Final

ELKHORN SLOUGH TIDAL MARSH RESTORATION PROJECT
Existing Conditions Report

Prepared for
Elkhorn Slough Foundation and
Elkhorn Slough National Estuarine
Research Reserve

July 1, 2014
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Our Commitment to Sustainability | ESA helps a variety of public and private sector clients plan and prepare for climate change and emerging regulations that limit GHG emissions. ESA is a registered assessor with the California Climate Action Registry, a Climate Leader, and founding reporter for the Climate Registry. ESA is also a corporate member of the U.S. Green Building Council and the Business Council on Climate Change (BC3). Internally, ESA has adopted a Sustainability Vision and Policy Statement and a plan to reduce waste and energy within our operations. This document was produced using recycled paper.
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1 Introduction

The Elkhorn Slough Marsh Restoration project proposes to restore 145 acres of vegetated tidal salt marsh, upland ecotone, and native grasslands in Monterey County. This report describes existing conditions at the restoration site (Figure 1 and Figure 2) for use in project planning and permitting.

This restoration project is occurring within the Elkhorn Slough National Estuarine Research Reserve, on land owned and managed by the California Department of Fish and Wildlife (CDFW) in partnership with NOAA and Elkhorn Slough Foundation (ESF). ESF is managing the grant funding to support this project on behalf of ESNERR and has retained Environmental Science Associates (ESA) to provide restoration planning and permitting services.

1.1 Project Background

The Elkhorn Slough estuary (Figure 1) is one of the largest estuaries in California and contains the state's largest salt marshes south of San Francisco Bay. The Slough provides critical habitat for an exceptionally broad range of resident and migratory birds, fish, and other wildlife, and plays a crucial role in the local estuarine and nearshore food webs.

The Slough system is currently facing unprecedented rates of tidal wetland loss and degradation. Over the past 150 years, human activities have altered the tidal, freshwater, and sediment processes which are essential to support and sustain Elkhorn Slough's estuarine habitats. Fifty percent of the tidal salt marsh in Elkhorn Slough has been lost in the past 70 years. This habitat loss is a result of increased tidal flooding, which "drowns" the vegetation, caused by past diking and draining of the marsh and construction of a harbor at the mouth of the Slough in 1947. The loss of riverine sediment inputs, subsidence of marsh areas, sea level rise, increased salinity, and increased nutrient inputs may also contribute to marsh drowning (Watson et al. 2010, Deegan et al. 2012). Bank and channel erosion in Elkhorn Slough are deepening and widening tidal creeks, causing salt marshes to collapse into the channel, and eroding sediments that provide important habitat and support estuarine food webs.

In 2004, ESNERR initiated a planning effort to evaluate marsh dieback and tidal erosion at Elkhorn Slough and to develop restoration and management strategies. Experts from multiple disciplines agreed that without intervention, excessive erosion would continue widening the tidal channels and that salt marsh would continue to convert to mudflat. This will result in a significant loss of habitat function and decrease in estuarine biodiversity. Habitat loss is expected to become more severe with accelerating sea level rise. Additional information about the Elkhorn Slough Tidal Wetland Project can be found at http://www.elkhornslough.org/tidalwetlandproject/index.html.

The current phase of the Elkhorn Slough Tidal Marsh Restoration Project (the Project) focuses on using imported sediment to restore tidal marsh habitats within the 145-acre Minhoto-Hester’s Marsh and Seal Bend areas (Figure 2). Raising subsided tidal areas to more sustainable marsh elevations will require approximately 210,000 to 340,000 cubic yards of sediment.
1.2  **Project Goals and Approach**

The project goals, developed by ESNERR staff, are:

- **Goal 1:** Increase the extent of tidal marsh in Elkhorn Slough
- **Goal 2:** Reduce tidal scour in Elkhorn Slough
- **Goal 3:** Protect and improve surface water quality in Elkhorn Slough
- **Goal 4:** Provide resilience to climate change to estuarine ecosystems in Elkhorn Slough
- **Goal 5:** Increase understanding of how best to create salt marsh

The project area includes 104 acres of former tidal marsh that have experienced approximately two feet of subsidence and no longer support extensive areas of vegetated marsh. The overall approach is to use imported and onsite sediments to raise ground elevations and restore tidal marsh habitats in these areas. Restoration will occur in phases. The first phase will use sediment stockpiled on the agricultural fields adjacent to Minhoto Marsh, which was imported from the Pajaro River Bench Excavation Project in the summer of 2013. Additional upland borrow from the adjacent agricultural fields will supply the remaining sediment needed for the Phase 1 project.

