Restoration in the Pit River Watershed

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BIOGRAPHIES

Daria Hoyer received a B.S. in Animal Science from UC Davis in 2001. She spent several months working as a Watershed Monitoring Technician with the Central Modoc Resource Conservation District, in Alturas, CA, and is currently a project coordinator for Salix Applied Earthcare, in Redding, CA.

Clifford Harvey holds a B.S. in Zoology (Southern Nazarene University, 1977) and a M.S. in Natural Resources/Interpretation - Recreation Planning (Humboldt State University, 1988). Mr. Harvey managed youth hostels for six seasons while pursuing his graduate degree. Ten years of service with various resource agencies provided experience in project coordination and environmental documentation. Since 1999, he has served as Watershed Coordinator for the Central Modoc RCD, where he leads a program of watershed monitoring and restoration projects. He actively participates in the District's education/outreach programs. He resides in Day, California, with his partner Jan Sorochtey.

John McCullah received a BS degree in Watershed Management from Humboldt State University in 1984, and he became a Certified Professional in Erosion and Sediment Control in 1988. John is currently the president of Salix Applied Earthcare, a natural resource consulting firm in California, and he is also the founder and director of the Sacramento Watersheds Action Group (SWAG), a non-profit watershed restoration organization. John is the author of the Erosion Draw 4.0 and Bio Draw 2.0 CDs, and is the instructor for the Watershed Restoration class at Shasta College. He currently teaches courses across the country, on topics ranging from NPDES Phase II Compliance to Biotechnical Streambank Stabilization.

ABSTRACT

The Upper Pit River has been impacted in numerous ways over the past century. It has been straightened, dammed, bound by levees, laid bare by grazing and drained by agriculture, to name a few impacts. However, today, the people living in the Upper Pit River Watershed want to see the river return to a more functional state. This shift in values has occurred due to changes in public knowledge about the environment as well as a dramatic decline in the river's recreational value in recent years. The Central Modoc Resource Conservation District has been working with area ranchers and property owners to inform the public of how they can maintain their river's ecological integrity, and restore some stretches of the river itself, using cost-effective and environmentally-sensitive biotechnical streambank stabilization techniques.

This paper will discuss 3 projects undertaken by the CMRCD, with the assistance of John McCullah of Salix Applied Earthcare. The project on the North Fork of the Pit River was a 2255 meter (7400 ft) long streambank stabilization undertaken in the late fall of 2000 that employed biotechnical techniques such as rootwad revetments with vegetated riprap, brush mattresses, and stone toe with brushlayering. Two projects were undertaken on the South Fork of the Pit River; they both involved levee removal and streambank stabilization, and one also involved realignment of the river. These projects were undertaken as demonstrations that were funded by a Proposition 319 grant. The specific interest of

the grant committee was development and testing of biotechnical streambank stabilization methods that could be implemented by ranchers with the equipment they had on hand.

The paper will review the historic causes of degradation at each site, and provide a rationale for the particular biotechnical measure, or combination of measures, employed for restoration. An overview of construction and maintenance guidelines will be given, and the success or failure of the installations at each project site will be described. Our review of these projects will give restoration practitioners the opportunity to evaluate environmentally sensitive streambank stabilization measures.

INTRODUCTION

One of the largest problems in lotic systems that pass through America's agricultural lands is the disappearance of riparian buffer zones. This is typically due either to overgrazing of the areas by livestock, or to clearing the area to expand crop field size. Initially, it seemed like a good idea, because the landowner could make more money with increased grazing area or crop production. However, many landowners have since watched their land fall into the river and float downstream, because there are no roots to hold the soil in place. In many cases, landowners have lost more land than the original riparian area occupied. This monetary loss, if not the decrease in aesthetic value, has induced many landowners to look for ways to restore their streambanks. Conservation Districts across the country have become an excellent resource for landowners to turn to for help with protecting or restoring their streambanks.

