

REVEGETATION OF RIPARIAN TREES AND SHRUBS ON ALLUVIAL SOILS ALONG THE UPPER SACRAMENTO RIVER, 1987-1988¹

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Abstract : Two sites on the Sacramento River near Red Bluff and Colusa, California were planted with seven native tree species plus valley elderberry (a shrub) in an effort to mitigate for the loss of woody riparian vegetation from bank protection construction projects in the area. The state-owned environmental easements on terraces on the river side of the levees had been planted unsuccessfully once before, following failure of native species to regenerate naturally. The new (1987-88) effort includes experimental plantings that are considered to represent state-of-the-art techniques. These are designed to protect the plants and promote survival and growth but require minimal maintenance activity. Fifteen different types of container stock as well as live cuttings of some species have been planted in a variety of situations, including deep-augered, backfilled holes. All plants were fertilized and protected from herbivory and insect damage. The 3-year monitoring program is yielding data on survival/mortality, growth rate, and plant vigor.

Native riparian tree and shrub species were planted in the winter of 1987-1988 at two sites along the banks of the upper Sacramento River near Red Bluff and Colusa, California. The purpose of these plantings was to mitigate for the loss of woody riparian vegetation caused by construction of riprap bank protection at the sites in 1982 and 1984. The revegetated areas are on state-owned "environmental easements" on high floodplains adjacent to the riprap. The U.S. Army Corps of Engineers (COE) Sacramento District sponsored the artificial revegetation project because natural revegetation had not occurred at either site and a previous attempt in 1985 to replant the Red Bluff site had suffered 100 percent mortality.

A second objective of this project is to perform a practical field test of planting techniques for riparian revegetation. Test results will be determined over a 3-year monitoring period through the winter of 1990-1991. Experimental treatments include various sizes, ages and container types of the planting stock used; augered planting holes to two different depths; and soil amendments. Monitoring will also attempt to detect the effects of different soil textures, measured depth to

the water table during the growing season, plant species adaptability to various microsite characteristics, and the effects of herbivory or insects on plant vigor and survival.

The eight native riparian species planted are boxelder (*Acer negundo*), buckeye (*Aesculus californica*), white alder (*Alnus rhombifolia*), valley elderberry (*Sambucus mexicana*), oregon ash (*Fraxinus latifolia*), sycamore (*Platanus racemosa*), Fremont cottonwood (*Populus fremontii*) and valley oak (*Quercus lobata*).

Soils at the Colusa site are primarily alluvial fine sandy barns with a low to moderate amount of organic matter. The site previously supported a dense riparian forest and is adjacent to a remnant stand of mature riparian trees and understory.

Conditions at the Red Bluff site are less favorable for plant establishment. The planting areas were recently graded to alluvial subsoil during reconstruction of adjacent private levees. Half the site's soils are coarse sandy loams, with the remainder in cobbly or gravelly exposed subsoil.

Planting Methods

Planting Hole Preparation

Planting holes were augered to two different depths. The purpose of the deeper holes was to penetrate through impermeable layers of subsoil and to eliminate stratification of alluvial deposits that may hinder deep root penetration to the water table.

Twenty percent of the planting holes, randomly assigned, were augered 3 meters (10 feet) deep. To overcome the torque resistance of the cobbly subsoil, a six-wheel-drive well-drilling rig with a 33-cm- (13-inch-) diameter bit was necessary. The average cost per 3-meter- (10-foot-) deep hole was \$15, including equipment transport, set-up, and two operators.

The remaining 800 planting holes were augered 0.6-meter- (2-foot-) deep using a tractor-mounted 26-cm- (10-inch-) diameter bit. With good vehicle access, the average cost per 0.6-meter- (2-foot-) deep hole was

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approximately \$2 including transport, handling, and one driver/operator.

Before backfilling, all angled holes were flooded with water pumped from the river and allowed to percolate for 24 to 48 hours. This preirrigation of planting holes was essential because of two consecutive winters of low rainfall. Even the 3-meter- (10-foot-) deep holes, including holes near the river banks, had bone-dry soil at the bottom. The normal summer water level in the Sacramento River averages about 3.0-4.5 meters (10-15 feet) below the planted terrace at Red Bluff and 8.5 meters (25 feet) at Colusa. Low rainfall prevented a sustained rise of the river stage adequate to saturate the soil below the planted terraces.

