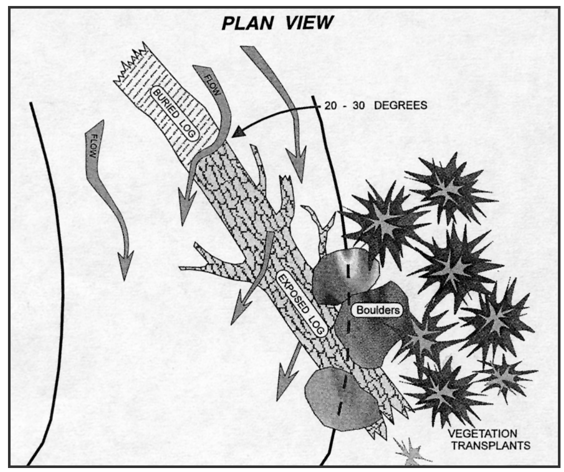
# BARBS / VANES

A barb, or vane, is a low profile, sloping stone sill angled upstream. Barbs help reduce bank erosion by re-directing currents away from the bank, and are commonly spaced along the bank similar to bendway weirs.

## Use barbs/vanes to:

- Reduce bank protection needs (rip-rap size and quantity) and promote natural banks.
- Protect banks for gentle (wide radius) meanders, or relatively straight banks.
- Help deflect ice and woody debris from vegetative bank treatments while they become established.

Barbs are constructed with a low sloping profile and gently “roll” the current away from the bank.




Log-spur bank feature. From Rosgen, 1993a.

## Design and construction techniques

- Design parameters, particularly for shape and orientation, are somewhat subjective.
- Design and installation requires a substantial amount of professional judgment.
- Spacing: variable with meander curve (75 to 150 feet is typical on major rivers).
- Key requirements: keyed into the bank (15 feet typical), and bed (4 to 6 feet typical) for larger rivers.
- Slope of barb: generally replicates natural point bars.
- Length: variable with channel (up to one-quarter base flow width in some cases).
- Barb angle: variable with radius of meander curve and current approach angle (20 to 30 degrees
  from bank is common, but can vary according to design criteria).
- Rock size: according to shear stress and scour (2 to 4 feet diameter rocks are typical).
- Barb elevation: variable, from matching natural gravel bars, to several feet above stream bed.
- Downstream “boil” or turbulence, or upstream eddy, indicates problems with installation.
- Can include a “j” hook at the end.
- Can be constructed out of rock, logs, or a combination of both.

**CAUTION:**

- Erosion (“scalloping”) will occur if incorrectly designed (too high, wrong angle in river, poor site).
- Barbs are not appropriate for tight radius meanders.
- Barbs often perform poorly in strongly aggrading or degrading channels.
- Design barbs for optimum performance at high flow.
- Incorrect design can cause scouring, destructive eddies along bank, and channel shifts.
- Experienced design and installation is important to success. Failure can be dramatic.

# BENDWAY WEIRS

A bendway weir is a low-profile upstream-angled stone sill keyed into the outer bank of a bed. Bendways are used to deflect flows away from the bank and can provide an alternative to rip-rap for bank protection. Bendway weirs reduce erosion by reducing flow velocities on the outer bank of the bend, and by re-directing current alignment through the bend and downstream crossing.

A bendway weir has a gradually sloping profile which shifts the main channel of the river to the outside of the structure. Peak flows continue to use the channel cross section above the weir elevation.

## Applications

- Use on long reaches of relatively straight or gently curving banks that need protection.
- Use to reduce bank protection needs and promote natural banks.
- Bendways should be designed by an engineer and constructed by an experienced contractor.

## Design and construction techniques

- Bendway design varies according to engineering specifications.
- Bendways are keyed into the bank (15 feet is typical).
- Spacing: variable with meander curve and tangent of current streamline (150 feet is typical on big rivers).
- Slope: replicate natural point bars, and sometimes steeper.
- Length: variable with channel width, ususally less than 20 percent of channel width.
- Weir angle: variable with meander curve (30- to 45-degree angle upstream typical).
- Rock size: according to shear stress/scour (2- to 3-foot rocks typical).
- Weir elevation: variable, from matching natural gravel bars, to several feet above bed.
- Permitting agencies will likely require flood modeling and an evaluation of channel capacity, sediment transport, and downstream effects.

