Case Study 10

Newaukum River, Lewis County, Washington

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Cover photo: Completed section of the Newaukum River, Lewis County, Washington

Advisory Note

Techniques and approaches contained in this handbook are not all-inclusive, nor universally applicable. Designing stream restorations requires appropriate training and experience, especially to identify conditions where various approaches, tools, and techniques are most applicable, as well as their limitations for design. Note also that product names are included only to show type and availability and do not constitute endorsement for their specific use.

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Introduction

Stream restoration and fish habitat have been a concern in the Northwest for many years. Often the practices used to stabilize a stream would have a negative impact on fish habitat, resulting in contentious relationships between implementation and regulatory agencies. In the late 1980s, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) and Washington Department of Fish and Wildlife (WDFW) agreed to work together to design and install mutually acceptable soil bioengineered methods on a number of sites. The goal of this project was to demonstrate acceptable practices for streambank stabilization and fish habitat. The project was initiated in 1989, and annual reports were prepared for a number of years. Numerous pictures were taken and filed with a narrative record of events for each of the planned 5 years of monitoring and evaluation. In the first 5 years after construction, the sites experienced a variety of hydrologic and climatic/environmental events: two significant floods, a drought, willow borer infestation, beavers harvesting woody vegetation, and a fire. In 2005, these projects were revisited to determine current condition and overall effectiveness of the intended objective. A rationale for success of these projects is also examined in this case study.

Project sites

The initial project started with three sites and later expanded to include monitoring of eight sites, four of which were designed by the Lewis County Soil Conservation District. All sites were on the Newaukum River, historically an important salmon and steelhead-rearing stream, located in Lewis County, in southwest Washington. Table CS10–1 provides the site name, location, and hydrologic characteristics for each site at the time of design. Frequency discharge values based on current data at two U.S. Geological Survey (USGS) gage stations are included for comparison purposes. Since the installation of these projects in 1989, numerous storm events have produced significant discharges.

Table CS10–1 Site hydrologic data (design) and current USGS gage data

Site	Newaukum River location (river mi)	Reach (ft)	D.A. (mi^2)	Channel slope (ft/ft)	2-yr discharge (ft^3/s)	100-yr discharge (ft^3/s)
Nygard	Mainstem (4.3)	450	155	0.0015	5,700	11,800
	USGS gage near site		155		5,780	13,300 (56-yr record)
Olson	Mainstem (9.3)	1,100	143	0.0019	5,400	11,300
Teitzel	North Fork (.85)	500	70.5	0.0021	3,400	7,500
Fitzgerald	North Fork (4.1)	400	49.3	0.0022	2,600	6,000
Burton	South Fork (14.1)	225	63.5	0.0029	3,100	7,000
Hadaller	South Fork (15.1)	500	62.8	0.0027	3,100	6,900
Wesson	South Fork (15.8)	This site removed from study—channel changed course the first season.				
Hirtzel	South Fork (22.2)	400	42.0	0.0046	2,500	5,400
	USGS gage near site		42.4		2,270	4,790 (26-yr record)

The 2-year discharge has been exceeded at least 12 times at the Nygard site, and the 100-year discharge was equaled at least once. These events were the result of widespread storms in the Northwest, so it can be assumed that all sites have experienced similar flows. Table CS10–2 provides the actual date and USGS-recorded discharges for these events.

