San Francisco Estuary Invasive Spartina Project Pilot Earthen Islands Interim Year-1 Monitoring Report

Project # 3415-02

Prepared by

H. T. Harvey & Associates

Prepared for

California Coastal Conservancy
1330 Broadway, Suite 1300
Oakland, CA 94612
(510) 286-4157
Attn: Marilyn Latta, Project Manager

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Executive Summary

The California Coastal Conservancy (Conservancy) plans to construct at least 22 earthen islands to provide high tide refuge habitat for California clapper rail (*Rallus longirostris obsoletus*) in the San Francisco Estuary, California. The Conservancy constructed the first 6 earthen islands on a pilot basis in December 2012-January 2013 in tidal marshes at Cooley Landing, MLK/New Marsh, Belmont Slough South, Belmont Slough North, Bird Island and Bair Island Northwest in San Francisco Bay. In May 2013, H. T. Harvey & Associates’ restoration ecologists inspected the sites and documented topography, vegetation and soils on the pilot islands to provide an early indication of the establishment trajectory of high tide refugia habitat on the islands. This *Interim Year-1 Monitoring Report* presents the results of the May 2013 field study and provides design recommendations for the subsequent 16 islands to be constructed in Fall 2013.

At pilot island sites, we measured earthen island and excavation area topography, and survival and height of gumplant (*Grindelia stricta*) planted on islands and compared these findings to the as-built conditions documented immediately after construction. We also sampled earthen island soil properties that influence gumplant growth (specifically, soil salinity, pH, organic matter and texture) and sampled adjacent marsh plain reference sediments to investigate whether earthen islands soils have acidified following excavation.

**Topography.** Five months after construction, earthen islands tops were on average -0.46 ft lower than island top design elevations of +1.0 ft above MHHW (Table E1). As-built topography shows that islands were constructed approximately -0.15 below design specifications and island tops have settled on average approximately -0.31 ft. This amount of island settlement is in line with the -0.5 ft of vertical settlement we anticipate over a 1-2 year period.

In areas excavated to provide sediment to construct earthen islands (excavation areas), sediment accreted on average by +0.10 ft. More sediment accumulated in excavation areas situated lower in the tidal frame.

**Vegetation.** Sixty-three percent of gumplant plantings survived on average across pilot islands. Gumplant survival varied from 34.5% (Belmont Slough South) to 98.1% (MLK/New Marsh) (Table E1). Regression analysis found gumplant survival was best predicted by elevation of island tops, with survival increasing with elevation above MHHW ($R^2 = 0.78; P = 0.02$). By contrast, there was no effect of salinity or pH on gumplant survival (see Soil below).
Table E-1: Summary of Interim Year-1 Earthen Island Monitoring Results

<table>
<thead>
<tr>
<th>Site</th>
<th>Topography</th>
<th>Vegetation</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Island Top Average Height (ft above MHHW)</td>
<td>Gumplant Survival (%)</td>
<td>Gumplant Height 2 (ft)</td>
</tr>
<tr>
<td>Cooley Landing</td>
<td>+0.71 ± 0.03</td>
<td>80.0</td>
<td>1.36 ± 0.04</td>
</tr>
<tr>
<td>Belmont Slough South</td>
<td>+0.22 ± 0.04</td>
<td>34.5</td>
<td>1.09 ± 0.11</td>
</tr>
<tr>
<td>Belmont Slough North</td>
<td>+0.44 ± 0.04</td>
<td>59.2</td>
<td>1.04 ± 0.09</td>
</tr>
<tr>
<td>Bird Island</td>
<td>+0.57 ± 0.05</td>
<td>52.5</td>
<td>0.94 ± 0.09</td>
</tr>
<tr>
<td>Bair Island Northwest</td>
<td>+0.60 ± 0.04</td>
<td>51.9</td>
<td>1.36 ± 0.08</td>
</tr>
<tr>
<td>MLK/New Marsh</td>
<td>+0.73 ± 0.05</td>
<td>98.1</td>
<td>1.61 ± 0.03</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>+0.56 ± 0.08</td>
<td>62.7 ± 9.3</td>
<td>1.23 ± 0.10</td>
</tr>
</tbody>
</table>

1 Earthen island heights designed to be +1.0 ft above MHHW.
2 Gumplant heights averaged across islands were 1.41 ± 0.03 ft immediately following planting.

Average gumplant heights decreased by -0.20 ft. on average across islands. This decrease in gumplant height occurred because tall gumplant stems and leaves died back while new stems and leaves re-sprouted from the base of plants. Contrary to this trend, gumplant heights increased at MLK/New Marsh by +0.25 ft where island construction used imported terrestrial soils.

**Soil.** Earthen island soil pH ranged from 5.8 to 6.8 across the 6 pilot islands; -0.8 pH units lower than the samples representing sediment conditions prior to excavation collected on the marsh plain. This indicates sediments used for earthen island construction have acidified following excavation and drainage. However, earthen island pH levels remain suitable for gumplant. Because the conversion of sulfides to sulfate (acidification) is mediated by relatively rapidly established microbial processes, further earthen island sediment acidification is unlikely.

Soil salinity on each earthen island ranged from 19.8 to 33.8 ppt, a range tolerable by gumplant and typical of high marsh soils. Regression analysis found no effect of soil salinity on marsh gumplant survival across islands. Soil organic matter on islands ranged from 3.3 to 5.1%, similar to levels found with gumplant at other locations in San Francisco Bay salt marshes. The texture of the upper 8 inches of sediment/soil at all earthen island sites was clay (USDA soil classification) with the exception of imported MLK/New Marsh soil which was a sandy clay.

**Earthen Island Function.** Earthen islands were expected to settle following construction to approximately +0.5 ft above MHHW and, with establishment of 2-3-ft tall gumplant, provide cover for California clapper rail during most high tide events. We found that 4 of 6 earthen islands remained above expected elevations of +0.5 ft above MHHW 5 months after construction and that gumplant was (on average) 1.2 ft tall. As
expected, the recent gumplant plantings are recovering from transplant shock and have not yet developed canopy architecture that would provide cover for rails. We anticipate that 2-4 growing seasons will be needed for gumplant to mature to provide good cover for rails. However, perennial pickleweed is establishing rapidly from the installed sod and already provides 40-70% cover to a height of approximately 0.5-1 ft above the island ground surface. We anticipate that gumplant, pickleweed, and saltgrass height and percent cover will rapidly increase over the first 3 growing seasons, creating earthen island refuge habitat for California clapper rails.

**Design Recommendations.** Based on these findings we provide the following recommendations for island design, planting and maintenance.

1. Select relatively well-drained, consolidated microsites for island construction
2. Increase constructed earthen island top elevations to 1.3 ft above MHHW
3. Accurately account for sod thickness during construction to achieve design height
4. Construct the remaining MLK/New Marsh islands with imported terrestrial soil
5. Consider constructing a few additional readily accessible islands with imported terrestrial soil
6. Reduce gaps between marsh sod squares on island by cutting larger sod pieces
7. Spread excess sod across excavation areas to speed recovery
8. Maintain earthen islands by filling gaps between marsh sod squares with sediment during first 1-2 growing seasons
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Preparers

Ron Duke, M.A., Principal-In-Charge
Max Busnardo, M.S., Project Manager, Sr. Associate Restoration Ecologist
Gavin Archbald, M.S., Restoration Ecologist
Joe Howard, M.L.A., Principal, Landscape Architect
Section 1.0 Introduction

1.1 Project Background

The California Coastal Conservancy’s (Conservancy) Invasive Spartina Project is currently implementing California Clapper Rail Habitat Enhancements to compensate for anticipated effects of treating invasive Spartina in 2012 on the California clapper rail (Rallus longirostris obsoletus) (USFWS 2012). Among the enhancements specified is the construction of 22 earthen islands designed to provide high tide refugia for California clapper rails to reduce predation losses. These islands can provide similar benefits for salt marsh harvest mice (Reithrodontomys raviventris).

In December 2012-January 2013, the Conservancy constructed the first 6 earthen islands on a pilot basis at the following locations: (1) Cooley Landing, (2) Belmont Slough South, (3) Belmont Slough North, (4) Bird Island, (5) Bair Island North Quadrant West (Northwest), and (6) MLK/New Marsh. H. T. Harvey & Associates’ restoration ecologists and Invasive Spartina Project biologists monitored earthen islands construction. Pilot earthen island as-built conditions and lessons learned during construction were summarized by H. T. Harvey & Associates (2013a; Appendix A). Maps of the approximate pilot island locations and GPS coordinates for earthen islands, excavation areas and elevation control stakes are provided in Invasive Spartina Project Pilot Earthen Island Construction Notes to Contractors (H. T. Harvey & Associates 2013b; Appendix B).

1.2 Pilot Earthen Island Design

The core of the earthen islands built at Cooley Landing, Belmont Slough South, Belmont Slough North, Bird Island and Bair Island Northwest were constructed using sediment excavated from the marsh plain adjacent to the earthen islands. At MLK/New Marsh, however, the core of the earthen island was constructed using imported terrestrial clay soil topped with 0.5 – 1.0 feet (ft) of sandy loam terrestrial soil because in-situ marsh sediment at MLK/New Marsh was unsuitable for island construction. At all island sites, earthen island cores were capped with an approximately 6-inch thick layer of marsh sod dominated by pickleweed (Salicornia pacifica) and then the island tops and sides were planted with gumplant (Grindelia stricta) and saltgrass (Distichlis spicata) container plants.