The 3-meter- (10-foot-) deep holes were initially backfilled and tamped to a depth of 0.6 meter (2 feet). All holes, both the backfilled 3-meter- (10-foot-) deep holes and the 0.6-meter- (2-foot-) deep holes, then received a 24-month slow-release fertilizer tablet (17-7-12) at the 45- to 60-cm (18- to 24-inch) depth. Most holes were then backfilled with a mix of soil augered from the holes and Columbia-series topsoil imported from orchards adjacent to the planting sites. Some holes at the Colusa site received no soil amendment for comparison of results.

To encourage horizontal root expansion, planting-hole soil should be similar in texture and composition to the existing soil surrounding the planting hole (Harris 1983). River terrace soils at both sites were typically droughty sandy loams or cobbly loams with an undeveloped soil profile. Therefore the imported topsoil amendment was considered essential to improve the fertility and, more importantly, the water-holding capacity of the soil immediately under the plantings.

After the holes were backfilled, low berms were mounded to create approximately 1-meter- (3-foot-) diameter watering basins around the holes. All planting holes were preirrigated a second time to fully soak the backfill material.

Selection of Plant Species

The eight tree and shrub species planted were stipulated in the COE revegetation contract based on COE surveys of average species composition at similar sites with undisturbed riparian forest. All are native Sacramento Valley riparian species.

In general, plants were randomly assigned to locations within the planting areas, regardless of species or microsite characteristics. Exceptions to this rule were made for extremes of microsite that seemed particularly inappropriate for certain species. For example, alder and ash were only planted close to the river bank. On very

shallow cobbly soils only elderberry or buckeye, particularly drought-tolerant species, were planted. Shady sites adjacent to tall forest stands were planted with mostly alders, boxelder, buckeye, and oak.

Planting Stock Acquisition

The short lead time for the contract precluded custom growing of specialized revegetation plant materials. Based on availability, nursery reputation, and quality and age of nursery stock, planting stock was acquired in various container types and sizes: tree bands; 0.5-, 1-, and 5-gallon cans; leach tubes; styrofoam cups; and bare-root stock. An attempt was made to include two or more types of container stock for each species to compare results.

Plant Protection Kits

Figure 1 illustrates the plant protection kits installed around all plants except 5-gallon elderberries. The screen mesh prevents damage from deer, rabbits, rodents, and leaf-chewing insects. The screen also shades the young plant and accumulates moisture at night from dew or fog.

The plastic collar anchors the screen and serves as a barrier to horizontal extension of weed roots. It also discourages gopher damage and promotes deep vertical rooting by the seedling. The plastic will disintegrate before stem girdling can occur, but the anchor wire around the collar must be removed in 2-3 years to prevent girdling, depending on species growth rate.

The 0.9-meter- (3-foot-) square weed cloth is an effective alternative to frequent hand weeding and also conserves soil moisture. The woven plastic fabric is permeable to rainwater but prevents virtually all weed seed germination. Plastic barriers less than 0.9 meter (3 feet) in diameter are not effective because weeds next to the barrier can easily root laterally under the barrier and into the planting hole. To prevent barrier loss in the wind, the corners must be anchored with long metal staples or large rocks.

Winter Planting

All plants were installed during the period from December 1987 to February 1988. Except for severe rain storms, planting proceeded regardless of weather. Planting crews included local residents and experienced revegetation personnel. To streamline the planting process, all holes were marked ahead of time with color-coded surveyors flags for each species and each container type to be used. Upon completion of planting, a detailed planting layout was prepared, indicating species, plant size and type, container types, soil texture, hole depth, and location for every plant.