**CAUTION:**

- Bendway weirs are generally not appropriate for rivers smaller than 100-feet bankfull width.
- Scalloping (bank erosion) will occur between weirs if incorrectly designed (too high or at the wrong angle in the river).
- Bendways are not appropriate for tightly meandering channels.
- Design bendways with high flow performance in mind.
- Incorrect design can cause the channel to cut a new path on the opposite bank.
- Projects should be designed by qualified, experienced professionals.

# ROCK V AND W WEIRS / CROSS VANES

Rock V and W weirs are used for grade control and adjustment of width-to-depth ratio in existing or reconstructed stream channels. Upstream pointing Vs or Ws are preferred for bank protection because they provide mid-channel scour pools below the weir, which may be used as holding and feeding areas for fish.

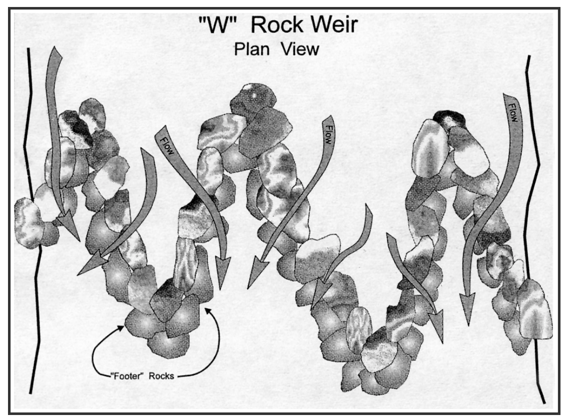
## Applications

- Use to control channel bed elevation and width-to-depth ratio.
- Reduces grade and directs flows to center of channel, which promotes bank stability.
- Can be used for irrigation diversion.
- Permanent bed elevation will not adversely affect channel stability.
- Provides wide shallow channels.
- Use “V” shape for narrow channels; “W” shape for larger channels.
- Adequately sized rock is usually available.

## Design and construction techniques

- Rule of thumb: maintain 1.5 feet or less of drop over each structure.
- Large angular boulders are most desirable to prevent movement during high flows.
- Require footer rocks keyed into the bank to prevent scour and undermining.
- An increased weir length will cause less fluctuation in water height with change in discharge.
- Pools rapidly fill with sediment in streams carrying heavy bed material loads.
- Boulder weirs are generally more permeable than other materials and might not perform well for diverting flows in irrigation applications.
- Designs should match natural width-to-depth ratio and avoid restricting channel cross sections.
- Downstream orientation can serve specific functions, but use caution to prevent failures.
- With center at lower elevation than the sides, weirs will maintain a concentrated low flow channel.

This crossvane weir is designed to control width-to-depth ratio alignment at a bridge cross section. **Caution:** Sediment transport can be reduced causing channel instability in high bedload rivers.



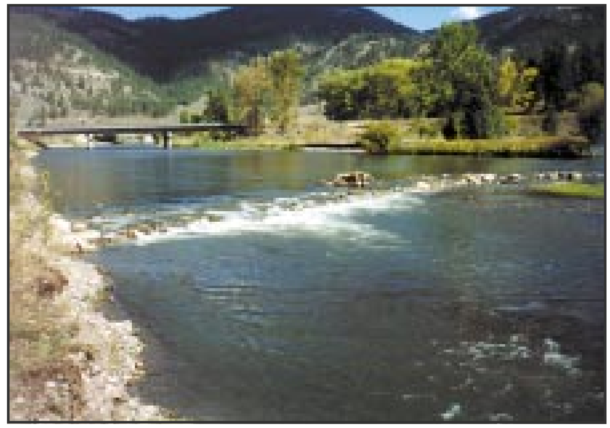

“W” rock weir. From Rosgen, 1993a.

