Tennessee Cedar Revetments - An Improved Twist on an Old Theme.

Dennis Gregg, Executive Director, Obed Watershed Community Association
John McFadden, Cedar City Consulting and TN Environmental Council

The use of woody material to stabilize stream banks has a long history reaching back to the Civilian Conservation Corps. Large logs are used for building vanes, palisades, and cribs to deflect the current and protect the bank from further erosion. Smaller branches and tree tops anchored to the bank, referred to as revetments, have been used to trap sediment as a technique to rebuild the slope. Brush mats are a variation on that theme, used when a bank has been reshaped to protect the bank (and trap sediment) until the shrub and tree species planted in the bank have developed sufficient root systems to hold the new bank. More recently, coir "logs," originally developed for sediment control, have been used effectively as a technique for toe protection and for trapping in-stream sediment to rebuild unstable eroded banks.

Both the UT Forest Resources Ag Research and Education Center and Tennessee Department of Environment and Conservation (TDEC):

> "Cedar trees stabilize eroding banks, add roughness to the stream channel capturing silt and providing aquatic habitat. [Revetments] increase the potential for capturing fine particulate organic matter, food for many benthic (bottom-dwelling) organisms. Anchor a row of 6 feet long cedar trees along the bank toe. A second row may be installed if necessary as a cost effective method of streambank stabilization and aquatic habitat improvement."
>
> University of Tennessee, Forest Resources Ag Research and Education Center, Cumberland Forest Unit, "Hornyhead Branch Restoration Techniques."
> (http://forestry.tennessee.edu/CUrestore.htm)

> "One successful method of streambank stabilization is known as bioengineering. Bioengineering uses natural materials such as trees, roots and logs to divert water away from a streambank and stabilize the bank. This drawing illustrates a cedar tree revetment project which uses live cedar trees anchored to the base or toe of the bank. Cedars are bushy and slow to rot. As sediment collects in their branches, they provide a natural seedbed for streamside trees such as willows and sycamores to take root and grow."

“Landowner’s Guide to Streambank Protection and Stabilization,” Wendy Smith, Melanie Catania and Dan Eagar, 1999. Tennessee Department of Environment and Conservation

The Natural Resource Conservation Service (NRCS) describes in some detail the use of both cedar revetments and coir logs (Chapter 16 Streambank and Shoreline Protection, United States Department of Agriculture, Natural Resources Conservation Service, Part 650 Engineering Field Handbook, 1996). Traditional tree revetments often use cedar, when available, because of its resistance to rot and the flexibility of its branches. Trees are selected for dense growth to maximize surface area for trapping sediment and absorbing the stress forces of the water.

The Tennessee Cedar Revetment (TCR)

While the technique of using cedar trees and branches has been used effectively in many applications, the practice does have limitations. Uncontrolled movement of the small branches can prevent sediment from attaching and from trapping particularly the smaller particles that may be temporarily in suspension. This is less of a factor when the heavier bed load is in motion. Coir logs also have limitations. The “hairiness” of the coir fibers is very effective at trapping small particles in suspension, which is why they are used extensively for erosion control, however the lower density (7 lbs/cu.ft.) logs can be overwhelmed by bed load sediment, compressing under the load and losing their shape, while the higher density (9 lbs/cu.ft.) gives up much of the flexibility necessary to conform to an uneven stream bank and provides less space for the entrapment of sediment.

The Tennessee Cedar Revetment (TCR) was developed to maximize the effectiveness of using locally harvested cedar trees and 700 gram coir matting while overcoming the above mentioned deficiencies by combining the two techniques into a relatively uniform product that can be installed without heavy equipment. In those parts of Tennessee and the nation where cedar trees are common, access to material through land clearing, fencerow or pasture maintenance, or thinning practices where cedar lumber is the goal is not difficult and cedars readily resprout so a continuous “crop” of cedar material might be harvested.

One can think of the TCR as a “burrito” constructed with small scrub cedar trees and branches as the filling and 700 gram coir matting as the “tortilla” or “wrap.” The coir is cut to a 10 ft. length which provides a wrapped length of 10 ft. with 12 – 20 inches of a cedar trunk or large branch sticking out of each end. The exposed woody material provides the overlap between revetments, thus creating an interlocking bank protecting structure. In order to provide a degree of rigidity to the revetment, typically two cedar trees or tops are used, each 7 - 12 feet in length, oriented in opposite directions and overlapping. Loose branches are used to provide for a uniform density the length of the revetment. The revetment is rolled and compressed by hand with the finished diameter ranging from 14 - 22 inches. The art of judging when there is enough material, and the mastery of a compressive rolling technique is the key to an effective, strong revetment. The finished product is flexible enough to be bent to the shape of the bank, but stiff enough to be carried by one or two people. When freshly made, the revetments weigh from 40 to 70 pounds. The TCR may be fabricated into any length or diameter needed, however, limited by the number of people that can participate in the rolling process and the ability to transport extra-long revetments.