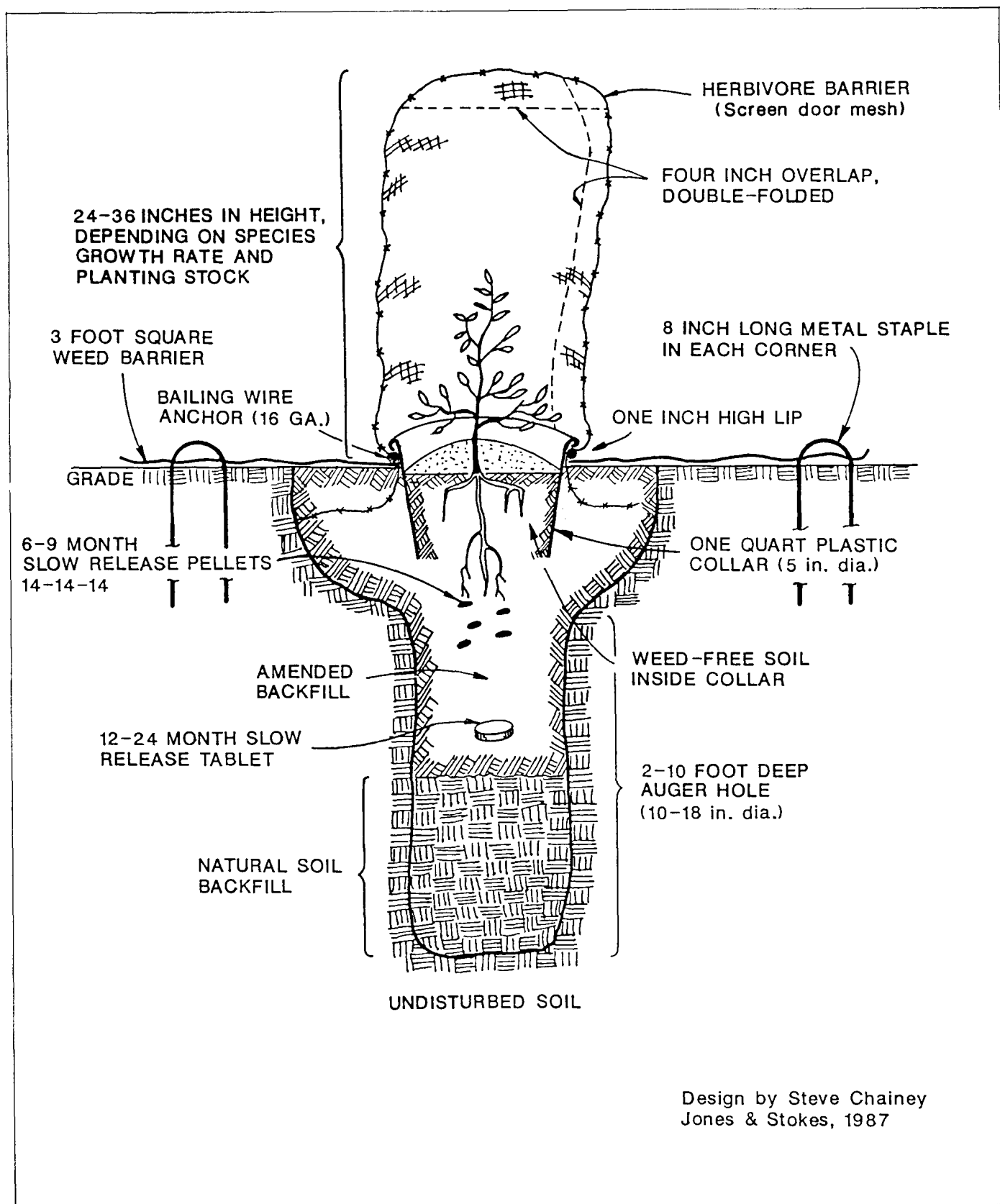


Figure 1—Conceptual sketch of plant protection kit (Section view not to scale).

Irrigation, Maintenance, and Monitoring

Performance Standards

The revegetation contract requires a 3-year maintenance and monitoring period. Contract performance standards require 90 percent survival at the end of the first year (i.e., by February 1989) and 75 percent survival at the end of the second year (i.e., by February 1990). Methods of irrigation and maintenance are at the contractor's discretion. To ensure satisfaction of the survival standards, 10 percent more plants were planted than were actually required in the contract.

Irrigation and Maintenance

Both the Red Bluff and Colusa sites are subjected to trespass for river-related recreational use. Because of the high risk of tampering and vandalism, repeat spot watering is used rather than installation of a surface-drip or overhead irrigation system.

Irrigation water is applied every 7-10 days in the driest months using a 757-liter (200-gallon) tractor-mounted tank with hand-held spray wand. Depending on plant size and soil water-holding capacity, 4-11 liters (1-3 gallons) are applied at each watering event. Irrigation began in mid-April 1988 and will continue through October. In August 1988, irrigation water was supplemented with a liquid nitrogen fertilizer.

As the plants grow vertically, the screen mesh is opened at the top. The mesh tube continues to shade the lower stem and prevent rodent girdling of stem tissue. Weeds inside the plastic collar are removed by hand. Maintenance visits occur every 2 weeks.

Monitoring

Starting height and vigor of the plants installed were recorded in February 1988. Beginning May 1, all plants were monitored every 2 weeks by the same observer at both sites. Periodic observations of each plant included the following parameters:

Parameter	Condition or Unit
Vigor	Excellent, good, fair, poor, dead
Height	Cm (inch)
Width (i.e., diameter of canopy)	Cm (inch)

Vigor is an overall qualitative observation based on leaf turgor, stem caliper, leaf color, foliage density, and leaf size. Vigor is rated relatively within a given species group.