**CAUTION:**

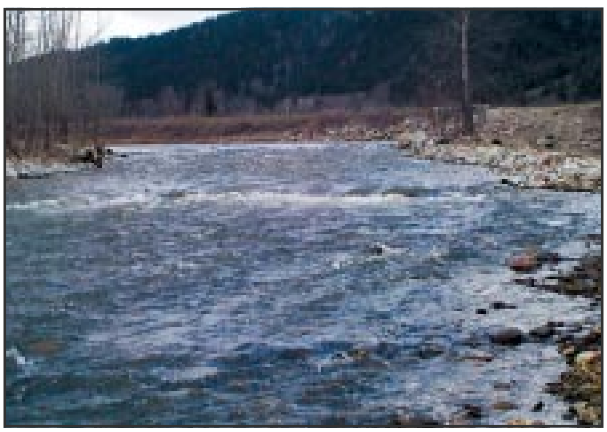
- Improper design (often excessively high elevation, construction of channel, or poor alignment) of structure can cause scouring (“whirlpool effect”) and destabilize channel.
- Weirs placed in sand bed streams are subject to failure by undermining.
- Weirs placed in strongly aggrading systems may become ineffective as sediments fill around structure.
- Potential to become low-flow fish migration barriers.
- Must avoid constricting high bedload channels.
- An experienced hydrologist or river engineer should assist with design of larger structures, or in unstable stream environments.

## ROCK V AND W WEIRS / CROSS VANES (*continued*)

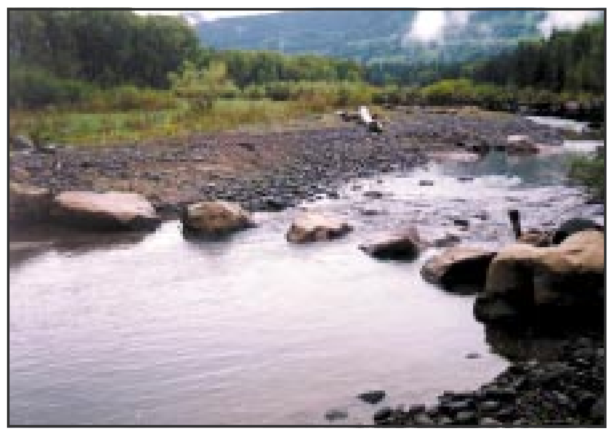
These large weirs eventually failed because they were built too high, and restricted sediment passage.



The same structure at left, prior to failure. The warning signs were apparent, notably the elevation of apex above the bed, and 2ft + high drop over the flat sill.



Large weirs must frequently be built in series to avoid large drops exceeding structural stability. Construction of weirs in high bedload transport streams always carries some risk of failure.



True “V” weirs generally have a row of cap rocks with spaces, rather than a flat sill. This promotes bedload passage (to some extent), but does not always work well for irrigation diversion needs.

Large weirs on unstable rivers can run to over $100,000 and still carry substantial risk of failure. Bedload deposition and scour can result in channel changes that bury weirs and scour away footings. Rivers may quickly cut new channels around the structure.

# CHECK DAMS

Check dams are rock, wood, earth, and other materials placed across the channel and anchored in the streambanks to provide a "hard point" in the streambed that resists downcutting. Check dams can also reduce the upstream energy slope to prevent bed scour.

## Use check dams:

- On intermittent or ephemeral gullies that are actively downcutting.
- To re-establish base grade or to build the bed of an incised stream to a higher elevation.
- To improve bank stability in an incised channel by reducing relative bank heights.
- To create fish barriers to protect genetically pure fish populations.

