Survey Results of Habitat Mitigation Features at Bank Protection Sites 1999-2011

Lessons Learned, Observations and Design Recommendations

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Purpose of Survey and Evaluation of Sites

• Evaluate mitigation features at bank protection sites to inform future bank repair and onsite habitat design and management.

• Build on past design innovations to improve the success of revegetation and the quality of fish habitat to meet or exceed mitigation targets.
# Summary of Lower American River (LAR) Sites Surveyed

<table>
<thead>
<tr>
<th>River Mile (Site Name)</th>
<th>General Location</th>
<th>Approximate Length (feet)</th>
<th>Date Constructed/Planted</th>
<th>Age of Vegetation</th>
<th>Date of Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.6L (Larchmont Park)</td>
<td>Larchmont Community Park</td>
<td>670</td>
<td>2011; 2011</td>
<td>5</td>
<td>12/15/2015</td>
</tr>
<tr>
<td>6.8L (Site 4, CSUS, Fairbairn)</td>
<td>At Guy West Bridge</td>
<td>3,322</td>
<td>1999; 1999</td>
<td>17</td>
<td>12/15/2015</td>
</tr>
<tr>
<td>4.4L (Site 3, Paradise Beach)</td>
<td>River Park Community</td>
<td>3,500</td>
<td>1996-1997, 1999; 1999</td>
<td>17</td>
<td>7/24/2015</td>
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<tr>
<td>3.7L (Site 2, Sutter’s Landing)</td>
<td>Between the railroad bridge and Business-80</td>
<td>650</td>
<td>1999; 1999</td>
<td>17</td>
<td>12/15/2015</td>
</tr>
<tr>
<td>0.9R (Discovery Park)</td>
<td>Discovery Park</td>
<td>800</td>
<td>2001-2002; 2002</td>
<td>14</td>
<td>2/23/2016</td>
</tr>
<tr>
<td>0.3L</td>
<td>Upstream of the I-5 bridge</td>
<td>520</td>
<td>2008; 2008</td>
<td>8</td>
<td>12/15/2015</td>
</tr>
</tbody>
</table>
Location of LAR Sites
## Summary of Sacramento River Sites Surveyed

<table>
<thead>
<tr>
<th>River Mile (Site Name)</th>
<th>General Location</th>
<th>Approximate Length (feet)</th>
<th>Date Constructed; Date Planted</th>
<th>Age of Vegetation</th>
<th>Date of Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>78.0L</td>
<td>South of Verona, CA</td>
<td>1,140</td>
<td>2007; 2007</td>
<td>9</td>
<td>2/23/2016</td>
</tr>
<tr>
<td>70.7R (Yolo County)</td>
<td>Upstream of I-5 bridge</td>
<td>450</td>
<td>2006; 2006</td>
<td>10</td>
<td>2/23/2016</td>
</tr>
<tr>
<td>68.9L</td>
<td>Downstream of I-5 bridge</td>
<td>942</td>
<td>2007; 2007</td>
<td>9</td>
<td>2/23/2016</td>
</tr>
<tr>
<td>56.7L (Miller Park)</td>
<td>Downstream of Miller Park Marina</td>
<td>1,575</td>
<td>2006; 2007</td>
<td>9</td>
<td>6/18/2015</td>
</tr>
<tr>
<td>52.3L</td>
<td>Big Pocket area</td>
<td>1,320</td>
<td>2008; 2008</td>
<td>8</td>
<td>6/18/2015</td>
</tr>
<tr>
<td>48.2R</td>
<td>1.5 miles downstream of Babel Slough Road</td>
<td>1,039</td>
<td>2007; 2007</td>
<td>9</td>
<td>6/18/2015</td>
</tr>
<tr>
<td>47.0L</td>
<td>Freeport Regional Water Intake Facility</td>
<td>1,157</td>
<td>2007; 2007</td>
<td>9</td>
<td>6/18/2015</td>
</tr>
</tbody>
</table>
Location of Sacramento River Sites
cbec Surveyor with RTK-GPS