Depth to water table was measured periodically in four 3-meter-(10-foot-) deep pipe wells at each of the two

sites. The pipe is a 10-cm- (4-inch-) diameter perforated drain pipe. A dipstick measures the standing water table at various times of the year. Maximum high water table in winter also indicates the depth to the moist soil zone in the spring (in the absence of competing vegetation). This past winter of 1987-88, the river water level never was high enough to raise the water table within 3 meters (10 feet) of the soil surface at either planting site. This condition is highly atypical and stressful to native phreatophytes.

Other incidental observations of plants include herbivory damage, insect infestation, drought stress, frost burn, poor planting stock, summer drought dormancy (buckeye and elderberry), winter dormancy, and vandalism.

First Year Results

Results are reported here from monitoring through July 1988 (Table 1). Monitoring will continue into the fall until plants are fully senescent.

Colusa Results

Overall plant survival at the Colusa site was 91 percent by July 1988. Nearly half the deaths were sycamore tubelings, many of which were severely damaged by unusual late frosts in early spring. This is the only species noticeably damaged by frost burn. The protective screens appear to have served as frost barriers for most species. Surviving sycamore plants experienced significant net growth in height (average = 25 cm, maximum = 90 cm) and good vigor.

First-year growth patterns were distinctly different among the species. Alder, boxelder, buckeye and elderberry experienced over half their total height growth before mid-May, when ash was just breaking bud. Cottonwood, oak, and sycamore showed steady growth in June and July and continued canopy growth into early September. Rooted oak acorns developed shoots with buds in April and first leaves in May.

Buckeye and elderberry seedlings went into early drought dormancy in July, a pattern similar to other plants of these species in the wild growing nearby. Elderberry developed new shoots and leaves as early as February, when all other species were still winter dormant.

Table 1-Propagule survival in flood and overhead sprinkler irrigated areas.*

Species/Container	Number Planted		Growth (cm) by May 19		Growth (cm) May to July 19		Height (cm) On July 19		Vigor* July 19		First Year Mortality		Percent Mortality	
	Colusa	Red Bluff	Colusa	Red Bluff	Colusa	Red Bluff	Colusa	Red Bluff	Colusa	Red Bluff	Colusa	Red Bluff	Colusa	Red Bluff
Alder/Tree bands	24	14	30.0	6.9	17.5	1.8	78.2	44.5	2.6	0.4	2	11	8	79
Ash/Bare root	35	36	7.4	4.3	14.2	1.8	38.4	25.4	3.0	1.3	3	16	9	44
Boxelder/1 gallon	53	31	32.0	30.7	14.2	6.6	87.4	73.4	2.9	1.9	4	4	7	13
Buckeye/Tree bands	26	22	14.2	3.8	2.8	3.8	30.0	29.2	2.0	1.3	3	9	12	41
Cottonwood/Tree bands	48	70	42.4	21.1	32.3	13.5	87.4	48.0	3.0	1.2	5	36	10	51
Cottonwood/1 gallon	38	—	33.8	0.0	41.1	0.0	115.6	0.0	3.3	—	1	—	3	—
Cottonwood/Tubes	—	15	0.0	18.0	0.0	7.1	0.0	35.3	—	0.7	—	9	—	1
Elderberry/5 gallon	121	85	50.3	47.0	10.4	9.1	113.8	112.8	1.9	1.3	0	15	0	18
Elderberry/1 gallon	43	23	70.6	49.3	11.9	8.6	90.7	70.1	2.3	0.9	0	13	0	56
Elderberry/Tubes	53	29	66.3	39.4	19.8	4.3	89.4	53.8	2.3	0.8	0	12	0	41
Valley oak/Tree bands	—	11	—	12.2	0.0	3.6	0.0	47.0	—	2.1	—	2	—	18
Valley oak/1/2 gallon	23	24	9.1	5.3	7.4	2.0	19.6	17.3	3.0	2.7	2	0	9	0
Valley oak/Bare root	52	28	10.9	13.5	7.6	10.9	25.7	30.7	3.1	3.5	11	0	21	0
Sycamore/Tubes	37	26	8.6	4.6	20.1	3.0	40.4	17.8	2.5	0	14	26	38	100
Sycamore/Cups	30	33	12.7	4.6	12.2	1.5	42.4	21.6	2.5	0	7	26	23	85
Totals	583	447									52	179	9	40

*Vigor: 4= excellent, 3=good, 2=fair, 0 dead.