In northeastern California, the Central Modoc RCD (CMRCD) serves as one example of this trend. Governed by an appointed board of volunteer directors, the CMRCD has no regulatory or enforcement authority. All CMRCD programs are 100% grant funded, and all projects are, as a matter of District policy, implemented in voluntary cooperation with willing landowners. Since 1997, CMRCD has organized, obtained grant funding for, and implemented various projects including the three described in this paper. Projects are planned throughout the watershed in order to learn and demonstrate management solutions for the variety of conditions encountered in this unique setting.

Salix Applied Earthcare, a biotechnical erosion control consulting firm in Redding, CA, designed the projects and provided training and construction oversight.

In 1999, CMRCD obtained a $500,000 grant of State of California water quality bond funds. These "Proposition 204" funds were administered by the Central Valley Regional Water Quality Control Board (RWQCB), a state agency. This grant was designed to provide watershed education, monitoring and restoration projects for the upper Pit River. Additional funding for these projects included a California Dept. of Conservation Watershed Coordination grant, and generous in-kind contributions from the Alturas Field Office of the Natural Resources Conservation Service and Modoc National Forest. Large in-kind contributions from participating landowners should also be recognized.

Approximately 60% of this grant was allocated for the development of demonstration projects that would serve to develop various relatively low-cost techniques that local landowners could implement and sustainably maintain. The emphasis was placed on environmentally-sensitive biotechnical techniques that combined vegetative plantings (which add the geotechnical strength of roots, branches and shoots) with structural components, such as rocks, logs, or sometimes, the cuttings themselves. Some geomorphic design accompanied the work; for example, the opposite banks sometimes had point bars lowered to allow the river access to the floodplain during bankfull discharges. All designs included analysis of bankfull (or Mean High Water) elevations.

This paper covers three case studies of biotechnical streambank stabilization and restoration on agricultural properties located on the Pit River. The techniques used, what worked well, what pitfalls were encountered, and possible methods of avoiding these pitfalls will be discussed. One thing that was discovered during these projects was the quantity of materials found on an average ranch; these projects were accomplished with little to no purchase of materials from outside sources. This makes these techniques economically feasible for the typical rancher in the Pit River watershed, and perhaps for other ranchers, as well.

Bushey Ranch

The Pit River, as it travels through the Bushey Ranch, has a sinuosity, gradient and substrate similar to a Rosgen C6 - type channel; that is, it is prone to a moderate degree of migration. As the channel meanders, it erodes the banks of the outer bends; a small amount of erosion in these areas is natural, but in this case, the erosion was severe, and downcutting in historic times was evident. The increased sedimentation rates allowed mid-channel bars to form, which directed stream flow to the outer banks, and caused further degradation of these banks, as well as spurring erosion on straight reaches and some inner banks.

One of the biggest reasons for the accelerated rates of erosion that were observed was the lack of riparian vegetation. During the first site visit in Jan. 1999, only moderately-rooted grasses and a few willows were noted on the most active erosive reaches. In most lotic systems, vegetation is one of the most important factors in bank stability. Old Mr. Bushey insists that an infestation of aphids precipitated the decline of the riparian vegetation that the younger Bushey's report as being so thick that access to the river edge was difficult only 40 years ago. Other observers have noted decades of year-round cattle access to the river, and have suggested that this, too, may have played a role in the loss of the willows. But a primary stressor to the site must also be the decades of change in the vast upper watershed. These historic changes almost certainly have increased the rate and intensity of runoff events, all of which must funnel through the constricting canyon in which lies the Bushey Ranch.

Likely Land and Livestock (LLL)

Likely Land and Livestock is located 32 km (20 miles) south of Alturas, on the South Fork of the Pit River. The ranch is owned by the Flournoy family, who recently celebrated 120 years of cattle and hay production in the community of Likely. During the 1940s or 50s, this reach of the South Fork was channelized by SCS or the US Army Corps of Engineers. Levees were created on both sides of the river by the sidecast material, effectively confining the channel. The slope on this reach of the South Fork of the Pit River is approximately 0.01%, and thus prone to meandering. The levees that had been built were eroded as the river meandered, leaving cut banks as high as 3.7 m (12 ft) in several cases. Where new meanders cut through the levees, very little riparian vegetation was found, apart from a few scattered willows. John Flournoy requested RCD assistance in treating these conditions to improve water quality and habitat value, as well as increased agricultural productivity.

