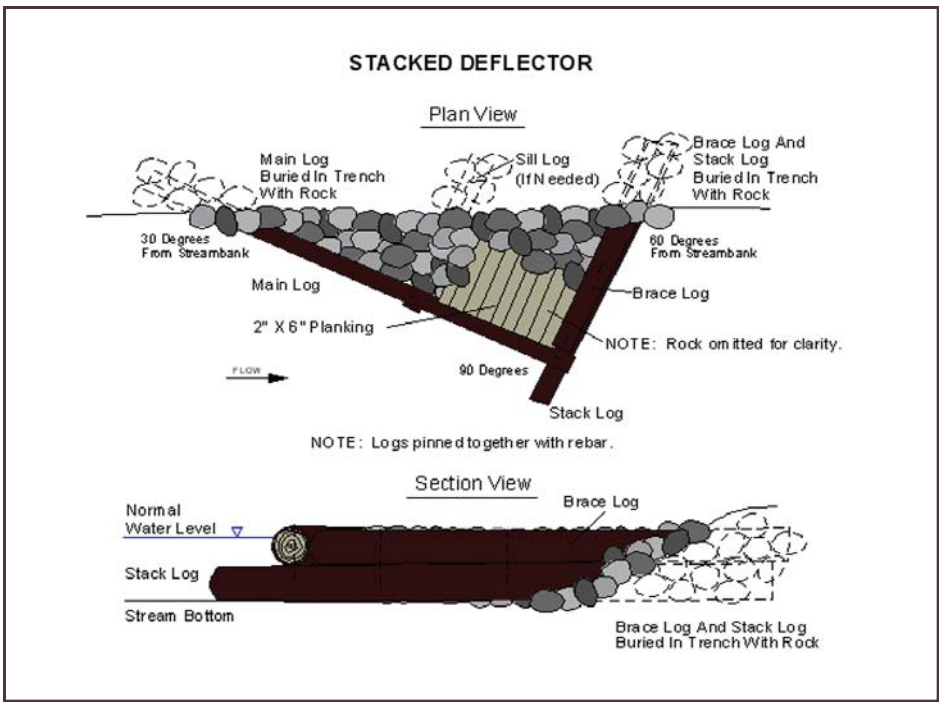

STONE DEFLECTOR
Plan View
30 Degrees
From Streambank
60 Degrees
From Streambank
FLOW
90 Degrees
Section View
Normal
Water Level
Stream Bottom

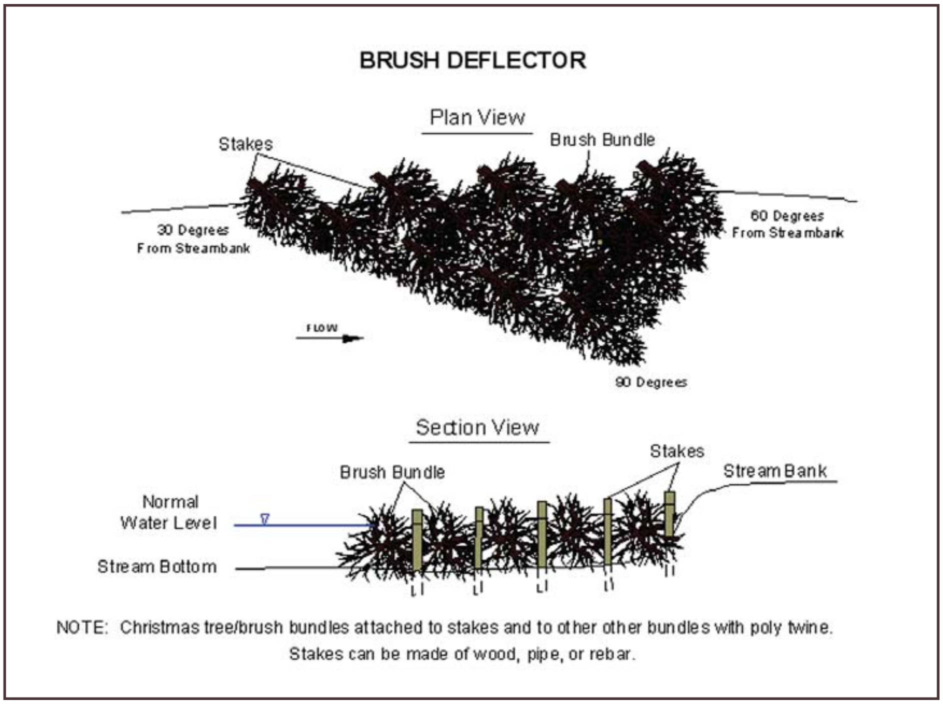

STONE DEFLECTOR WITH SINGLE LOG
Plan View
30 Degrees
From Streambank
60 Degrees
From Streambank
FLOW
90 Degrees
Single Log
Buried In Rock
Section View
Normal
Water Level
Single Log
Stream Bottom