The most unexpected growth responses were for boxelder, elderberry tubelings, and oaks from rooted acorns. By May 19, boxelder growth rivaled that of cottonwood. Height growth by elderberry tubelings equaled or exceeded that by 5-gallon elderberry plants. Elderberry tubelings were about 2 years younger than the 5-gallon plants. Some plants from tubelings had nearly as much total canopy volume as the 5-gallon elderberry by July 1988.

Although average height of sprouted acorns in July was less than 22 cm (9 inches), numerous individuals were 46-75 cm (18-30 inches) in height by July 19, with excellent vigor. Current-year oak acorns with taproots planted in February were considerably larger and more vigorous than oaks in 0.5-gallon containers from last year's acorn crop.

The most serious herbivory at the Colusa site is from gophers (often fatal) and deer (rarely fatal). The screens effectively prevented rabbit and rodent girdling of young stems as well as caterpillar and grasshopper defoliation.

Red Bluff Results

A heat wave in June 1988 was a severe problem at the Red Bluff site. On one day the temperature reached 118oF with 20-mph winds. On that day, nearby crops and orchard trees were losing turgor even as they were being irrigated. By July 1988, seedling mortality on this site approached 40 percent. Drought stress was the overwhelming cause of death for all species of newly planted seedlings. Browse and vandalism were minimal. No gophers are present in the cobbly soils.

Mortality varied greatly by species. Only two of 63 oaks (all taprooted acorn stock) have died and oak vigor remains in the good range. Also, 90 percent of the boxelders and 80 percent of the elderberry have survived. Many plants appearing to have died by July are resprouting in September. On the other end of the spectrum, nearly all of the alders and sycamores died in the heat wave. Half the ash, buckeye, and cottonwood also died.

Growth responses of boxelder, elderberry, and valley oak were good at Red Bluff and similar to the pattern at Colusa. For the surviving plants at Red Bluff, height growth was typically 25-50 percent of the average values at Colusa.

To satisfy the contract performance standards, approximately 150-200 new plants will be installed during winter 1988-89 to compensate for first-year losses. Overall stand vigor and turgor at the Red Bluff site has improved in August since plants were irrigated with a fertilizer supplement.

Discussion

For elderberry, the similar growth performance by 5-gallon seedlings and small tubelings is an important finding. Considerably less time and expense is required to handle and plant small tubelings, compared to 5-gallon containers.

Similarly for valley oaks, rooted acorns can be handled more cost effectively (and contract-grown on shorter

order) than larger oak seedlings in 0.5- or 1-gallon containers. Bare root sprouted acorns also have an undisturbed tap root 15- to 30-cm (6- to 12-inches) long at the time of planting in early February. The superior root:shoot ratio of taprooted acorns is a major advantage in drought avoidance and therefore survival.

Frost damage to sycamore seedlings can be avoided in the future by purchasing cold-hardened stock from nurseries in colder climate zones. Buckeye direct seeded in the field may have better growth and survival than using nursery-grown stock in containers because of the exceptional taproot growth of this species. This species, like oaks, becomes pot-bound well before significant shoot elongation has occurred. Direct-seeded buckeye has shown a high rate of germination and survival in several previous revegetation efforts (Chan 1985).

The quality of nursery planting stock is a good predictor of first-year survival and growth. A preponderance of mortalities and plants of low vigor observed in May and July had been previously recorded as inferior plants at the start in February. The quality and source of planting stock should be the last area of budget trimming for revegetation contracts.

The mesh screens and the weed barriers used were highly effective at preventing herbivory and reducing weed competition. The protection kits have withstood extremely high winds and gopher burrowing activity. It appears that the screens also protected young plants from frost burn last spring. Using weed barriers also cut maintenance costs measurably and enhanced plant vigor and survival by reducing competition with weeds.

Spot watering at the Colusa site has been cost effective and adequate for plant growth and survival (based on a 7- to 10-day repeat cycle). At the more droughty Red Bluff site, more frequent watering events or a drip

irrigation system may have averted the high mortalities during the heat wave. Another consideration to overcome low soil water-holding-capacity is to use deep pole-planted stock for species known to root adventitiously (cottonwood, willow). One- or 2-year-old bare root stock may also be effective for some species (alder, sycamore) by providing a higher root:shoot ratio.

Species should be thoughtfully matched to microsites for which they are known to be adapted and not planted in arbitrary mixes in random locations. Adequate lead time (9 months minimum prior to planting time in early winter or early spring for bare root and cuttings) should be provided in revegetation contracts to collect seed or cuttings to grow high quality nursery stock. Custom wholesale nurseries specializing in revegetation container stock (tree bands, tubes, and bare root with a high root:shoot ratio) will match age and container type to the revegetation techniques required for each site.

Acknowledgements

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