Case Study 18 Wiley Creek, Sweet Home, Oregon



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Cover photo: Embankment treatment on Wiley Creek in Oregon

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

The Wiley Creek Streambank Protection Project in Linn County, Oregon, was designed in 2003 and 2004 by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), Oregon State Office. The project goals included the protection of two structures located 5 feet from the edge of a 23-foot-high vertical bank, bank stabilization, and fisheries habitat improvement.

The project was constructed in summer 2004 and consisted of a 180-foot-long reinforced earth embankment protected by three engineered log jams (ELJ) and two stream barbs. Bankfull discharge was determined at approximately 3,200 cubic feet per second with a 100-year discharge of more than 12,000 cubic feet per second. The project demonstrates the use of geosynthetic reinforced earth fills and soil bioengineering techniques for bank stabilization in a high-energy river system. Additionally, the project provides a demonstration of infrastructure and bank protection methods that achieve Endangered Species Act regulatory considerations through creation and enhancement of salmonid habitat. The project was constructed for $107,000 under the NRCS Environmental Quality Incentives Program (EQIP). Figures CS18–1 and CS18–2 show the preproject bank condition and 1 year following construction.

Background

The Wiley Creek Streambank Protection Project consisted of stabilizing and creating fish habitat along approximately 180 linear feet of streambank and the protection of two buildings. The project is located near Sweet Home, Oregon, along Wiley Creek, a tributary to the Santiam River, which flows to the Willamette River. Federally listed steelhead and Chinook salmon use the project reach of Wiley Creek for spawning and rearing habitat, which necessitated environmentally sensitive engineering design, more stringent permitting requirements, and additional implementation considerations. The preproject site consisted of a 23-foot-high vertical

Figure CS18–1 Preproject riverbank along Wiley Creek, December 2003. Note location of buildings at the top of bank.



Figure CS18–2 Completed reinforced earth embankment, stream barb, and bank vegetation 1 year following construction



bank with two structures approximately 5 feet from the top edge of the bank (fig. CS18–1). Anecdotal information from the landowner and analysis of historical photographs indicated that the river's left bank had eroded more than 40 feet since the rain-on-snow flood event of 1996 (fig. CS18–3).

Design objective

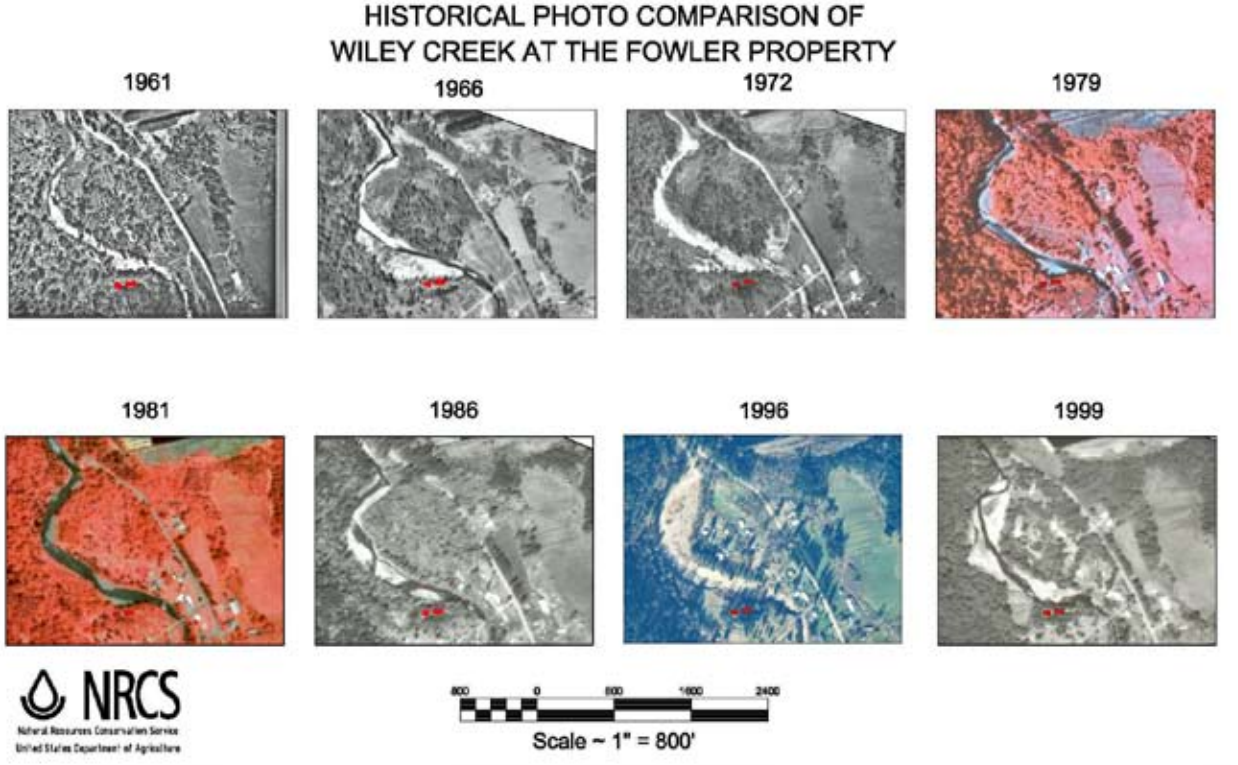
Design objectives included protection of two streamside structures, stabilization of the eroding left bank, and enhancement of salmonid habitat along Wiley Creek through the project reach. Additional considerations required no significant increase in the preproject flood elevations and implementation between July 15 to September 30 during the Oregon Department of Fish and Wildlife's instream work window.

The project design incorporated a reinforced earth embankment consisting of thirteen 2-foot soil lifts, encapsulated with geotextile-geogrid that extended from the toe of the eroded bank to the top of the bankline. Scour and erosion protection of the embankment was provided through the construction of two stream barbs and four ELJs.