Earthen island tops were designed to be situated at +1.0 ft above MHHW immediately after construction. This resulted in an average of 1.9 vertical ft of fill, given the pilot island pre-construction marsh plain elevations. The island top design elevation was set to rapidly create high quality clapper rail refugia while remaining within the tidal range of the sites. Therefore, the island top elevation was set such that following short term settlement (1-2 years) the site would still be within the mid-upper elevation range of gumplant occurrence. Islands were expected to settle by approximately 0.5 ft to a top of earthen island elevation of approximately +0.5 ft above MHHW. Field surveys and literature review conducted by H. T. Harvey &
Associates found gumplant in the San Francisco Estuary grows from -0.75 ft below to +2.21 ft above MHHW, with an average range of -0.10 below to + 0.82 ft above MHHW. Based on these assumptions, after earthen islands settle (to roughly +0.5 ft MHHW), they will provide approximately 0.6 vertical ft of habitat suitable for gumplant. Gumplant plantings, when mature, are expected to provide an additional 2-3 vertical ft of cover above the island tops, sufficient to provide California clapper rail with refuge from aerial predators during most high tide events. Design specifications are further described in Invasive Spartina Project Pilot Earthen Island Construction Notes to Contractors (H. T. Harvey & Associates 2013b; Appendix B).

1.3 Study Purpose and Limitations

The purpose of this study was to monitor changes in topography, vegetation and soils at the 6 constructed pilot earthen islands to, (1) assess whether the earthen islands are on a trajectory to provide high tide refugia cover for California clapper rails, and; (2) identify design elements (e.g., elevation, material and methods used to construct earthen islands) that should be adjusted in future earthen island construction phases to maximize the benefit of the earthen islands for California clapper rail.

This interim Year-1 monitoring field study was conducted in mid-May 2013, approximately 5 months after pilot island installation and in the early portion of the first growing season. The monitoring work was scheduled early in Year-1 to allow the Conservancy time to incorporate any design modifications into the contracting and construction process for the 18 islands to be constructed in Fall 2013.
Section 2.0 Methods

H. T. Harvey & Associates’ restoration ecologists, G. Archbald and M. Busnardo, together with Invasive Spartina Project biologists, J. McBroom and D. Kerr, monitored pilot earthen islands on 16, 17 and 20 May 2013. Pilot earthen islands at Cooley Landing, Belmont Slough South, Belmont Slough North, and MLK/New Marsh were accessed by foot at low tide during a neap tide cycle. Bird Island and Bair Island Northwest sites were accessed via airboat during an outgoing 5.4 ft high tide. Excavation areas at Bird Island and Bair Island Northwest were fully above water and able to be surveyed when the tide dropped below approximately 5.25 ft (MLLW tidal datum).

2.1 Topography

We conducted topographic surveys to measure settlement of earthen islands and changes in the depth of excavation areas since construction. Topographic surveys used the same methods described to document as-built topography (H. T. Harvey & Associates 2013a; Appendix B).

Surveys were carried out using a Leica Rugby 50 laser level. Elevations were measured relative to an elevation control stake installed at each site prior to earthen island construction. The top of each elevation control stake is situated at MHHW and all elevation control stakes are PVC pipes except for MLK/New Marsh which is a rebar stake.

2.1.1 Earthen Islands

We measured the longitudinal profile of each earthen island. A transect tape was stretched between rebar stakes previously installed at the upstream and downstream end such that the transect tape fell across the center of the long axis of each earthen island. Elevation measures were collected beginning at the upstream rebar stake and thereafter every 3 ft and at topographic hinge points (e.g., toe of slope, top of slope), ending at the downstream rebar stake. We recorded the distance along the transect tape with each elevation measurement. We then determined the island’s average top elevation by averaging elevation measurements collected across the top of the island.

2.1.2 Excavation Areas

We measured the longitudinal profile and cross section of each excavation area. A transect tape was stretched between rebar stakes previously installed at the upstream and downstream ends of the center of each excavation area to measure the longitudinal profile and a second transect was run from a previously installed rebar stake on the marsh plain to the channel bordering the excavation area to measure the cross section. Elevation measures and distances were collected beginning at the upstream rebar stake (longitudinal profiles) and the marsh plain stake (cross sections) and thereafter every 3 feet or at topographic hinge points. We
averaged points collected from the bottom of the excavation area along the longitudinal profile and cross section to determine the elevation of the bottom of excavation area.

### 2.2 Vegetation

We measured the height and survival of gumplant on each earthen island. We also estimated vegetation cover on the earthen islands and in the excavation areas and noted other pertinent vegetation observations (e.g., vegetation response in trampled work areas).

#### 2.2.1 Earthen Islands

**2.2.1.1 Gumplant Survival**

Approximately 58 gumplant plantings were originally installed on the top and side slopes of each earthen island. All gumplant plantings were examined and scored as “alive” if green leaves were present and “dead” if no green leaves were present. Gumplant survival on the top of the island, the tidal-channel side of the island and marsh plain side of the island (zones) were recorded separately. Survival was calculated by dividing the number of living plants by the total count of living and dead plants within each zone and for each island as a whole.

**2.2.1.2 Gumplant Heights**

The height of all gumplant plants were measured from the top of the root ball to the tallest green leaf. Gumplant heights (living plants only) were recorded separately within the same zones summarized above for survival counts. Average gumplant heights were calculated for zones, and the average height was calculated as the average of all living gumplant plants per island.

**2.2.1.3 Gumplant Elevation Range**

We measured the elevation of the three lowest surviving gumplant plants on each earthen island. We subtracted this metric from the elevation of the top of the earthen island to calculate gumplant’s elevation range per island.

**2.2.1.4 Qualitative Observations**

The general health and vigor of gumplant plants and saltgrass plants installed on earthen islands was visually/qualitatively assessed. We also estimated percent vegetation cover on each earthen island and recorded all plant species present. We noted signs of wildlife use.
2.2.2 Excavation Areas

2.2.2.1 Qualitative Observations

We estimated the percent cover and recorded the species of plants established on the side slopes and bottom of the excavation areas.

2.3 Soil

2.3.1 Earthen Islands

We sampled the earthen islands for soil parameters that could affect gumplant survival and growth. We collected 3 sub-samples, 8 inches in depth from the top and sides of each earthen island and combined these into one composite sample per island for analysis. Soil samples were analyzed by the Soil and Plant Laboratory for the following parameters:

- Salinity (Electrical conductivity)
- pH
- Organic Matter (%)
- Texture

2.3.2 Marsh Plain Reference Soils

Marsh sediments used to construct earthen islands may become acidified as sulfides convert to sulfate after being drained and exposed to oxygen. This bacterially mediated process could lower pH levels and impede the growth and/or survival of gumplant and other halophytes. We sampled marsh locations representative of conditions prior to excavation for comparison to the earthen island samples (see above section) to assess whether earthen island sediments have acidified. We collected one composite sample \( (n = 3) \) from the top 8 inches of sediment on the marsh plain adjacent to the excavation area. Soil samples were analyzed by the Soil and Plant Laboratory for the following parameters:

- Salinity (Electrical conductivity)
- pH
- Organic Matter (%)

We compared marsh plain sediment pH, salinity and organic matter (%) levels with samples from earthen islands.

2.4 Gumplant Survival versus Abiotic Factors

Hydroperiod, soil salinity, and pH are abiotic factors that could explain differences in gumplant survival between earthen island sites. We used regression analysis (Microsoft Excel) and t-tests (R statistical package)
to evaluate the strength of the relationship between gumplant survival and, (1) elevation relative to MHHW (as a proxy for hydroperiod), (2) soil salinity (parts per thousand (ppt)) and, (3) pH. We interpreted the results to inform design recommendations.

## 2.5 Photo-documentation

Earthen islands and excavation areas were photographed from fixed locations, described below.

### Table 1. Photo-documentation Locations at Cooley Landing, Belmont Slough South, Belmont Slough North, Bird Island, Bair Island Northwest

<table>
<thead>
<tr>
<th>Photopoint</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>View from the control stake to the excavation area</td>
</tr>
<tr>
<td>2</td>
<td>View from the control stake to between the earthen island and the excavation area</td>
</tr>
<tr>
<td>3</td>
<td>View from the control stake to the earthen island</td>
</tr>
<tr>
<td>4</td>
<td>View from the foot of the earthen island facing downstream</td>
</tr>
<tr>
<td>5</td>
<td>View from the foot of the earthen island facing upstream</td>
</tr>
<tr>
<td>6</td>
<td>View from the foot of the excavation area facing upstream</td>
</tr>
</tbody>
</table>

### Table 2. Photo-documentation Locations at MLK/ New Marsh

<table>
<thead>
<tr>
<th>Photopoint</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>View from the control stake to the earthen island site</td>
</tr>
<tr>
<td>2</td>
<td>View from the foot of the earthen island facing downstream</td>
</tr>
<tr>
<td>3</td>
<td>View from the foot of the earthen island facing upstream</td>
</tr>
<tr>
<td>4</td>
<td>View from the slough channel west of the earthen island facing the earthen island</td>
</tr>
</tbody>
</table>
Section 3.0 Results and Discussion

3.1 Topography

3.1.1 Earthen Islands

Five months after construction in May 2013, earthen islands tops were situated between +0.73 ft (MLK/New Marsh) and +0.22 ft (Belmont Slough South) above MHHW (+0.54 ft above MHHW on average). This corresponds to between 0.27 and 0.78 ft below design elevations (0.46 ft on average) (Table 3). Of this difference, we estimate approximately 0.31 ft is due to island settlement (~17% relative to the ~1.87 vertical ft of fill) and 0.15 ft (~8% relative to vertical fill) is due to construction of islands below design specifications based on comparison with as-built measurements.