By wrapping the cedar in coir matting, the branches are protected from the vibration of the current and this, combined with the sediment trapping properties of the coir itself, greatly speeds up the rate at which the revetments becomes “filled” or embedded with sediment. The cedar provides structural strength to the coir matting so that the shape and volume is maintained even as it fills with sediment. The combined product is less expensive than coir logs, but has the advantage of being a relatively uniform yet flexible product for installation.

## Development History

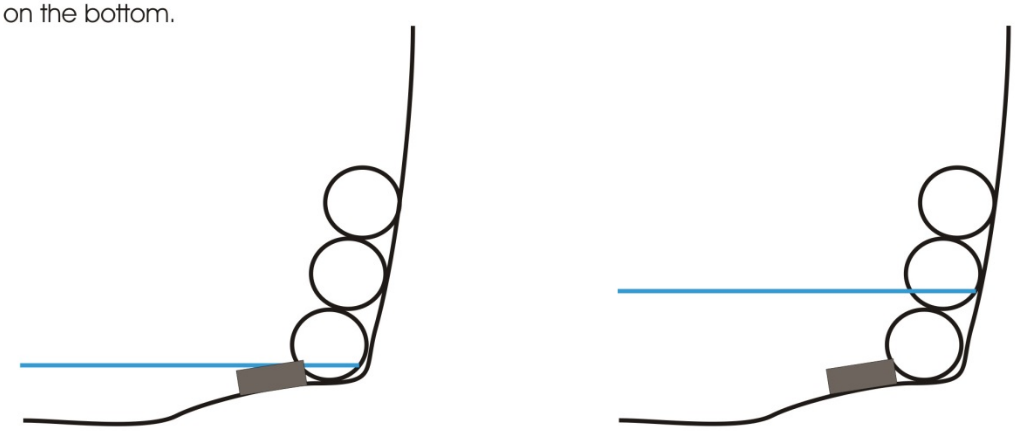
To the best of our knowledge, the use of the TCR was initially developed by Gary Moody (Jen-Hill Construction); however Mr. Moody used jute for the matting wrap. He shared his method with John McFadden in 2003, when Dr. McFadden was working with the Tennessee Scenic Rivers Association. The use of coir was adopted by McFadden when working for the Harpeth River Watershed Association and later with the Tennessee Environmental Council, and the construction and application of the TCR was further refined by Dennis Gregg in his work with the Obed Watershed Community Association over the past five years.

## Applications

Use of the TCR is most effective and appropriate when stream bank erosion has occurred, the stream channel is wide enough for typical high flows, but the banks are still eroding. It fits well in situations where the streambanks are vegetated with trees and other woody species and where removal of the vegetation to reshape the bank would be disturbing to stream health and function. It can also be used to treat undercut banks that are subject to collapse. Depending on the geomorphology, it may be combined with rock toe protection and/or rock vanes to prevent future erosion. It is always combined with a herbaceous and woody planting program, in some cases planting grasses and low growth bushes in early fall behind the revetment followed by live stakes and other woody vegetation the following late winter or early spring, once the revetments have filled with soil.

Typical cross-sections are included in Figures 1 – 3. Depending on the nature and size of the stream, the first layer may be above normal low flow, at normal low flow, or below normal low flow. Sometimes one layer of revetments is used, either to fill undercut banks, or to help create a bench within a channel. More often, multiple layers are used, usually extending no higher than 2/3 total bank height. Rock toes are often used in combination with the TCR to prevent future toe erosion, but may be omitted when the stream has a rocky bottom or access is difficult.

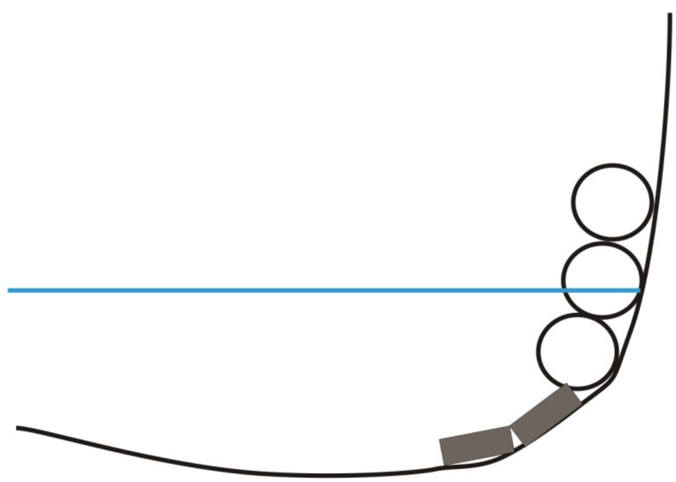
Cross-section of typical cedar revetment placement with stone placed at toes. Number of rows of revetments varies with bank height and slope. Revetments trap sediment and become new bank and are vegetated both through the native seed bank and planting with woody species. Revetments are typically from 16 - 22 inches in diameter. Larger ones are placed on the bottom.