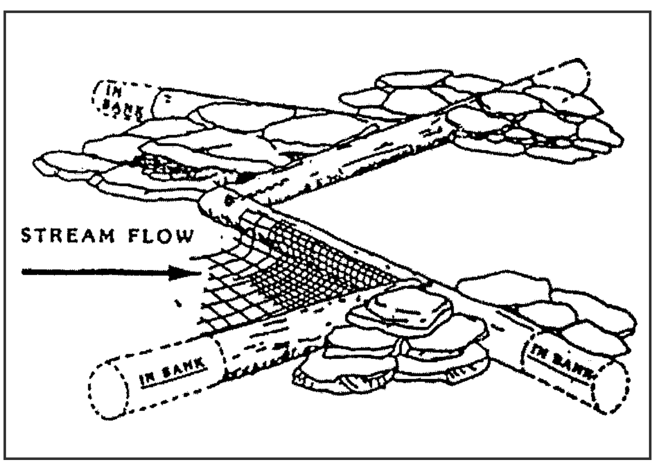
Check dams are most often used to stabilize actively downcutting channels (gullies), and are not generally recommended for use in perennial channels.

## Design and construction techniques

- Common materials include rock, logs, wire fence and rock, and gabion baskets.
- Key the dam into bed and bank below scour depths and effects of lateral movement.
- Select rock size, spillway and apron, and crest shape based on a 25- to 100-year flood event.

**CAUTION:**

- Generally use check dams only on actively downcutting, ephemeral gullies.
- Downstream channel downcutting may continue and eventually undermine the dam.
- Siting of large structures may require geotechnical engineering.
- In perennial streams, check dams may block fish migration during low flows.
- An experienced hydrologist or river engineer should review the design of grade control structures.




Low stage check dam. From Seehorn, 1985.

# RIP-RAP

Rip-rap and other hard armoring methods should be discouraged for stabilizing banks. Impacts on channel stability and fisheries can be significant. Consider other options, such as root wads, geotextiles, barbs, vanes, and bendway weirs. Where high strength is needed, consider turf reinforcement mats with a rock toe.

## Use rip-rap only when:

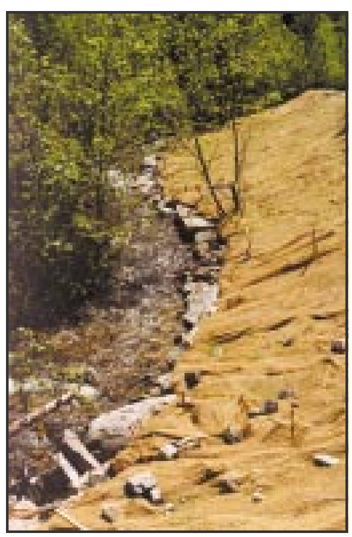
- Long-term durability is needed.
- Design discharge and shear stress is high.
- There is significant threat to high-value property.
- Impacts to channel stability and fisheries would be minimal.
- There is no practical way to incorporate vegetation or wood into the design.
- Effective alternative practices are unavailable.

## Design and construction techniques

- If you must install rip-rap, use it with bio-engineering and vegetative plantings to stabilize the upper bank.
- The key must be placed below scour depth.
- The toe is the most important part of a rip-rap project; this is the zone of highest erosion.
- Rock is unnecessary above high water mark.
- 2:1 is the recommended slope; 1.5:1 is the steepest slop on which rip-rap will stabilize.
- Rock must be angular, not rounded, for greatest strength.
- Rock is sized according to shear stress criteria for engineered designs.
- Filter fabric is needed where sandy textures will result in loss of fines through rock.
- Can be vegetated (see Pole Plantings, page 5.10).
- Rip-rap is flexible and not impaired by slight movement from settlement.

An engineered rip-rap bank provides a high degree of protection, but diminishes natural river values.

A well designed rip-rap job has 2:1 slopes and does not encroach on the river. This bank could probably have been stabilized using geotextile and vegetative methods with equal success.



This bank treatment has a rip-rap toe but uses geotextile for the bank and is a good compromise solution.

HARD ENGINEERING METHODS

## RIP-RAP (*continued*)

Receding bank upstream of a rip-rap job will eventually lead to failure.

Rip-rap on channelized reaches will limit the ability of the stream to re-establish equilibrium.

Concrete is generally not acceptable for rip-rap.