Initial conditions

Typical site characteristics consisted of:

- a gravel-bed stream with thalweg at the toe of slope
- high, near vertical, raw banks on the outside of curve
- high banks on the outside of a curved reach with seasonal erosion at toe, resulting in periodic upper bank sloughing

Table CS10–2 USGS-recorded annual peak flows, Newaukum River, WA

Water year	Date	Peak flow (ft^3/s) Mainstem USGS gage 12 025 000	Peak flow (ft^3/s) South Fork USGS gage 12 024 000
1990	01/09/90	10,400	NA
1991	11/24/90	10,300	NA
1992	NA	3,990	NA
1993	NA	3,730	NA
1994	NA	3,170	NA
1995	12/27/94	6,040	NA
1996	02/08/96	13,300	4,200
1997	12/29/97	9,700	NA
1998	01/14/98	6,580	NA
1999	11/26/98	10,000	NA
	12/27/98	NA	3,240
2000	12/15/99	NA	3,240
	12/16/99	8,100	NA
2001	NA	2,030	715
2002	12/17/01	7,920	NA
	01/25/02	NA	2,140
2003	01/31/03	8,940	2,640
2004	01/29/04	NA	2,740
	01/30/04	7,460	NA
2005	01/18/05	7,740	3,740

NA= Information not available or missing

Bank soils varied from fine sandy silts with clay to fine sand with lenses of sand and gravel. The banks were devoid of woody vegetation. Raw slopes generally had herbaceous cover by late spring.

The ratios of radius of curve to channel width varied from <2 to 20, a nearly straight reach. The oversteepened bank slopes, combined with saturated soils, resulted in active bank sloughing during and following winter and spring high water events. These sites were not fenced prior to the project and were subject to livestock grazing.

Figure CS10–1 shows typical conditions that existed at the project sites prior to design treatments. Table CS10–3 lists site characteristics, stream classification (Rosgen 1996), treatment measures used at each site, and a summary of current conditions. Descriptions in this case study are generally limited to four of the sites which represent the range of site conditions, techniques used, and experience gained. The four sites selected are the Nygard, Teitzel, Fitzgerald, and Olson.

Design using rock is addressed in NEH654 TS14C and NEH654 TS14K, soil bioengineering techniques are addressed in NEH654 TS14I, and redirective techniques are addressed in NEH654 TS14H.

Figure CS10–1 Typical conditions that existed at the project sites prior to design treatments

Table CS10–3 Site characteristics, stream classification, treatment, and condition

Site	W:D	Ent[1/]	Soils (bank)	Rosgen stream classification	R:W [2/]	Treatment [3/]	Bank stability—2005
Nygard	56.2	1.3	SM	F4	1.6 us 2.6 ds	RB, LS, FX, TR (limited to part of reach)	Stable with established willow canopy
Olson	66.8	2.7	ML SM	C4	11	RR, TR, ECB, BS, F, LS, FX	Stable with points of scour
Teitzel	24.6	5.5	ML CL	C4	2.1	F at top of TR, LS, S, FX	Stable/scour hole above project
Fitzgerald	34.5	4.5	ML SM	C4	20	RB, LS, no TR, S, FX	Stable/significant sediment deposition
Burton	42.6	1.1	ML CL	F4		SB, TR, BS, RW, FX	Stable/braided/rock weir downstream
Hadaller	61.4	3.4	SM	C4		LS, TR, boulders, FX	Stable/complete canopy over stream
Hirtzel	45.7	1.9	ML SM	B4c		RR full bank	Channel shifted away from rock bank; upstream reach unstable

1/ Entrenchment ratio
2/ Bend radius to water surface width (within bank flow)
3/ RB = rock and brush (willow) structures
LS = live stakes
TR = toe rock
F = willow fascine
BS = bank shaping
ECB = erosion control blanket
S = bank seeding
RW = root wad
RR = rock riprap
FX = fenced to exclude livestock

Selected treatments

The Newaukum River is important for fish rearing, so the selected treatment measures were designed not only to stabilize the bank but also to improve habitat. Critical habitat objectives were to reduce sediment, establish tree cover to reduce the water temperature, minimize rock riprap on banks, and remove livestock from direct access to the river. A description and function of treatments installed are shown in table CS10–4.