Placement of rock at toe of revetment with near vertical bank meeting near horizontal bed. The two diagrams show that the rock placement is not dependent on water depth.

 Symbol for revetment

 Symbol for rock



Rock placement to protect toe of revetments when the bank slopes towards the center of the stream. Rock is placed to prevent the rock directly underneath the revetments from sliding away from the bank.

Installation Procedure

1. Start at the downstream end of the project and work upstream to a stable point so that subsequent revetments overlap the downstream revetments. Duck bill anchors with a 3/32" aircraft cable and loop attached are most commonly used to provide attachment points for the revetments. Depending on the soil/rock composition of the bank, different

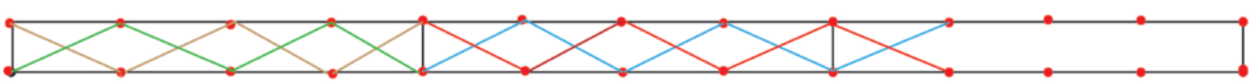
length anchors are used to ensure sufficient holding capacity. On extremely soft soils, special anchors designed for soft soils are used. Anchors are driven into the bank until only the loop of the cable is visible. Then the driving rod is removed and the cable is pulled until the anchor sets. Repeat in two rows either directly above each other or offset depending on the cabling pattern, with the anchors placed about 2 – 2 1/2 feet apart. The bottom row should be as close to the streambed as possible or in the streambed if possible. A second row is installed about 14 inches above the first row.

2. Once the anchors are installed, the cedar revetment is put in place. It is helpful to attach the ends of cables that will start on a bottom anchor before placing the revetment. 3/32 inch cable is run in a zigzag pattern across the revetment to each of the anchors, using a gripple (a patented and trademarked cable tie device) at each end. The gripple allows tightening of the cable once the installation is complete. Start at the downstream end of the project and work upstream so that subsequent revetments overlap the downstream revetments. Do not tie off the upstream end of the cable until the next upstream revetment is in place because it will cross the lower end of the next revetment. Three alternative cabling patterns are illustrated below. In each case, more than one length of wire is used for each revetment so that if there is an anchor or cable failure, the revetment is not entirely released. Each system overlaps the ends with two wires for the same reason and all systems avoid using the same anchor as an end point for more than one cable.

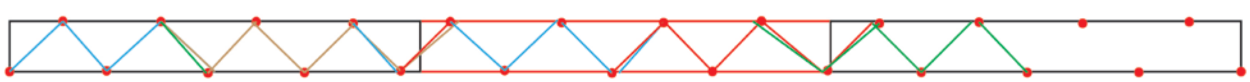
Figure 4a. Duckbill anchor with cable


Figure 4b. Gripple

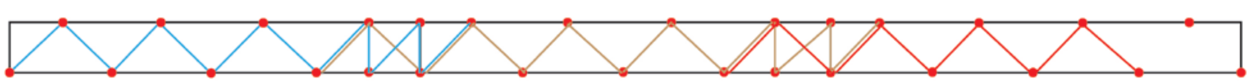
Figure 5. Alternate Cable Patterns. Red dots denote anchors. Anchors are placed approximately 30 inches apart. While the diagram shows a vertical line to designate adjoining revetments, the revetments actually overlap a minimum of one foot.



Cable Pattern 1 Each color denotes a new piece of cable. Vertical cables may also be used where necessary.



Cable Pattern 2. Each color denotes a new piece of cable. There are double cables at each overlap and at the center of each revetment.



Cable Pattern 3. Each color denotes a new piece of cable. There are double cables at each overlap and there is an X pattern over the overlapping end.