Earthen islands settled most relative to as-built elevations at Belmont Slough North (0.56 ft) and Belmont Slough South (Table 3). Excavated marsh sediments used for construction at Belmont Slough North and South were noticeably more saturated than material used to construct the other pilot sites. Saturated sediments are likely to shrink and settle more than unsaturated sediments following drainage and drying. This may explain the greater earthen island settlement observed at Belmont Slough sites.

The earthen island at MLK/New Marsh settled the least (0.14 ft) relative to as-built elevations. This is likely because, (1) the MLK/New Marsh earthen island was constructed with imported terrestrial fill that had lower water content and therefore, less potential for shrinkage following placement than other pilot islands, and (2) the MLK/New Marsh is a restored marsh created through excavation of upland fill and the marsh substrate consists of gravelly/firmly packed material that likely supports the weight of the constructed earthen island more than do natural marsh clay sediments.

Table 3. Topographic Change in Top of Earthen Island Elevation

<table>
<thead>
<tr>
<th>Site</th>
<th>Design Elevation (ft)</th>
<th>As-Built Elevation (Dec–Jan 2013) (ft ± standard error)</th>
<th>Year-1 (May 2013) (ft ± standard error)</th>
<th>Change from As-built (ft)</th>
<th>Difference from Design (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooley Landing</td>
<td>+1.0</td>
<td>+0.98 ± 0.03</td>
<td>+0.71 ± 0.03</td>
<td>0.27</td>
<td>0.29</td>
</tr>
<tr>
<td>Belmont Slough South</td>
<td>+1.0</td>
<td>+0.48 ± 0.05</td>
<td>+0.22 ± 0.04</td>
<td>0.26</td>
<td>0.78</td>
</tr>
<tr>
<td>Belmont Slough North</td>
<td>+1.0</td>
<td>+1.00 ± 0.03</td>
<td>+0.44 ± 0.04</td>
<td>0.56</td>
<td>0.56</td>
</tr>
<tr>
<td>Bird Island</td>
<td>+1.0</td>
<td>+0.90 ± 0.05</td>
<td>+0.57 ± 0.05</td>
<td>0.33</td>
<td>0.43</td>
</tr>
<tr>
<td>Bair Island Northwest</td>
<td>+1.0</td>
<td>+0.88 ± 0.06</td>
<td>+0.60 ± 0.04</td>
<td>0.28</td>
<td>0.40</td>
</tr>
<tr>
<td>MLK/New Marsh</td>
<td>+1.0</td>
<td>+0.87 ± 0.05</td>
<td>+0.73 ± 0.05</td>
<td>0.14</td>
<td>0.27</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>+1.0</td>
<td><strong>+0.85 ± 0.08</strong></td>
<td><strong>+0.54 ± 0.08</strong></td>
<td><strong>0.31</strong></td>
<td><strong>0.46</strong></td>
</tr>
</tbody>
</table>

1 Belmont South topography survey was measured 13 days after island construction. All other sites were measured 1-3 days following island construction (H. T. Harvey & Associates 2013b; Appendix A).
3.1.2 Excavation Areas

Sediment at the bottom of excavation areas accreted on average by 0.10 ft. Excavation areas with lower initial elevations accreted sediment most rapidly (Belmont Slough South, Bair Island Northwest, Bird Island). No distinguishable change in elevation was detected at the Cooley Landing and Belmont Slough North sites.

Table 4. Topographic Change in Bottom of Excavation Areas

<table>
<thead>
<tr>
<th>Site</th>
<th>Average Bottom Elevation of Excavation Area (ft ± standard error) Relative to MHHW&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Change from As-Built (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>As-Built (Dec - Jan 2013) Year-1(May 2013)</td>
<td></td>
</tr>
<tr>
<td>Cooley Landing</td>
<td>-1.34 ± 0.05</td>
<td>-0.01</td>
</tr>
<tr>
<td>Belmont Slough South</td>
<td>-2.85 ± 0.02</td>
<td>+0.23</td>
</tr>
<tr>
<td>Belmont Slough North</td>
<td>-2.23 ± 0.13</td>
<td>-0.09</td>
</tr>
<tr>
<td>Bird Island</td>
<td>-2.78 ± 0.05</td>
<td>+0.18</td>
</tr>
<tr>
<td>Bair Island Northwest</td>
<td>-2.83 ± 0.03</td>
<td>+0.15</td>
</tr>
<tr>
<td>MLK/New Marsh&lt;sup&gt;2&lt;/sup&gt;</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Average</td>
<td>-2.41 ± 0.29</td>
<td>+0.10</td>
</tr>
</tbody>
</table>

<sup>1</sup>Average of all longitudinal profile and cross sections points below excavation area side slopes.

<sup>2</sup>An excavation area was not constructed at this site since fill was imported.

3.2 Vegetation

3.2.1 Earthen Islands

3.2.1.1 Gumplant Survival

Gumplant survival on the earthen islands ranged between 34.5% at Belmont Slough South and 98.1% at MLK/New Marsh with 62.7% of gumplant plantings surviving on average across islands (Table 5). Survival was higher on island tops (average = 76.3%) than on earthen island sides (average = 53.9%). These results suggest that the small elevation increase between the earthen island top compared to the side slopes had a positive effect on gumplant survival.
### Table 5. Gumplant Percent Survival on Earthen Islands

<table>
<thead>
<tr>
<th>Site</th>
<th>Marsh Plain Side</th>
<th>Channel Side</th>
<th>Island Top</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooley Landing</td>
<td>56.3</td>
<td>94.7</td>
<td>84.0</td>
<td>80.0</td>
</tr>
<tr>
<td>Belmont Slough South</td>
<td>17.6</td>
<td>5.6</td>
<td>75.0</td>
<td>34.5</td>
</tr>
<tr>
<td>Belmont Slough North</td>
<td>46.2</td>
<td>47.1</td>
<td>78.9</td>
<td>59.2</td>
</tr>
<tr>
<td>Bird Island</td>
<td>55.6</td>
<td>50.0</td>
<td>51.7</td>
<td>52.5</td>
</tr>
<tr>
<td>Bair Island Northwest</td>
<td>37.5</td>
<td>42.9</td>
<td>68.2</td>
<td>51.9</td>
</tr>
<tr>
<td>MLK/New Marsh</td>
<td>100.0</td>
<td>92.9</td>
<td>100.0</td>
<td>98.1</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>52.3</strong></td>
<td><strong>55.7</strong></td>
<td><strong>76.3</strong></td>
<td><strong>62.7</strong></td>
</tr>
</tbody>
</table>

### 3.2.1.2 Gumplant Heights

Gumplant heights decreased on average across islands as tall gumplant leaves died back and were replaced by leaves of lower height which re-sprouted from the base of many plants (Table 6). Gumplant transplanted into saline conditions often experience transplant shock and initially die back above ground (pers. observation).

In contrast to other marsh sites, gumplant heights increased by 0.25 ft at MLK/New Marsh. The earthen island at MLK/New Marsh was constructed using non-saline, relatively dry upland soils; and the island was situated relatively high in the tidal frame during our May 2013 survey. These factors likely have reduced salinity and inundation stress for gumplant at MLK/New Marsh relative to the other sites.

There was no clear difference in gumplant height between the marsh plain side, channel side and island tops (results not shown). This is because decreased gumplant height was observed regardless of position on earthen islands.

### Table 6. Gumplant Height on Earthen Islands

<table>
<thead>
<tr>
<th>Site</th>
<th>Average Gumplant Height (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>As-Built (Dec - Jan 2013)</td>
</tr>
<tr>
<td>Cooley Landing</td>
<td>1.38 ±0.02</td>
</tr>
<tr>
<td>Belmont Slough South</td>
<td>1.40 ±0.03</td>
</tr>
<tr>
<td>Belmont Slough North</td>
<td>1.42 ±0.04</td>
</tr>
<tr>
<td>Bird Island</td>
<td>1.36 ±0.03</td>
</tr>
<tr>
<td>Bair Island Northwest</td>
<td>1.57 ±0.04</td>
</tr>
<tr>
<td>MLK/New Marsh</td>
<td>1.34 ±0.02</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>1.41 ±0.03</strong></td>
</tr>
</tbody>
</table>
3.2.1.3 Gumplant Elevation Range

On average, surviving gumplant was limited to elevations above -0.23 ft below MHHW on the pilot earthen islands. We found that the vertical range of gumplant on the earthen islands was 0.78 ft on average (Table 7). This is larger than the vertical range of gumplant observed along naturally occurring tidal sloughs at Belmont South, Laumeister Marsh, Bird Island and Palo Alto Baylands (average gumplant range = 0.35 ft), equivalent to the vertical range of gumplant observed along constructed berms at Belmont Slough and Laumeister Marsh (average gumplant range = 0.71 ft) and less than the average range observed along levees at Belmont Slough and Laumeister (average gumplant range = 1.52 ft) (USGS 1983; H. T. Harvey & Associates, unpublished data).