1.3  **Purpose of the Existing Conditions Report**

The Existing Conditions Report describes the current physical and biological conditions within the restoration site. The purpose of the report is to inform the development of the restoration plan and provide necessary information for future regulatory compliance. The ECR is organized into the following sections:

- Geographic Setting and Land Use History
- Topography, Hydrology, and Water Quality
- Geology and Soils
- Biological Conditions
- Conceptual Model of Habitat Restoration.

The last section, Conceptual Model of Habitat Restoration ties together the previous chapters and presents an integrated conceptual model of how the addition of sediment to the restoration site is expected to affect its evolutionary trajectory and dependent habitats. The model identifies opportunities and constraints to habitat enhancement and restoration, and lays the groundwork for how these might be addressed during the design phase of the project.
2 Geographic Setting and Land Use History

The geographic setting and land use history within Elkhorn Slough and the larger Pajaro-Elkhorn-Salinas basin are primary drivers of both physical conditions and biological communities within and adjacent to the restoration site. This section describes both regional and site-scale geography and land use history.

2.1 Elkhorn Slough

The Elkhorn Slough system is a network of intertidal marshes, mudflats, and subtidal channels located at the center of the Monterey Bay shoreline. Like many estuarine systems along the Central Coast, tidal marshes in the slough only contain high marsh pickleweed (Sarcocornia) vegetation communities, not the low marsh cordgrass (Spartina) communities found in other tidal marsh systems such as those in San Francisco Bay. The Slough has a complex geologic and human history that is explained in detail by a number of documents published by ESNERR scientists and others (Van Dyke and Wasson 2005, Woolfolk 2005, PWA 2008, Watson et al. 2011, and many more). Prior to European colonization, the system contained broad expanses of tidal marsh, fresh-brackish marsh, and related habitats throughout Elkhorn, Parsons, Moro Cojo, Bennett, and Tembladero Sloughs. Major anthropogenic modifications to the Slough commenced in the late 1800s with the diking and draining of marshes in Moro Cojo and Tembladero Sloughs. Around the same time, the Union Pacific Railroad was constructed along the Slough’s eastern edge. In the early 1900s, large portions of tidal wetlands within Elkhorn and Parsons Slough were reclaimed for agriculture, duck hunting, and other uses, and the Salinas and Pajaro Rivers were diverted from the slough. These activities significantly decreased both fluvial flows and tidal prisms within the Elkhorn Slough system, leading to increased shoaling and periodic closure of the slough mouth near Moss Landing (A. Woolfolk, pers. comm.). The diversion of the Salinas and Pajaro Rivers also eliminated a likely significant source of sediment from the Slough (Watson et al. 2011). The construction of Moss Landing Harbor in 1946-1947 dramatically altered the hydrodynamics in Elkhorn Slough by permanently opening the system to the full range of the tides. The increased tidal range resulted in the increased inundation of the Slough’s remaining salt marsh habitats, which has been compounded by shallow subsidence, a sediment deficit, and sea level rise within the Slough (Callaway et al. 2012). Overall, human activities have led to the loss and/or degradation of over 2/3 of the former marsh habitats in Elkhorn Slough, severely impacting the Slough’s ecosystem (Van Dyke and Wasson 2005).

Existing habitats within the estuarine portion of the Slough include areas of open water, mudflats, salt flats, diked marsh, and tidal marsh. Many of the tidal marshes in lower Elkhorn Slough and Parsons Slough are in various stages of recovery from the recent history of human activities described above. Section 2.2 below describes the areas that have been targeted for restoration as part of the Project.