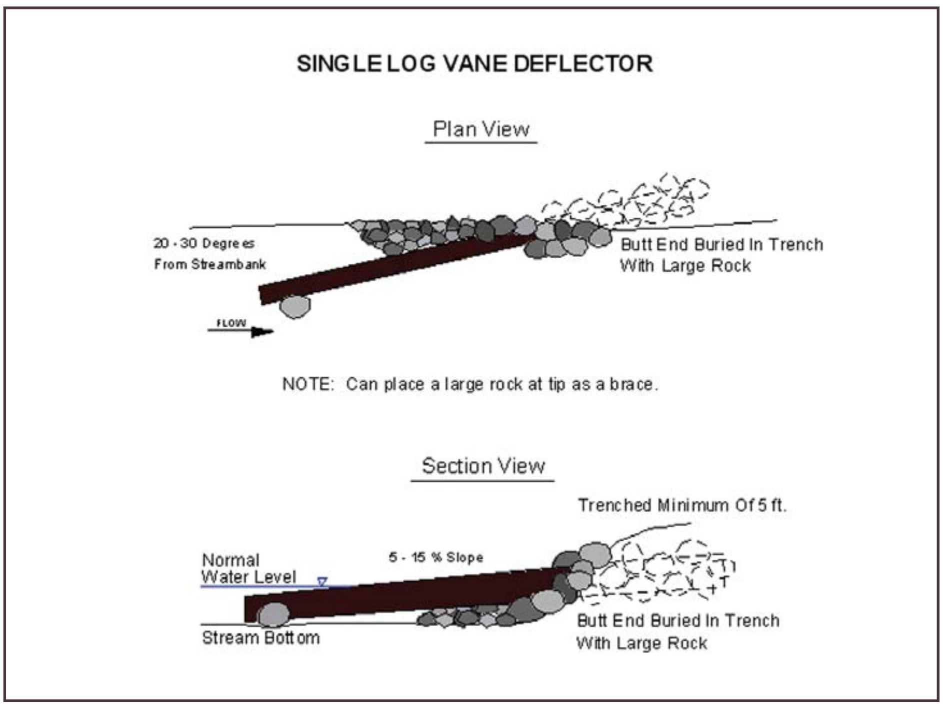

LOG FACED STONE DEFLECTOR
Plan View
30 Degrees From Streambank
60 Degrees From Streambank
Sill Logs Buried In Rock
FLOW
1 or 2 Face Logs Pinned To Sill Logs
90 Degrees
Section View
Normal Water Level
1 or 2 Face Logs
Stream Bottom
Sill Logs Buried In Rock


LOG FRAMED STONE DEFLECTOR
Plan View
Main Log Buried In Trench With Rock
Brace Log Buried In Trench With Rock
30 Degrees From Streambank
60 Degrees From Streambank
Main Log
Brace Log
FLOW
Logs Pinned At Tip With Rebar
90 Degrees
Section View
Normal Water Level
Stream Bottom
Brace Log Buried In Trench With Rock

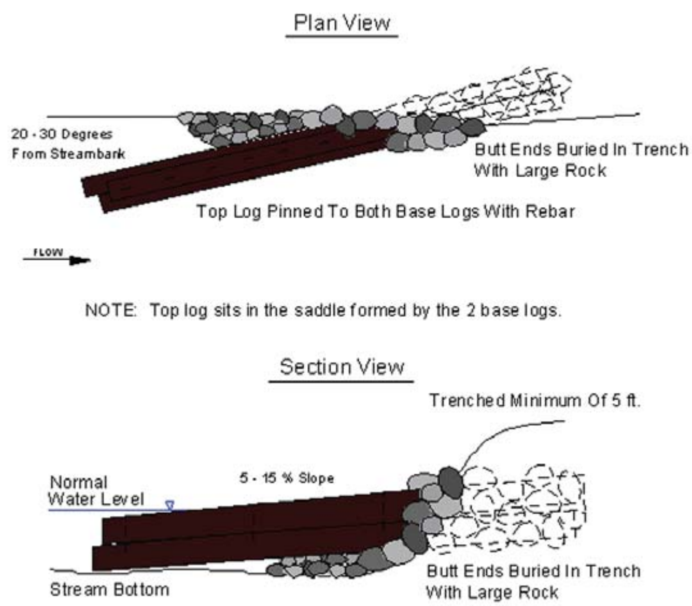

IMPROVED OVERHEAD COVER DEFLECTOR
Plan View
Main Logs
Buried In Trench
With Rock
Brace Logs
Buried In Trench
With Rock
30 Degrees
From Streambank
60 Degrees
From Streambank
2 Main Logs
2 Brace Logs
2" X 6" Planking
Nailed To Bottom Main Log
NOTE: Rock omitted for clarity.
FLOW
Logs Pinned At Tips
With Rebar
90 Degrees
Section View
Normal
Water Level
Stream Bottom
Brace Logs
Buried In Trench With Rock


STACKED DEFLECTOR
Plan View
Main Log
Buried In Trench
With Rock
Sill Log
(If Needed)
Brace Log And
Stack Log
Buried In Trench
With Rock
30 Degrees
From Streambank
60 Degrees
From Streambank
Main Log
Brace Log
2" X 6" Planking
NOTE: Rock omitted for clarity.
FLOW
90 Degrees
Stack Log
NOTE: Logs pinned together with rebar.
Section View
Brace Log
Normal
Water Level
Stack Log
Stream Bottom
Brace Log And Stack Log
Buried In Trench With Rock