3.  Install the next (upstream) revetment, with its downstream end overlapping the previous revetment with about a six inch overlap of the coir wrapping.  This will also allow about a 1.5 to 2 foot overlap totally, counting the cedar woody material sticking out the end of the revetment.  Start the cable for the second revetment on the downstream anchor that will capture both the end of the new upstream revetment and the downstream revetment.  Once this is in place, the end of the wire of the first revetment can be continued until it comes to an end and captures the ends of both revetments.  By starting the cable for the second revetment in a different place than the first, there is a double cable over the ends of the revetments but the pull on the anchors is spread to different points.  After the new cable on the second revetment has been threaded through, the first cable can be tightened.  This should be done starting at the downstream end working toward the upstream.   Have several people lean on the revetment to push it into the bank and pull on the cable to remove the slack.  This slack is then removed as the gripple is tightened.  A gripple tool may be used to provide for significant pressure in drawing the revetment into the bank. **IMPORTANT – make sure that the revetment is tight against the bank – if water gets behind the structure it can do more damage than good.**
4.  This process continues for the length of the revetment treatment area.  If there is to be a second row (or more), install another row of anchors, offset from the anchors at the top of the previous revetments.  This row of anchors will end up being above the anchors for the bottom of the previous revetment.  Once in, the cabling is done the same way, with the exception that the top anchors of the previous revetment are now the bottom anchors for the next row.  Where possible, the revetments should be offset somewhat, whereby the joints in the first row are completely spanned (as one would lay bricks) by the second row. While this is not always practical, it should be accomplished where possible.
5.  If a rock toe is to be installed, it should be made of relatively flat stone of the same type as is currently in the stream so that water chemistry is not altered.  Generally one or two layers of rock are all that is used.
6.  In the following fall, where possible, native herbaceous vegetation (i.e. grasses) can be planted and in fall, late winter or early spring, woody species, trees and shrubs that can tolerate immersion, are planted in and between the revetments.

Figure 6.  Driving rod and anchors.  Loops at end of anchor have ribbons to make finding them quickly easier.  This is especially necessary for lower anchors that may be partially submerged or easily covered in bottom sediment.

Figure 7. Close-up of driving rod and anchor.

Figure 8. Site with anchors installed. Note anchors installed underwater at the base of the bank use fishing leaders and floats to indicate the ends of the cable position.

Figure 9. Revetments installed and cabled in with revetment seams against bank. In this case, layers were not offset.

Figure 10.  Same site the following spring showing exposed rock toe, filled revetments, and beginning of plant growth.

## Discussion

After seven years of extensive experience in a variety of small to medium-sized streams, there are clear advantages to the Tennessee Cedar Revetment (TCR) over alternative treatments.  First, the TCR provides an immediate protective layer over the bank to prevent further scouring.  Second, by trapping silt and sediment inside the TCR, it effectively removes sediment from the stream, the primary cause of stream degradation in Tennessee.  Using a typical dimension of ten feet by sixteen inch diameter, each revetment may remove as much as 10 cubic feet of sediment from the stream.  Third, this removed sediment becomes the new bank, but the structure of cedar branches creates a "reinforced" bank that will be less subject to erosion than a reformed bank made up of new soil material alone.  Fourth, the filled revetments become not only a staple platform for planted woody species, but the revetment itself traps seeds transported by both air and water.

Failures of the TCR have been extremely rare.  The failures have not been due to failure of the anchoring system, but where large floating logs have snagged and torn the coir matting and released the smaller cedar branches.  Since this has occurred only where the installation was in the outside of a hard bend, where additional structures to deflect the current were not installed, it strongly indicates the need to use vanes or barbs in combination with the TCR in those situations. A limitation that should be noted, however, is the practical difficulty of installing TCRs in larger, deeper streams. Installing anchors in water deeper than two to three feet is nearly impossible without putting the workers in jeopardy. However, many streams with four to ten foot banks have low water periods when TCRs could be installed.

There are a number of advantages of using the TCRs in addition to its effectiveness in stabilizing banks. The first, mentioned above is the use of locally produced materials, with a local positive economic impact. The second is the relatively low skill level required. While a highly experienced team will be more efficient in terms of installation time, one highly experienced team leader can ensure a high quality installation working with workers or volunteers with no previous experience. This makes this technique appropriate for watershed groups and other volunteer-using organizations that wish to have a positive impact on degraded local streams, working only with hand tools. Third, the technique can be applied in situations where utilizing heavy equipment is either impractical or undesirable. This is particularly true for wooded sites where trees would have to be removed in order to bring in heavy equipment to reshape a bank, or where the relatively small size of the project would make mobilization of equipment impractical. Finally, there is extremely low disruption to the stream system with this technique. Existing bank and riparian vegetation is not removed, bank structure is not weakened, and the impact of people walking in the stream on benthic organisms and stream aquatic life is limited.

At a time when the awareness of stream degradation is rising, along with the miles of impaired streams listed by regulatory agencies, real progress in improving water quality will require thousands of small but effective interventions. The use of the TCR is one very effective method that can be used by both professional and citizen groups to have a positive impact.