Table CS10–4 Description and function of treatments installed

Rock and brush structures (RB)	RB structures were 5-ft-wide trenches excavated into the bank perpendicular to streamflow. The trench bottom was excavated into the bed approximately 3 ft and filled with rock sloping up the bank at a 1.5H:1V slope to a predetermined elevation. Above this elevation, the trench was excavated into the bank 5 to 8 ft and filled with layers of rock and brush. The trenches were spaced at 25-ft intervals. Figures CS10–2 and CS10–3 are excerpts from the original design showing layout and detail of these trenches which later became known as RB structures. The design intent of this structure was threefold, (1) establish a hard point on the bank that would control bank cutting during flood events, (2) increase hydraulic roughness, and (3) provide points with dense woody vegetation for habitat enhancement. Some of these structures were installed in conjunction with toe rock and at other locations without toe rock. Installation required excavation at the bank toe and placement of rock under water.
Rock riprap (RR)	Since these projects were intended to improve fish habitat and reduce rock riprap, the use of rock was limited to critical areas for stability and other areas for habitat purposes. The Hirtzel site, initially designed separate from the study with full bank riprap, was installed as designed to serve as a control for comparison purposes. Failure of the upstream reach, as noted in table CS10–3, is not indicative of the design, but rather a result of not being able to treat an active eroding area due to a different property owner.
Toe rock (TR)	Placement of rock at toe of bank slope with the top of rock at or below the bankfull discharge elevation. Toe rock was placed in locations to demonstrate that full bank riprap was not needed when soil bioengineering techniques were installed.
Instream boulders	Selective placement of single, large rocks in the stream. This was intended as a habitat enhancement measure to create deeper pools and protection/resting areas for fish. The large rocks generally were in the range of 4-ft to 6-ft size and were placed 2 to 3 diameters apart near the center of the riverbed in a staggered fashion.
Live staking (LS)	Live cuttings of willow and red leaf dogwood. Cuttings were obtained from nearby sites and were 1 to 2 inches in diameter, 4 ft in length and inserted to a minimum depth of 24 inches. The exposed portion extended above the ground 8 to 12 inches. The stakes were driven to a depth where they would be in moisture during the drier parts of year to assure survival. Live staking provides rapid development of woody vegetation on the sloped banks for increased hydraulic roughness and bank stability and provides future shade for the stream and cover for wildlife (fig. CS10–4).
Fascines (F)	Long willow branches tied together forming a dense, continuous roll 6 to 8 inches in diameter. The roll was placed in a shallow trench and covered with loose soil. Fascines were located near the normal low water line to assure adequate supply of moisture. Live stakes at 4- to 6-ft intervals were used to help anchor the fascine. Fascines provide a dense line of willows along the water line providing shade and fish habitat during low water periods and reduced near-bank velocity during higher flows.
Fencing (FX)	All sites were fenced for livestock exclusion and the buffer area planted with an assortment of woody vegetation including, alder, dogwood, and willow. Livestock exclusion is a proven and necessary bank restoration measure.