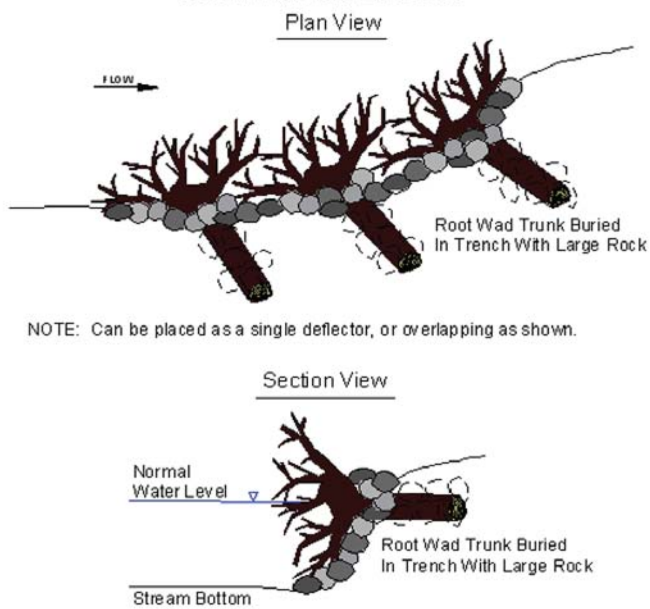

BRUSH DEFLECTOR
Plan View
Stakes
Brush Bundle
30 Degrees From Streambank
60 Degrees From Streambank
FLOW
90 Degrees
Section View
Stakes
Brush Bundle
Stream Bank
Normal Water Level
Stream Bottom
NOTE: Christmas tree/brush bundles attached to stakes and to other other bundles with poly twine.
Stakes can be made of wood, pipe, or rebar.

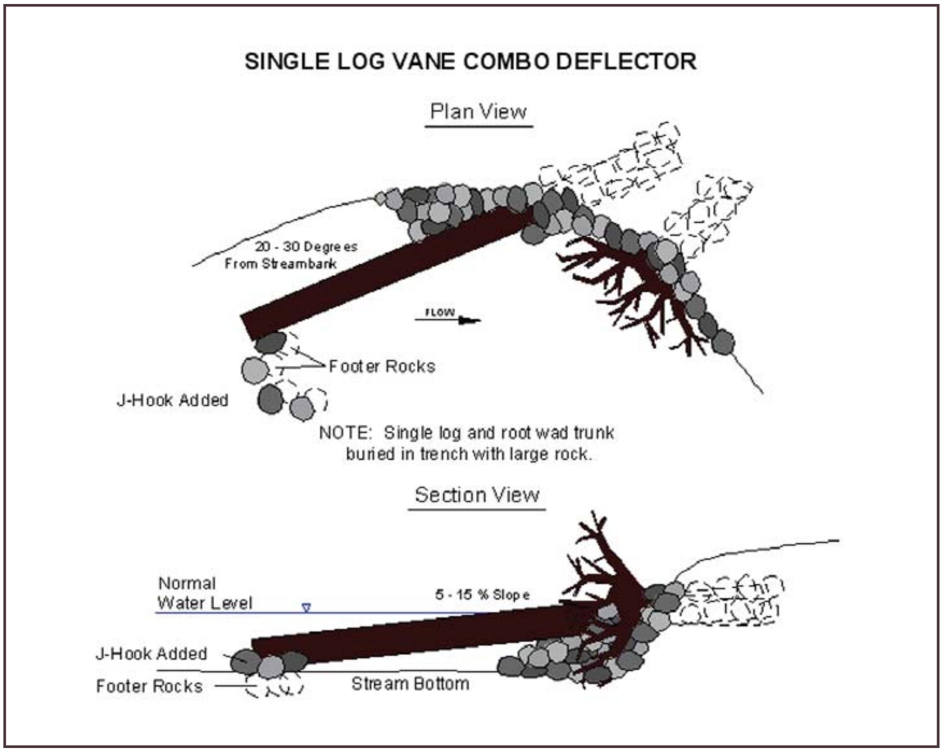

SINGLE LOG VANE DEFLECTOR
Plan View
20 - 30 Degrees From Streambank
Butt End Buried In Trench With Large Rock
FLOW
NOTE: Can place a large rock at tip as a brace.
Section View
Trenched Minimum Of 5 ft.
5 - 15 % Slope
Normal Water Level
Stream Bottom
Butt End Buried In Trench With Large Rock