Geomorphology

Watershed condition has changed dramatically within the Willamette Basin in the past century, and Wiley Creek is no exception. Many of the streams in the western Cascades were splash-dammed to transport logged timber downstream to receiving lumber mills. This activity had a significant effect on geomorphic condition of the rivers and streams and a severe im-

Figure CS18–3 Historical aerial photographs of Wiley Creek along the project reach showing morphologic changes over time



pact on instream habitat and biodiversity. The extensive timber-cutting in the watersheds also modified the magnitude, timing, and duration of the hydrograph, along with increased sediment production and transport processes. The contributing watershed area at the project location is 57 square miles, with nearly 3,700 feet of watershed relief.

The Wiley Creek project site is located within a transitional morphologic reach of Wiley Creek. The upstream reach is narrowly confined, has low sinuosity, and is bedrock controlled. The Rosgen stream classification (Rosgen 1994) for this reach appears to be B1c. Minimal sediment deposition occurs within this reach, except for a few areas along the active channel margins. The reach is hydraulically smooth and, with the exception of a few boulders, is scoured to bedrock (fig. CS18–4).

Wiley Creek transitions abruptly from this transport-dominated reach over an 8-foot-high bedrock overfall ledge to an over-widened depositional reach. This section of Wiley Creek is adjacent to the project and is characterized by distributary flow and a large mid-channel willow dominated bar. The excessive sediment deposition in this reach resulted in an anastomosed pattern, forcing the channel against the river's left streambank adjacent to the project. This reach was classified as a Rosgen D4 stream type (Rosgen 1994) (fig. CS18–5). The project bank is located in the trees on the right side of the photo. Note the variable pattern and excessive sediment deposition. The bedrock overfall is immediately upstream, just beyond the limits of the photo.

A topographic survey was performed through the composite stream reach and was used for the geomorphic analysis and as base information for the hydraulic and geotechnical modeling. Survey data were collected by transferring georeferenced control points to the project area with a Topcon Survey Grade Global Positioning System. The topographic survey was performed using a Topcon total station and reduced in Eagle Point software. The project site map is shown in figure CS18–6.

Hydrology

Hydrologic analysis of Wiley Creek was performed using the U.S. Army Corps of Engineers (USACE) software program, HEC–FFA CPD–59 (formerly known as HEC–WRC) (USACE 1992). The flood frequency analysis is based on the methods present within Bulletin 17B guidelines of the U.S. Water Resources Council. Two gages were analyzed including USGS# 14187100, Wiley Creek at Foster, Oregon, and USGS# 14187000, Wiley Creek near Foster, Oregon. The two gages did not contain sequent records, which necessitated the use of watershed areal weighting to adjust discharge values for a composite record. Results of the flood frequency analysis are provided in table CS18–1.

Table CS18–1 Flood frequency analyses

Return period (yr)	Flow rate (ft^3/s)
2	3,251
10	6,111
25	7,437
50	8,365
75	9,243
100	12,092

Figure CS18–4 (a) Looking upstream from the Wiley Creek Bridge at the B1c reach above the project; (b) looking upstream to the bedrock overfall ledge. The Wiley Creek Bridge can be seen in the background. This location marked the transition from the B1c to D4 reach.

(a)



(b)