TREATMENTS

Bushey Ranch

The RCD Directors envisioned this project as an opportunity to demonstrate and compare a variety of stabilization treatments. Construction on this site occurred in the fall and winter of 2000. Because one of the biggest factors contributing to erosion of the banks was a lack of riparian vegetation, all treatments incorporated significant vegetative establishment practices. The banks were planted with over 40 willow stems per linear meter (12 stems/ft), in many cases. The prescribed treatment included a variety of techniques, which are briefly outlined below.

Reach A was a 192 m (631 ft) long cut bank that received a rock toe with brushlayering, along with a brush mattress. Because the right bank received a ‘hard’ treatment, the point bar on the left bank was graded back to allow energy dissipation. Reach B had similar cut banks, but because it was an outer bend, it received a vegetated riprap revetment to the top of bank; and, as in Reach A, the opposite bank was graded back. Reach D was treated with a 61 m (200 ft) long rock toe with brushlayering. Reach E received a brush mattress to top of bank, with a willow wattle toe. Reach H was subject to in-channel work, with removal of center channel depositional features to create a single thread channel. Reach I featured a rootwad/rock revetment structure with pole planting. A stone bridge abutment that had washed out in the 1920s or 30s, was removed from both banks of the river, as it was having a substantial effect on upstream deposition rates.

Bushey Project: Vegetated Riprap 1 month and 1.5 years after construction

LLL

The restoration work on the South Fork of the Pit River at Likely Land and Livestock was completed in two phases; the plans for Reach A were implemented in January of 2001, and Reach B was restored in September through November, 2001. Willow densities used at LLL were similar to those at the Bushey Ranch. Reach A was a basic bank stabilization, and gravel bar redesign. Reach B, however, entailed a realignment of the river and the physical removal of thousands of cubic meters of potential erosion to create a more functional flood plain. The site also featured creation of nutrient uptake ponds to serve an adjacent winter livestock feeding area.

Reach A

In Reach A, a gravel bar had formed mid-channel, and was redirecting flow into the streambank, which was consequently experiencing severe erosion. The gravel bar was removed, placed at the toe of the adjacent bank, and secured with brushlayers, which were to slow water and encourage sediment deposition. Willow and Cottonwood pole plantings were placed at the back of the toe. Upstream of the gravel bar, a 107 m (350 ft) long vertical cut-bank, the relict of the old levees, was laid back at a 2:1 slope, and stabilized with a brush mattress. At the toe of the brushmattress, one rank of live siltation was installed, and both treatments were secured with a continuous 30 cm (1 ft) diameter willow wattle. The levee relicts were removed, and the excess earth was graded into the adjacent meadow, which had ceased to function as a flood plain and wetland when the river was channelized.


LLL-Reach A Project: During and After Construction of Live Siltation, Willow Wattle, and Brush Mattress

Upon completion of the Reach A treatment, LLL leveled the meadow and placed it in production. This new 5.7 ha (13 acre) flood irrigated meadow produced its first hay crop in over 30 years, and allowed greater efficiency in use of water allocations. The noxious weed problems that had previously been experienced in the meadow were eliminated.

Reach B

The Reach B project encompassed a 610 m (2000 ft) long stretch of the South Fork of the Pit, and a 305 m (1000 ft) long stretch of irrigation channel. This irrigation channel is a relict alternate river channel that was controlled decades ago for irrigation. It passed through a winter feeding area, and drained directly into the South Fork Pit at the downstream end of the project.