MULTI-LOG VANE DEFLECTOR

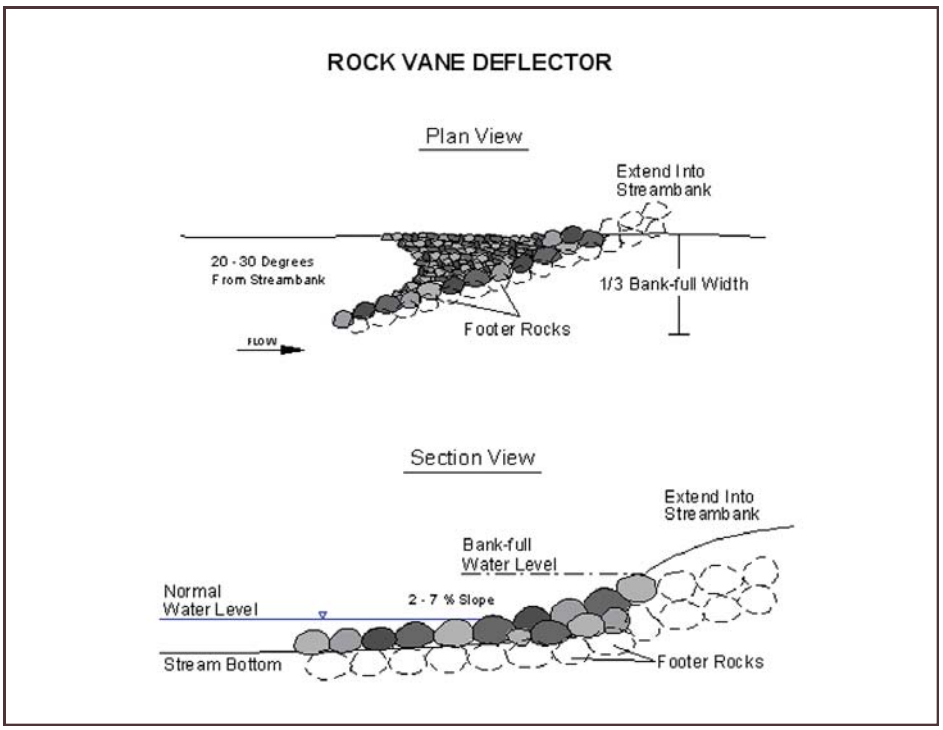


ROOT WAD DEFLECTOR



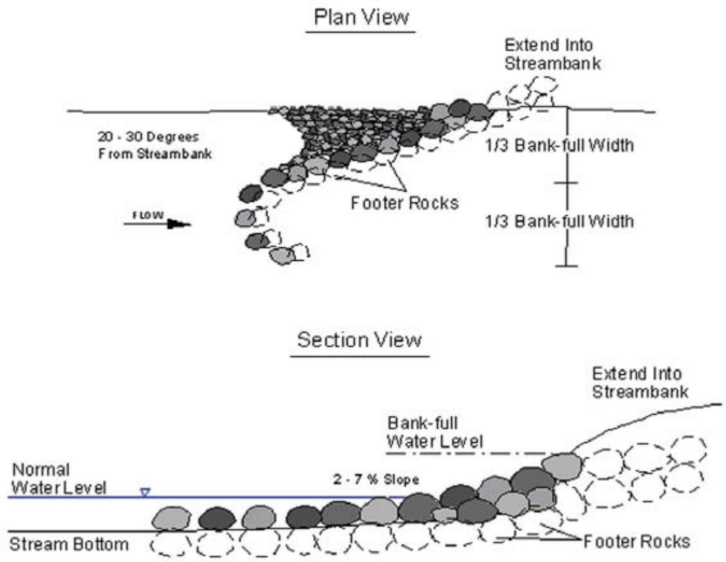


SINGLE LOG VANE COMBO DEFLECTOR
Plan View
20 - 30 Degrees From Streambank
FLOW
Footer Rocks
J-Hook Added
NOTE: Single log and root wad trunk buried in trench with large rock.
Section View
Normal Water Level
5 - 15 % Slope
J-Hook Added
Footer Rocks
Stream Bottom

