TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE
BOISE, IDAHO July 1, 2001

ENGINEERING – NO. 12

DESIGN OF STREAM BARBS

DESCRIPTION

Stream barbs are rock structures that extend into the stream flow to modify flow patterns and bed topography. They are very low structures that should be completely overtopped during channel-forming flow events (approximately a 1.5-year flow event). Channel-forming flow or bankfull is defined as the flow that transports the greatest amount of sediment over a long period of time and controls the channel geometry. Bankfull flow DOES NOT mean flow to the top of the channel bank.

Each stream channel and project site is unique. Geomorphic characteristics, such as meander pattern, width/depth ratio, radius of curvature, particle size distribution, channel gradient, and pool/riffle spacing, all impact the effectiveness of stream barbs. Onsite evaluation of the appropriateness and utility of stream barbs is necessary. They are most effective in gravel and cobble bedded streams with slopes less than three percent.

Stream barbs redirect stream flow with a very low weir and disrupt the velocity gradient in the near-bank region. The low weir section is pointed upstream and forces the water flowing over the weir into a hydraulic jump. Flowing water turns to an angle perpendicular to the downstream weir face causing the flow to be directed away from the streambank. The weir effect continues to influence the bottom currents even when the barb is submerged by flows greater than the channel-forming flow. The disruption of the velocity gradient reduces channel bed shear stress and interrupts sediment transport -- this results in sediment deposition adjacent to the barb. The local flattening of water slope upstream of the barb causes an eddy and sediment deposition. The flow separation caused by the hydraulic jump and flow redirection downstream of the barb creates an eddy, which also promotes deposition.

Stream barbs are used for bank protection measures, to increase scour of point and lateral bars, to direct stream flow towards instream diversions, and to change bedload transport and deposition patterns. Other benefits of stream barbs include reducing the width to depth ratio of a stream channel and providing pool habitat for fish. Although trees with rootwads can be added into barbs to increase habitat value, they increase the risk of voids in the rock fill, poor foundation conditions and increased uplift forces. If fish habitat is limited, consider creating habitat elements separate from the rocks barbs if feasible.

Using stream barbs in conjunction with bioengineering methods is the most favorable combination. The barbs relieve direct streambank pressure from flow and vegetation provides for energy dissipation and sediment deposition. The vegetation is the long-term stabilizing factor.

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GENERAL MATERIAL SPECIFICATIONS

Rock for barbs shall be durable and of suitable quality to assure permanence in the climate in which it is to be used. The rock shall be sound and dense, free from cracks, seams, and other defects that would tend to increase deterioration from weathering, freezing and thawing, or other natural causes. The rock fragments shall be angular to subrounded in shape. The least dimension of an individual rock fragment shall not be less than one-third the greatest dimension of the fragment. Rock will have a minimum specific gravity of 2.5.

Material sizing should follow standard riprap sizing criteria for turbulent flow (Idaho Engineering Technical Note #6) for the design flow and be modified with the following formulas:

$$D_{50\text{-barb}} = 2 \times D_{50\text{-riprap}}$$

$$D_{100\text{-barb}} = 2 \times D_{50\text{-barb}}$$

$$D_{minimum} = 0.75 \times D_{50\text{-riprap}}$$

Once the riprap D_{50} is obtained, use the gradation listed above. When the ratio of curve radius to channel width is less than six, rock sizes become extremely large, and result in a very conservative design.

Rock in the weir section of the barb should be well graded in the D_{50} to D_{100} range. The largest rocks should be used in the exposed weir section of the barb. DO NOT use the Isbash Curve when sizing rock for stream barbs as it results in sizes too small for this application.

Rock sizing depends on the size of the stream, maximum depth of flow, planform, entrenchment, and ice and debris loading. Adjustments may be necessary for your local area.