Figure CS10–2 Nygard site plan—excerpt from original drawings

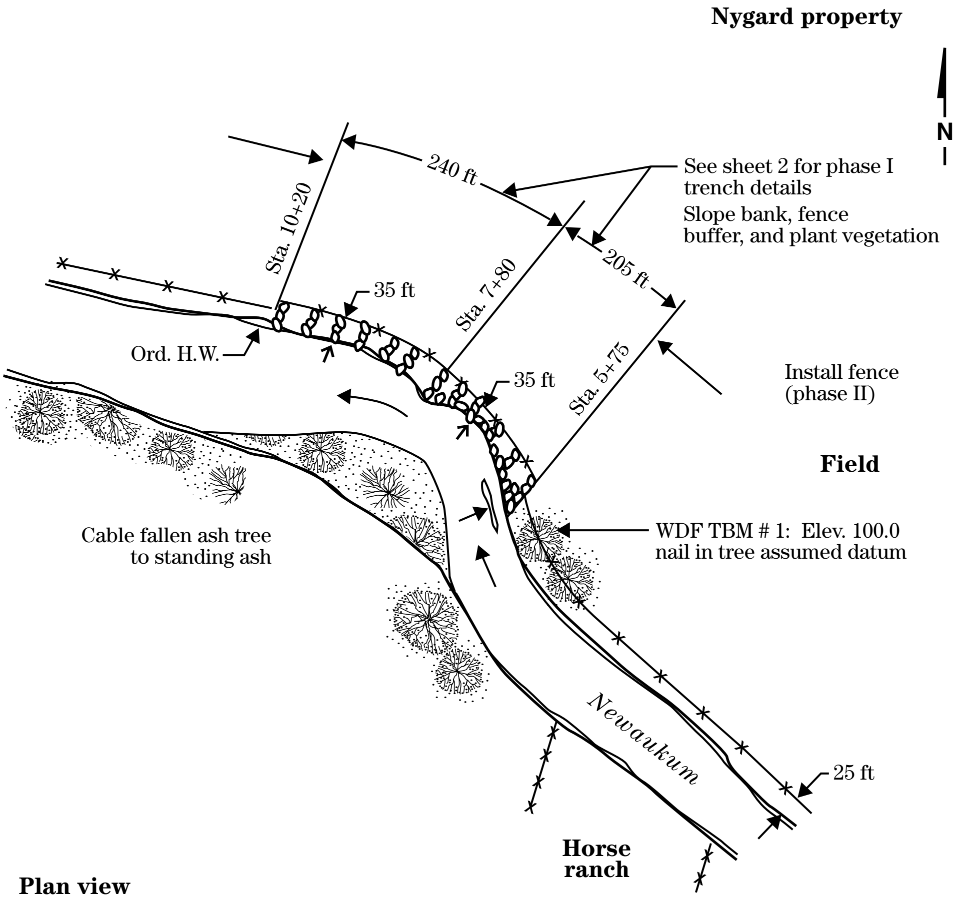

Figure CS10–3 Nygard site, RB detail—excerpt from original drawings

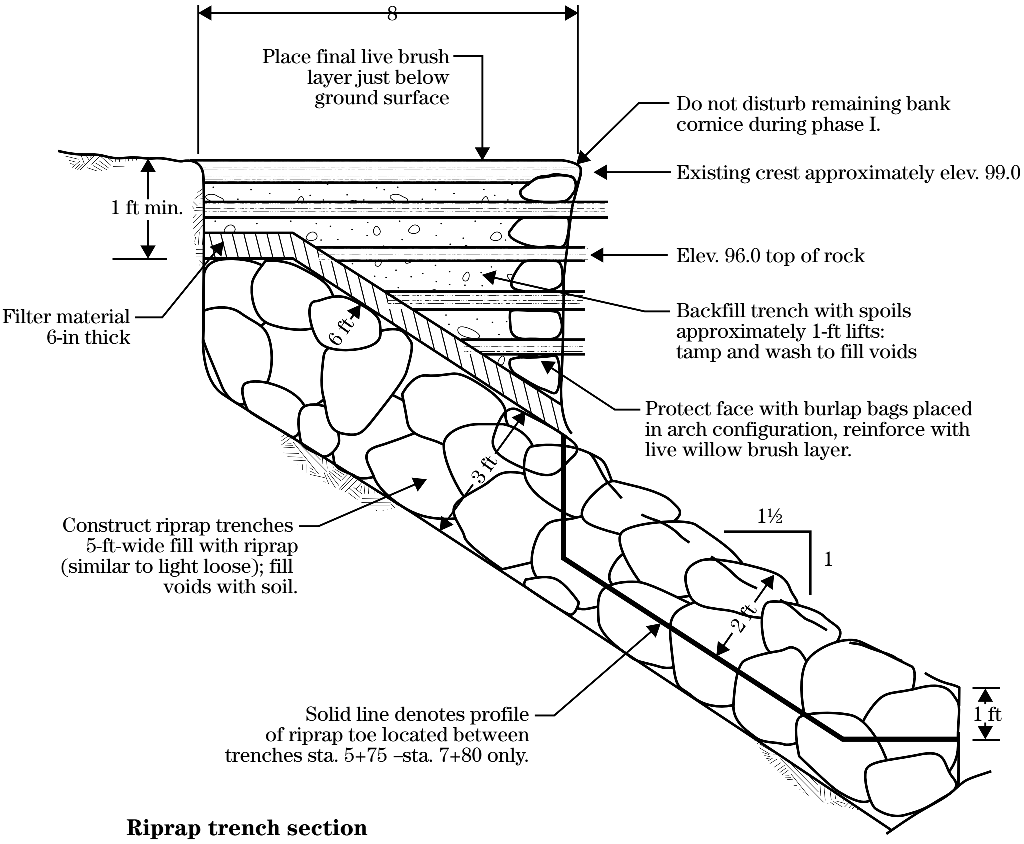

Figure CS10–4 Willow growth at RB structure


(a) Shading effect of willows

(b) Willow development above toe rock. There appears to be some loss of fine soils at the interface.

Description of treatments

The physical characteristics of the four sites described in this study are similar except for the ratios of curve radius to bankfull width (R:W), bank soils, and bank exposure. These characteristics are shown in tables CS10–1 and CS10–3 and further described herein.

The curve ratio has become a common tool in recent years for determining appropriate application of stream redirective-type structures such as stream barbs (refer to NEH654 TS14H). At the time these sites were designed, the ratio of curve radius to channel bottom width (or design surface width) were more commonly associated with design of manmade channels and a means to locate areas and magnitude of maximum stress in bends (USDA Soil Conservation Service (SCS) 1977).

The Teitzel site, with the lowest R:W ratio, was initially treated with narrow (approximately 12-in-wide) rock and brush (RB) structures at 8- to 10-foot intervals. These failed in the first season during an over-bank flood event. Following the flood, the bank was reshaped and treatments applied as indicated in table CS10–4. The live stakes produced an extensive stand of woody bank cover the first year after repair. This was followed by an extremely dry year and infestation of the willow borer, which killed off 80 to 90 percent of the willows. Natural recovery was further decimated by beaver activity in subsequent years. Currently, the bank is stable with heavy grass cover, but no woody vegetation (fig. CS10–5).