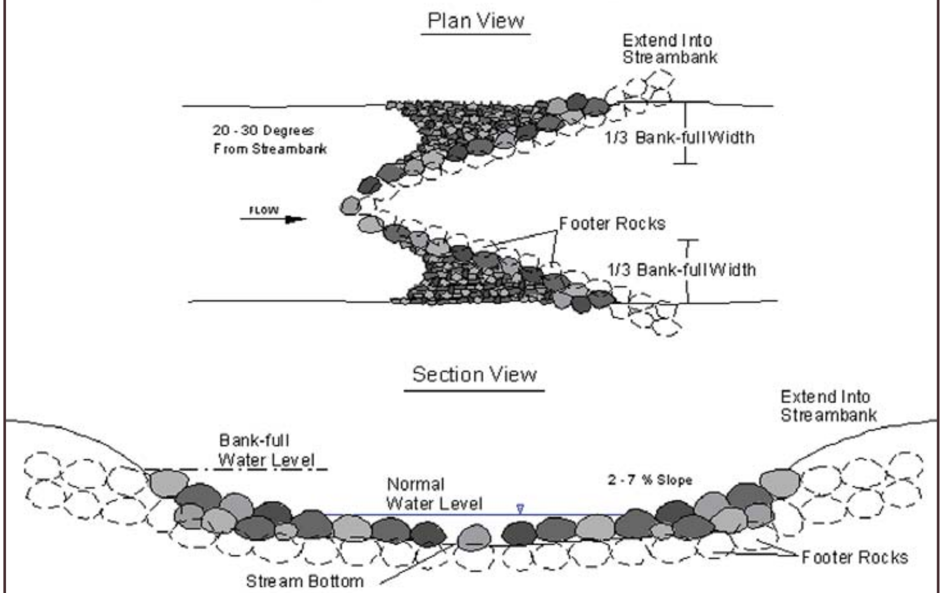


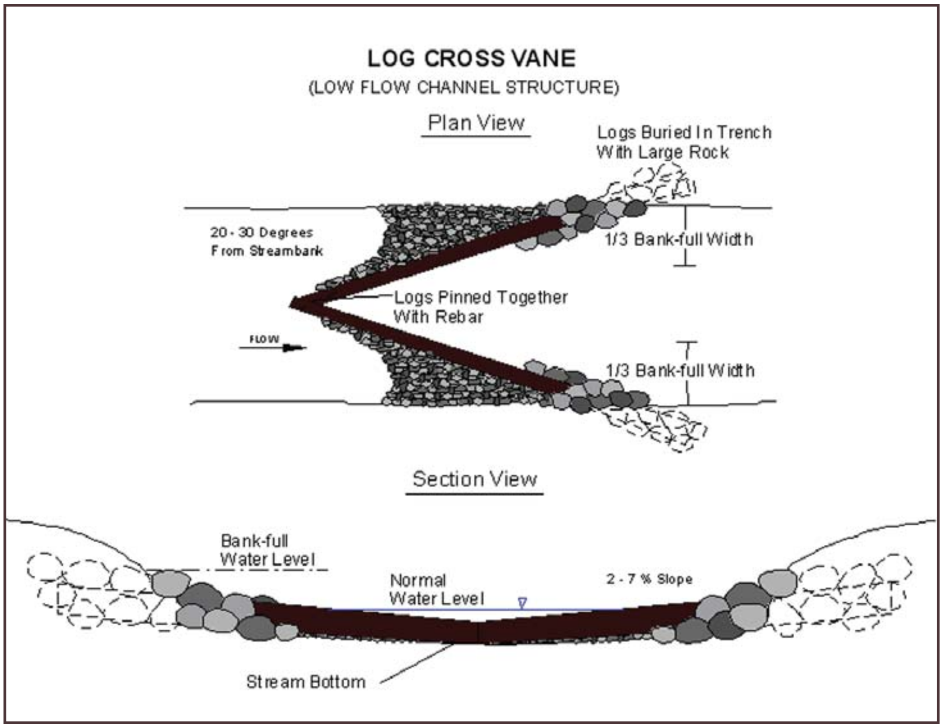
ROCK VANE DEFLECTOR
Plan View
Extend Into Streambank
20 - 30 Degrees From Streambank
1/3 Bank-full Width
Footer Rocks
FLOW
Section View
Extend Into Streambank
Bank-full Water Level
Normal Water Level
2 - 7 % Slope
Stream Bottom
Footer Rocks

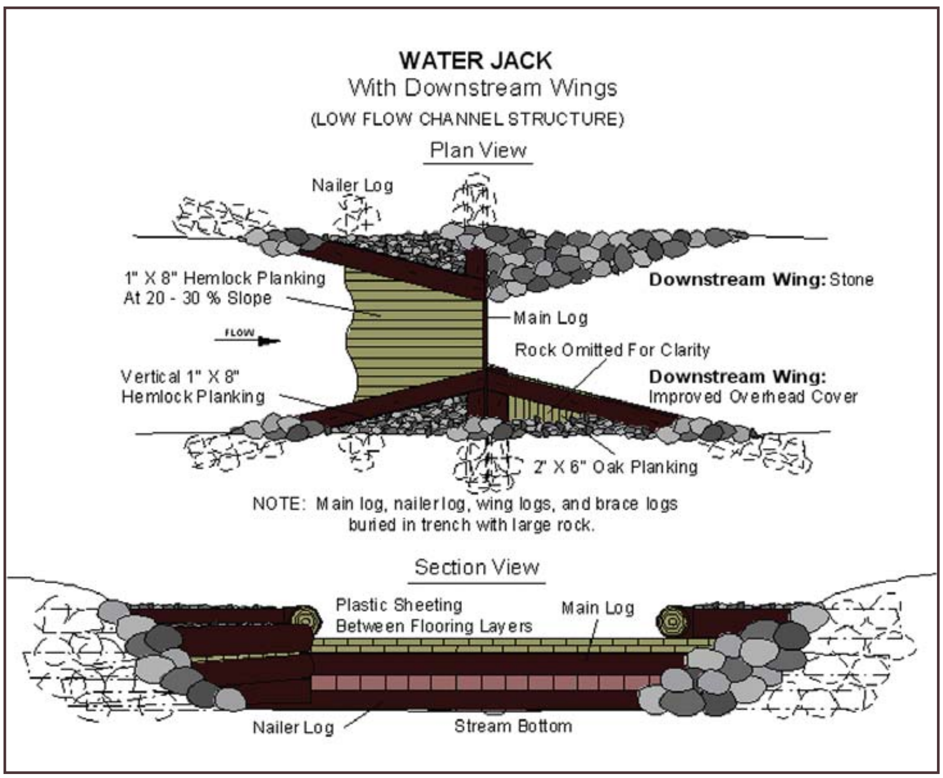
J-HOOK ROCK VANE DEFLECTOR



ROCK CROSS VANE
(LOW FLOW CHANNEL STRUCTURE)