GENERAL DESIGN GUIDANCE

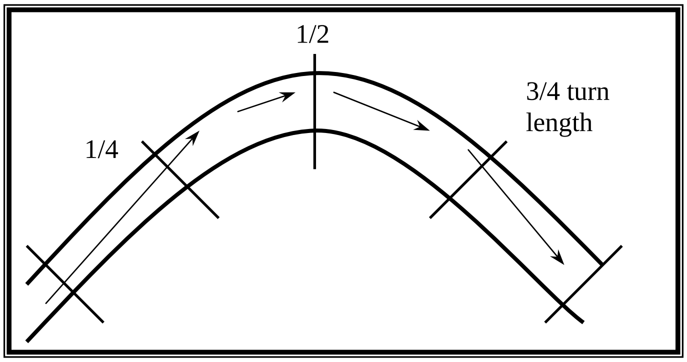
see attached figures for reference

(1) **<u>Location and Number of Barbs</u>** – Stream barbs are typically placed along the outside of a bend where the thalweg is near the streambank. If the thalweg (deepest part of the channel) is in the center of the channel, other bank protection measures should be considered. Stream barbs will not protect banks that are eroding due to rapid drawdown or mass slope failure.

The number of barbs required at any given site will be determined by (1) barb spacing, (2) the length of the eroding meander bend, (3) channel geometry, (4) bedload, and (5) desired effect for overall watershed management.

The furthest upstream barb should be located just upstream of the area that is first impacted by flood flow erosion. This is often above the actively eroding bank and the location can be difficult to determine during low flows. Often barbs do not need to extend to the downstream extent of the eroding bank, as upstream barbs will modify the angle and distribution of velocity, stopping the erosion. In general, in a stream with moderately regular meander patterns, barbs should not be placed downstream of 3/4 of the turn length (Figure 1).

Figure 1.



(2) **<u>Height</u>** – The height of the stream barb (H) is generally determined by the elevation of channel-forming flow discharge (approximately a 1.5-year event). For ungaged streams, channel-forming discharge can be determined using field indicators such as bed features and the presence or absence of vegetation. The channel-forming or "bankfull" elevation is not necessarily the top of the bank; for most streams, "bankfull" is equal to or slightly above ordinary high water.

The structure is intended to function as a weir and is therefore nearly flat (slope should not exceed 1V: 5H) but <u>MUST</u> always have a <u>downward slope away from the streambank</u>. Barbs constructed with flat weir sections may lose a few rocks from the center of the barb resulting in a negative slope and essentially force water closer to the bank.

H_{max} = 1/3 D_{avg} to 1/2 D_{avg}

D_{avg} = average channel-forming flow depth

The relative height between successive barbs is very important. The difference in height between barbs should approximate the energy grade line of the stream regardless of local variations in bed topography.

To reduce scour depths, decrease the barb height. Higher barbs, up to the channel forming flow elevation, cause greater flow convergence, and thus greater scour depths.

(3) **<u>Spacing</u>** – Proper spacing of barbs is necessary to prevent the stream flow from cutting between two barbs and eroding the bank. A vector analysis (plotting the proposed barbs with vectors projecting at right angles to the downstream side of the barb) can give some indication of flow lines and flow interception by subsequent barbs. Given that the flow will leave the barb in a direction perpendicular to the

downstream weir face, the subsequent barb should be placed so that the flow will be captured in the center portion of the barb before the stream flow intersects the bank.

Typically, barbs influence the flow patterns for a distance downstream equal to 5 to 10 times the barbs perpendicular projection into the stream, although there is much local variation.

(4) **Angle** – The structure should project upstream such that the flow is directed away from the streambank. The angle can vary from 20 to 45 degrees from the tangent to the bank depending upon the curvature of the bend and the intended realignment of the thalweg. If the purpose is to maintain a deep thalweg near the streambank, then a tight angle (20 degrees) is required. A vector analysis can be used to estimate the angle required to turn the flow. The downstream side of the barb should be a straight, uniform line because it controls the flow direction.