Figure CS18–5 Looking upstream at the D4 reach



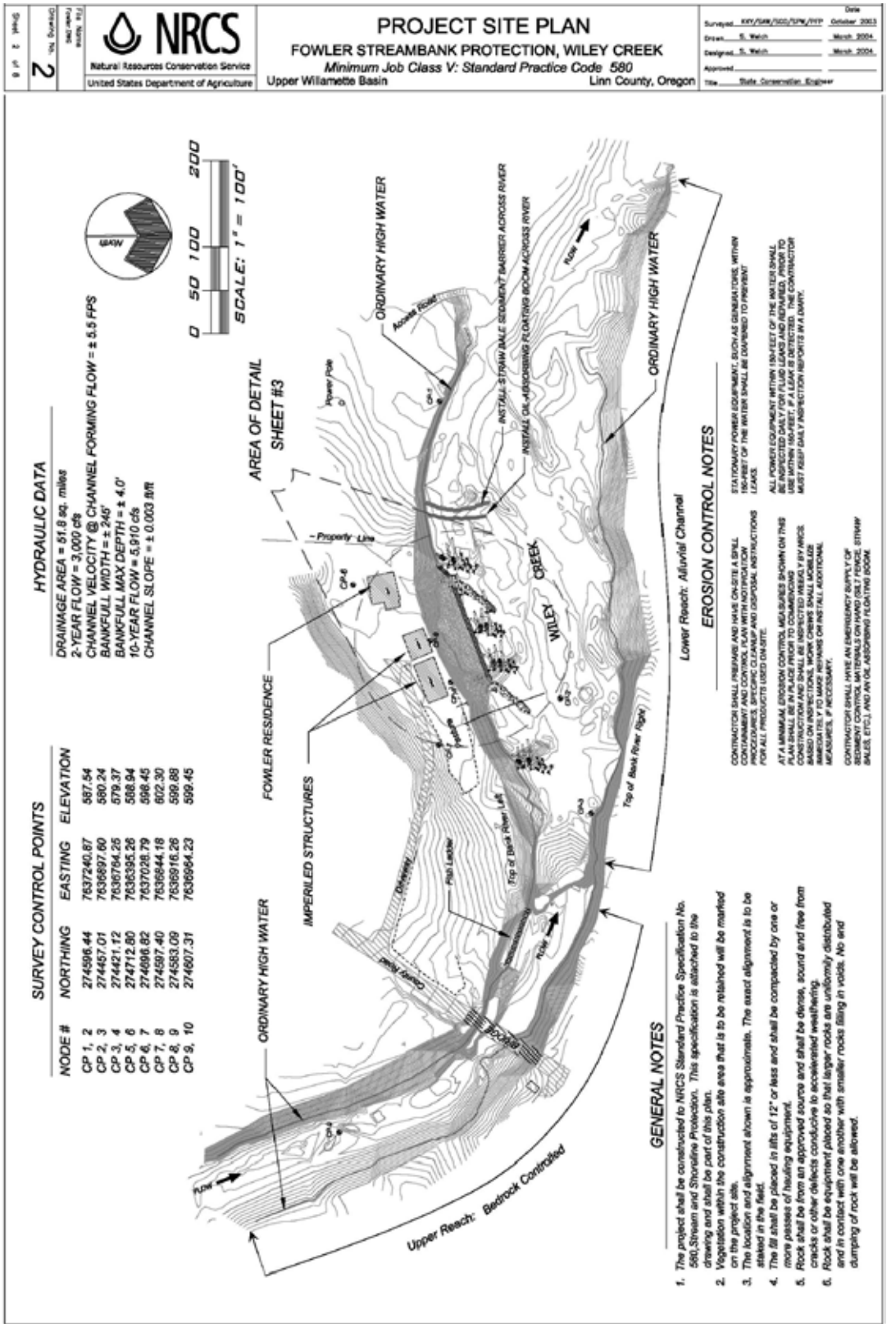


Figure CS18–6 Topographic site map of the Wiley Creek Project

Reach scale hydraulics

Wiley Creek was modeled with the USACE's River Analysis System (HEC–RAS) (USACE 1995a), using the topographic survey data as base information. The geometric data model included sections, reach lengths, and overbank stations and was developed in AutoCAD and exported to HEC–RAS for hydraulic analysis. Information obtained from the HEC–RAS model included average velocity, shear stress, stream power, and a reach length water surface and energy grade profiles at discharges ranging from the 2-year to 100-year flood. Velocity distribution output using the ArcView HEC-GeoRAS extension is shown in figure CS18–7.

The hydraulic model extended from the upstream-bedrock-dominated B1c channel, across the bedrock overfall, and through the high width-depth ratio D4 channel adjacent to the project. Model results were used to interpret reach-scale sediment transport processes by identifying areas of high hydraulic stress and depositional potential through the transitional channel morphology. Large energy losses were computed across the bedrock overfall that defined the break between the upstream transport dominated reach and the depositional project reach. The mixed flow regime was used to compute subcritical and supercritical water surface profiles including the large hydraulic jump at the bedrock overfall (fig. CS18–8).

Figure CS18–7 Quasi, two-dimensional velocity distribution for the 2-year flood computed by HEC–RAS. Contours and model cross sections (black lines) are also shown.

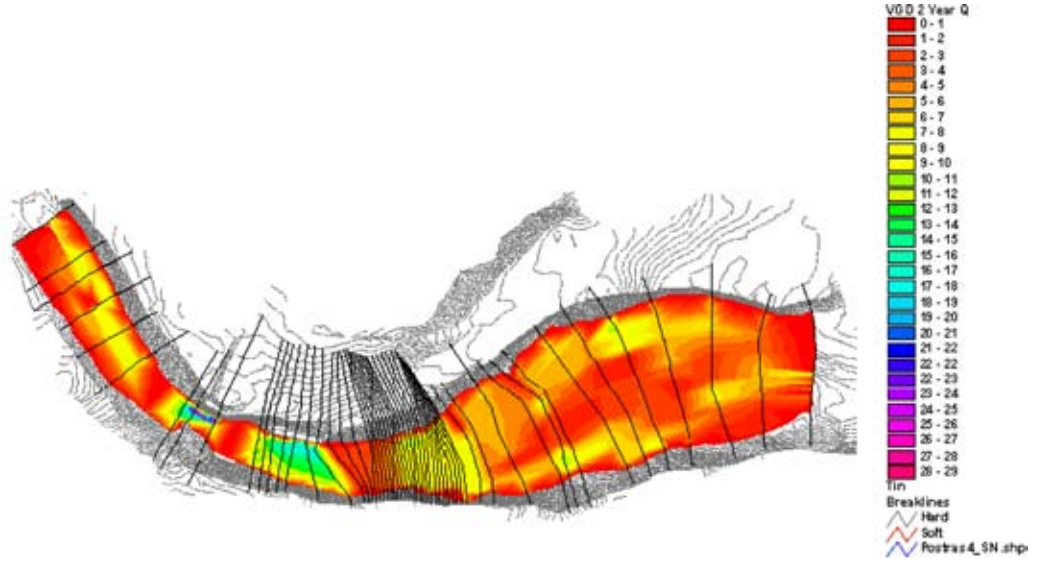
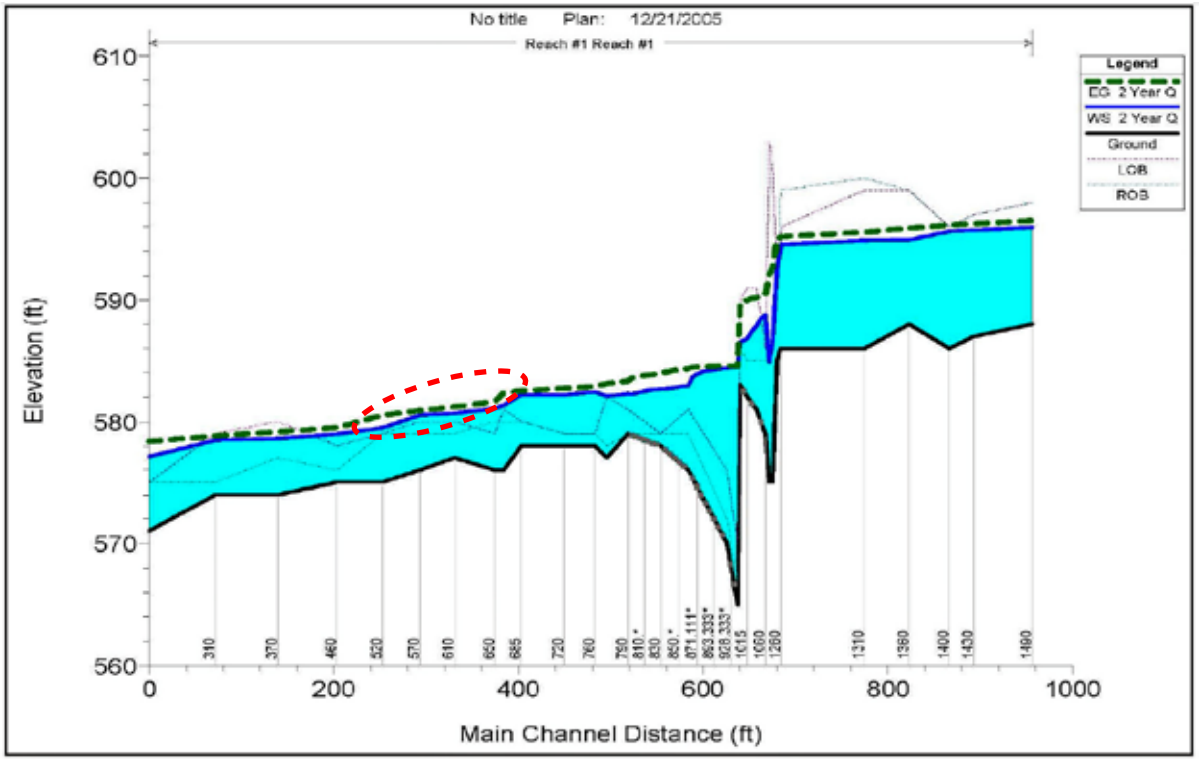