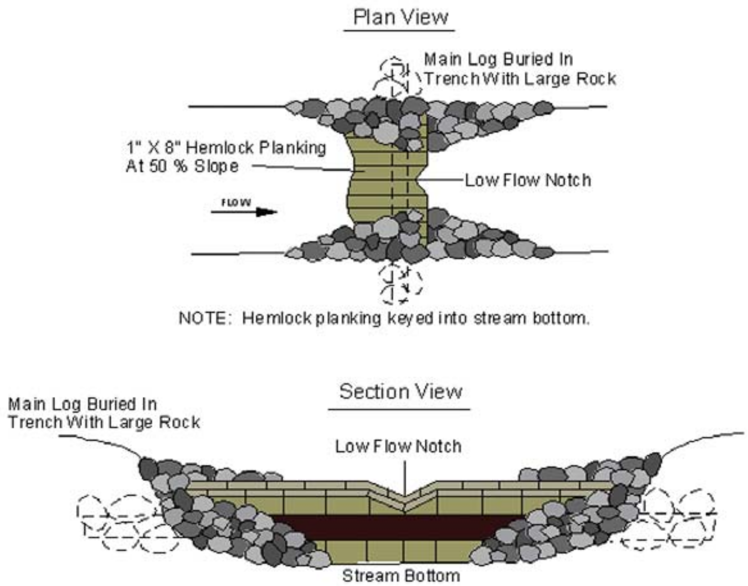



LOG CROSS VANE
(LOW FLOW CHANNEL STRUCTURE)
Plan View
Logs Buried In Trench
With Large Rock
20 - 30 Degrees
From Streambank
1/3 Bank-full Width
Logs Pinned Together
With Rebar
FLOW
1/3 Bank-full Width
Section View
Bank-full
Water Level
Normal
Water Level
2 - 7 % Slope
Stream Bottom

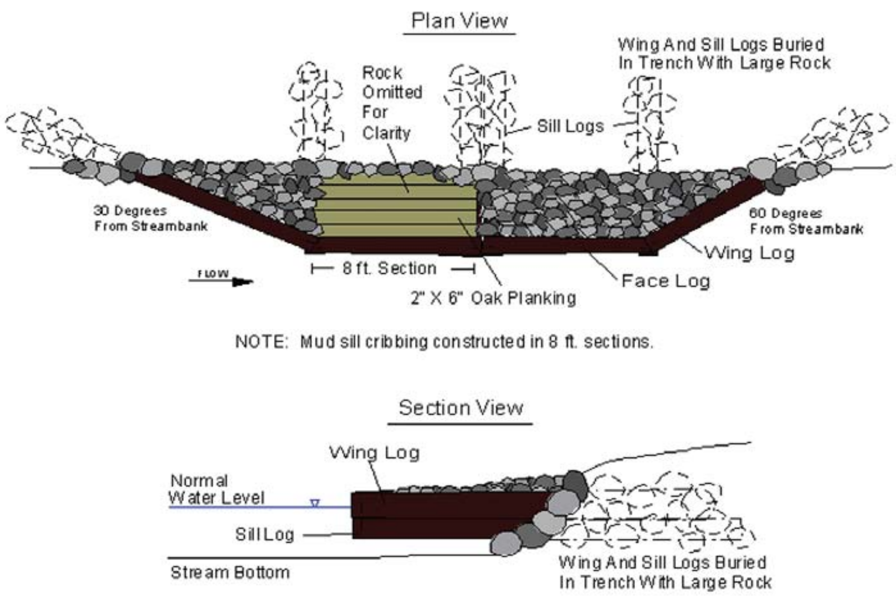

WATER JACK
With Downstream Wings
(LOW FLOW CHANNEL STRUCTURE)
Plan View
Nailer Log
1" X 8" Hemlock Planking
At 20 - 30 % Slope
Downstream Wing: Stone
Main Log
FLOW
Rock Omitted For Clarity
Vertical 1" X 8"
Hemlock Planking
Downstream Wing:
Improved Overhead Cover
2' X 6" Oak Planking
NOTE: Main log, nailer log, wing logs, and brace logs
buried in trench with large rock.
Section View
Plastic Sheeting
Between Flooring Layers
Main Log
Nailer Log
Stream Bottom