2.2 Restoration Site

The low lying areas of the site were historically dominated by mature tidal salt marsh plains drained by dendritic channel networks. Diking and draining of these areas occurred at various times after 1872 in order to convert the tidal marshes into areas more suitable for agricultural use and economic production. Portions of the Minhoto-Hester’s area were purchased by the Empire Gun Club in 1902 and were actively managed in a way to encourage their use by waterfowl. The gun club constructed an extensive network of levees and ponds, managed water levels, and “baited” ducks by placing grain in...
the ponds (King 1982; Silberstein et al. 2002). Portions of the Seal Bend and Minhoto-Hester’s restoration areas were later converted to pasture for dairy cattle during the early 20th century (Figure 5, Silverstein et al. 2002). The draining of the tidal marsh caused the marsh sediments to desiccate, compact, decompose, and subside. Over time, as the parcels were acquired by various resource agencies and non-profits (both the Seal Bend and Minhoto-Hester’s parcels are owned by CDFW¹), the levees around these areas failed or were removed to restore tidal exchange. By 1983, tidal action had been returned to most of these areas (the levees are still intact at the westernmost impoundment in Minhoto-Hester’s Marsh). Remnant levees persist around the outboard edges of most of these areas, but in some places, particularly Seal Bend, these levees are highly eroded.

The Seal Bend and Minhoto-Hester’s areas have multiple elements in common, including (1) historic diking, draining, and subsidence of tidal marsh, (2) the conversion of marsh habitats to unvegetated mudflat, (3) benthic invertebrate communities that result in marsh sediments having a pronounced pockmarked, “Swiss cheese” morphology (making the sediments more susceptible to erosion), and (4) various anthropogenic features such as levees and dredged channels. The morphology of the two restoration areas is discussed in greater individual detail below.

2.2.1 Seal Bend Restoration Area

As discussed in detail in Section 3.1, the Seal Bend restoration area is the higher (by approximately half a foot) of the two restoration areas, and as such contains the largest proportion of vegetated tidal salt marsh. The marsh has had multiple cross-levees constructed across its surface, and the heavily eroded remnants of a perimeter levee along its outboard side. The erosion of this levee, and the resulting reintroduction of tidal action to the site, has scoured the borrow channel for the perimeter levee. There is little to no mudflat outboard of the remnant perimeter levee, and eelgrass beds have become established in the Elkhorn Slough channel approximately 150 ft from the levee edge. Dendritic channel networks drain the site; many of these channels exhibit evidence of historic dredging, straightening, and/or rerouting.

2.2.2 Minhoto-Hester’s Restoration Area

Ground surface elevations within the Minhoto-Hester’s restoration area are approximately half a foot lower than those at Seal Bend (see Section 3.1), and as a result, the tidal marsh community here is much less robust. Certain subareas within Minhoto-Hester’s (e.g. M4b) are relatively higher, and have pickleweed throughout the marsh plain, while others (e.g. M5) are lower, and only have pickleweed along wetland-upland transitional areas. Similar to Seal Bend, the Minhoto-Hester’s area contains multiple cross-levees and dredged channels, and the borrow channel for one of the levees has turned into a major (over 100 ft wide in some locations) north-south trending tidal connection between the site and Elkhorn Slough. The perimeter levee at the Minhoto-Hester’s area appears to be slightly less eroded than that at Seal Bend, which could potentially be due to the extensive (up to 350 ft wide in some locations) mudflat within Elkhorn Slough that is outboard of the levee. Mudflats within the Minhoto-

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¹ The State of California is listed on the property deeds.
Hester’s restoration area often develop extensive beds of the macroalga *Ulva* and others during the summer.

To the east of the Minhoto-Hester’s area is Yampah Marsh, an area of tidal marsh that has not been diked or drained. Due to its relatively undisturbed history, it serves as a point of reference for tidal wetlands in Elkhorn Slough that have not been diked and drained, and have only been subject to the increased tidal range induced by the construction of the Moss Landing inlet. As discussed further below in Section 3.1, mature tidal marshes in San Francisco Bay serve as a point of reference for tidal systems with relatively unaltered tidal hydrology.