Table 7. Gumplant Elevation Range

<table>
<thead>
<tr>
<th>Site</th>
<th>Lowest Observed Living Gumplant (ft relative to MHHW)</th>
<th>Top of Earthen Island (ft relative to MHHW)</th>
<th>Gumplant Elevation Range (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooley Landing</td>
<td>+0.19 ±0.08</td>
<td>+0.71 ±0.03</td>
<td>0.52</td>
</tr>
<tr>
<td>Belmont Slough South</td>
<td>-0.27 ±0.16</td>
<td>+0.22 ±0.04</td>
<td>0.49</td>
</tr>
<tr>
<td>Belmont Slough North</td>
<td>-0.69 ±0.07</td>
<td>+0.44 ±0.04</td>
<td>1.13</td>
</tr>
<tr>
<td>Bird Island</td>
<td>-0.06 ±0.13</td>
<td>+0.57 ±0.05</td>
<td>0.63</td>
</tr>
<tr>
<td>Bair Island Northwest</td>
<td>-0.21 ±0.06</td>
<td>+0.60 ±0.04</td>
<td>0.81</td>
</tr>
<tr>
<td>MLK/New Marsh</td>
<td>-0.34 ±0.04</td>
<td>+0.73 ±0.05</td>
<td>1.07</td>
</tr>
<tr>
<td>Average</td>
<td>-0.23 ±0.11</td>
<td>+0.54 ±0.08</td>
<td>0.78 ±0.11</td>
</tr>
</tbody>
</table>

3.2.1.4 Qualitative Observations

There was robust growth of perennial pickleweed from the transplanted sod on all earthen islands. Survival of saltgrass plantings appeared high, but saltgrass spread little at most earthen islands. No obligate upland plants were found on any earthen islands. Below we provide qualitative observations specific to each island.

Cooley Landing. Perennial pickleweed covered approximately 70% of the earthen island. Saltgrass plantings were alive, but no spread was observed. Surviving gumplant looked healthy. A single annual pickleweed (*Salicornia depressa*) plant established on the island channel side slope. A distinct wrack line was visible at 0.29 ft relative to MHHW. No other plant species were present on the island. Bird droppings [possibly Canada goose (*Branta canadensis*) and song sparrow (*Melospiza melodia*)] were observed on the island.

Belmont Slough South. Perennial pickleweed covered approximately 50% of the island. Saltgrass plantings appeared healthy and had begun to spread in some locations. Gumplant that was planted lower on the island was mostly dead while upper plantings had mixed survival. Living gumplant looked stressed, but healthy regrowth was observed from the base of many plants. No other plant species were present on the earthen island.
Belmont Slough North. Perennial pickleweed covered approximately 70% of the island. The lower half of the island had a light covering of tidally deposited silt. Saltgrass was present, but had spread little. Many gumplant plantings were re-sprouting at the base. No other plant species were present. The top of the island was dry (3-inches depth) and had soil cracks.

Bird Island. Perennial pickleweed covered approximately 50% of the island. Gumplant looked relatively stressed. Saltgrass plantings were alive, but appeared to suffer from desiccation stress. No other plant species were present. There were relatively large soil gaps (up to 2 inches wide) between some sod pieces and overall the earthen island topsoil was relatively dry, particularly on the island top.

Bair Island. Perennial pickleweed covered approximately 40% of the island. Gumplant appeared healthy with large leaves, some branching and good regrowth at the base of plants. The tops of the root ball of some gumplant plantings were exposed, suggesting as the island dried and settled these plantings have become more exposed. Healthy patches of saltgrass and alkali heath (*Frankenia salina*) were present on the island, the result of transplanting these species onto the island via marsh sod. There were relatively large soil gaps between some sod pieces (up to 2 inches wide) and some larger bare patches on the island. Bird droppings (probably Canada goose) were abundant on the island.

MLK/New Marsh. Perennial pickleweed covered approximately 70% of the island. Gumplant was thriving, evidenced by increased height, branching and large, healthy leaves. *Jaumea (Jaumea carnosa)*, alkali heath and saltgrass were present in patches and appeared to be spreading. The use of marsh sod with these species present is beneficial for earthen island plant diversity. Some large gaps were present between sod pieces (up to 2 inches wide). Sod pieces were placed packed closely together at this site, yet shrinking and cracking of marsh sod still occurred. Some invasive hybrid *Spartina* was present on the island, which we pulled by hand.

3.2.2 Excavation Areas

Excavation areas ranged from completely un-vegetated to well vegetated. Perennial pickleweed was present where marsh sod was placed along the bottom and side slopes of excavation areas.

3.2.2.1 Qualitative Observations

Cooley Landing. Perennial pickleweed was well distributed across approximately 30% of the bottom and side slopes of the excavation area. Annual pickleweed was present in trace amounts.
Belmont Slough South. Perennial pickleweed covered approximately 10% of the side slopes, but the bottom of the excavation area was un-vegetated. Mud was unconsolidated on the excavation area bottom, suggesting rapid sediment deposition.

Belmont Slough North. Perennial pickleweed covered approximately 30% of the side slopes and 10% of the excavation area bottom.

Bird Island. Perennial pickleweed covered approximately 30% of the side slopes and 2% of the excavation area bottom.

Bair Island. Perennial pickleweed covered approximately 30% of the side slopes. The bottom of the excavation areas was unvegetated. Pacific cordgrass (Spartina foliosa) was observed growing along the channel immediately below the bottom of the excavation area.

MLK/New Marsh. This site does not have an excavation area since upland soils were imported to construction the island.

3.3 Soil

3.3.1 Earthen Islands

Earthen island soil pH ranged from 5.8 (moderately acidic) to 6.8 (neutral) across the 6 pilot islands (Table 8). This range is likely a suitable range for gumnplant growth as nutrient uptake by most plants is not substantially restricted by pH until values fall below 4 (USDA 1957). A prior review of literature carried out by H. T. Harvey & Associates (2013) found gumnplant soil pH ranging from 6.4 (slightly acidic) to 7.7 (slightly alkaline).

Table 8. Soil Characteristics of Earthen Islands

<table>
<thead>
<tr>
<th>Site</th>
<th>Salinity (ppt)</th>
<th>pH</th>
<th>Organic Matter (% dry weight)</th>
<th>USDA Soil Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooley Landing</td>
<td>27.7</td>
<td>6.4</td>
<td>3.5</td>
<td>Clay</td>
</tr>
<tr>
<td>Belmont Slough South</td>
<td>27.3</td>
<td>6.0</td>
<td>4.4</td>
<td>Clay</td>
</tr>
<tr>
<td>Belmont Slough North</td>
<td>28.6</td>
<td>5.8</td>
<td>4.2</td>
<td>Clay</td>
</tr>
<tr>
<td>Bird Island</td>
<td>33.8</td>
<td>6.5</td>
<td>5.1</td>
<td>Clay</td>
</tr>
<tr>
<td>Bair Island Northwest</td>
<td>26.1</td>
<td>6.6</td>
<td>3.6</td>
<td>Clay</td>
</tr>
<tr>
<td>MLK/ New Marsh</td>
<td>19.8</td>
<td>6.8</td>
<td>3.3</td>
<td>Sandy Clay</td>
</tr>
</tbody>
</table>

| Average               | 27.2           | 6.4 | 4.0                           |

Soil salinity on each earthen island ranged from 19.8 to 33.8 ppt, a range typical of high marsh soils. Soil organic matter on islands ranged from 3.3 to 5.1%, similar to levels of organic matter found with gumnplant at
other locations in the San Francisco Bay salt marshes (H. T. Harvey & Associates 2013). All earthen island sites were clay (USDA soil classification) with the exception of MLK/New Marsh which was a sandy clay (Table 8). Soils on the top of earthen islands were relatively dry within the top 3 inches.

### 3.3.2 Earthen Island Sediment Acidification

Soil pH measurements on earthen islands were, on average, 0.8 pH units lower than reference excavation area soil conditions (Table 9). This soil acidification was likely due to the microbially mediated oxidation of sulfide to sulfate following drainage of relatively anaerobic sediments used for earthen island construction. We suspect that the soil pH has equilibrated to the new/constructed condition. There was no clear trend towards a change in soil salinity or organic matter between earthen islands and the marsh plain (Table 9; only soil pH and salinity shown).