RTK-GPS is Real-Time Kinematic Survey Grade GPS
Measurements taken at Bank Protection Sites

NOTES:
1. MAXIMUM DAILY WSES SHOWN BELOW
2. SOIL PROBE MEASUREMENTS WERE USED TO DETERMINE MAXIMUM AND AVERAGE SOIL THICKNESS.
### cbec Survey Elevations

<table>
<thead>
<tr>
<th>River Mile (Site Name)</th>
<th>Average Soil Thickness (ft)</th>
<th>Distance from Average Top of Rock to Average Daily Summer WSE (ft)</th>
<th>Distance from average soil bottom elevation to Summer WSE (ft)</th>
<th>Distance from average Top of Bench to Average Daily Summer WSE (ft)</th>
<th>Distance Between Minimum Bench Elevation(^1) and Average Daily Summer WSE (ft)</th>
<th>Distance Between Maximum Bench Elevation(^1) and Average Daily Summer WSE (ft)</th>
<th>Bench Slope (H:V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.6L (Larchmont Park)</td>
<td>0.9</td>
<td>7.2</td>
<td>7.2</td>
<td>8.1</td>
<td>6.8</td>
<td>9.3</td>
<td>5.2</td>
</tr>
<tr>
<td>8.7R (Site 5, Howe-to-Watt)</td>
<td>3.2</td>
<td>2.3</td>
<td>0.4</td>
<td>3.7</td>
<td>2.7</td>
<td>5.2</td>
<td>8.3</td>
</tr>
<tr>
<td>6.8L (Site 4, CSUS, Fairbairn)</td>
<td>2.8</td>
<td>5.5</td>
<td>3.8</td>
<td>6.6</td>
<td>4.5</td>
<td>9.3</td>
<td>12.5</td>
</tr>
<tr>
<td>4.4L(^2) (Site 3, Paradise Beach)</td>
<td>5.1</td>
<td>2.9</td>
<td>-2.9</td>
<td>2.9</td>
<td>1.3</td>
<td>4.6</td>
<td>50.0</td>
</tr>
<tr>
<td>0.3L</td>
<td>0.7</td>
<td>1.1</td>
<td>1.3</td>
<td>2.0</td>
<td>1.2</td>
<td>2.7</td>
<td>6.5</td>
</tr>
</tbody>
</table>

\(^1\)Minimum and maximum bench elevations are the extremes of all transects surveyed at a site.

\(^2\)This site was evaluated based on as-built plans, not survey data.
Typical Design Cross Sections (3) of Bank Repair Sites with Onsite Mitigation Features
Toe Rock Embankment Fill
Sacramento RM 62.0L (Sand Cove)

Pre-construction. Bank and toe erosion.

Post-construction. Revegetated.
Soil-Rock Mix (typically 70%:30%) with soil cover (typically 6-inch by design),

- American RM 10.6L and 0.3L
- Sacramento RM 78.0L, 70.7R, 68.9L, 52.3, 48.2R, 47.0L, and many other SRBP sites
Example of typical Soil-Rock Mix design under construction

Sac RM 50.2L
American RM 8.7R, 6.8L, 4.4L, and 3.7L (Sites 5, 4, 3 and 2)
Key Observations at Completed Mitigation Habitat Features

with Recommendations for Future Design and Management Improvements
Key Observation #1 - Stunting and mortality caused by inadequate soil volume, low moisture-holding capacity, or soil placed too high above dry-season river stage

Recommendations:

• use planting trenches to ensure adequate soil volume and moisture availability in dry season
• soil-filled trenches need bottom at least 1-2 feet below summer WSE for capillary rise of moisture
• use silt/clay loam soil, avoid sandy loam (low WHC)
• where unavoidable, soil-rock-mix designs require higher % soil volume and/or contact with natural bank soil
• avoid soil-over-rock unless herbaceous cover is needed (trees will not survive)
Key Observation #1

30% Soil-70%Rock fill at Sac RM 50.2L results in low soil moisture capacity of shallow root zone.
16 year sycamore tree (approx. 12in DBH and 50ft tall) at LAR Mile 6.8L (Site 4).