Erosion has moved downstream below this rip-rapped bank.

### Consider using softer vegetative techniques to stabilize banks whenever possible.

**CAUTION:**

- Do not use rip-rap where vegetative or soil bioengineering methods are viable.
- Rip-rap should not extend above the bankfull elevation.
- Rip-rap can be expensive if materials are not locally available.
- Install fabric or gravel bedding to prevent piping of fines.
- The design slope should not be steeper than 1.5:1.
- The bank should be sloped back to minimize rip-rap encroachment on the river.
- Keyed rock toe and key at ends of project are essential to long-term performance.
- Rip-rap may increase velocities and depth along treated bank, with significant impacts up and downstream.
- Rip-rap frequently interferes with natural stream dynamics, shifting problems to adjoining banks.

# GEOGRID / GEOWEB CELLULAR CONFINEMENT TECHNIQUES

Geoweb cellular confinement systems can be used in a variety of configurations, including flat mattresses, stacking layers, and shapes assembled from combinations of baskets and mats. Cellular confinement systems can be vegetated for aesthetic or habitat purposes.

## Use geoweb:

- Near vertical retaining walls on steep banks where sloping options are limited.
- To reduce rip-rap encroachments by constructing a steeper face above water levels.
- On engineered channels.
- To reinforce fords (using mattress style geoweb).

A cellular confinement system can be effective for steep slope stabilization and revegetation.

## Design and construction techniques

- Geoweb can be cost-effective where a structural solution is needed and other materials are not readily available or must be brought in from distant sources.
- Fill material can be earth or rock depending on the application.
- Geoweb can be used with geotextile fabric and vegetative plantings to stabilize the upper bank.
- A stable foundation is required: often use a rock toe for river bank applications.
- Can be used on steep slopes (nearly vertical).
- More costly than rip-rap if rock is readily available.

**CAUTION:**

- Not appropriate for many instream applications.
- Best used above high water levels for bank stabilization.
- Requires experienced design and construction if installed on more extreme slopes or as retaining walls.

# GABIONS

Wire gabion baskets can be used in a variety of configurations, including rectangular baskets, flat mattresses, and combinations of the two. Gabions can be vegetated for aesthetic or habitat purposes, but plant survival may be limited by poor growing conditions.

This gabion basket was undercut because of inadequate footing.

## Applications

- Use gabions to make nearly vertical retaining walls on steep banks where sloping options are limited.
- Gabions can also form small bridge abutments, or headwalls for culverts.
- Gabions can be built where abundant 4- to 6-inch rock is available, and larger rip-rap is scarce.

## Alternatives

- Live Crib Walls (steep slopes), see 6.12
- Geoweb Cellular Confinement (steep slopes)
- Geotextile Banks (1.5:1 slopes or less)