#### Table 9. pH and Salinity on Earthen Islands Relative to Marsh Plain Reference Areas

<table>
<thead>
<tr>
<th>Site</th>
<th>pH</th>
<th>Marsh Plain</th>
<th>Earthen Island</th>
<th>Difference</th>
<th>Salinity (ppt)</th>
<th>Marsh Plain</th>
<th>Earthen Island</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooley Landing</td>
<td>6.7</td>
<td>6.4</td>
<td>-0.3</td>
<td>24.7</td>
<td>27.7</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belmont Slough South</td>
<td>6.6</td>
<td>6.0</td>
<td>-0.6</td>
<td>28.5</td>
<td>27.3</td>
<td>-1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belmont Slough North</td>
<td>6.9</td>
<td>5.8</td>
<td>-1.1</td>
<td>27.5</td>
<td>28.6</td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bird Island</td>
<td>7.7</td>
<td>6.5</td>
<td>-1.2</td>
<td>40.2</td>
<td>33.8</td>
<td>-6.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bair Island Northwest</td>
<td>7.3</td>
<td>6.6</td>
<td>-0.7</td>
<td>30.4</td>
<td>26.1</td>
<td>-4.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLK/ New Marsh</td>
<td>NA</td>
<td>6.8</td>
<td>NA¹</td>
<td>NA¹</td>
<td>NA¹</td>
<td>NA¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>7.0±0.2</td>
<td>6.4±0.1</td>
<td>-0.8±0.2</td>
<td>30.3±2.7</td>
<td>27.2±1.2</td>
<td>-1.6±1.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹No excavation area at MLK/New Marsh

### 3.4 Gumplant Survival versus Abiotic Factors

Gumplant survival was greater at sites located higher in the tidal frame (Figure 1). Elevation relative to MHHW was a strong predictor ($R^2 = 0.78$) of gumplant survival and this relationship was significant at $\alpha = 0.05$ ($P = 0.02$). Gumplant survival was 80% and above at earthen islands sites with tops situated at or above approximately +0.70 ft above MHHW.
Figure 1. Gumplant Survival Versus Elevation

By contrast, no statistically significant relationships were found between gumplant survival and soil salinity ($R^2 = 0.39; P = 0.22$; Figure 2) or pH ($R^2 = 0.32; P = 0.18$; Figure 3). Excessively high salinity and/or excessively low or high pH can detrimentally affect growth and survival of marsh plants. However, these findings indicated that the salinity and pH range at pilot earthen island sites are suitable for gumplant survival.

These results also indicate that gumplant survival and growth is likely to be increased by adjusting the design of earthen islands so that the earthen island tops, after settlement, are situated at or above +0.7 ft relative to MHHW. This conclusion is supported by the finding that gumplant survival was higher on the tops than the side slopes of earthen islands (see Section 3.2.1.1).

Figure 2. Gumplant Survival Versus Soil Salinity
3.5 Photo-documentation

Photo-documentation comparing earthen islands and excavation areas in December-January 2013 (As-Built) versus May 2013 is provided in Appendix C.

3.6 Status of Earthen Island Function

Earthen islands were expected to settle (during first 1-2 years) following construction to about +0.5 ft above MHHW and, with the establishment of 2-3 ft tall, dense gumplant, provide cover for California clapper rail during most high tide events. We found that 4 of 6 earthen islands remained above expected elevations of +0.5 ft above MHHW at 5 months after construction and that gumplant heights were (on average) 1.2 ft. At the time of this survey, the island at MLK/ New Marsh provides the most effective cover (island elevation + average gumplant height = 2.34 ft above MHHW, gumplant survival = 98.1%, relatively robust gumplant canopy for 5 month old plants). The island at Belmont Slough South provides the least effective cover (island elevation + average gumplant height = 1.31 ft above MHHW, gumplant survival = 34.5%).

As expected, the recent gumplant plantings are recovering from transplant shock and have not yet developed canopy architecture that would provide cover for rails. We anticipate that 2-4 growing seasons will be needed for gumplant to mature to provide good cover for rails. However, perennial pickleweed is establishing rapidly from the installed sod and already provides 40-70% cover to a height of approximately 0.5-1 ft above the island ground surface. We anticipate that gumplant, pickleweed, and saltgrass height and percent cover will rapidly increase over the first 3 growing seasons, creating earthen island refuge habitat for California clapper rails.
Section 4.0 Earthen Island Design Recommendations

Here we provide design, planting and management recommendations to improve growing conditions for gumplant and transplanted sod on the additional 16 earthen islands that remain to be constructed. These design recommendations build on an initial set of “lessons learned” presented to the Conservancy by H. T. Harvey & Associates submitted following earthen island construction (H. T. Harvey & Associates 2013a; Appendix A).

4.1.1 Island Design and Construction

Select Relatively Well-drained, Consolidated Microsites for Island Construction. Earthen islands settled most when saturated, less consolidated, in-situ marsh sediments were used for island construction (e.g., Belmont Slough South). Therefore, we recommend selecting locations for excavation and fill that have relatively firm, well-drained sediments (e.g., as near to MHHW as possible).

Increase Constructed Earthen Island Top Elevations. We recommend increasing the constructed island top elevation from 1.0 ft above MHHW to 1.3 ft above MHHW based on the data we collected. We observed at pilot earthen islands that gumplant survival increased with elevation above MHHW (Figure 1). Earthen islands with tops situated less than about 0.6 ft above MHHW have about 50% and lower gumplant survival while those sites at about 0.7 ft have survival 80% and higher. Therefore, to raise the elevation of gumplant plantings to a more suitable elevation, we recommend constructing the future earthen island top elevations at 1.3 ft above MHHW. This will situate future earthen island tops, after an assumed initial settlement of 0.5 ft, at approximately 0.8 ft above MHHW and provide a larger suitable range at each island for robust gumplant growth. The maximum footprint (250 sq. ft) and top width (2 ft) of the island should remain the same and the side slopes should be constructed slightly steeper to accommodate the design height adjustment.

Our assumed initial (1-2 years) settlement of 0.5 ft is based upon preliminary input from a professional hydrologist that did not include review of site specific data on relevant physical parameters. Based on the small data set from our May 2013 elevation sampling which shows an average of 0.31 ft of settlement over 5 months, it appears the 0.5 ft estimate of settlement over a 1-2 year period is a reasonable estimation. However, given the importance of accurately estimating settlement for earthen island function, the Conservancy might consider consulting a geotechnical engineer with tidal marsh project experience to review the pilot project’s soil texture and elevation data and provide an assessment of the estimated amount of initial settlement for the subsequent islands to be constructed. This input would then be utilized to further refine our design height recommendation.

Accurately Account for Sod Thickness During Construction to Achieve Design Height. The islands were built approximately 0.15 ft less than the design maximum height, on average. While a relatively small
departure from the design (~8% of vertical fill thickness), the Contractor should take care to accurately estimate the installed sod thickness when grade checking the subgrade prior to sod installation, to arrive at or slightly above the design height.

**Construct the Remaining MLK/New Marsh Islands With Imported Terrestrial Soil.** The MLK/New Marsh island is performing well. Moreover, the existing coarse, compacted fill substrate that comprises the MLK/New Marsh site is not suitable for cost-effective/manual excavation and also may not be horticulturally suitable as island substrate. Therefore, the remaining 2 islands at the MLK/New Marsh should be constructed using similar terrestrial imported fill utilized for the pilot island. However, the impacts to MLK/New Marsh caused by haul trucks used for pilot island soil placement should be evaluated. If marsh vegetation recovery is deemed to be too slow, alternative soil transport methods should be used.

**Consider Constructing Readily Accessible Islands with Imported Terrestrial Soil.** The imported terrestrial soils used to construct the MLK/New Marsh island were composed of a clay core and a 1-foot thick sandy loam topsoil layer. These soils may have enhanced gumplant survival and growth by providing low salinity and well-drained, initially relatively oxygenated conditions for establishment. By contrast, while the earthen island at Cooley Landing is situated at a similar elevation as MLK/New Marsh, it had lower gumplant height, survival, and vigor. While our data do not show an significant effect of soil salinity or pH on gumplant survival, gumplant vigor and canopy density (based on qualitative observations at 4-5 months after construction) appeared greater the MLK/New Marsh site compared to all of the islands built with excavated marsh sediment. This could be due to increased salinity and saturated initial growing conditions at the sites built with marsh sediment. There is uncertainty regarding the validity of the above hypothesis because only one island was constructed with imported terrestrial soil and the limited time between construction and the interim Year-1 monitoring. Nonetheless, the difference in gumplant establishment was striking enough between MLK/New Marsh and other sites that the Conservancy should consider building a few additional islands from imported terrestrial soils similar to those used for the MLK/New Marsh island. Terrestrial soil should only be used where damage to existing marsh from soil import would be minimal.

### 4.1.2 Marsh Sod Installation

**Reduce Gaps Between Marsh Sod Squares On Island By Cutting Larger Sod Pieces.** Gaps between marsh sod pieces may lead to desiccation of earthen island tops and increase stress for vegetation. We recommend cutting larger sod pieces (e.g. use a 18 inch snow shovel for sod harvest) to reduce the number of gaps.

**Spread Excess Sod Across Excavation Areas To Speed Recovery.** Sites where pickleweed sod was placed across the excavation area are revegetating more quickly than sites where pickleweed sod was only place along the edge of the excavation area. We recommend spreading sod pieces evenly across the excavation area and side slopes to speed recovery via vegetative growth from pickleweed sod nuclei.
4.1.3 Maintenance

Maintain Earthen Islands by Filling Gaps Between Marsh Sod Squares During First 1-2 Growing Seasons. We have observed that regardless of the care taken during construction to tightly pack marsh sod squares, as sod dries and shrinks, gaps and cracks form on earthen islands. This can lead to desiccation of marsh vegetation during the summer months. Therefore, we recommend filling gaps between marsh sod squares with marsh sediment prior to onset of the summer dry season during the first 1-2 growing seasons.
Section 5.0 Literature Cited


Appendix A. Lessons Learned From Construction of California Clapper Rail Earthen High Tide Refuge Islands
8 April 2013

To: Marilyn Latta, Project Manager, State Coastal Conservancy

From: Max Busnardo and Gavin Archbald

Subject: Lessons Learned from Construction of California Clapper Rail Earthen High Tide Refuge Islands

H. T Harvey & Associates (HTH) monitored construction of 6 pilot earthen high tide refuge islands (hereafter “earthen islands”) built to enhance California clapper rail (*Rallus longirostris obsoletus*) habitat. One pilot earthen island was constructed at each of the following locations: (1) Cooley Landing, (2) Belmont Slough South, (3) Belmont Slough North, (4) Bird Island, (5) Bair Island northwest, and (6) MLK/New Marsh (Geographic coordinates provided in Table 1, Appendix A). In this memorandum, we provide a record of construction methods, as-built topographic data, a summary of lessons learned during pilot earthen island construction and illustrative photos (Appendix A). In addition, we include the following products on the CD submitted with this memorandum:

- Photos from fixed photo-point locations with directions to re-occupy photo-points.
- An Excel file with as-built topographic data of earthen islands and excavation areas.
- An Excel file with gumplant (*Grindelia stricta*) planting measurements.
- A Google Earth KMZ file with earthen island, excavation and elevation control point locations.