Figure CS18–8 Computed water surface profile and energy grade line for the 2-year flood. Note hydraulic jumps between sections 1260 and 928 across the bedrock overfall upstream of project reach. Project reach is defined by red oval.



Geotechnical design

During the initial site reconnaissance, the bank condition was evaluated for both hydraulic and geotechnical stability. The bank had eroded to a near vertical condition and was well beyond the stable angle of repose (fig. CS18–9). Bank stratigraphy consisted of poorly consolidated alluvium (fig. CS18–10). The buildings at the top of bank were an additional destabilizing factor as point loads. The dominant bank failure mechanism was hydraulic stress undercutting the bank with subsequent tension-block failure of the overburden. Rapid drawdown of the saturated soils and positive pore water pressure within the bank also contributed to instability.

The combination of hydraulic stress, low strength of the earth materials, and loading condition at the top of the bank required a design that would provide free-draining support to the bank, while resisting hydraulic stresses. Preliminary alternatives were identified that included an out-sloped embankment with a rock-reinforced toe or a structural fill section using cellular confinement or reinforced earth.

Reinforced earth combined with soil bioengineering techniques was chosen based on proven transportation applications, ease of permitting, and ability to incorporate habitat enhancement features. Two references provided the technical basis for the embankment design:

- Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines (U.S. Department of Transportation Federal Highway Administration (FHWA) (2001c)
- Forest Service Retaining Wall Design Guide (USDA Forest Service 1994)

These references provided two methods for determining the required geogrid, lift height, and tendon lengths for the reinforced earth embankment based on user-supplied geotechnical information. Additional information regarding these features is provided in technical supplements 14D and 14I of this handbook. Figures CS18–11 and CS18–12 show output from the FHWA RSSA (FHWA 2001c) program (companion software to Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines) that was used to analyze multiple water table and loading conditions for internal and global embankment stability.

The program solves the modified Bishop's method for bank stability for a user-provided factor of safety assuming both linear and rotational failure planes. The

Figure CS18–9 Looking upstream at the project bank. Less than 5 feet of bank remained from the building to the edge.



Figure CS18–10 Instream view of project bank. Note vertical condition and poorly consolidated sandy-silt alluvium bank material.



Figure CS18–11 RSSA model showing bank materials, loading, and computed tendon configuration for a mid-bank water table condition