This "back channel" was realigned slightly and impounded so that winter runoff (i.e., the low flow season in this watershed) would cycle slowly through it, allowing a degree of nutrient uptake. An overflow channel, berms and rock armor at the impoundments were installed to prevent blowouts during high-flow events.

LLL-Reach B Project: Before, During and After Realignment and Installation of Brushlayering with Rock Toe

Along the main channel, the levees and stranded flood plains were dropped an average of about 1.2 m (4 ft) with a self-loading scraper. Spoils were graded into the new hay meadow. A gravel bar that had formed and grown into an island mid-channel was removed, and placed at the toe of the bank that it had eroded. The sod growing on it was salvaged for placement later. The meanders that had been carved into the levees were narrowed, and more stable meanders were installed. All outer bends were armored with a rock toe with brushlayering, and all point bars were graded back, such that the tops were at Mean High Water. Sod was collected from point bars and the island; when the project was done, these were placed over the brushlayers, and watered in.

HANDLING OF MATERIALS

Bushey Ranch

For the Bushey Project, some 50,000 live willow cuttings were harvested by a temporary crew of 12 laborers. Various species were collected, primarily *Salix exigua, lasiandra, and lemmonii*. Stems were cut, clipped of excess foliage, sorted by length and tied into approximately 30 cm (1 ft) diameter bundles for easy handling. The bundles ranged from 1.2 to 2.4 m (4 to 8 ft) in length, but there were a large number of 3-4.9 m (10-16 ft) poles as well. Bundles were tied with scrap baling twine, of which there seemed to be an endless supply.

Harvesting and handling of the cuttings for the Bushey Ranch was affected by unseasonably hot late-September weather, a 30-40 minute haul time, and difficulty in keeping prepared cuttings fully submerged in the storage pond. Cuttings collected later in the project, after the weather cooled, had a much higher survival rate, as noted below, in the discussion.

LLL

The willows collected at LLL - Reach A were collected in February, when it was freezing most days, and as the cuttings were dormant from harvesting through installation, they showed a much higher success rate.

At LLL - Reach B, experience with early autumn problems at Bushey's led to greater care in collection. A smaller, more nimble and more experienced crew were employed. The haul was shorter this time, and stock was more fully submerged. Some bundles of stems were fully submerged for up to 6 weeks with no observable ill effect. Because over 25,000 stems had to be harvested, most of the willow cutting occurred during the 2 weeks prior to construction. Unfortunately, the willows had not yet entered dormancy, and therefore, particular care had to be taken with the cuttings. A 4-6 person crew was able to harvest upward of 1,000 stems per day. The crew rotated tasks, with 2 people cutting, and 2 people tying and loading the willow bundles to be driven to the project site. At the project site, the willows were stored in a pond, just below the spillway of an irrigation diversion dam. 70-80% submersion was attempted; however, many of the bundles ended up fully submerged at the bottom of the pond. The cuttings were stored in this pond anywhere from 2 weeks to 6 weeks, or more. On a mid-project site visit, the principal consultant from Salix reviewed procedures. Additional top pruning and watering-in of newly planted cuttings was prescribed.