Future monitoring will be used to determine gumplant planting success and measure changes in earthen island and excavation area topography.

**Construction Timing and Personnel**

Construction was carried out between 18 December 2012 and 18 January 2013 by Hanford ARC and Aquatic Resources. The contractors utilized the conceptual design and associated notes provided in *Invasive Spartina Project Pilot Earthen Island Construction Notes to Contactors* (H. T. Harvey & Associates 2012) as a guide during construction. HTH restoration ecologists M. Busnardo, M.S. and G. Archbald, M.S. monitored the entirety of
the construction effort. HTH’s ecologists were accompanied by at least one ISP biologist, with project-specific clapper rail construction monitoring approval from the U. S. Fish and Wildlife Service.

**As-Built Topography and Settlement**

We measured the topography of earthen islands following construction and found that islands were constructed per the guidelines developed for contractors (H. T. Harvey & Associates 2012) and that settlement (i.e., compaction and sinking) began to occur shortly after island construction at one site. Contractors measured island heights via laser level during and immediately following island construction and HTH restoration ecologists G. Archbald and B. Busnardo observed that islands were built within approximately 0.1 feet (ft) of design elevations (+1.0 ft above MHHW).

To set up a baseline for future monitoring, HTH restoration ecologists measured the topography of constructed islands by taking spot elevations every 3 ft along a transect centered across the long axis of each island. In addition, the depths of excavation areas were measured via laser level. These data were collected within 1-3 days of construction at all sites except for Belmont Slough South. Baseline topography data were collected at this site 13 days following construction due to rains which rendered the laser level inoperable. Baseline elevations were comparable to the design (within approximately 0.1 ft) for the Cooley Landing, Belmont Slough North, Bird Island, Bair Island and MLK Marsh sites. Belmont Slough South measurably settled shortly after construction (Table 1). Belmont Slough South was measured 13 days after construction and had settled nearly -0.5 ft.

<table>
<thead>
<tr>
<th>Site</th>
<th>Island Height (ft ± standard error) above MHHW</th>
<th>Excavation Depth (ft ± standard error) below MHHW</th>
<th>Impact of Island and Excavation Area (ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
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</tr>
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<td>+0.87 ± 0.05</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Belmont South topography survey was measured 13 days after island construction.

**Project Impacts**

Project permits require that total tidal marsh impacts within the footprints of excavation and island fill be no more than 504 square feet (ft²) per island (or 3028 ft² for 6 pilot islands). The total impacts of the 6 pilot islands (fill and excavation areas) totaled 2600 ft², less than the permitted amount of 3028 ft² (Table 2).
Lesson Learned

We evaluated the efficiency of construction of earthen islands via manual and mechanized equipment; and noted a number of opportunities to reduce marsh impacts during construction and to increase successful vegetation establishment on earthen islands. We recommend that these lessons learned be incorporated into a revised version of the Invasive Spartina Project Pilot Earthen Island Construction Notes to Contractors (H. T. Harvey & Associates 2012).

Efficiency of Construction Methods- Manual versus Mechanized Equipment

Both contractors used shovels to remove marsh sod from the excavation and island fill sites (Appendix A, Photos A-1 and A-2); however, Hanford ARC excavated fill for island construction using shovels and manual labor while Aquatic resources excavated fill for island construction using a mechanized Marsh Master (Table 2; Photos A-3 and A-4). During excavation, both contractors used wheel barrows to transport excavated mud to the island fill locations and both contractors built islands via manual shovel work (Photos A-5 and A-6). At MLK/New Marsh, soil was not excavated; soil was brought in by truck (Photo A-7). Both contractors placed marsh sod on earthen islands by hand (Photo A-8) and planted the earthen islands with gumplant (Grindelia stricta) and saltgrass (Distichlis spicata) on the second day of island construction (Photo A-9). The Marsh Master was limited to excavation only because Olofson Environmental, HTH and the Coastal Conservancy agreed that the marsh plain would be severely damaged if the vehicle repeatedly maneuvered between the excavation and island fill areas.

To help the Coastal Conservancy compare the efficiency of the construction methods used, we recorded in the field the time each contractor spent per island excavating sediment relative to the island fill height (Table 2). Island fill height provides a rough relative approximation of the amount of sediment required to build each earthen island. The Marsh Master took longer (4.1 hours) than manual labor (3.2 hours) to excavate a similar average volume of sediment (Table 2).

Moreover, mobilization primarily in the transportation of the Marsh Master to and from the sites took additional time not shown in Table 2 and was constrained by the tides. Aquatic Environments deployed the Marsh Master during the peak of the higher high tides to facilitate access to the marsh plain. Even with higher high tide deployment, at the Bair Island site, Aquatic Environments had difficulty getting the Marsh Master across the steep side slope of a large slough channel and up onto the marsh plain. Aquatic Environments had to expend extra time and effort using an airboat and rope to pull the Marsh Master onto the marsh plain at this site (Drew Kerr, pers. comm. 2013).

Given the above observations, we recommend the use of manual labor for subsequent earthen island construction.
Table 2. Pilot Earthen Island Construction Details

<table>
<thead>
<tr>
<th>Site</th>
<th>Construction Dates</th>
<th>Contractor</th>
<th>Crew Size</th>
<th>Excavation Method</th>
<th>Excavation Time (hours)</th>
<th>Island Fill Height (ft)</th>
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<td>Manual</td>
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<td>1.55</td>
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<td>Manual</td>
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<td>1.99</td>
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<td>Marsh Master</td>
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<td>1.73</td>
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<td>8, 9 Jan 2013</td>
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<td>6</td>
<td>Marsh Master</td>
<td>4.25</td>
<td>1.99</td>
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<tr>
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<td>Hanford ARC</td>
<td>4</td>
<td>Soil trucked in</td>
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<td></td>
<td>Manual</td>
<td></td>
<td></td>
<td>Average</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Marsh Master</td>
<td></td>
<td></td>
<td>3.2</td>
<td>1.84</td>
</tr>
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</table>

Efficiency of Construction Methods - Access by Boat versus by Land

Earthen Island construction mobilization times differed by whether sites required access via boat or were accessible by land. It took Hanford ARC about 1.5 days to construct and plant earthen islands at Cooley Island, Belmont Slough South, Belmont Slough North and Cooley Landing. These sites were accessible from land and were accessed by walking through the marsh. It took Aquatic Resources about 2 days per earthen island at the Bird Island and Bair Island Northwest sites, which required transport of crew and equipment to and from construction sites via boat. Additional mobilization time associated with transporting the Marsh Master to, from and between sites was not observed by HTH and is not included in this comparison.

Protect Existing Marsh Vegetation

More care should be taken to protect existing marsh vegetation during construction of earthen islands. Workers and ecologists caused damage to vegetation by trampling during construction. In some locations, particularly in the areas immediately around earthen islands and excavation areas, marsh vegetation root structure was damaged when walking punctured the marsh surface (Photo A-10). Damage to existing vegetation also occurred where the treaded truck made sharp turns during soil delivery to the island site at MLK/ New Marsh (Photo A-11).

Marsh vegetation was effectively protected when contractors placed plywood over vegetation prior to construction. Contractors should place plywood or functionally equivalent material in all areas of repeated foot traffic including the entire perimeter of the island fill and excavation sites. If plywood is used, the plywood surface should be modified to improve traction for workers (e.g., by securing lathe via screws to plywood). Plywood or an equivalent material should be placed in areas where vehicles turn around (Photo A-12) and where materials are staged and/or stockpiled.

Additionally, care should be taken to stay outside of the fill and excavation areas to protect marsh sod prior to and during sod harvest.
Consider Adjusting Island Design Elevations

It is anticipated that island elevations will decrease due to settlement. Island elevations were designed to account for some settlement and still provide sufficient high tide refugia cover during peak high tides. As settlement is monitored, the design elevation should be reconsidered if settlement is likely to reduce island heights to MHHW or lower. Assuming planted gumplant grows 3 ft tall on island tops, if island tops are below MHHW, gumplant would likely be covered by water during an estimated 100 year tide (US Army Corps of Engineers 1984). However, building islands too high may result in acidic soils and/or ecotone weed invasions. These trade-offs should be considered following monitoring of pilot island topography and prior to construction of the remaining earthen islands.