Lack of vegetation establishment on bench due to drought stress caused by inadequate soil moisture at Sac RM 47.0L.
Key Observation #2- Soil loss on slopes

Soil loss has left soil bridges and exposed subsurface voids. Soil loss on lower slopes consistently observed with soil-over-rock and soil-rock-mix designs. Subsurface voids common to soil-over-rock designs.
Key Observation #2

Soil loss from surface of waterside slope and low berm slope at LAR Mile 0.3L →
Key Observation #2

Recommendations:

• incorporate wave attenuation with dense willows and IWM
• “ballast” plantings of tule bands on submerged bench
• include woody vines on low-berm to increase roughness and deposition
Key Observation #3 - Mortality and stress where species are poorly adapted to site-specific conditions

Recommendations:

• master list of species tolerance, vulnerabilities, and benefits

• match species (e.g., alder) to appropriate locations along typical cross section of bank repair design

• vulnerability includes beaver preference; shade and drought intolerance; long inundation

• list best shoreline SRA species and tallest tree species

Sac RM 52.3L  Dead Alders
Key Observation #4 - Mortality and stunted growth caused by too much shade and resource competition in dense stands

Recommendations:

• decrease tree density per acre
• minimum tree spacing 15-20 ft oc (more for sycamore, cottonwood and black willow)
• use shade-tolerant species in existing or anticipated shaded conditions

Breakage of tree trunks resulting from lack of taper due to crowding and shade stress at LAR Mile 3.7L.
Key Observation #5 - Lack of shoreline overhead cover, shade, and food sources for small fish during low river stages

Recommendations:

- construct riparian planting benches as low as possible; include submerged tule benches
- design to sustain dense hedgerows of willow, alder, and buttonbush along waterside bank
- improve designs to protect fascine willow bundles from beaver damage
- improve survival of willow bundles by increasing moist soil contact with cuttings

Complete mortality of willow bundles placed in rock on low-bench face at LAR Mile 0.3L.
**Key Observation #5**

Depleted SRA willow bundles mostly dead, near-shore willows heavily pruned by beavers, LAR Mile 10.6L, but surviving alders reach over water.

Exposed and unvegetated waterside slope and “fish bench” lacking overhanging vegetation at LAR Mile 8.7R (Site 5).
Key Observation #6 - IWM too sparse, too coarse, or too high above water surface to benefit juvenile fish

Good anchor, but inappropriate texture and depth of IWM at LAR Mile 4.4L (above). Depleted, sparse IWM at RM 70.7R (right).
Inappropriately sized and placed IWM at Sac RM 56.7L (above) and Sac RM 48.2R (right).

Most IWM at RM 48.2R placed on top of riparian bench at Mean Winter WSE.
Key Observation #6

Recommendations:

• place IWM low on waterside slope (½ above and ½ submerged below fall WSE), wood should straddle the water surface

• establish minimum IWM shoreline density or % shoreline cover

• use reliable anchorage designs to counter buoyancy (e.g., Sac RM 47.0L, Sac RM 48.2R)


• add IWM with tules to submerged benches as a retrofit, or in future designs
Natural IWM with appropriate texture and location to provide quality instream habitat (SAFCA 2010).