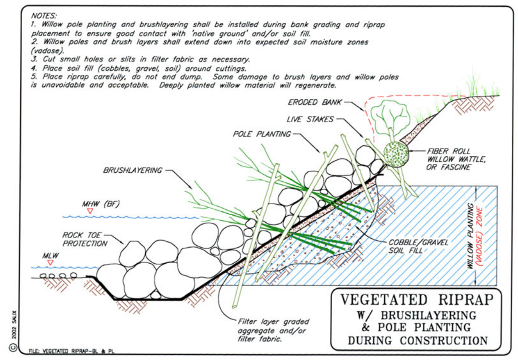
INSTALLATION OF STRUCTURES

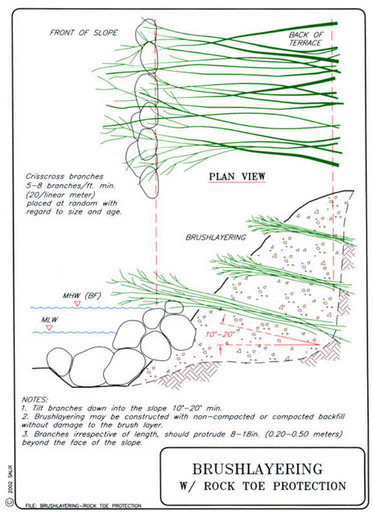
During excavation at the Bushey Ranch, a considerable portion of the work was accomplished with the ranch's heavy equipment. All bulldozer and backhoe work, and a considerable part of the spoils disposal was contributed by the Busheys, along many small tools, pickup truck time, and family labor. Family representative Mike Bushey had his belly-dump tractor trailer combination on the project while turning down paying construction jobs. At LLL, John Flournoy and his family and crew also contributed greatly to the success of the project. Fencing materials, farm equipment time, water conduits, rocks from the Ranch's quarry, and willow cuttings were provided along with a lot of labor on the ranch's payroll. Commitment like this makes projects possible.

Bushey Ranch

Vegetated Riprap (Reach B & D) (see Typical Drawing)

The vegetated riprap was installed with the "Brushlayering" method. The bank was laid to a slope somewhat less than the desired finished grade and a key trench was excavated down to an elevation level with the lowest part of the channel. The rock toe was then placed in this trench, and a first course of brushlayering was installed at a density of 16-23 stems per linear meter (5-7 stems/ft) and watered. The next layer of stones was placed on top of the initial rocks, but graded slightly back (at the desired slope), and the soil and brush layering process was repeated. Reach B was rocked to the top of the 3.7 m (12 ft) tall slope, as this was judged to be a high stress reach. Reach D, on a less critical bend, was rocked about half way up the 3.7 m (12 ft) tall slope.



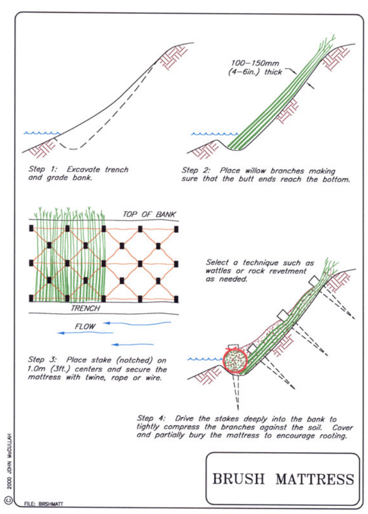


Brushlayering with Rock Toe (Reach A, about 122 m (400 ft))

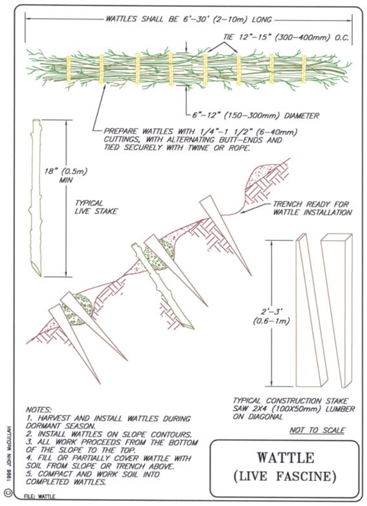
The brushlayering with rock toe was installed in much the same manner as the vegetated riprap, with the exception being that only one rank of rocks was installed.

Brush Mattress (Reach E & A, about 260 m (850 ft), total) (see Typical Drawing)

In Reach A, above the brushlayering with rock toe, a brush mattress was installed. The slope was graded to the desired final slope. Approximately 50-65 cuttings per linear meter (15-20 cuttings/ft) were laid flat against the graded slope, slightly crisscrossed, with the basal ends placed at the bottom, just above the rock toe, and the tips at the top. The installed mat gave ground coverage of about 80% and was about 15-30 cm (6-12 in) thick. A grid of 61 cm (24 in) long stakes was pounded into the mattress at .9 to 1.2 m (3 to 4 ft) centers (see typical drawing: Brush Mattress, below), such that the stake was driven about ¼ of its length into the ground. The brush mattress was secured by using ¼ inch polypropylene rope, tied in a diamond pattern between each row of stakes. After the ropes were laced onto the stakes, the stakes were driven in further to compress the mattress tightly against the slope.