Select Well-Drained Areas for Construction Close to Channel Edges

We recommend constructing future earthen island sites from and on well-drained marsh sediments to enhance island stability. At Belmont Slough South, for example, both the island fill site and the excavation area were quite wet and less consolidated that at other sites (Photo A-13). This may lead to greater settlement of excavated material and sinking into marsh sediments under the weight of the constructed island. In addition, marsh islands should be placed as close to channel edges as possible to mimic locations of natural high elevation gumplant lined marsh channels, while still allowing access to the island for construction.

Access Marsh Sites via Boat

Marsh vegetation was disturbed least when sites were accessed by airboat. Walking to and from earthen island sites, particularly in saturated areas, lead to incised trails. This could be avoided by transporting crew and equipment (including plywood or equivalent) via airboat to construction sites. This, however, would limit construction to sites readily accessible via airboat (i.e., sites with large channels or extensive mudflat adjacent to the construction location). If sites are accessed by foot, channels were affectively crossed via the construction of temporary bridges using joined 2’ x 12’ planks anchored in place with metal rods (Photo A-14).

Sod Excavation, Storage, and Placement

Flat head spade (versus rounded) shovels were particularly effective at removing sod (Photo A-15). Workers using straight edged spades can (1) cut square pieces of sod and (2) harvest sod at a consistent depth. Uniform, straight edge sod pieces fit together more closely during placement on earthen islands, thereby improving the ability of sod to retain moisture. Sod should be temporarily stored on geotextile fabric to protect underlying, in-situ marsh vegetation. In addition, sod should be stacked no more than one sod piece deep during stockpiling prior to placement on an earthen island (Photo A-16). This prevents damage to sod vegetation. Sod should be handled with care transport from excavation areas to storage areas and from storage areas to placement areas.
Care should be taken fit sod pieces together tightly by hand. This works best with uniform size sod pieces. Small sod pieces should be used to fill all gaps between sod pieces following planting to help with moisture retention.

Sod should be placed at the top of the island first and then planted before placing sod on side slopes. During sod placement and planting on island tops, plywood can be used to protect the shape of earthen island side slopes. Material (e.g., wood strips) should be secured to plywood to increase grip. Once the top is covered with sod and planted, side slopes should be planted (Photo A-17).

**Planting**

Plants should be carefully transported to island sites (e.g., carried to the island site without holding plants by their stems). Plastic sleds were useful to transport plants to the site without damaging plant material. When planning 1-gallon containers, a post-hole digger is the appropriate width and shape to cut into marsh sod without damaging more sod vegetation then necessary. A wide shovel should not be used as this results in excess damage to marsh sod.

**References**


**Personal Communications**

Appendix A. Photos to Exemplify Lessons Learned

Photo A-1. Both contractors removed marsh sod by shovel (Photo from Belmont Slough South)

Photo A-2. After excavation, sod was temporarily stored for later use (Photo from Belmont Slough North)
Photo A-3. Aquatic Environments excavated sediment to build the earthen island using a mechanized Marsh Master (Photo from Bair Island North)

Photo A-4. Hanford ARC excavated sediment to build the earthen island using shovels (Photo from Belmont Slough South)
Photo A-5. Both contractors transported sediment from the excavation area to the earthen island fill site by wheelbarrow (Photo from Belmont Slough South)

Photo A-6. Both contractors formed and shaped earthen islands via manual shovel work (Photo from Belmont Slough South)
Photo A-7. Terrestrial soil was brought in to MLK/New Marsh via truck (Photo from MLK/ New Marsh).

Photo A-8. Marsh sod was placed on earthen islands by hand (Photo from Belmont Slough South)
Photo A-9. Gumplant and saltgrass were planted on the tops and side slopes of earthen islands (Photo from Cooley Landing)

Photo A-10. Impact to marsh vegetation from walking around earthen islands were considerably greater in areas where plywood was not placed for protection (Photo from Belmont Slough North)
Photo A-11. Impacts to marsh vegetation of a tracked dump truck transporting soil to MLK/ New Marsh

Photo A-12. Impacts from tracked dump truck transport of soil could be reduced by placing plywood or equivalent material in locations where vehicles turn around (Photo from MLK/ New Marsh)
Photo A-13. Saturated sediment conditions at the earthen island fill location at Belmont Slough South made construction more difficult and may increase island settlement. Building with and on saturated sediments should be avoided.

Photo A-14. Wooden 2” x 12” wooden planks were effectively used to cross tidal channels (Photo from Belmont Slough North)
Photo A-15. Flat edged shovels allowed for square sod pieces to be cut which improved fit of sod pieces during placement on earthen islands (Photo from Belmont Slough South)

Photo A-16. Sod should not be stacked to avoid damage to sod vegetation (Photo from Bird Island)
Photo A-17. Sod should be placed and container plants planted at the top of the island prior to sod placement on earthen island side slopes to reduce trampling of sod during planting (Photo from Belmont Slough North)
Appendix B. Invasive Spartina Project Pilot Earthen Island Construction Notes to Contractors
Invasive Spartina Project
Pilot Earthen Island Construction Notes to Contractors

Prepared by:

H. T. Harvey & Associates

10 December, 2012
Project # 3352-01
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Construction Notes

The following notes, tables and figures provide information to support construction of 6 pilot earthen islands; one at each of the 6 following marsh locations: MLK/New Marsh, Belmont Slough South, Belmont Slough North, Bird Island, Cooley Landing, and Bair Island North Quadrant West.

Construction Work Window

Excavation and fill placement shall be done when sediments are not inundated and prior to 1 February 2013. Ideally, the excavation of material and construction of the island will be completed during one low-tide cycle. If earthen island construction is not completed before the tide rises, measures such as tarping the excavated and salvaged materials will be employed to prevent the materials from entering the tidal waters and prevent erosion.

Location

Each pilot earthen island marsh location (with the exception of MLK/New Marsh) consists of an earthen island fill area, an excavation area, and an elevation control stake; all within 20-30 feet (ft) of each other and each marked with a 1.25 inch diameter white PVC post. The MLK/New Marsh site consists of an earthen island and an elevation control stake. This site does not include an excavation area because the earthen island will be constructed from clean, imported fill.

On the day of construction, an H. T. Harvey & Associates’ restoration ecologist will be present to flag the footprints of the excavation and earthen island fill areas and point out the location of the elevation control stake at each pilot island marsh location. However, the contractor is responsible for being able to navigate to these locations in the absence of an H. T. Harvey & Associates restoration ecologist. The geographic coordinates of these locations are provided in Table 1. In addition, an ESRI shapefile (viewable in ArcMap) and a KMZ file (viewable in Google Earth) are provided with this document. Figures 1 and 2 provide plan and cross-section views of a generalized earthen island construction area (excluding the control stake). Figures 3 through 7 provide the general location of pilot earthen island construction areas. Note that the artificial floating islands shown in Figure 1 will be constructed by others (U.S. Geologic Survey Staff).
**Elevation Control Stake/ Grade Control**

The Contractor is responsible for grade control to meet the requirements in Tables 2, 3, 4 and Figure 2. An elevation control stake is situated approximately 20-40 ft from each island location and consists of a 1.25 inch diameter white PVC pipe with top of pipe cut at Mean Higher High Water (MHHW). The location (latitude and longitude) of elevation control stakes are provided in Table 1 and the specific elevation (in ft NAVD88) of each control stake is provided by marsh location in Table 2. The maximum depth of excavation and the height of island construction were determined relative to the control stake elevation (Tables 2 and 3). Heavy equipment should be kept at least 10 ft from control stakes at all times and physical contact with control stakes should be avoided to prevent control stake disturbance.

**Excavation Area**

Each island (with the exception of the MLK/New Marsh island) will be constructed from approximately 6 to 15 cubic yards of bay mud material that will be excavated from an adjacent vegetated slough channel bank (the excavation area) from a maximum area of 250 square feet (ft²) (Figure 1). Prior to excavation, the top six vertical inches (0.5 ft) of the existing marsh vegetation, root structure and sediment (marsh sod) will be salvaged from the surface of the excavation area and 1) planted on the earthen island after excavation is complete and 2) planted on the side slopes of the excavation area after excavation is complete. At the site of bay mud excavation, the slough channel segment will be contoured to create a low-elevation bench with 1 H: 1 V side slopes between the unexcavated marsh plain and the excavated low-elevation bench. Table 2 provides the design grade of the low elevation bench (i.e. the maximum depth of the low-elevation bench) in ft NAVD88 and relative to MHHW (the height of control stake). The estimated vertical depth of sediment between the existing marsh plain surface and the design grade of the low elevation bench is presented in Table 2. During excavation and construction of the marsh island, the profile (vertical orientation) of the excavated marsh sediments should be preserved to the extent feasible within the Contractor’s 1 to 2 day construction time and budget per site.

No excavation will be conducted at the MLK/New Marsh site.
Earthen Island Construction

The top six vertical inches (0.5 ft) of the existing marsh vegetation, root structure and sediment (mash sod) will be salvaged from the surface of the earthen island construction area and set aside, to be planted on the earthen island after fill placement is complete. Bay mud from the excavation area (or imported fill at the MLK/New Marsh site) will then be placed in the island footprint in such a way as to minimize air pockets in the fill material.

After fill is complete, marsh sod salvaged from the earthen island construction area and from the excavation area (if additional marsh sod is needed to cover island) will be installed across the top and side slopes of the constructed earthen island to a finished design elevation of 1.0 ft above MHHW with 2 H: 1 V side slopes (Figure 2).