### 2.3 Minhoto Stockpile Area and Adjacent Uplands

The stockpile area upslope of the Minhoto-Hester’s restoration area is located on gently sloping uplands adjacent to the historic tidal marsh. Historically, both the stockpile area and the adjacent agricultural fields were used to grow crops such as strawberries and artichokes as well as bulb/flower production (Andrea Woolfolk, pers. comm.). Since 2012, the stockpile area has been kept fallow; it has at times been planted with sterile annual barley to prevent erosion of sediment into the Slough. The fields outside of the stockpile area are still in active production and are used primarily for bulb production, with some areas in food production (currently artichokes; strawberries have also been grown in these fields). The fields’ current lease ends in 2014, and a new tenant could grow flowers/bulbs or food crops (Andrea Woolfolk, pers. comm.). Portions of the agricultural fields, including the stockpile area, may be tilled for drainage. As of the publication of this document, this possibility was being investigated by ESF and ESNERR staff (Monique Fountain, pers. comm.). Uplands adjacent to the Seal Bend restoration area include an extensive eucalyptus-Monterey pine forest.
3 Topography, Hydrology and Water Quality

3.1 Topography

Topography of the Minhoto-Hester’s Marsh and Seal Bend areas are shown in Figure 6. This data is derived from a LiDAR dataset produced by NOAA. Ground-truthing by ESA PWA in the Minhoto-Hester’s area revealed that the LiDAR data overstate ground elevations in vegetated areas. In areas with approximately 50 – 100% pickleweed cover, LiDAR elevations are approximately 0.3 to 0.4 feet higher than surveyed ground elevations. In more heavily vegetated areas, LiDAR elevations are up to 1.5 feet above surveyed ground elevations. Appendix A provides additional detail about field topographic surveys in the Minhoto-Hester’s area.

Elevations across the site are strongly influenced by its history of diking and draining, which has resulted in subsidence of marsh plain elevations relative to MHHW (Mean Higher High Water, the average of all higher high tides) (Table 1). Drainage caused the marsh sediments to dry out, compact, decompose, and subside by approximately 1-2 feet (ft). Today, most of the Minhoto-Hester’s and Seal Bend restoration areas are subsided to elevations between Mean Tide Level (MTL, the average elevation of all tides) to Mean High Water (MHW, the average elevation of all high tides) (for further discussion of tidal datums, see Section 3.2.1.1 below). On average, the Seal Bend area has the highest existing elevations, with elevations a little more than a foot below MHHW. The Minhoto-Hester’s area is approximately half a foot lower.
Table 1. Restoration Site Elevations

<table>
<thead>
<tr>
<th>Sub-Site Name</th>
<th>Area at Target Elevation (ac)</th>
<th>Average Depth below MHHW (ft)</th>
<th>Average Elevation (ft NAVD88)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minhoto-Hester’s</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1</td>
<td>14.1</td>
<td>1.9</td>
<td>3.8</td>
</tr>
<tr>
<td>M1a</td>
<td>3.8</td>
<td>1.7</td>
<td>4.0</td>
</tr>
<tr>
<td>M1b</td>
<td>2.7</td>
<td>2.1</td>
<td>3.6</td>
</tr>
<tr>
<td>M1c</td>
<td>3.0</td>
<td>2.0</td>
<td>3.7</td>
</tr>
<tr>
<td>M2</td>
<td>4.5</td>
<td>1.6</td>
<td>4.1</td>
</tr>
<tr>
<td>M3</td>
<td>8.3</td>
<td>2.0</td>
<td>3.7</td>
</tr>
<tr>
<td>M4a</td>
<td>1.0</td>
<td>1.6</td>
<td>4.1</td>
</tr>
<tr>
<td>M4b</td>
<td>7.3</td>
<td>1.5</td>
<td>4.2</td>
</tr>
<tr>
<td>M5</td>
<td>7.8</td>
<td>1.8</td>
<td>3.9</td>
</tr>
<tr>
<td>M6</td>
<td>5.5</td>
<td>1.5</td>
<td>4.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>58.1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Seal Bend</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>4.5</td>
<td>1.8</td>
<td>3.9</td>
</tr>
<tr>
<td>S2</td>
<td>6.4</td>
<td>1.4</td>
<td>4.3</td>
</tr>
<tr>
<td>S3</td>
<td>3.0</td>
<td>1.5</td>
<td>4.2</td>
</tr>
<tr>
<td>S4</td>
<td>8.8</td>
<td>1.2</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22.8</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: MHHW is 5.78 ft NAVD88

To understand the significance of site topography, it is useful to understand the topography of reference tidal salt marsh systems. The undisturbed tidal marshes of San Francisco Bay are the closest reference sites for which data are available. Most tidal marshes around San Francisco Bay were also diked and drained, as they were at Elkhorn Slough, but those San Francisco Bay sites that were not diked and drained (and have not been subject to the sort of tidal alterations induced by construction of the Moss Landing inlet) typically have mature marsh plain at elevations between MHW and MHHW. Therefore, it is realistic to presume that before human activity began to interfere with the slough’s natural hydrology, the system likely had tidal marshes in or near this range, and current elevations reflect between approximately one to two feet of subsidence.