 Appropriately textured IWM placed at mean summer WSE on riparian-bench face at LAR Mile 10.6L. Few willow bundles interspersed with IWM survived (above).
Appropriately sized and placed IWM at LAR Mile 0.5R, an offsite mitigation project.
IWM is best placed on submerged bench, partially submerged, to allow aquatic life to colonize organic debris and create food web for fish.
Harvesting good quality IWM from abandoned orchard trees with intact roots
Key Observation #7 - Lack of forest age-class diversity and organic inputs to aquatic ecosystem at high water stages

Recommendations:

• retain large trees and allow dead wood to remain onsite; less mitigation required and lowers mitigation cost

• incorporate combination of submerged benches and embayments to trap/retain sediment and organic material on shallow shoreline

• design for complex trophic structure

Planted trees/willows (growth year 9) and existing backslope oak trees at sac RM 78.0L.
Retention of existing native trees provides roosting and nesting habitat, and an eventual source of IWM at Sac RM 78.0L.

Ground covered with woody debris and leaf litter (*allochthonous* inputs) at LAR Mile 8.7R contributes to nutrient cycling, soil development and creates terrestrial habitat.
**Allochthonous material and the River Continuum Concept**

Retained older trees provide woody material to the site that increase roughness, nutrient cycling, food sources, habitat complexity, and may become IWM and SRA habitat.

Increased allochthonous inputs improve the trophic structure (food web) from the bottom up.

Ground covered with woody debris and leaf litter (allochthonous inputs) are consumed and decomposed by microbes, worms and other soil biota. This leads to nutrient cycling and soil development, which promotes plant growth and creates terrestrial habitat.

Woody material and decomposed leaves fall into the water, becoming substrate and food for aquatic invertebrates that can be consumed by fish.

Decomposing material that falls into the water becomes nutrients for zooplankton, which is also consumed by fish.

Vannote et al. 1980
Key Observations – Post-Construction Management Challenges with Design Implications
Key Observation #8 - Mortality and stunting caused by foraging beaver populations

Recommendations:

• always protect vulnerable species (e.g. cottonwood, alder) with cages on each tree, and allow for expansion of tree girth

• install 4-ft high beaver barrier fence at 4-5ft above mean summer WSE to deter beaver access at higher river stages

• to prevent damage by people to barrier fence, mark trails with hinged gates or stiles for human access to shoreline

• plant wild rose and blackberry thickets around trees to discourage girdling by beavers

Stunted, shrubby growth of willow from repeated beaver pruning at LAR Mile 6.8L.
Harvest of alder trees (2-5in DBH) by beavers cause gaps in canopy continuity at LAR Mile 10.6L (left and right above).

Recent beaver damage on alder at Sacramento RM 52.3L.
Extensive beaver damage to large trees formerly protected by barrier fence at Sacramento RM 62.0L.
Beaver cages girdling a large cottonwood tree at LAR Mile 3.7L.

Intact beaver fencing of appropriate height and distance from summer WSE at Sacramento RM 48.2R.
Key Observation #9 - Damage Caused by Recreational Users and Unlawful Activity

Recommendations:

- better signage, marked access trails, and gates or stiles in fences
- discourage, remove, and/or report illegal campsites within mitigation sites
- better monitoring and enforcement, and more effective fire prevention
- plant barrier vegetation (e.g., wild rose, blackberry, poison oak, and stinging-nettle)

Vandalized trees and damage to beaver cages girdles trees at LAR Mile 3.7L.
Illegal encampment with campfire ring at LAR Mile 0.3L.
High quality IWM at Sac RM 62.0L, Sand Cove Park in 2005.

Depleted IWM from human activity (firewood) at Sac RM 62.0L, Sand Cove Park in 2016.
The **Overarching Goal** of these recommendations is to provide high quality mitigation habitat and successful revegetation outcomes by restoring river ecosystem processes and functions so they contribute to species recovery.
Other Design Concepts Not Included in This Report

- Submerged rock slope protection limited to spring or summer WSEL.
- Armored bed (e.g. cobble layer), and other grade control designs to prevent bed scour.
- Rock groins to divert high velocity flow away from bank/levee slope.
- Realignment (dredge/fill) of main channel away from levees.
Questions and Discussion
Individual LAR Site Observations
LAR Mile 10.6L (Larchmont Park; 2011)

Design features include:

- upper bench (zone 3 to top of rock), lower berm (zone 2) and riparian bench (zone 1)
- soil-filled quarry stone on bank covered with approx. 0.5 ft of soil
- IWM and fascine willow bundles (live cuttings)
Coyote bush was overplanted (too dense) in the understory and outcompeted other planted species.