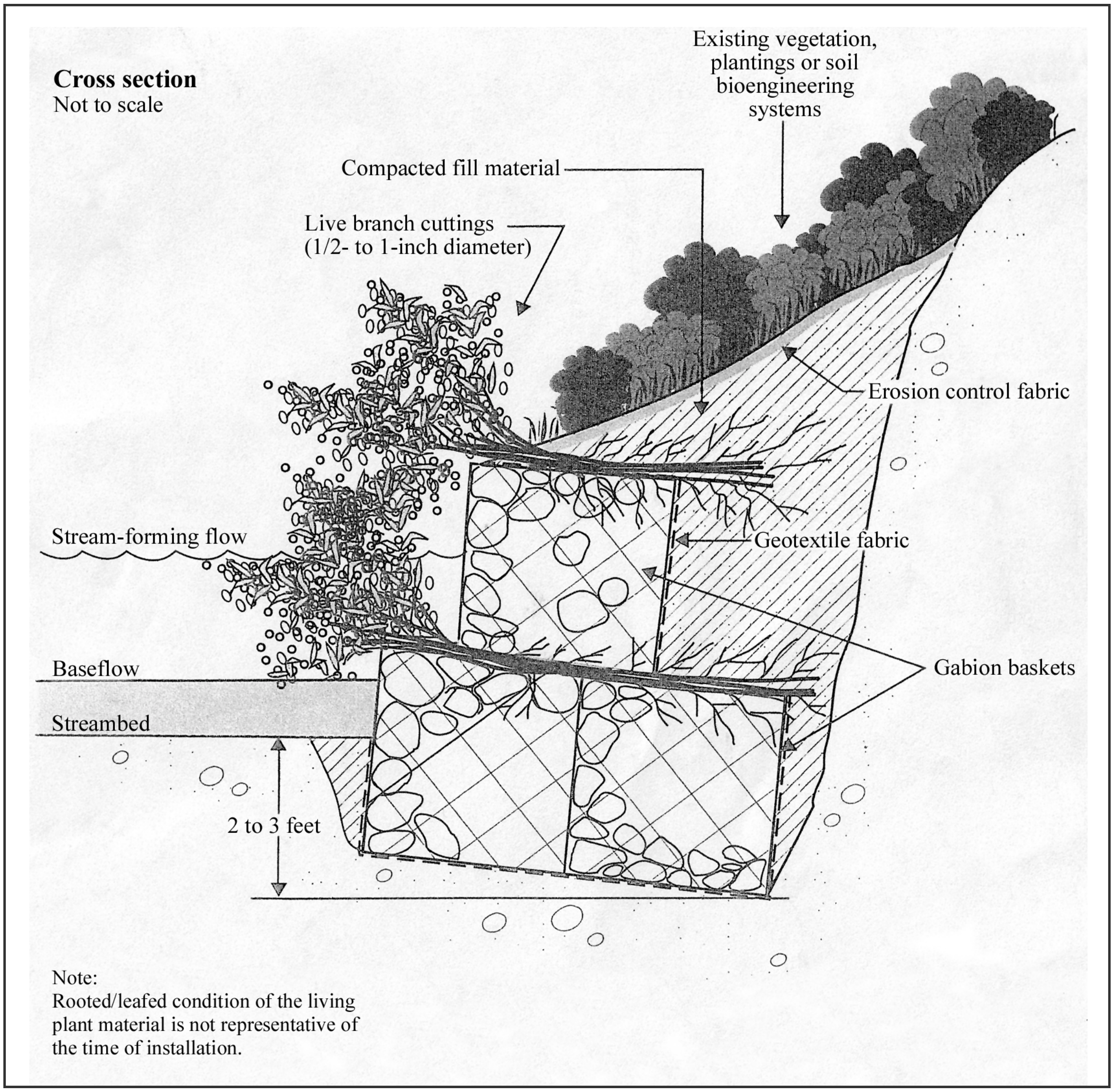
## Design and construction techniques

- Gabions can be cost-effective where a structural solution is needed and other materials are not readily available or must be brought in from distant sources.
- Typical rock size is 4 to 6 inches.
- Use bioengineering and vegetative plantings to stabilize the upper bank.
- Adding soil to the basket will allow inserted cuttings to become established.
- A stable foundation is required, often uses a rock toe to bankfull elevation.
- Gabions are available in vinyl-coated wire and galvanized steel to improve durability.
- Rectangular baskets and flat mattresses are available.

**CAUTION:**

- Typically provide very poor fish habitats.
- Not appropriate in high bedload transport streams for bank stabilization or instream hydraulic structures.
- Abrasion or corrosive conditions can cut single or double wire baskets within 2 to 3 years.
- Wires can be hazardous for fishermen and boaters, and may be unsightly.
- Will not resist large lateral earth stresses from behind the gabion wall without special design.
- Can be labor intensive to install.

## GABIONS *(continued)*




Vegetated rock gabion details, cross section view. 210-vi-EFH, December 1996.

