# What I've Learned About Streambank Stabilization

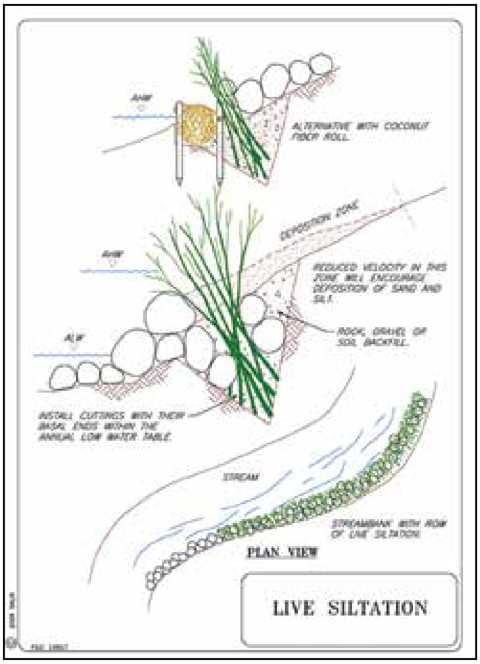
**Above: Rock Vanes on Old Man River, 3 years after installation. No damage from record storm. Below: Old Man River, Fort Macleod, AB. Seven months after construction, the Rock Vanes and Flood Terrace experience a 30-yr flood. The high erosive energy and thalweg is directed streamward off the ends of the vanes.**

The title of this article might better be "What Rivers Have Taught Me". Rivers and streams will give you feedback, sometimes quickly or sometimes years later. It may take longer, for example, to get a 2-year return interval flow. It seems there is always more to learn if the student is willing. I have learned most from being out in the field, solving problems "on the fly", brainstorming with other river practitioners, and going back to study various projects and the rivers reaction to the project structures, good or bad! "Lessons learned" should always be a part of our personal and professional curriculum.

Generally I've learned that the 'natural way' is often a signpost to the best and most sustainable solution. When looking at a potential project site or reach, I ask myself, "How did this stream system (or reach) historically dissipate excessive energy, pass storm flows, and transport stream sediment?" Hidden in the answer to this question are many potential clues to a sustainable and environmentally appropriate design. For example, was there a large riparian corridor that provided large woody debris (LWD)? Maybe LWD would be beneficial to incorporate into the design. Did a floodplain or flood terraces allow the stream to pass high flood flows? Then maybe the best design would be one, which reconnected the stream to a floodplain if possible, or, at least, some floodplain benches or flood terraces can be integrated into the design.

Had the river meandered as a way of dissipating energy and now was it straightened and downcutting? Colleague, Doug Shields, P.E., PhD, Shields Engineering, once told me; "The best grade control structure is a natural meander bend". There are caveats to this metaphor but the gist of the statement is worthy. Most importantly, an understanding of how the native plants and trees functioned to stabilize the banks will help determine the types, the species and role of plants in the project design.

My greatest influences in bioengineering came from the early practioners and researchers who wrote technical papers, books, and gave presentations on bioengineering. These included Andrew Leiser, Department of Envl. Horticulture, UC Davis; Donald Gray, Professor (Emeritus) Civil Engineering, Univ. of Michigan; Robbin Sotir (Robbin B. Sotir & Assoc); and Wendi Goldsmith, Bioengineering Group. Also, H. Schiechtl H.M. and Stern, R. (1994) produced some extremely useful and informative books on environmentally compatible stream bank protection methods using woody plants. Gray presented and published engineering-based arguments on the geotechnical benefits of these bioengineering methods, e.g., root reinforcement effects and their influence on soil shear strength, root architecture and distribution, effects of surcharge, and optimal compaction conditions to meet both engineering requirements and plant growth needs. Dr. Gray's body of work has been increasingly accepted by traditionally trained civil engineers.




**Live Siltation from NCHRP Report 544.**

We realize that practicing bioengineering on streambanks requires innovation or sometimes just going back to the "tried and trued". See BioDraw 3.0 (McCullah, 2003) for an interesting treatise on the history of bioengineering. Even with guidance, often in the form of case histories, it seems streambank stabilization with anything but riprap or armor revetments has been an enterprise fraught with risk and fear of failure. The main reason bioengineering or biotechnical practices are now being chosen for a particular project are because of habitat concerns. David Derrick, Potomologist, USACOE retired, River Research and Design, points out that, "The hydraulic roughness and stability provided by plants are just as important, but possibly overlooked". Recently resource agencies now require that the project proponents and designers provide biotechnical alternatives to riprap. These alternatives might range from vegetated riprap to rock toe with live siltation.