Uplands (areas above MHHW) in the vicinity of the restoration areas (including the stockpile areas) tend to be gently sloped. None of the stockpile areas are bisected by any obvious drainage divides, swales, ridges, or other prominent topographic features.

3.2 Vegetation-Elevation-Inundation Relationships

ESA and H.T. Harvey conducted surveys to inform vegetation-elevation relationships at the site (Appendix A). Figures 2-1 and 2-3 in Appendix A display elevation transects and vegetation cover across upland ecotone, marsh, and mudflat areas in Minhoto-Hester’s, and Figure 2-7 displays an elevation transect across Yampah Marsh. In general, as elevation increases (and inundation frequency/duration decreases), vegetation cover in the marsh increases. Since Yampah Marsh was never diked or drained,
elevations there are approximately a foot higher than the subsided, formerly diked areas within Minhoto-Hester’s Marsh, and most of the Yampah Marsh plain is vegetated (though with less than 100% cover due to marsh dieback). Figure 7 presents elevations for habitat transitions surveyed at a number of locations around the Minhoto-Hester’s restoration site. The relationship between elevation and marsh vegetation percent cover at Seal Bend is expected to be consistent with that of Minhoto-Hester’s and Yampah Marsh.

Inundation frequency is one of the most important drivers in the observed habitat-elevation relationships. 6-months of water level data from the Yampah NOAA tide gage (#9413631) was used to estimate the % of time the water was at or above each habitat transition band in the site. Areas vegetated with pickleweed were estimated to be inundated 0.2 to 33% of the time. Mudflat is inundated 33 to 94% of the time. These estimates are similar to a study by PWA et al. (2008), which found that salt marsh (MHW-MHHW) is inundated approximately 1 to 12% of the time and intertidal mudflat (MLLW-MHW) 12 to 99% of the time.

3.3 Hydrology

Hydrology at the site is primarily governed by tidal inundation, as the small watersheds of each area (see Section 3.2.2 below) contribute small volumes of runoff relative to tidal flows. This section describes tidal, surface, and groundwater flows.

3.3.1 Tides

Tides at the site are similar to those observed in Monterey Bay. Tides are mixed semi-diurnal, meaning each tidal cycle includes two high tides and two low tides of unequal values each day. The strongest spring tides tend to occur in December and June, while the weakest occur in March and September (Caffrey and Broenkow 2002). Measured lag times between tides within the head of Elkhorn Slough and the project site are relatively short (Woolfolk, pers. comm.).

3.3.1.1 Tidal Datums

The National Oceanic and Atmospheric Administration’s Center for Operational Oceanographic Products and Services (NOAA CO-OPS) maintains a network of tidal water level monitoring stations throughout Monterey Bay and Elkhorn Slough, including stations at the Highway 1 bridge (#941-3616), Moss Landing (#941-3616), and Monterey (#941-3450). The Monterey station is a reference station against which tidal datums for the other subordinate stations are calculated. ESNERR also collects water level data at 15 minute increments for four stations in the estuary: at the mouth of the Slough (Vierra Mouth, between Seal Bend and the Hwy 1 bridge), South Marsh (Parsons Slough), North Marsh (south of Kirby Park), and Azevedo Pond (north of Kirby Park).

The precise elevations of tidal datums within Elkhorn Slough have been a source of analysis over the years. The calculation of tidal datums from subordinate stations within the slough system is made exceptionally difficult due to previous and ongoing subsidence of many of the National Geodetic Survey (NGS) benchmarks upon which the tidal elevations are measured. A recent, comprehensive analysis of benchmark subsidence and tidal data by ESNERR staff resulted in the publication of an updated set of
tidal datums for multiple locations throughout Elkhorn Slough (Van Dyke 2012). Table 2 below describes the tidal datums within the Pacific Ocean at the Monterey station, and the results of the new tidal datum reckoning within Yampah Marsh.