The height of each island top relative to the marsh plain is specified in Table 3. The dimensions (length and width) of the island top and base are specified in Table 4. The top of the earthen island should be contoured to prevent water from ponding on the top of the island and the sediment and sod on the top and sides of the island lightly compacted to reduce erosion from tidal fluctuations before planting the island with container plants. The elevation of earthen islands will be verified via measurement (e.g., with a laser level) of the vertical difference between the control stake and top of island.

Planting

The portion of each island from 0.5 ft below MHHW (0.5 ft below top of control stake) to the top of the island will then be planted with marsh gumplant (*Grindelia stricta*) on 2 ft centers. Saltgrass (*Distichlis spicata*) will also be installed from container stock at all islands, with two plants next to every other marsh gumplant planting (Table 5). Plants should be installed in gaps between marsh sod clumps, to the extent feasible. Care should be taken to install plants with as much nursery soil around the roots of gumplant and saltgrass plantings as possible. Following planting, no air pockets should remain between installed plants and earthen island construction material.
### Table 1. Locations of Earthen Island, Excavation Areas and Elevation Control Stakes

<table>
<thead>
<tr>
<th>Pilot Island Marsh Location</th>
<th>GPS Coordinates (NAVD 88)</th>
<th></th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Earthen Island Center Point</td>
<td>Excavation Area Center Point</td>
</tr>
<tr>
<td></td>
<td>Latitude</td>
<td>Longitude</td>
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</table>

* MKL/New Marsh will be constructed from clean imported fill. Therefore, coordinates for an excavation area are not provided.

### Table 2. Limits of Excavation Area

<table>
<thead>
<tr>
<th>Pilot Island Marsh Location</th>
<th>Elevation of Top of Control Stake (Situated at MHHW) (ft NAVD88)</th>
<th>Maximum Excavation Depth (ft) Below MHHW</th>
<th>Maximum Depth of Excavation Below Existing Ground Surface (ft)</th>
<th>Total Maximum Excavation Area Surface Area (ft²)</th>
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<tbody>
<tr>
<td>MLK/New Marsh*</td>
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<td>NA</td>
<td>NA</td>
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<td>Belmont Slough South</td>
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<td>3.08</td>
<td>2.39</td>
<td>250</td>
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</tbody>
</table>

* MKL/New Marsh will be constructed from clean imported fill. Therefore, no excavation area dimensions are provided. Horticultural specifications for imported fill to the MLK/New Marsh island will be provided, but is not presenter herein.
### Table 3. Earthen Island Vertical Construction Dimensions

<table>
<thead>
<tr>
<th>Pilot Island Marsh Location</th>
<th>Elevation of Top of Control Stake (Situated at MHHW) (ft NAVD88)</th>
<th>Height of Island Tops above MHHW (ft)</th>
<th>Design Elevation for Top of Islands (ft NAVD88)</th>
<th>Average Elevation of Ground Surface at Fill Site (ft NAVD88)</th>
<th>Average Fill Height above Ground Surface (ft NAVD88)</th>
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</thead>
<tbody>
<tr>
<td>MLK/New Marsh</td>
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### Table 4. Earthen Island Planimetric Construction Dimensions

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<thead>
<tr>
<th>Pilot Island Marsh Location</th>
<th>Total Island Length Including Side Slopes (ft NAVD88)</th>
<th>Total Island Width Including Side Slopes (ft NAVD88)</th>
<th>Maximum Surface Area of Island Fill (ft²)</th>
<th>Length of Island Top At 1ft Above MHHW (ft)</th>
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### Table 5. Container Plant Quantities per Earthen Island

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<th>Species</th>
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<th>On-Center Spacing</th>
<th>Quantity per Earthen Island</th>
<th>Total Quantity (5 islands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grindelia stricta</td>
<td>gumplant</td>
<td>2 ft</td>
<td>58</td>
<td>348</td>
</tr>
<tr>
<td>Distichlis spicata</td>
<td>saltgrass</td>
<td>2 plants installed adjacent to every other gumplant planting</td>
<td>58</td>
<td>348</td>
</tr>
</tbody>
</table>
Figure 3: USACE Jurisdictional Delineation -
Pilot Islands Location at MLK New Marsh

LEGEND

Survey Area (2.88 ac)

Pilot Island Location (1 Earthen + 1 Floating)

USACE Section 10/404 Jurisdictional Features

Wetland (2.74 ac)

Other Waters (0.14 ac)

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Figure 4: USACE Jurisdictional Delineation - Pilot Island Location at Belmont Slough South

LEGEND
- Survey Area (2.79 ac)
- Pilot Island Location (1 Earthen + 1 Floating)
- Upland (0.06 ac)

USACE Section 10/404 Jurisdictional Features
- Wetland (2.17 ac)
- Other Waters (0.62 ac)
Figure 5: Island Location at Belmont Slough North

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Figure 6: USACE Jurisdictional Delineation - Pilot Island Location at Bird Island

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Figure 7: USACE Jurisdictional Delineation - Pilot Island Location at Cooley Landing Central

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Figure 8: USACE Jurisdictional Delineation - Pilot Island Location at Bair Island North Quadrant West

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Appendix C. Photo-documentation
Cooley Landing

Photopoint CL1: View From the Control Stake to the Excavation Area. December 2012 (left), May 2013 (right).

Photopoint CL2: View From the Control Stake to Between the Earthen Island and the Excavation Area. December 2012 (left), May 2013 (right).

Photopoint CL3: View From the Control Stake to the Earthen Island. December 2012 (left), May 2013 (right).
Photopoint CL4: View From the Foot of the Earthen Island Facing Downstream. December 2012 (left), May 2013 (right).

Photopoint CL5: View From the Foot of the Earthen Island Facing Upstream. December 2012 (left), May 2013 (right).

Photopoint CL6: View From the Foot of the Excavation Area Facing Upstream. December 2012 (left), May 2013 (right).
Belmont Slough South

Photopoint BSS1: View From the Control Stake to the Excavation Area. December 2012 (left), May 2013 (right).

Photopoint BSS2: View From the Control Stake to Between the Earthen Island and the Excavation Area. December 2012 (left), May 2013 (right).

Photopoint BSS3: View From the Control Stake to the Earthen Island. December 2012 (left), May 2013 (right).
Photopoint BSS4: View From the Foot of the Earthen Island Facing Downstream. December 2012 (left), May 2013 (right).

Photopoint BSS5: View From the Foot of the Earthen Island Facing Upstream. December 2012 (left), May 2013 (right).

Photopoint BSS6: View From the Foot of the Excavation Area Facing Upstream, December 2012 (left) and Downstream, May 2013 (right).
Belmont Slough North

Photopoint BSN1: View From the Control Stake to the Excavation Area. December 2012 (left), May 2013 (right).

Photopoint BSN2: View From the Control Stake to Between the Earthen Island and the Excavation Area. December 2012 (left), May 2013 (right).

Photopoint BSN3: View From the Control Stake to the Earthen Island. December 2012 (left), May 2013 (right).
Photopoint BSN4: View From the Foot of the Earthen Island Facing Downstream. December 2012 (left), May 2013 (right).

Photopoint BSN5: View From the Foot of the Earthen Island Facing Upstream. December 2012 (left), May 2013 (right).

Photopoint BSN6: View From the Foot of the Excavation Area Facing Upstream. December 2012 (left), May 2013 (right).
Bird Island

Photopoint BI1: View From the Control Stake to the Excavation Area. January 2013 (left), May 2013 (right).

Photopoint BI2: View From the Control Stake to Between the Earthen Island and the Excavation Area. January 2013 (left), May 2013 (right).

Photopoint BI3: View From the Control Stake to the Earthen Island. January 2013 (left), May 2013 (right).
Photopoint BI4: View From the Foot of the Earthen Island Facing Downstream. January 2013 (left), May 2013 (right).

Photopoint BI5: View From the Foot of the Earthen Island Facing Upstream. January 2013 (left), May 2013 (right).

Photopoint BI6: View From the Foot of the Excavation Area Facing Downstream. January 2013 (left), May 2013 (right).
Bair Island

Photopoint BAI1: View From the Control Stake to the Excavation Area. January 2013 (left), May 2013 (right).

Photopoint BAI2: View From the Control Stake to Between the Earthen Island and the Excavation Area. January 2013 (left), May 2013 (right).

Photopoint BAI3: View From the Control Stake to the Earthen Island. January 2013 (left), May 2013 (right).
Photopoint BAI4: View From the Foot of the Earthen Island Facing Downstream. January 2013 (left), May 2013 (right).

Photopoint BAI5: View From the Foot of the Earthen Island Facing Upstream. January 2013 (left), May 2013 (right).

Photopoint BAI6: View From the Foot of the Excavation Area Facing Upstream. January 2013 (left), May 2013 (right).
MLK/ New Marsh

Photopoint MLK 1: View From Control Stake to the earthen Island. January 2013 (left), May 2013 (right).

Photopoint MLK 2: View From the Foot of the Earthen Island Facing Downstream. January 2013 (left), May 2013 (right).

Photopoint MLK 3: View From the Foot of the Earthen Island Facing Upstream. January 2013 (left), May 2013 (right).

Photopoint MLK 4: View From the Slough Channel West of the Earthen Island Facing the Earthen Island. January 2013 (left), May 2013 (right).