(5) **Length** – For most barbs, the effective length (L_{eff}) should not exceed 1/4 the channel-forming flow width (W). Barbs that extend beyond this length tend to alter the meander pattern of the stream and the stream flow that may affect the opposite bank. Stream barbs should not be used to change the meander pattern of an entire stream system or to "channelize" the stream flow. Caution should be used anytime a stream barb is installed, especially if the barb is longer than 1/4 the channel width, because they are very powerful hydraulic structures. For bank protection, the barb generally can be less than ¼ the channel-forming flow width of the channel.

Maximum $L_{eff} = W/4$

Barb Length for Bank Protection $W/10 < L_{eff} < W/4$

For the barbs to affect the dominant flow pattern, they must cross the thalweg. Shorter barbs will affect only secondary, near-bank currents. If the calculated effective length results in barbs that do not influence the dominant flow path, then adjustments should be made to the barb length and subsequently the key length and barb spacing. If this is not feasible, other techniques should be considered.

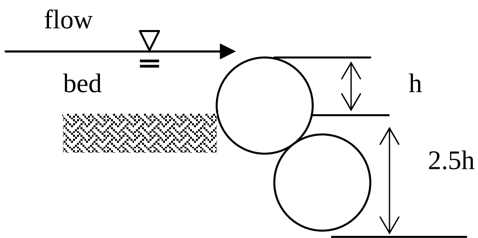
(6) **Profile** – The barb transitions from the exposed barb section to the bank key on a slope of 1V: 1.5H to 1V: 2H. The weir section at the streambank should not exceed the channel-forming flow level (1.5-year flow) as this results in a jetty rather than a barb. The top of the key must be high enough to prevent water from flowing around and eroding behind the structure. Banks that are frequently overtopped will require a more extensive key that extends further back into the bank. Bank material will also need to be considered when designing the dimensions of the key.

(7) **Width** – The width of a barb generally ranges from one to three-times the D_{100}. The width does not need to be more than two rock diameters and can even be the width of a single large rock at the tip of the barb. The barb width may need to be increased (10 to 15 feet total width) to accommodate construction equipment in large rivers or where necessary. Wider structures will result in a more uniform, stronger hydraulic jump. Wider structures should be used if a deep scour hole downstream of the barb is expected.

(8) **Length of Bank Key** – The purpose of the bank key is to protect the structure from flanking due to erosion in the near bank region. The length of the bank key is generally about half of the length of a short barb to 1/5th the length of a long barb or 4 times the D_{100}. Bank key length should not be less than 1.5 times the bank height or eight feet (whichever is greater).

(9) **Depth of the Bed Key** -- The bed key depth should be determined by calculating expected scour depth around the tip of the structure. If a bed key is not incorporated, or if the bed key is too shallow, scour may erode the bed material downstream, causing the rock to fall into the scour hole. The bed key is typically placed to a depth of D_{100}. Note that scour depth will likely exceed the depth of the thalweg (deepest part of the channel).

In lieu of a scour analysis, scour depth can be estimated using the following:



Expected scour depth for gravel or cobble bed streams can be estimated by:

Scour = 2.5*h

Where h = height of exposed rock relative to bed elevation.

For sand, use 3 to 3.5*h

To reduce scour depths, decrease the barb height. Higher barbs cause greater flow convergence, and thus greater scour depths.

(10) **Hydraulics** – The amount of flow forced over the barb can be approximated by the amount of channel area the barb crosses:

$Q_b = A_b/A_t\ (Q_t)$ where

Q_b is portion of channel forming flow over the barb in cfs
A_b is the channel area the barb impacts
A_t is the total channel forming flow area
Q_t is the total channel forming flow in cfs

In order for the barb to have an impact on the stream, Qb/Qt should be greater than 0.1.

The height of flow over the barb should be checked using a weir formula:

$H = (\ Q_b\ /\ C\ /\ L)^{2/3}$ where

Q_b is the flow over the barb in cfs
C is a broad crested weir coefficient generally of about 2.8
L is the total length of the barb

The height of flow over the barb added to the height of the barb should not be more than 120% of the average depth of channel forming flow, or excessive backwater effects will be created.