Table 2. Tidal Datums

<table>
<thead>
<tr>
<th>Tidal Datum</th>
<th>Elevations at Monterey (NOAA CO-OPS 941-3450), ft NAVD88</th>
<th>Elevations at Yampah Marsh (Van Dyke 2012), ft NAVD88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Higher High Water (MHHW)</td>
<td>5.48</td>
<td>5.78</td>
</tr>
<tr>
<td>Mean High Water (MHW)</td>
<td>4.77</td>
<td>5.07</td>
</tr>
<tr>
<td>Mean Sea Level (MSL)</td>
<td>3.01</td>
<td></td>
</tr>
<tr>
<td>Mean Tide Level (MTL)</td>
<td>2.97</td>
<td>3.26</td>
</tr>
<tr>
<td>Mean Low Water (MLW)</td>
<td>1.23</td>
<td>1.44</td>
</tr>
<tr>
<td>Mean Lower Low Water (MLLW)</td>
<td>0.14</td>
<td>0.42</td>
</tr>
<tr>
<td>Tidal Range (ft)</td>
<td>5.34</td>
<td>5.37</td>
</tr>
</tbody>
</table>

3.3.1.2 Tidal Prisms

The term “tidal prism” refers to the amount of water that gets transported into and out of a tidal basin during a typical tidal cycle. This is the amount of water within a basin that lies between mean higher high water (MHHW) and mean lower low water (MLLW). The tidal prisms for the Seal Bend and Minhoto-Hester’s restoration sites are 17 and 81 acre-feet, respectively (ESA PWA calculations). These represent 0.3% and 1.5% of the total tidal prism in Elkhorn Slough (~5400 acre-ft, PWA 1992).

3.3.1.3 Tidal Flow Velocities

The increase in tidal action within Elkhorn Slough has resulted in an increase in tidal velocities, which in turn increases the amount of material scoured from intertidal and subtidal habitats and exported out of the slough. Studies of both Parsons and Elkhorn Slough have found them to be consistently ebb-dominated, meaning that tidal flows on an ebb (receding) tide are faster than flows on a flood tide (and therefore capable of mobilizing relatively more sediment). Broenkow and Breaker (2005) measured maximum tidal flow velocities upstream of the HWY 1 bridge during one 6-hour ebb cycle to be 120 centimeter per second (cm/sec) (3.9 feet per second [ft/sec]), well above the range sufficient to mobilize sediments from mudflats and channels within the slough complex (0.8 to 1.5 ft/sec) (Sea Engineering 2006). Tidal flow velocities are partially dependent on the magnitude of the tidal prism: the smaller the tidal prism that moves through a given cross-section, the lower the flow velocities will be.

3.3.1.4 Sea Level Rise

Sea level rise due to climate change affects coastal areas including Elkhorn Slough. Over 100 years of tidal water level data collected at NOAA’s tide gauge in San Francisco indicate that the California coast has already experienced approximately 8 inches of sea level rise in the last century. The International

2 This range only applies to inorganic sediments such as muds, clays, and fine silts; the Sea Engineering report does not describe critical shear velocities for peats and unconsolidated organic material.
Panel on Climate Change (IPCC), in its latest report from 2013 describes a potential increase in mean sea level rise of 0.42 to 0.80 meter (16 to 32 inches) relative to the 1996 baseline (Church et al 2013).

On March 15, 2013, the Ocean Protection Council (OPC) published an update to the State of California Sea-Level Rise Interim Guidance Document (2011). The purpose of the document is to help state agencies incorporate future sea-level rise impacts into planning decisions, and was updated to include the best available science from the National Research Council’s (NRC) 2012 report titled “Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future” (NRC 2012). The NRC report discusses regional and local contributions to sea level rise. Four regional sea level rise estimates are reported for the West Coast, with San Francisco as the nearest projection to Elkhorn Slough. The regional projection for San Francisco is 36 inches by 2100, relative to 2000 (range of 16.7 and 65.5 inches). These values include subsidence of 1.5 mm/year ± 1.3 mm/year, which is assumed the same for all of California south of Cape Mendocino.