The Fitzgerald site is a near linear reach (highest R:W ratio), at the opposite end of the spectrum for curve radius. In the first years of monitoring, the RB structures appeared to be on the verge of failure with

Figure CS10–5 Teitzel site

(a) 1992, aerial view

(b) 1992, after installation of live stakes. Note the fascine just above the toe rock.

(c) 1992

(d) 2005

considerable erosion and scour of loose bank material (sand-gravel lenses) adjacent to the structures. As the willows in the RB structures developed, the roughness element is believed to have slowed the near-bank velocity and allowed for sediment deposition. Currently, the thalweg has moved away from the toe, and significant sediment deposition has occurred along this reach. Woody vegetation is dense at the RB structures and between structures as evident in figure CS10–6.

The Nygard site has a moderate R:W ratio and perhaps is the more consistent of all the sites in steady progress towards stability. It, too, has experienced the flood events and dry seasons, but lower losses (50%) from infestation of the willow borer and not significantly affected by beaver activity. The treatment at this site combines toe rock with the RB structures in the upper curved portion of the reach. Very little bank shaping was done at this site, other than what occurred during excavation of the rock and brush trenches. The steep bank slope was still evident during the site visit in 2005. As figure CS10–7 shows, the water level was above the toe rock. The RBs continue downstream through a shallower bend without toe rock. The thalweg remains at the toe of the bank in the upper curved reach. The willows are dense and extend out over the stream providing heavy shading over the thalweg.