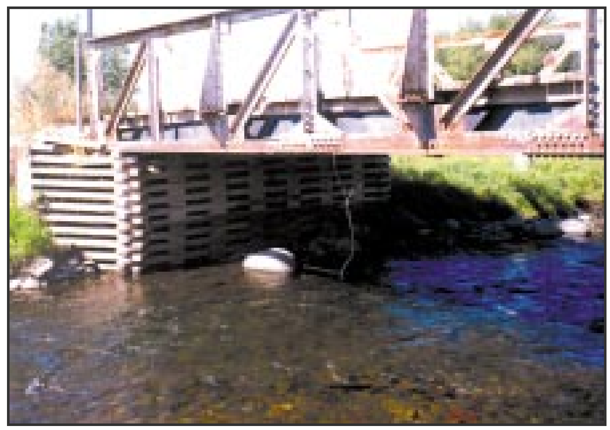
# RETAINING WALLS

## Rock, timber crib, concrete, gabion

Median barriers don't usually make very good bridge abutments, or retaining walls.

An engineered gabion wall with a rock toe prevents abrasion of wire and undercutting of the footing.

Rigid structures such as median barriers rarely afford long-term success for bank stabilization.



A timber crib wall can use dimensional or raw logs.

### Design and construction techniques

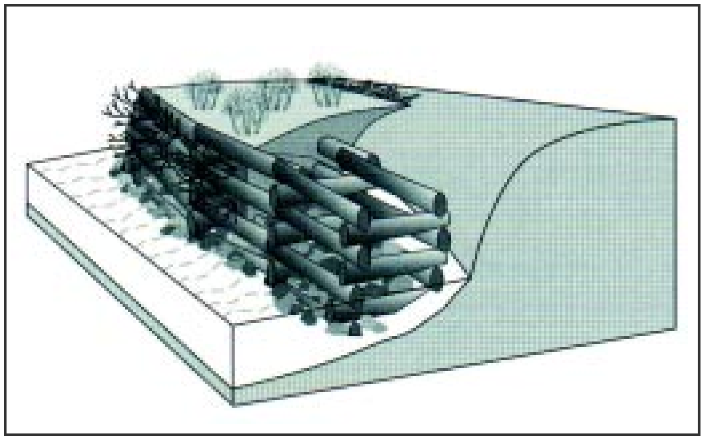
- Retaining walls require a solid footing keyed into the bed below scour depth.
- Walls must be designed to resist lateral pressure from behind wall.
- In unstable materials or for walls greater than 10 feet high, hire a qualified professional to design the wall.

**CAUTION:**

- The stream environment is a dynamic, flexible system.
- Use of rigid structures such as concrete walls, median barriers, gabions, and log sills frequently results in failure during natural channel adjustments.
- Avoid long, continuous retaining walls in streams.
- Retaining walls typically provide very poor fish habitat.

# LIVE CRIB WALL

Live crib walls are box-like, interlocking untreated logs or timbers filled with alternating layers of soil material and live branch cuttings. Mature vegetation eventually takes over the structural functions of the cribbing. Crib walls are a possible alternative to gabion baskets.



Live crib walls can provide an alternative to gabion baskets for stabilizing steep banks.

## Crib walls:

- Protect streambank with near-vertical banks where bank sloping options are limited.
- Afford a natural appearance and immediate protection, and they promote woody vegetation.
- Can be effective where a low wall might be required to stabilize the toe and reduce slope steepness.
- Are appropriate above and below water level where stable streambeds exist.

## Design and construction techniques

- Cribbing may be raw logs or dimensional lumber.
- Crib slots must retain backfill material (streambank rock or cobbles).
- Crib should be anchored at least 6 feet into the banks.
- Alternating layers of fill and branch cuttings can be compacted into fill to provide vegetated walls.
- When possible, should be used with vegetative plantings to stabilize the upper bank or structure.
- Use untreated materials.

**CAUTION:**

- Keying cribs into banks requires a backhoe or excavator.
- Consider sloping bank back instead of vertical stabilization to reduce project costs.
- Crib walls are subject to undermining in downcutting channels.
- On slopes greater than 10 feet high or subject to mass failure, crib walls should be designed by a qualified professional.
- Crib walls are susceptible to damage from debris like ice, flooding, and rot.