Sea level rise will increase the frequency, magnitude, and duration of inundation within Elkhorn Slough habitats, offset at least in part by sedimentation. It will increase tidal energy and tidal prisms within the system if sediment accretion is slower than the rate of sea level rise. These changes would likely induce further net loss of sediment from the system and further loss of vegetated tidal marsh. A conceptual model of these changes is described in Section 5.

3.3.2 Watershed Characteristics

The primary contributors of fresh water to the project site are direct rainfall and runoff from the slough’s watershed. The local watersheds for the Minhoto-Hester’s and Seal Bend restoration areas are 145 and 74 acres, respectively. Most of the Minhoto-Hester’s watershed is comprised of agricultural fields used for cattle grazing and the production of row crops, as discussed above. Most of the Seal Bend watershed is comprised of Moon Glow Dairy operations and uplands grasslands/forest.

3.3.3 Surface Water Hydrology

Like most coastal California sites, Elkhorn Slough has a Mediterranean climate that features cool, rainy winters and springs, foggy summers, and warm falls. The slough averages 55.2 centimeters (21.7 inches) of rain annually, with most precipitation falling between the months of October and May, though annual rainfall can be highly variable (Caffrey 2002). Precipitation that falls within the Slough’s watershed drains from the uplands through ephemeral drainages into slough habitats, and eventually flows to Elkhorn Slough and Monterey Bay. It is not known how much water is removed from tributaries to the Slough by pumps and other diversions, but such diversions (if any exist) are likely to be small due to the tributaries’ ephemeral nature.

3.3.4 Groundwater Hydrology

Relatively little is known about groundwater within the Elkhorn basin. It has been suggested that groundwater contributions to slough hydrology have decreased as agricultural pumping operations in the basin have increased; the main evidence for this claim is the lack of artesian wells and seeps that were once common in the area (Caffrey and Broenkow 2002; Moffatt & Nichol 2008) as well as the decrease in rushes, cattails, and sedges in tidal marshes (Watson et al. 2011). These claims are bolstered
by increases in chloride concentrations in wells near Elkhorn Slough (including the well on the Minhoto parcel, shown in Figure 2), as saline influence from the slough has progressed farther inland, potentially in response to increased groundwater pumping (MCWRA 2005).

### 3.4 Water Quality

Water quality within Elkhorn Slough changes in response to seasonal fluctuations in tides, watershed inputs, weather patterns, and other factors. Water quality within Elkhorn Slough is discussed in detail in numerous reports (Caffrey et al. 2002, Moffatt & Nichol 2008, PWA 2008, Hughes et al. 2011). Overall trends and observations in water quality parameters of relevance to restoration are summarized below and described in further detail in Appendix B.

#### 3.4.1 Temperature

Temperatures in Elkhorn Slough demonstrate an expected seasonal pattern, with warmest temperatures (15-20°C) in the late summer and fall and coolest temperatures (< 10°C) during the winter and early spring (ESNERR data). In deeper areas closer to the slough mouth, tidal forcing can affect temperature by moving cold marine waters into the Slough on a flood tide, and out of the Slough on an ebb tide. Like many shallow estuaries, temperature stratification (warmer temperatures near the top of the water column, and cooler temperatures near the bottom) typically occurs during slack low tides in shallower (less than 1 meter deep) areas of the slough, especially in the summer. Significant stratification is unlikely during the winter-spring months due to the mixing effects of watershed inputs and strong winds and rains from winter storms.

#### 3.4.2 Salinity

Typically, salinity in Elkhorn Slough is near-marine, averaging approximately 30 parts per thousand (ppt) (ocean salinity is typically about 35 ppt) (ESNERR data). However, salinity temporarily decreases in response to freshwater inputs from the watershed, and during particularly significant winter storm events can dip well below 20 ppt and even (very rarely) approach freshwater values (ESNERR data, Moffatt & Nichol 2008). On ebb tides, more saline waters draining from shallow marsh and mudflat areas (due to evapotranspiration) mix with cooler, less saline waters from the mainstems of Elkhorn and Parsons Sloughs, causing a semi-diurnal increase in salinity that can be observed during both warm and cool months (Caffrey and Broenkow 2002).