A small backhoe backfilled around and in between the branches of the mattress by using material excavated from the trench, working the soil in well. The installed mattress was watered thoroughly with a fire hose.

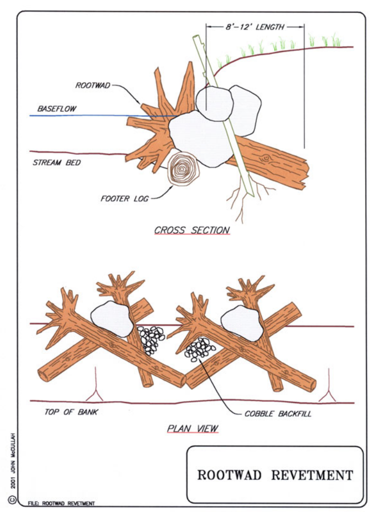


Reach E also was protected with a Brush Mattress, but the bottom of the Brush Mattress was placed below the mean high water level, with a willow wattle at the toe.

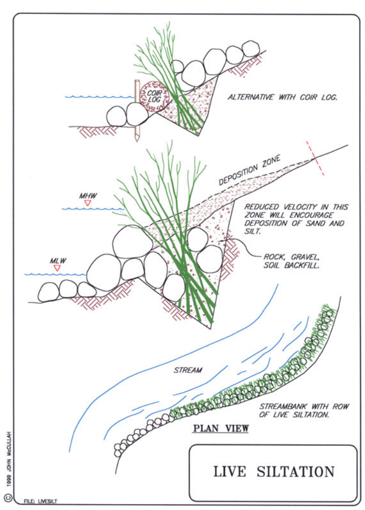
Willow Wattle (see Typical Drawing)

Willow bundles, typically 2.4-3.7 m (8-12 ft) long and 30 cm (12 in) in diameter were laced together with 61 cm (24 in) overlap to form nearly continuous wattle structures for the length of the reaches. Growing tips and butt ends were oriented in alternating directions. The cuttings were staggered in the bundles, so that the tips were evenly distributed throughout the length of the wattle bundle. The bundles were then compressed and tightly tied with 6.3 mm (¼ in) polypropylene rope. The bundles were tied approximately every 0.3-0.4 m (12-15 in).

Rootwad Revetment (see Typical Drawing)



A backhoe was used to set a “footer” log in a trench excavated below the thalwag, running roughly parallel with the bank. A second log, with the root wad attached, was set on top of the footer log diagonally, with the root wad end pointing upstream into the flow, and the butt end lying downstream 45-60° degrees. The butt end of the root wad was set in a trench excavated into the bank, and large boulders and willow poles were used to secure it. Subsequent rootwads in the revetment were installed in a similar fashion, progressing from downstream up. The willow poles were placed into the excavations to ensure they were deeply embedded and able to contact the water table.



LLL - Reach A

Live Siltation (see Typical Drawing)

A V-shaped trench was excavated just below the Mean High Water level, parallel to the toe of the streambank. A thick layer of willow branches was laid in the trench, such that ½ of the length of the branches was above the trench and the branches angled out toward the stream. A minimum of 40 willow branches per meter (12 branches/ft) were placed in the trench. The branches were backfilled over with a gravel/soil mix and the top was secured with a willow wattle.

Brush Mattress and Willow Wattle

The willow wattle and brush mattress installed at LLL - Reach A was similar to that installed at Bushey, Reach E.