The shallowest depth of water flow over the barb can be approximated by the formula:

$y_2 = (D_{avg} - h)/2$ where

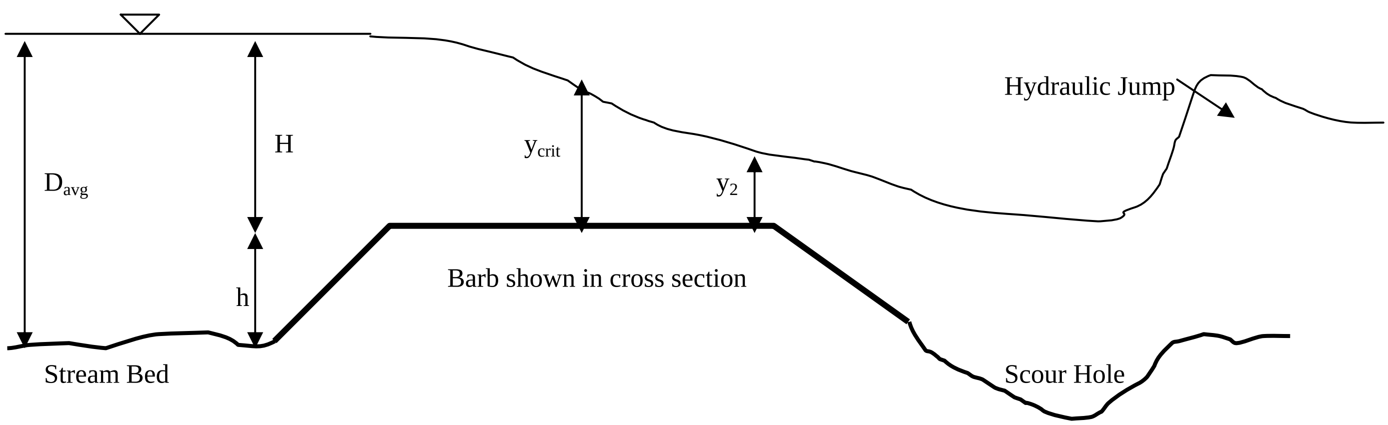
y_2 is the shallowest depth of flow passing over the barb in feet
D_{avg} is the average depth of flow upstream of the barb in feet
h is the average height of the barb above the stream bed in feet

The force of the hydraulic jump can then be estimated by calculating the Froude number:

$F = Q_b/((L\ y_2)\ (g\ y_2)^{1/2})$ where

g is the acceleration due to gravity, 32.2 ft/s^2

A Froude number of >1.7 is required. A Froude number of greater than 2.5 is desired. To achieve a higher Froude number, increase the barb height, h, slightly.



(11) **<u>Construction</u>** – Stream barbs should be constructed during low flow conditions to minimize instream disturbances. Short barbs can be constructed from the bank while long barbs may require the use of the barb surface as a platform during construction. The barb width can be reduced as the equipment works back from the tip of the barb towards the bank. <u>The rock should never be end dumped</u>. Construction should always start at the upstream end of the project site. Alterations

to the design during construction are sometimes necessary -- be sure to have someone on site to insure proper installation and get concurrence from the designer.