The Olson site was originally installed with no rock riprap and only vegetative treatment for bank stabilization. Before the vegetation became established, it was subjected to the January 1990 flood, which resulted in the failure of this project. The site was then redesigned and constructed with multiple treatments as noted in table CS10–3. During field investigation in the fall of 2005, several points of bank scour were noted. Closer examination revealed that these scour points, some only 10 feet long, coincided with segments of reach without any toe rock. A review of the construction drawings verified that there were gaps in the toe rock. The toe rock was associated with various treatments and varied from rock placed in a single layer to the more typical placement of rock at toe of slope to a designed elevation. The bank has a northern exposure, but development of woody vegetation is somewhat random along the project reach and may be more a reflection of the bank treatments than site conditions.

The relationship between soils and willow condition is shown in table CS10–5. This table was developed from observations of the relative willow condition at each site in December 1998. Generally, the willow stands appear to be more dense and vigorous on the soils that contain less clay and more sand, especially on a south or east-facing bank.

Figure CS10–6 Fitzgerald site, photos taken from similar view points. Initial erosion at toe adjacent to RB; structures filled with sediment as vegetation developed


(a) 1990

(b) 2005

Figure CS10–7 Nygard site

(a) 1 year after installation

(b) Panorama of right bank on outside of curve. The appearance of an inside curve is due to stitching of several photos.

Table CS10–5 Bank exposure and soils relative to willow establishment

Site	Percent clay	Bank orientation	Soil series	Relative willow condition (1998 evaluation)
Teitzel	15–30	South	Chehalis silt loam	Failed
Burton	25–32	East	Chehalis silt loam	Failed (native willow starting to establish)
Fitzgerald	30–33	Southeast	Chehalis silt loam	Poor stand
Wesson	25–30	Northeast	Chehalis silt loam	Fair stand
Olson 1992	7–14	North	Newberg fine sandy loam	Good stand
Olson 1992	15–23	North	Chehalis silt loam	Good stand
Fitzgerald	12–20	Southeast	Newberg fine sandy loam	Very good stand
Nygard	12–15	Southwest	Newberg fine sandy loam	Very good stand
Hirtzel	12–18	Southwest	Cloquato silt loam	Excellent stand
Hadaller	12–18	South	Newberg fine sandy loam	Excellent stand
Hirtzel	15	Southwest	Newberg fine sandy loam	Excellent stand

Rationale for success

These projects have been successful in meeting the original objectives. The objectives were to demonstrate practices that would (1) reduce the use of rock riprap; (2) improve fish and wildlife habitat; (3) provide a stable bank; and, although not originally expressed, provide cost-effective designs. It was readily apparent to the authors during a field investigation in the fall of 2005 that stated objectives were satisfied. Following is a qualitative assessment of the underlying principles believed responsible for the success of these projects in general and, specifically, the four sites identified in the introduction.

It is almost a certainty that the Nygard and Teitzel sites would have failed without toe rock. Visual inspections in the fall of 2005 indicated that the thalweg continued to flow along the toe of bank. Even at low flow, the water depth along the toe was estimated at 4 to 5 feet. Without the rock toe protection, the bank would likely undercut during seasonal high water events with upper bank sloughing as flow subsides. The upper bank sloughing would be slowed because of dense vegetation, but slope failures would likely occur.

The effectiveness of toe rock is further demonstrated at the Olson site where bank scour has occurred at locations where there are small interruptions in the rock toe. Surprisingly, only a single line of rock has protected the toe along segments of this site. This contrasts with the Fitzgerald site where the RB structures were installed without toe rock. Although initial scour occurred adjacent to the RBs, this site now appears to be very stable. The differences in the R:W ratios should be noted. The Fitzgerald site with R:W≈20 and the Olson site with R:W≈8.8 are both relatively linear reaches. The results from these two sites seem to indicate that toe rock may not be necessary for high R:W ratios, other factors being equal.