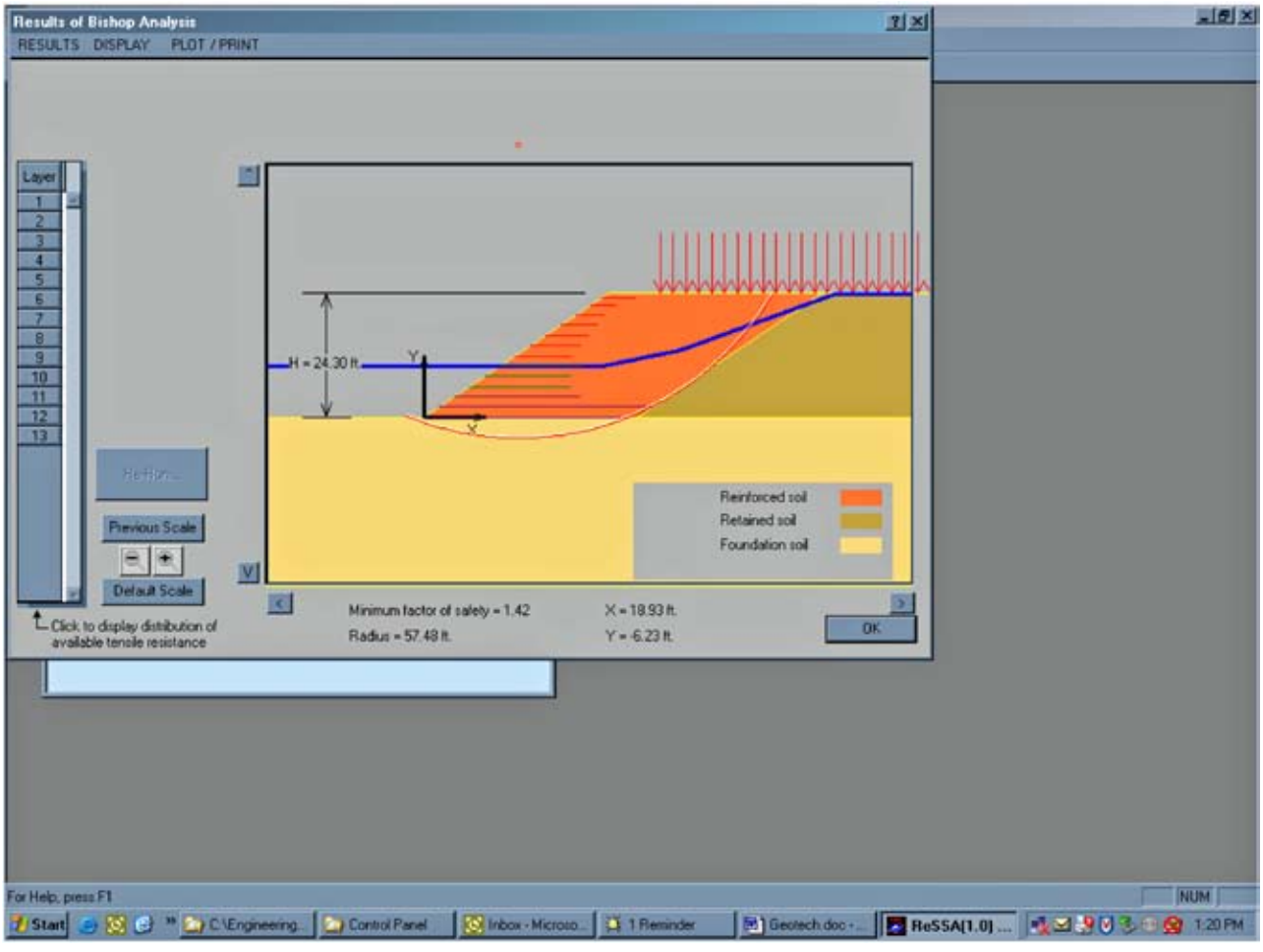
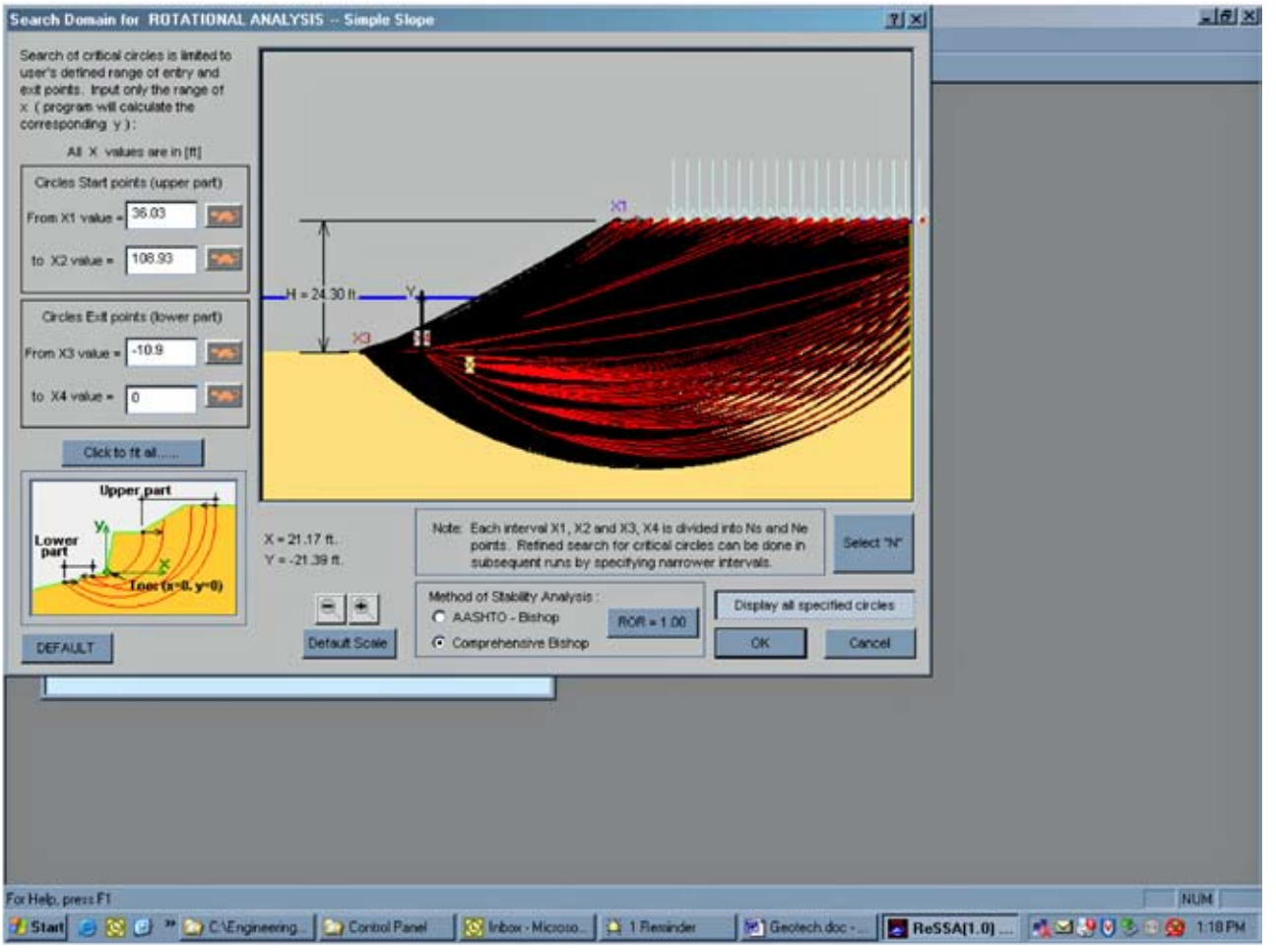


Figure CS18–12 Bishop slices showing optimization results for rotational bank failure



program optimizes on these two failure scenarios and computes required geogrid tendon lengths based on a user-provided elevation schedule.