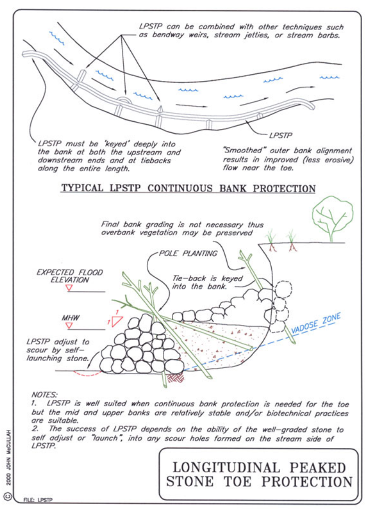
LLL - Reach B

Brushlayering with Rock Toe

Different site conditions dictated that the brushlayering with rock toe be installed differently at LLL - Reach B, than it was at the Bushey Ranch. At LLL, the toe helped to define the new bank, when the river was realigned; therefore, a single row of rocks was placed where the new bank was desired. Tops of the rock toe were placed approximately at the bankfull level. Willow cuttings were placed behind these rocks, and soil from the old banks was backfilled behind the rocks. This soil was watered in by taking scoops of water from the river with the excavator bucket, and dousing the newly-planted willows. After the willows were watered in, sod plugs that had been removed when the point bars were graded back, were placed just behind the brushlayers, and the whole thing was watered in again.

A second method of brushlayering with rock toe was employed as well. In areas where the rocks were placed at the toe of an existing bank, an excavator bucket was used to pull back a plug of earth just behind the rocks. The bucket was raised such that there was a 1.2-1.5 m (4-5 ft) space for hand crews to throw some willow cuttings in, and the bucket then released the earth. This was a very quick method of brushlayering that minimized sod disturbance, while digging deep enough for the willows to be well within the vadose zone.

Longitudinal Peaked Stone Toe Protections (LPSTP)
(see Typical Drawing)



The LPSTP was constructed from upstream to downstream, placing rocks along an alignment that was staked out prior to construction with metal T-posts, connected by rope. The peaked profile was maintained by using an excavator with a thumb to place the rock. As the excavator placed the rock, hand crews followed behind, planting willow poles and cuttings. The keyways were constructed by digging a one-bucket (1.8 m (6 ft)) wide trench at the upstream and downstream ends, as indicated on the ground prior to construction. The trench was dug down to meet the base of the LPSTP, and sloped 9.1 m (30 ft) up into the bank. Once the trenches were dug, they were filled .9 m (3 ft) deep with rock, planted with willow poles, watered-in, and backfilled. The two tie-backs were constructed in a similar fashion.

RESULTS

Willow survival rates were determined by counting live stems versus dead stems within 15 cm (6 in) either side of a rope laid vertically on the slope, at 9.1 m (30 ft) intervals. Survival counts were made at Bushey Ranch in the summer of 2001.

The average willow survival rate for Reach A was 17.5%; however, survival of the brushlayers was much higher than the average, and brush mattress survival was much lower. The vegetated riprap at Reach B showed a 24.6% average survival. Reach D (Brushlayering with Rock Toe) had an average survival of 34. The average survival of the brush mattress and willow wattle at Reach E could not be determined, but it was noted to be similar to Reach B, which experienced a 24.6% survival. The rootwad revetment and vegetated riprap at Reach I had a 38% average survival. Reaches B, D and E all showed a trend of having much higher willow survival at the toe of the bank, than at the top.

DISCUSSION

Bushey Project:

After an early wet start, the winter of 2000-2001 was one of the driest in recent memory, which led to exceptionally low soil moisture at the onset of spring. A subsequent hot, dry spring and summer did its work on the already desiccated plantings, and the summer irrigation called for in the project plans to sustain the cuttings over the first summer was not possible due to the water shortage. Consequently, the vigor of the new willow shoots was much lower than optimum. Other negative factors included inadequate foliage removal and inadequate soaking during storage. All cuttings were stored in a pond before delivery to the site, but most were not adequately submerged. The willows were frequently stored with only the butt ends in the water, instead of the recommended 80 % (McCullah, 2002). While most foliage was removed, too much was left, and terminal buds were not removed; Experience shows that when the terminal buds are removed from willows, root growth is increased. This allows the plants to put energy into developing root systems to obtain nutrients before new shoots use up all of the energy stored in the cutting. Early root development increases the chances for long-term survival. Therefore, when the terminal buds were left on the willow cuttings at Bushey Ranch, their chances for survival were decreased. These factors underscore the need for close communication between the project coordinator, labor crew leaders, and biotechnical design staff throughout the project, to ensure that the best possible practices are employed.

The brush mattress at Reach A was the first one installed on the Bushey project, and was placed above the rock toe with brushlayering. It was realized shortly after installation that the brush mattress should have been planted behind, instead of above the rock toe and brushlayering; that is, the butt ends of the willow cuttings used in the technique should have been well below the top of the rocks that were installed. The fact they were planted so high, in such an arid environment, is probably one of the biggest reasons for the very low survival observed. This poor design feature was exacerbated by the dry winter and spring.

The second brush mattress that was installed (Reach E) was planted much lower, with the butt ends of the cuttings below the mean high water elevation, and secured there with a willow wattle. In addition, the willows on this reach were installed near the end of construction, when the crew had run out of willows to plant, and therefore, had to harvest new cuttings, and allow them to soak for a day or less; because of the decrease in storage time, the willows may have been in better shape upon planting. The next year, however, was a very low water year, and the river did not reach bankfull, which left the brush mattress high and dry for much of the first growing season. The higher survival rate (24.6% versus well below 17.4%) was likely due to a combination of lower planting, and better cutting care.

Another trend that can be found among the various reaches at Bushey Ranch is the relatively high survival rate of the brushlayering technique as compared to the brush mattress technique. This is likely due to the fact that when brushlayers are installed, the willow cuttings are planted deep enough that they reach the vadose zone. Moisture retention is very high, due to the clayey nature of the soil in this area. In low water years, the moisture content below the soil fluctuates much less dramatically than it does on the surface. Therefore, in some arid areas with clayey soils, brushlayering may be the optimum revegetation method, as it serves as a sort of 'insurance' that even in dry years, establishment is possible.

Although the percent survival observed at the Bushey Project were low, it should be noted that revegetation overall was at least sufficient, and that this project was by no means a failure. During the course of this project, nearly 50,000 willow cuttings were planted. In Reach A, which showed the lowest survival rate (17.5%), there was an average of 3.3 live stems per square meter. Some frequently cited sources suggest spacing cuttings more than 1.8 m (6 ft) apart (Hoag, 2002); therefore, establishment on this project was high. Another factor that should be noted is that all of the survival data discussed was obtained after only one growing season. During the second growing season, the authors revisited the site, and found the there had been much more willow sprouting and growth. Survival studies have not been conducted for the second growing season, but it is apparent that one should not give up if superior growth is not observed in the first year.

Our findings suggest that the number of cuttings could be reduced on these sites, because the area had very cohesive soils, and geotechnical failures were consequently less likely. The time saved by a reduction in the number of cuttings should be spent in increasing the care with which the cuttings are handled.

Flournoy Project:

Initial revegetation survival rates at both Reaches A and B show over 90% of the installed cuttings sprouting. This can be attributed to better care conditions during planting and to the fact that the South Fork at this site has a regulated flow from an upstream reservoir that ensures higher water throughout most of the growing season.

CONCLUSIONS

All three of these projects show that substantial watershed restoration projects can be accomplished with very little external material acquisition, but with substantial cooperation between public and private parties. The success of the projects from an engineering standpoint will be tested when a series of high flow events occurs. A final judgment will not be practical for many years to come, but by all current indications, success seems likely. For the immediate future, the success in demonstrating and comparing biotechnical stream restoration methods, the value of riparian/wetland buffers, and the ability of private/public partnerships to bring about this success is the real story.

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