**Geyserville Bridge project installing Live Siltation behind LST. Note how the self-filtering gradations minimize turbidity.**

**Alternatives to Riprap**

In early 2000, the Transportation Research Board (TRB) received requests from their members (State DOTs) for more research on alternatives to riprap. It seemed one of the biggest obstacles facing highway engineers were obtaining environmental permits to build highway projects in or even near rivers.

Resource agencies require that bioengineering methods be employed, that geomorphologists be consulted, and appropriate indigenous plant materials be incorporated. Permits frequently require that the designs within the stream corridor improve aquatic habitat by; 1) providing shade, 2) providing substrate complexity, 3) developing refugia, 4) increasing aesthetic value of our roadways, 5) enhancing hydrologic function and ecological health, and 6) improving riparian function. It became apparent that the designers and project managers now had at least two goals – to build a safe, strong and cost-effective highway infrastructure and, to improve habitat and ecosystem function.

In 2002 the TRB and National Cooperative Highway Research Program (NCHRP) issued an RFP for research and development of guidelines and design criteria for methods determined to be "environmentally-sensitive". The 3-year research, conducted by Donald Gray, Doug Shields and myself was reported and published as NCHRP Report 544 – Environmentally Sensitive Channel and Bank Protection Methods (McCullah and Gray, 2005). A version of this report titled ESenSS was also published separately (McCullah, 2005). Over 50 environmentally-sensitive methods were presented with design criteria, typical drawings, construction specifications, costs and much more. NCHRP and TRB have recently developed a second research project, headed by Pete Lagasse, Ayers and Associates, which is intended to collect more empirical data and present it in a new report focused on an evaluation of flume trials and actual case studies.

**Redirective vs. Resistive Methods**

Two career epiphanies were my association with Donald Gray and hearing David Derrick give a keynote presentation in 1995 at IECA's Environmental Connection conference in Seattle, about bendway weirs. I'd been having some great success with biotechnical methods, i.e., combining plant (willow sp.) materials with structural elements in a mutually-beneficial manner (Gray and Sotir, 1996). However, the civil engineering community was generally averse to approving these unknown and sometimes 'unproven' methods. Primarily their concerns were the longevity of plants and the unknown hydraulic resistance to tractive stresses that the vegetation provided. When David Derrick provided evidence that "re-directive methods" could effectively move high velocity flow vectors away from the outer bends, I was immediately interested. This scientific information was extremely important, because it meant that these banks could be treated with bioengineering with little to no risk from excessive scour forces as the plants were subjected to reduced shear when coupled with the redirective techniques.

During the synthesis phase of the ESenSS research we found that several of these redirective methods, specifically rock vanes and bendway weirs, actually provided in-stream refugia, developed substrate complexity and, hydraulic flow diversity that combined to improve habitat for aquatic organisms. These research papers and others are all part of ESenSS so the user can read them and make their own inferences. These habitat enhancements were not observed or documented for the most commonly used resistive methods, such as riprap or gabions, nor do all other redirective methods such as groins (groynes) or deflectors provide the same benefits.

One of the last and possibly most important things I learned from "hanging out" with experienced practioners such as David Derrick, Phil Balch, Wildhorse Riverworks, Inc., Kansas, and Ron Redmond, Arkansas National Resource Commission, was the importance of using "self-launching" (well-graded) and self-filtering stone. Use of clean self-launching rock can preclude the need for excavating the channel bottom and allows construction in a live stream with little to no increases in turbidity.

**Scour Trenches Require Excavation**

Because any resistive method used on an outer bank of a bend will ensure that the thalweg (highest velocity, deepest section of the active channel) is at the toe of the stone. This concentrates high velocities at the bank line and results in scour at the toe of the stone. As 'fisher-people' will attest, this scour zone at the toe of riprap is not a good place for fish or other aquatic organisms to hang out.

So a scour analysis is often conducted to determine anticipated scour depth. Construction then requires digging a scour trench into the bottom of the river and lining that trench with filter fabric and then filling that trench with stone. This procedure is standard practice to arrest the scour.