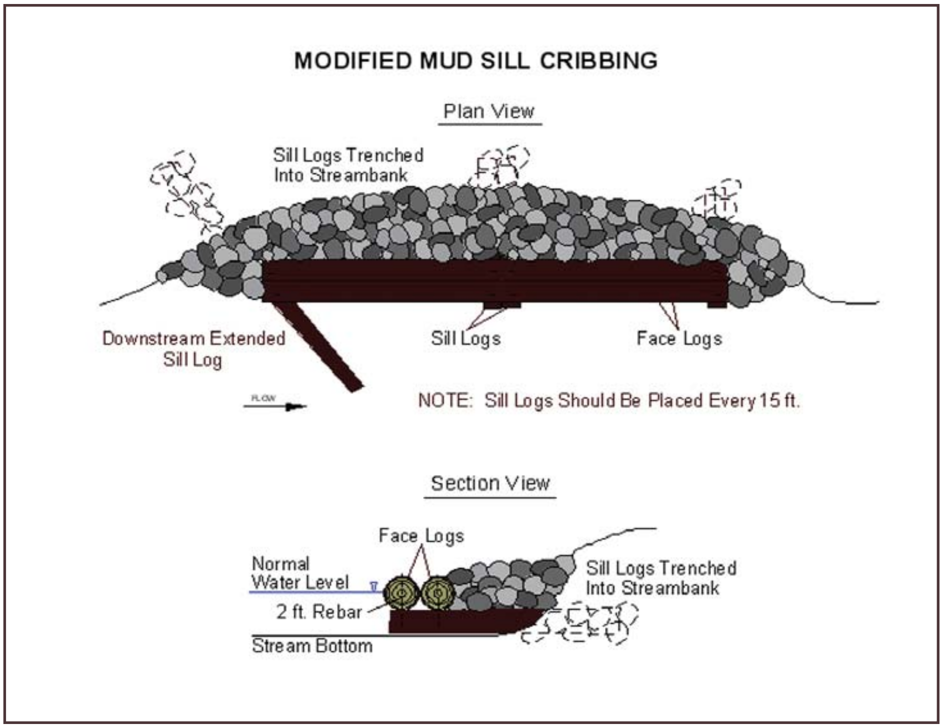
BROOKIE WATER JACK

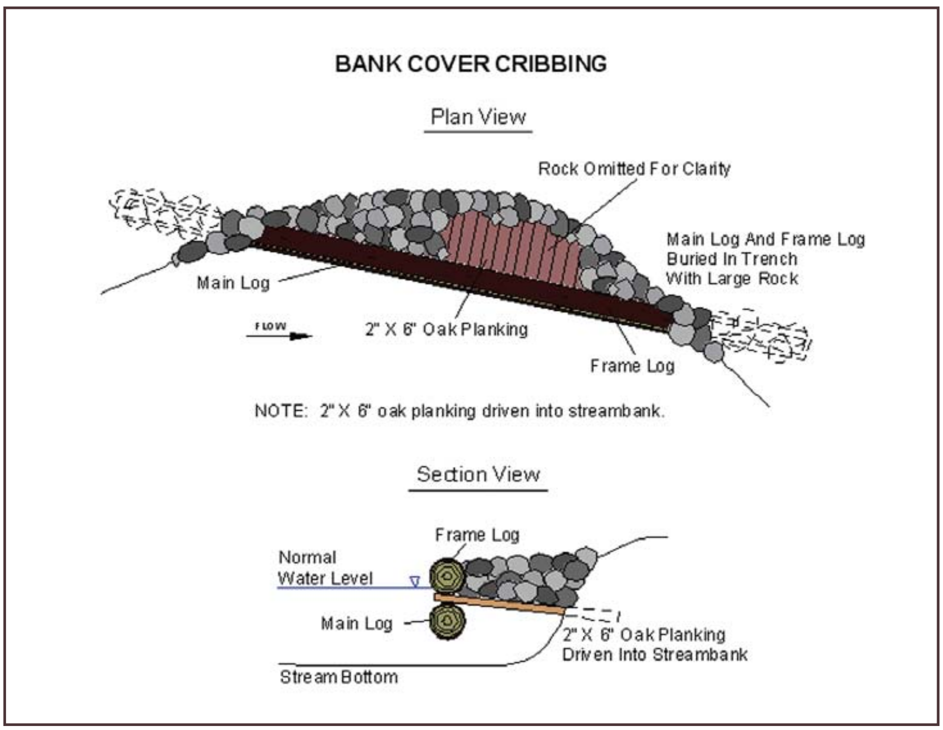
(LOW FLOW CHANNEL STRUCTURE)