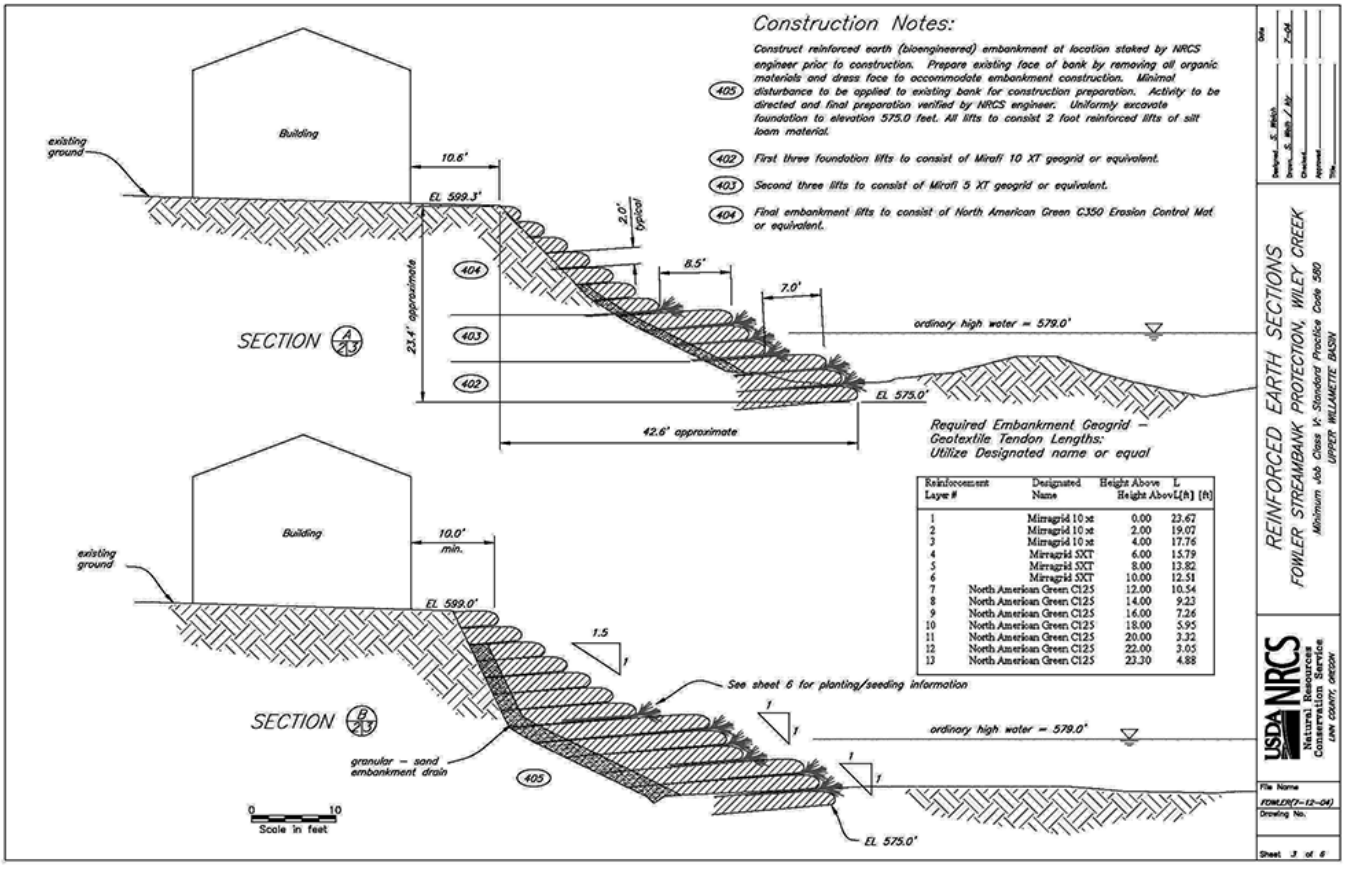
Tendon materials were chosen based on tensile strength, cost, and manufacturer's recommendations for the given condition. Lift design consisted of 2-foot compacted silt loam soil reinforced with a woven geogrid, and faced with a long-term erosion control fabric. The design also included a filter drain at the interface between the pre-project bankline and the imported material.

Vegetation design

The Aberdeen, Idaho, and Corvallis, Oregon, NRCS Plant Materials Centers were consulted for specifications on the appropriate vegetative components for the project. Increased boundary roughness using vegetation was critical for reduction in near-bank shear stress and velocity reduction along the face of the constructed embankment. Vegetation components were based on a hydric-to-mesic compositional transition from the base-flow elevation to the top of the top of bank. Native willow (*Salix lucida Muhl* ssp. *lasiandra*) was abundant at the project location and was harvested and placed between the embankment lifts. The embankment was protected by placing complete willow clumps along the toe-of-slope per NRCS PMC TN–42, Willow Clump Plantings and NRCS PMC TN–23, How to Plant Willows and Cottonwoods for Riparian Rehabilitation.

Figure CS18–13 shows construction documentation (section view) of the reinforced earth embankment, with the tendon schedule and willow placement within the lower lifts. The embankment drain is also shown at the original section-design section interface.

Figure CS18–13 Section drawings of reinforced earth embankment



Hydraulic design

Stability of the embankment required near-bank hydraulics to be controlled to threshold values less than the permissible maximum. The silt-loam embankment material could be readily entrained at velocities between 3 to 5 feet per second, even under optimum compaction. However, with appropriate measures, it was recognized that the geotechnical design was feasible. Methods used to reduce the near-bank shear stress included an increase in boundary roughness and large-scale roughness through the use of aggressive revegetation and ELJs, and flow redirection using stream barbs and ELJs.

Three ELJs were constructed using design methods presented by D'Aoust and Millar (2000). This information is similar to that presented in NEH654 TS14J. Their criteria are based on the systematic review and analysis of 90 constructed projects in western Canada, and they recommend a minimum factor of safety against buoyant forces on the ELJ structure of 1.5 or greater. Oregon NRCS uses this design analysis methodology, but does not use cable for connecting ballast to the log members. Based on experience and regulatory considerations, it is found that bolting the ELJ members together creates a composite structure and allows for competent framework for the rock ballast. Additional research in the Northwest has shown the habitat benefits of incorporating large wood in streambank protection projects for salmonid velocity refugia, cover, diversity complexity, and macroinvertebrate production.