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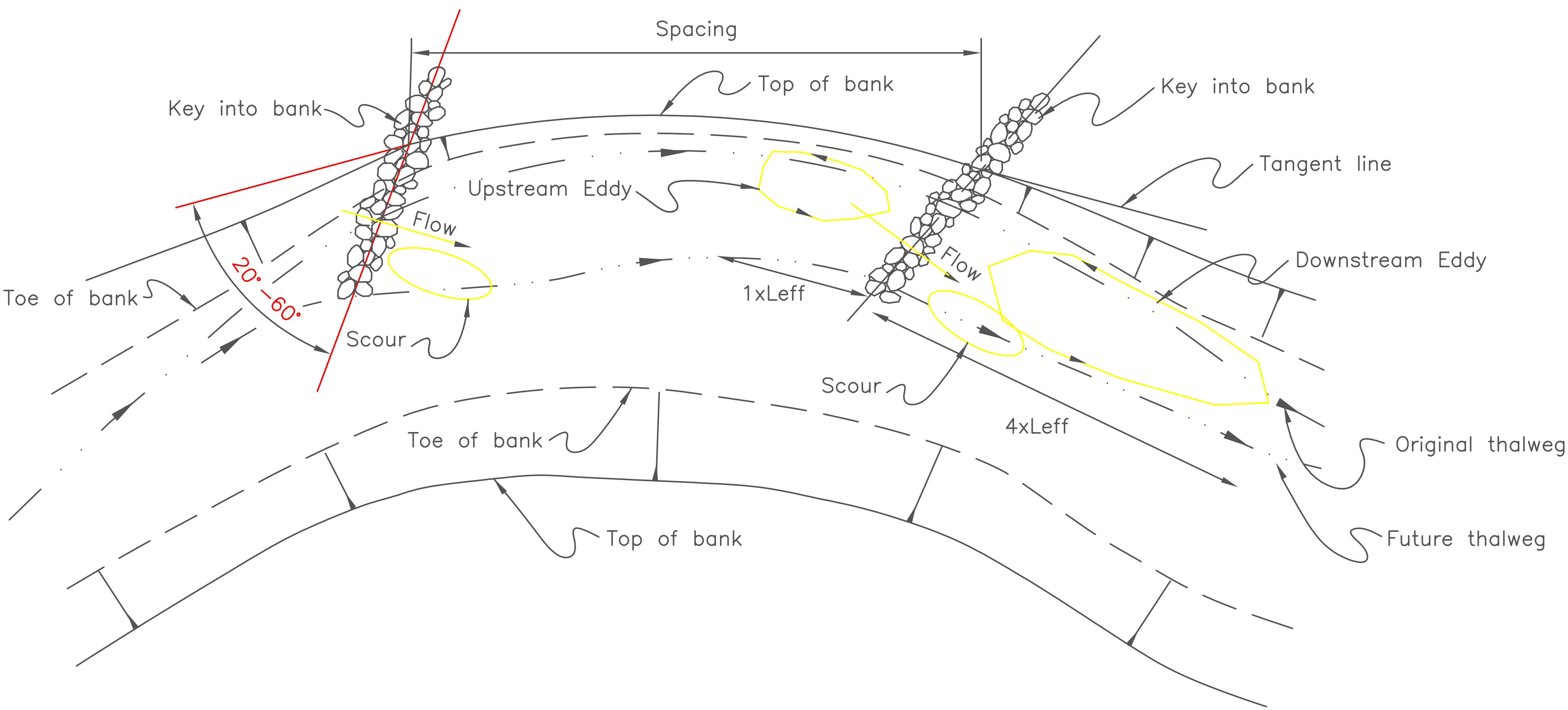
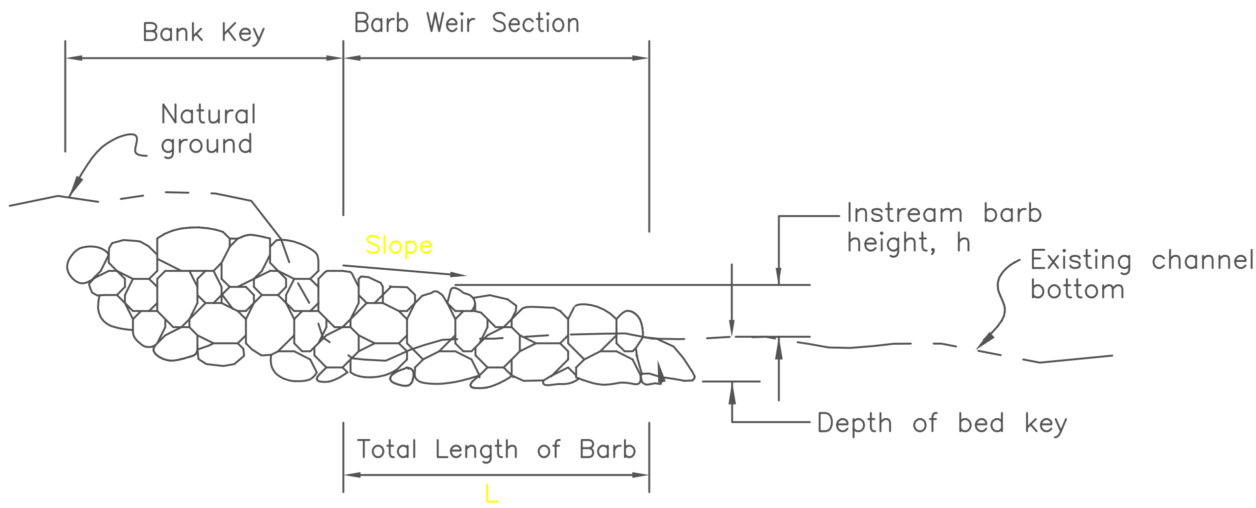