Some planted trees are at least 18 feet and now cantilevering the shoreline.

Beaver activity has killed / severely stunted many alder and willow plantings.

No beaver fencing/caging observed (removed?).
LAR Mile 10.6L Site Observations
(Larchmont Park; 2011)

- dead willow bundles (above)
- floating debris trapped in IWM and on rocks (top right)
- intact IWM and willow bundles in rock face (bottom right)
- retained existing large trees on upper bench/berm shade the site

IWM, large trees and dense understory (above).
LAR Mile 8.7R (Site 5, Howe-to-Watt; 1999)

Design features include:

• planting on undulating cobble-lined low-bench surface and backslope

• biotechnical plantings on rock tie backs (partitions) in the low-bench surface

• biotechnical plantings in coir logs at the toe of the backslope
LAR Mile 8.7R (Site 5, Howe-to-Watt; 1999)

Design features include:

- irregular shoreline promotes deposition and natural fluvial processes
- submerged wetland bench with fine textured IWM (now absent)

Natural deposition on submerged bench promoting growth of rushes.
LAR Mile 8.7R Site Observations
(Site 5, Howe-to-Watt; 1999)

- unvegetated rock slope with no IWM, food sources, shade or refugia for fish

- dense sedges on the riparian bench provide instream and foraging habitat at higher river stages

- beaver cages observed around preferred species but repeated pruning damage evident to some
LAR Mile 8.7R Site Observations
(Site 5, Howe-to-Watt; 1999)

Retained existing large trees cantilever over the water and contribute to IWM and allochthonous inputs. →

← Dense herbaceous understory and accumulation of leaf litter on backslope and bench stabilizes slope, develops soil, and contributes to nutrient cycling.
LAR Mile 6.8L (Site 4, CSUS/Fairbairn; 1999)

Design features include:

• built on the old cobble revetment

• low-bench soil-filled planting trench with an undulating, cobble-lined surface

• planting on the low-berm face, low bench, and upper backslope planting surfaces

• no IWM
LAR Mile 6.8L Site Observations (Site 4, CSUS/Fairbairn; 1999)

Upstream of Guy West Bridge

Downstream
LAR Mile 6.8L Site Observations (Site 4, CSUS/Fairbairn; 1999)

- beaver cages and fencing observed, cages girdling some trees
- planted trees on riparian bench should have been planted less densely
- dense herbaceous (sedges and blackberry) understory and accumulation of leaf litter on backslope and bench
LAR Mile 6.8L Site Observations (Site 4, CSUS/Fairbairn; 1999)

- blackberry thickets protect the site
- no homeless encampments observed
LAR Mile 6.8L Site Observations (Site 4, CSUS/Fairbairn; 1999)

Trees planted above the grade break and cobble revetment at LAR Mile 6.8L were larger than trees planted on the riparian bench and slope. These plantings had 1) greater soil volume, 2) less resource competition, and 3) less heat and light stress during early growth stages than the densely planted cobble-lined bench.
LAR Mile 4.4L
(Site 3, Paradise Beach; 1999)

Design features include:

• vegetation planted on outer rock face, low bench, upper slope and middle bench
• IWM in the slope below water surface
LAR Mile 4.4L (Site 3, Paradise Beach; 1999)

Design features include:

- hardpoints and embayments along shoreline creates hydraulic diversity (riffles and eddies), reestablishing natural processes
LAR Mile 4.4L
(Site 3, Paradise Beach; 1999)

Design features include:

- low-bench soil-filled planting trenches with undulating surface and geotextile fabric

- cobble revetment layer exists on portions of low-bench surface

Typical cross section of soil-filled planting trench at hardpoint (above)

Typical cross section of soil-filled planting trench (below)
Healthy tree plantings growing along the toe and up the slope from the riparian bench to the levee.