Digging a scour trench and disturbing the bottom of a live stream is a HUGE problem from a resource agency perspective. How do you maintain water quality

**On December 29, 2010, 2 months after completion the Russian River at Geyserville Bridge gets high flows (>10,000 cfs), 9 ft. over the Rock Vanes.**

under these conditions? The Water Quality Certification and 401 permit can be many pages long and require rigorous monitoring. How effective and expensive are "isolation techniques"? We all realize, I hope, that putting a silt fence in a live stream is not a viable option. Will there be a need to include, therefore, a more elaborate boom or aqua barrier system? And most importantly, where does the captured silt go when you remove the barrier. These techniques can be very effective but are likely to be costly, and the effectiveness is dependent on experience and precise methods.

Does the sediment barrier or scour trench need a dewatering permit? Dewatering permits are often site and region specific and can be very onerous. Is the project in an area with endangered and protected species and will the scour trench and riprap and the resulting loss of habitat be acceptable to USFWS or the State Fish and Game, Department of Ecology or other? Will the project require mitigation for loss of natural stream function? Will the placement of materials below the average high water require a Section 404 permit from USACOE? And lastly, will the riprap-lined bank (revetment) require mitigation, either onsite or off-site, to compensate for lost or degraded habitat?

**Self-Mitigating Methods**

The above requirements are often a strong impetus to consider more environmentally sensitive stabilization methods, design, and construction methods. Quite often a design proposing environmentally sensitive methods will expedite the permitting. Often resource agencies will consider the work "self-mitigating". This designation is important when working in streams and “wetlands”, and USACOE regulators are more comfortable having projects that enhance the ecosystem.

**Self-Launching Rock Gradations**

One of the first methods that come to mind is the “tried and trued” use of “self-launching”, well graded, and washed clean stone. David Derrick and the ACOE refer to a gradation with small fractions as “self-filtering”. Constructing bank protection with self-launching stone greatly reduces water quality problems. The use of these rock gradations eliminates the need for digging a scour trench and the self-filtering properties can eliminate the need for filter fabric. Note that “filter fabric” is a barrier to root penetration and if used thoughtlessly the practice can annul the geotechnical benefits of the bioengineering plants. Specifying self-launching rock is very cost effective, quite often 1/3 the cost of constructed riprap . The savings can be even greater if the riprap construction permits require isolation techniques, dewatering, developing mitigation measure, and monitoring water quality.

**The Russian River project after high flows recede. Note the rock, the live siltation and the pole plantings are still in place. January 13, 2011**

I have designed, built and documented many projects where “clean”, self-launching rock was strategically placed (sometimes carefully, sometimes end-dumped but always well mixed with respect to gradations) on the existing stream or river bottom. Rigorous water quality monitoring performed 100 to 300 feet downstream revealed little to no water quality problems. On a project in central California we placed over 1100 tons of clean rock (500 ft. of Longitudinal Stone Toe (LST) and 5 rock vanes) in a live stream and did not exceed our Water Quality Standards of approximately 10 NTUs measured 300 ft. downstream. In the Canadian Rockies project with Alberta Infrastructure and Transportation we built 7 rock vanes and 1000 ft. Longitudinal Peaked Stone Toe (LPSTP), while being allowed increases of <5 NTUs!! There were 60 people in the workshop and about a dozen from the regulatory DFO. Needless to say that the work was carefully monitored! See Dirt Time "Hinton Project, Episodes 7,8, and 9".

The rock structure can be built as a peaked longitudinal row or have a wide crest. Either way the stone will generally stand at about 1:1.5 angle of repose. When, or if, scour occurs at the toe of the stone, the pile of rock will become oversteepened and fall (self-launch) into the scour. If more scour is anticipated the pile of rock can be made thicker in cross-section (Longitudinal Fill Stone Toe Protection, thereby providing sufficient "sacrificial stone" to self-fill any future scour.

When rock vane or bendway weir redirective methods are employed, the chance of scour at the toe of the bank is eliminated or minimized. The NCHRP Report 544 documents that two rock vanes, for instance, can effectively move the thalweg streamward 20% of the bankfull width. The Russian River Streambank and Channel Stabilization Project at the Geyserville Bridge, completed by Caltrans in 2010, provides an excellent case study on how environmentally-sensitive techniques can be applied to a extremely important salmonid river in Northern California. **L&W**

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