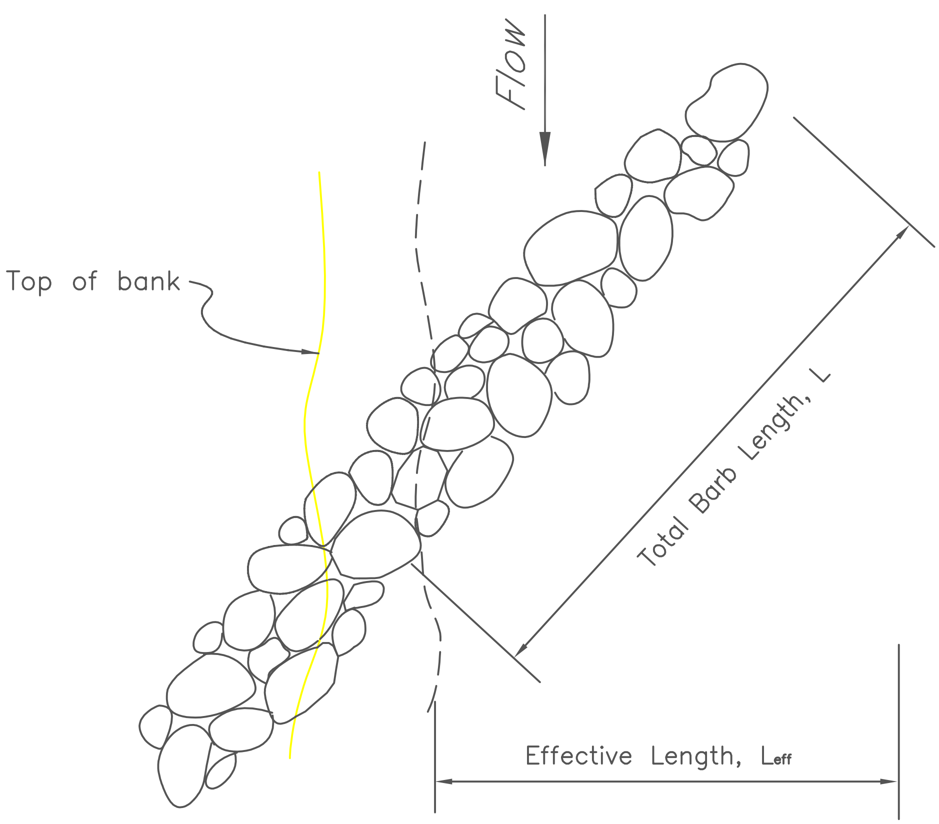


STREAM BARB

Not to Scale



SIDE VIEW



PLAN

STREAM BARB