A stable toe is critical to establish a good stand of woody vegetation on the upper banks. However, as noted in this study, factors such as an insect infestation or other natural events can destroy juvenile plantings. It is important that maintenance be a part of plant establishment. This was demonstrated on the Nygard site after the insect infestation wiped out most of the willows on the upper portion of site. Live staking was repeated to replace willows lost from insect infestation. The results are clearly evident in figure CS10–6, as the willows are now well established. Maintenance is an issue that is often neglected after the initial project installation. When live materials are used, it is important that follow-up care is provided through the establishment period.

Sometimes, even with proper maintenance, establishment of vegetative treatments can be difficult. The Teitzle site was also restaked after the willow borer infestation, but did not recover. Beaver activity and southern exposure at this site exacerbated the situation. In the fall of 2005, the banks were well grassed, but with no woody cover. It appears from table CS10–4 that soils and perhaps soil fertility have played a role at this site. Those sites with Chehalis silt loam soil series and south or east facing slopes did not fair well for establishment of woody vegetation.

When soil bioengineering methods became popular for stream rehabilitation in the 1980s, most engineers remained skeptical. The value of herbaceous cover to provide surface protection and woody vegetation to increase channel roughness are now better understood. The effect of root mass in strengthening soil, however, seemed reasonable, but very difficult to quantify. The major concern for engineers that affected both of these parameters was how to protect the streambank during the establishment period, which could take years. The net result for most engineers was to provide more positive protection measures, usually rock, until vegetation became established.

Initially, rock was placed well up on the bank to protect to a design storm event frequency, say a 10-year or 25-year event. With experience, it was noted that storm events that produced flow depths exceeding the top of rock most often caused little, if any, damage to the bank. Later, the concept of full bank discharge became the recognized elevation of choice for protecting the bank. Currently, this is the accepted practice for many NRCS engineers.

Classical streambed and bank analysis indicates that tractive stress is highest near the toe of the bank. Placing rock at the toe and partially up the bank make good analytical sense. In straight trapezoidal channels where the flow is parallel to the centerline, Lane and others (USDA SCS 1979) have shown that maximum shear stress is near the center of the bed and on the lower half of the bank side slope. Critical variables in determining the shear stress are depth of flow and velocity. In channels with bends, the flow is no longer parallel and must be considered more in a three-dimensional sense with transverse velocities, impinging flow, and spiral motion. In lieu of complex computations, experience shows that flow in bends moves the thalweg towards the outer bank. So the deeper channel is now at the toe of the side slope. With higher shear stress at the toe of slope, erosion and removal of loose soils can be expected. In locations where the bank material is susceptible to erosion, the weak soils are removed, and the bank is undercut. As the flood event subsides and water level drops, the undercut bank begins to slough due to gravity and excess pore water pressure. Placing rock at these points of higher stress prevents undercutting of the bank and provides opportunity for vegetation to become established.

Conclusion

The foregoing rationale seems simple, but was not readily accepted when these projects were first installed. Some proponents of soil bioengineering methods argued against the use of any rock. Promoters of rock riprap argued that soil bioengineering methods would fail during significant flood events. Fifteen years of experience has shown that soil bioengineering methods can work, with limitations.

Current practice for NRCS in this area is to approach streambank protection with two general strategies. One is to reinforce the bank in such a manner that it can resist forces from the impinging flows using a combination of rock and soil bioengineering measures similar to those used in these projects. The second strategy is to redirect the thalweg away from the bank with instream structures such as stream barbs. When the flow is not impinging on the bank, it is much easier to establish vegetative measures. Redirective structures often require as much rock, or perhaps even more rock, than a riprapped bank, but have distinct advantages for stream restoration. These structures roughen the bed and do not increase velocity as does most bank riprap. Combining these two strategies has worked well and has found favor with most state and Federal regulatory agencies.