Two stream barbs incorporating large wood were used for hydraulic control at the upstream and downstream ends of the reinforced earth embankment. Barbs are a proven technology for near-bank velocity reduction and bank protection. NEH654 TS14H provides design guidance for these structures including geometric design, spacing-layout, and rock sizing criteria. Figure CS18–14 shows construction of an ELJ and stream barb, while figure CS18–15 shows the layout all of the project components.

Figure CS18–14 (a) Construction of the upstream ELJ. A temporary cofferdam was placed to dewater the construction area; (b) construction of one of the project stream barbs. Photo is taken looking up the axis of the barb structure.

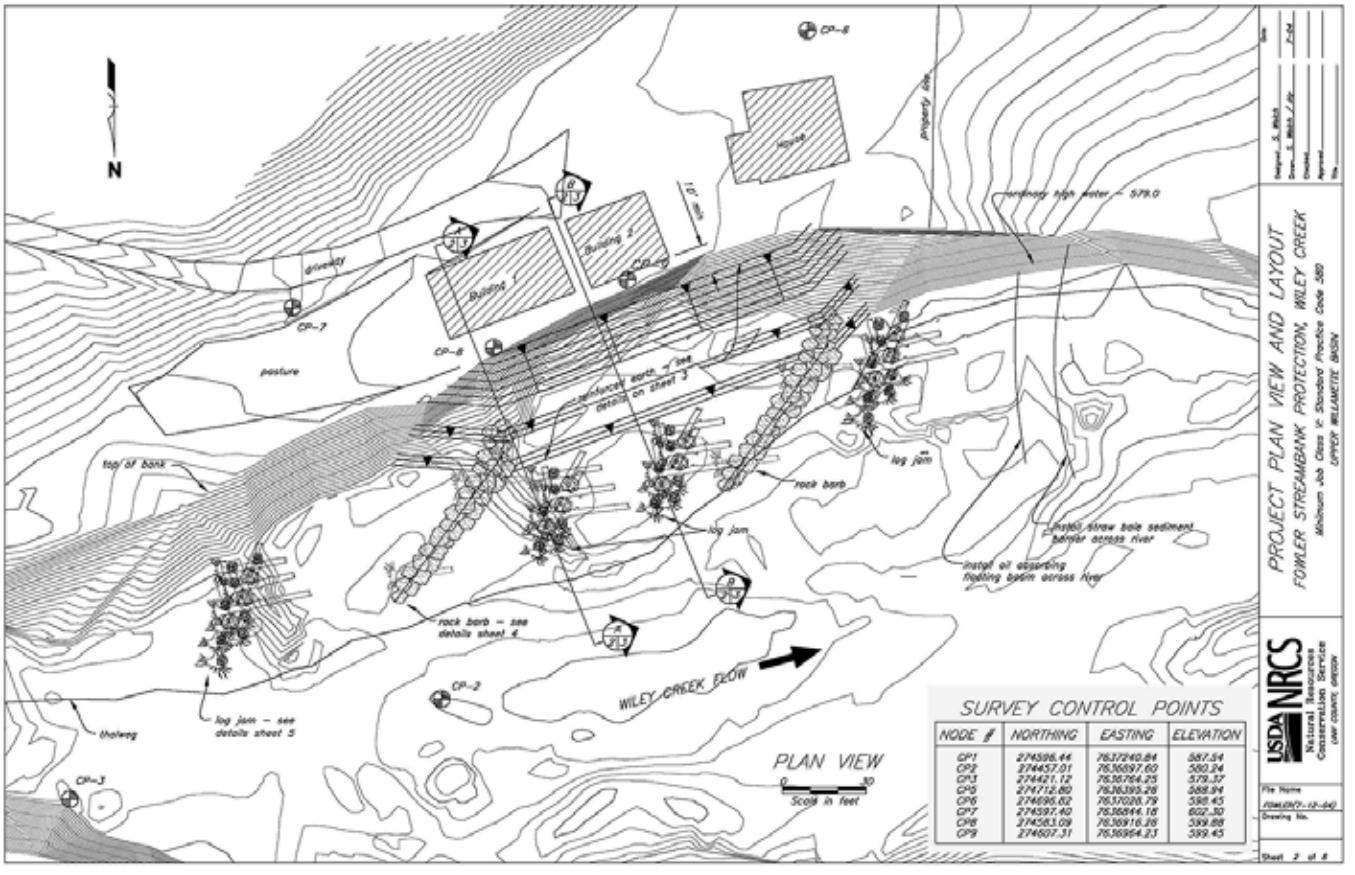
(a)



(b)



Figure CS18–15 Plan view layout of reinforced earth embankment, ELJs, and stream barbs



Construction: project cost

Contractor selection was performed by the landowner and although the selected company had limited instream construction experience, implementation progressed on time and within schedule. Design, permitting, and construction management were provided by the NRCS. Due to the presence of threatened and endangered salmonid species within many Northwest rivers, most states, including Oregon, have designated periods when instream work can be performed. This process requires all state and Federal permits be acquired before the limited construction window including endangered species act consultation, if required.

All equipment that operated instream was required to be cleaned and leak free with a spill management plan available from the contractor. Project equipment included: one D6 bulldozer, one 130-horsepower excavator, a front–end loader, and three 12- to 14-cubic yard dump trucks hauling fill material on a constant rotation. Total project cost was $107,000 including all construction labor and materials. The cost estimate and quantities of materials are shown in figure CS18–16.

Construction began with an access road to the bottom of the project bank and placement of a temporary cofferdam to divert flow from the project site. With site preparation complete, materials were delivered including large wood, rock, geotextiles, and embankment fill. The following list identifies the progression of project elements during construction:

- construction of the downstream stream barb
- foundation preparation and construction of the reinforced earth embankment
- construction of the upstream stream barb
- completion of the embankment
- construction of the four engineered log jams
- vegetation planting at toe of embankment and around large wood structures.
- vegetation planting of the embankment

Figures CS18–17 through CS18–21 document construction of the primary project components.