Herbaceous understory provides good instream habitat at high river stages, and an established recreation trail on the riparian bench directs foot traffic.
LAR Mile 4.4L
(Site 3, Paradise Beach; 1999)

• beaver damage during high river stages (right)
• evidence of beavers feeding their young (below)
LAR Mile 3.7L (Site 2, Sutter’s Landing; 1999)

Design features include:

- hardpoints and embayments along shoreline for hydraulic diversity
- low-bench soil-filled planting trench with an undulating surface covered by geotextile fabric
LAR Mile 3.7L (Site 2, Sutter’s Landing; 1999)

Design features include:

- riprap on top of soil on the upper slope and middle berm
- low bench planting trench
- planted low bench, upper slope, and middle bench planting surfaces
- planted low-bench face without IWM
LAR Mile 3.7L Planting Trench Cross Section (Site 2, Sutter’s Landing; 1999)
LAR Mile 3.7L Site Observations
(Site 2, Sutter’s Landing; 1999)

Trees planted too densely in a shaded microclimate on the low bench are breaking 7-8ft up the trunk and falling onto the shoreline due to poor growth as a result of light competition. Falling trees are contributing to IWM.

Trees planted above the grade break and cobble-lined slope were larger and healthier than trees planted on the crowded low bench.
LAR Mile 3.7L Site Observations
(Site 2, Sutter’s Landing; 1999)

• leaf litter accumulation contributes to allochthonous inputs, soil formation and nutrient cycling

• litter accumulation on the LAR is a result of the flow regimes over the last several years

• beaver cages prevent but highly vandalized
LAR Mile 0.9R (Discovery Park; 2002)

Design features include:

• offsite mitigation and floodplain/riparian restoration

• no structural bank protection (i.e., rip-rap, soil-rock mix layers, revetment, or cobble layering)

• terracing and regrading the low floodplain

• excavated high water back channels in floodplain

• planting included an offsite elderberry mitigation area and installation of a willow brush mattress near the shoreline
LAR Mile 0.9R Site Observations
(Discovery Park; 2002)

- dense sedge meadows provide good terrestrial habitat during low flows, and good instream habitat during high flows and flooding
- quality terrestrial habitat from established upland plantings, growth of healthy/vigorous tree stands, and retention of existing trees where possible
LAR Mile 0.9R Site Observations
(Discovery Park; 2002)

• existing snags and large trees provide habitat for avian species and roosting bats
• some beaver fencing and cages intact
• gate installed in the beaver fence was highly damaged and constantly left open

• numerous encampments, with generators
LAR Mile 0.3L (Upstream of I-5 Bridge; 2008)

Design features include:

- upper bench (zone 3A), low berm (zone 3B) and riparian bench (zone 3C)
- soil-filled quarry stone covered with approx. 0.5ft of soil
- 1ft of sand fill below soil-filled quarry stone on low bench (mineral filter)
LAR Mile 0.3L Site Observations
(Upstream of I-5 Bridge; 2008)

- IWM placed at the Mean Winter WSE

- fascine willow bundles placed at water’s edge did not survive

- soil lost from slopes
LAR Mile 0.3L Site Observations
(Upstream of I-5 Bridge; 2008)

- no beaver fencing (removed?)
- repeated beaver pruning to majority of willows causing shrubby growth

Bench face and riparian bench with existing trees in back of site (above).
LAR Mile 0.3L
Site Observations
(Upstream of I-5 Bridge; 2008)

Moderately dense herbaceous cover on upper slopes (mugwort, poison oak etc.).
LAR Mile 0.3L Site Observations  
(Upstream of I-5 Bridge; 2008)

- willows and box elder establishing in IWM placed at the MWWSE
- riparian bench and IWM placed too high to provide instream habitat and cover for outmigrating juvenile fish species during low flow when it is needed most (during lower flows)