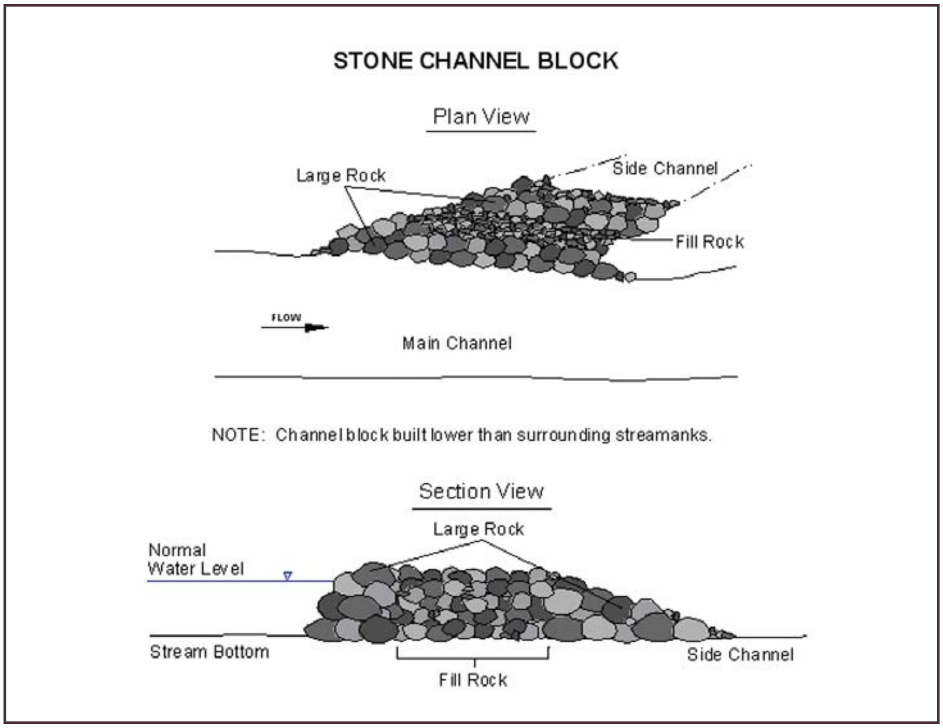


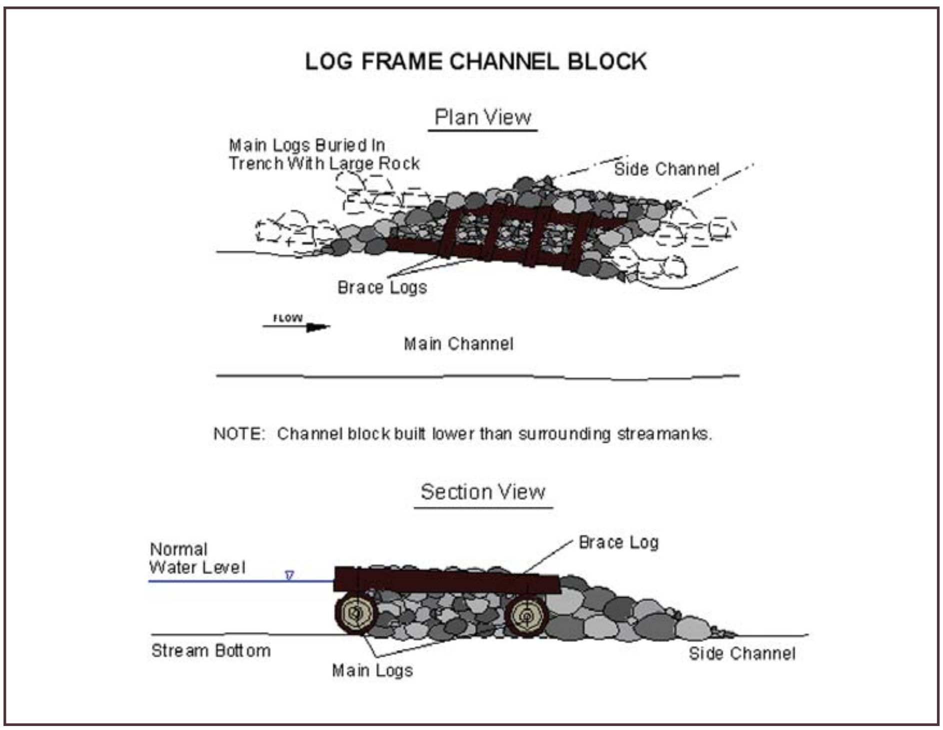
MUD SILL CRIBBING




MODIFIED MUD SILL CRIBBING
Plan View
Sill Logs Trenched Into Streambank
Downstream Extended Sill Log
Sill Logs
Face Logs
FLOW
NOTE: Sill Logs Should Be Placed Every 15 ft.
Section View
Face Logs
Normal Water Level
2 ft. Rebar
Stream Bottom
Sill Logs Trenched Into Streambank


BANK COVER CRIBBING
Plan View
Rock Omitted For Clarity
Main Log And Frame Log Buried In Trench With Large Rock
Main Log
FLOW
2" X 6" Oak Planking
Frame Log
NOTE: 2" X 6" oak planking driven into streambank.
Section View
Frame Log
Normal Water Level
Main Log
2" X 6" Oak Planking Driven Into Streambank
Stream Bottom


STONE CHANNEL BLOCK
Plan View
Large Rock
Side Channel
Fill Rock
FLOW
Main Channel
NOTE: Channel block built lower than surrounding streamanks.
Section View
Large Rock
Normal
Water Level
Stream Bottom
Fill Rock
Side Channel


LOG FRAME CHANNEL BLOCK
Plan View
Main Logs Buried In
Trench With Large Rock
Side Channel
Brace Logs
FLOW
Main Channel
NOTE: Channel block built lower than surrounding streamanks.
Section View
Brace Log
Normal
Water Level
Stream Bottom
Main Logs
Side Channel