Figure CS18–16 Engineer's cost estimate and materials estimate for the Wiley Creek project

ITEM	ESTIMATED QUANTITY	UNIT	UNIT COST	ESTIMATE	
EROSION CONTROL & GEOTEXTILES					
NAG "C350" Erosion Control Mat, installed	1800	yd^2	$ 5.50	$ 9,900	550 yds^2 lifts, 350 yds^2 caps (Cost from NAG)
Mirafi soil reinforcement grid 10XT, installed	1200	yd^2	$ 5.00	$ 6,000	180' long x (32+27+26) tendon, cap & wrap
Mirafi soil reinforcement grid 5XT, installed	900	yd^2	$ 3.00	$ 2,700	180' long x (24+22+20.5) tendon, cap & wrap
Temporary Erosion Control	1	lump sum	$ 1,500.00	$ 1,500	
				$ 20,100	
ROCK & LARGE WOOD					
Large boulders delivered					
(large ELJ = 3, 6' & 8, 4' - small ELJ = 3, 6' & 4, 4')	112.5	ton	$ 21.00	$ 2,363	mid-valley gravel pit (NRCS Basin Engineer)
Large boulders delivered & installed in barb (avg 3' diam)	600	yd^3	$ 45.00	$ 27,000	mid-valley gravel pit (NRCS Basin Engineer)
Large Wood log jams installed	4	each	$ 5,000.00	$ 20,000	
				$ 49,363	
EARTHWORK & VEGETATION					
Compacted earth fill delivered & installed	3250	yd^3	$ 10.00	$ 32,500	mid-valley gravel pit (Cost from S.Wright)
Vegetation					
Willow Avg. 5.5'	2800	ft.	$ 0.20	$ 3,080	Salem SWCD
Red Osier Dogwood 5'	230	each	$ 0.20	$ 230	Salem SWCD
Potted Plants	455	each	$ 3.50	$ 1,593	Salem SWCD
Columbia Sedge	920	each	$ 0.60	$ 552	Salem SWCD
				$ 5,455	
			TOTAL ESTIMATE =	$ 107,417	

Figure CS18–17 (a) Access road was constructed to allow haul trucks to drive onto each lift, dump fill material, and provide compaction; (b) fill material was spread uniformly with a dozer.

(a)



(b)



Figure CS18–18 (a) First soil lift on top of the base foundation geogrid. Portion of upstream stream barb is in foreground, and downstream barb is seen in distance. Geogrid extending from the soil is wrapped over to encapsulate the lift after compaction and grade have met specification; (b) Grade was checked at multiple locations on each soil lift. Base course geogrid can be seen underlying fill material.

(a)



(b)



Figure CS18–19 (a) First lift is complete for grade and compaction, and geogrid has been wrapped and staked. Lift is being faced with erosion control fabric to minimize soil piping and reduce photo-degradation of the geogrid tendon. (b) First lift is completed, and willow cuttings are being placed. Willows were harvested onsite and placed between the first three lifts to the bankfull elevation.

(a)



(b)



Figure CS18–20 (a) Embankment construction continues on lift #9. Note the terrace setback about midway up the bank. This feature provided a flat zone to facilitate shrub planting. Another terrace setback was placed at lift #9. (b) Embankment construction is complete and vegetation planting has started. The NRCS Plant Material Center provided guidance on native vegetation selection and appropriate species for the project.

(a)



(b)



Figure CS18–21 (a) Excavator used a chain to place log members in position for the construction of the engineered log jams. Individual log members were bolted together, and rock ballast was placed. Note pool in background. (b) The presence of salmon in the immediate vicinity of the construction area required careful management of turbidity and site runoff. Photo was taken at the pool noted in figure CS18–21a.

(a)



(b)



Project performance

High flows tested the project after construction was completed in August 2004. A late December storm brought significant snowfall to the Cascades which rapidly melted during a warming trend. This snowmelt-driven runoff, combined with rainfall, resulted in considerable discharge in many of the Cascade River systems. The project experienced a flow of approximately 2,500 cubic feet per second without any erosion (fig. CS18–22). The revegetation and plantings were in a dormant condition and offered little benefit of hydraulic resistance, which served as a testament to the effectiveness of the ELJ and stream barb design incorporated into the project. Currently, the growth of the vegetation components, including willow cuttings used in the embankment and the clump plantings placed along the toe, have provided an additional factor of safety against erosion (figs. CS18–23 through CS18–25).

The objectives of the project in providing bank stabilization and habitat improvement were met completely. The landowner was originally faced with imminent loss of property and now has a bank that is restored to a stable condition, and the buildings are protected. From a technical standpoint, the project has proven that earthen embankments can be used in a dynamic fluvial environment if appropriate hydraulic control is incorporated. Additionally, bank protection projects and fisheries habitat improvement are not mutually exclusive applications, but can be designed in concert to meet multiple engineering and ecosystem-based objectives.

Figure CS18–22 (a) Project nearing completion. All primary project components are complete except for embankment vegetation. (b) November 2004 flooding approximately 2 months after the completion of construction. Note high velocities deflected at the upstream log jam (on left of photo) and the subcritical, low-shear stress flow condition in the near bank region along the embankment toe.

(a)



(b)



Figure CS18–23 (a) Looking downstream along the embankment immediately after construction and before planting of vegetation (August 2004); (b) Same view of project in December 2005 showing vegetation establishment. Note location of buildings in both photos.

(a)



(b)



Figure CS18–24 (a) Looking upstream along the embankment immediately following placement of vegetation (August 2004); (b) Same view of project in December 2005 showing establishment of vegetation with vigorous willow growth along the embankment toe. Note location of buildings in both photos.

(a)



(b)



Figure CS18–25 (a) Preproject bank condition (June 2004); (b) Bank condition 1 year after project completion

(a)



(b)