#### 3.4.3 Dissolved Oxygen and Eutrophication

In its recent updates to the Clean Water Act (CWA) 303(d) list of impaired water bodies, Elkhorn Slough was listed by the Central Coast Regional Water Quality Control Board (CCRWQCB) as impaired for low DO, a decision supported by ESNERR scientists (ESNERR 2009). Monitoring data from within Elkhorn Slough demonstrates that the system typically has DO levels within acceptable ranges, but episodic events can drive extreme increases or decreases in DO (LOBO data, Moffatt & Nichol 2008). In Elkhorn Slough, severe low DO events are frequent during the summer and early fall, when nighttime DO crashes become cumulatively worse as the system accumulates both respiring algae and decomposing organic material due to summertime productivity and eutrophication. Sudden decreases in DO can also occur when there is turbulence in the water column, which can re-suspend organic material with high
biological oxygen demand (BOD) from the benthos and cause a corresponding decrease in DO. Water quality data collected by ESNERR and MBARI indicates that eutrophication in Elkhorn Slough is a concern, especially in tidally restricted areas (Hughes et al. 2011, ESF 2012).

Recent research by Deegan et al. (2012) indicates that eutrophication can be a primary driver of tidal marsh in nutrient-enriched estuaries such as Elkhorn Slough. Their work was conducted in East Coast salt marshes, which contain plant species that can grow relatively lower in the tidal frame than pickleweed, such as smooth cordgrass (Spartina alterniflora) and saltmeadow cordgrass (Spartina patens). Conceptually, therefore, East Coast marshes should be relatively more resistant to marsh loss mechanisms than Elkhorn marshes, because plant root systems can stabilize sediments across a broader range of tidal depths. Nevertheless, their research demonstrated that:

“...nutrient levels commonly associated with coastal eutrophication increased above-ground biomass, decreased the dense, below-ground biomass of bank-stabilizing roots, and increased microbial decomposition of organic matter. Alterations in these key ecosystem properties reduced geomorphic stability, resulting in creek-bank collapse with significant areas of creek-bank marsh converted to unvegetated mud. This pattern of marsh loss parallels observations for anthropogenically nutrient-enriched marshes worldwide, with creek-edge and bay-edge marsh evolving into mudflats and tidal creeks.” (Deegan et al. 2012)

It can be expected that sea level rise, with its attendant increases in tidal prisms and wave energy, will further exacerbate this and other marsh loss mechanisms within the Slough. This new research indicates that efforts by local farmers and farming organizations to manage nutrient loading can complement the efforts of scientists working with the Slough to help restore tidal marsh habitats.

### 3.4.4 Nutrients

The primary inorganic nutrients of interest within Elkhorn Slough are nitrogen and phosphorus. Both are necessary for the growth of algae and other plants, and as such are important components of a productive marsh food web. However, in excessive quantities, such as are found under anthropogenically-altered conditions, these same nutrients can negatively impact water quality and ecosystem health within the slough. The primary source of external nutrients to the Elkhorn Slough system is runoff from the system’s watershed, especially from agricultural operations (e.g., fertilizers, manure); relatively smaller inputs include atmospheric deposition and bacterial fixation (Caffrey 2002b).

Nutrient levels, and particularly nitrate levels, throughout the entire Elkhorn Slough system have increased dramatically over the past 60 years, primarily in response to increases in the proportion of agricultural land within the slough’s watershed (Caffrey 2002b). Nitrate levels, which were once within the range of those measured within Monterey Bay, are now among the highest of any coastal estuary. To address these elevated nutrient levels, ESNERR scientists have requested that Elkhorn Slough be listed as a CWA 303(d) impaired water body for nitrate, ammonia, and phosphate. As of the most recent update (2010, approved in 2011), however, the system is not yet listed by the CCRWQCB as impaired for these constituents.
3.4.5 Turbidity and Suspended Sediment

Turbidity is a measure of the amount of material suspended in the water column, and is a commonly measured water quality constituent along with temperature and salinity. In tidal systems, turbidity monitoring can often help indicate the relative amounts of sediment that are entering a site on flood tides and leaving on ebb tides. Turbidity can also be an indicator of other water quality constituents, such as primary productivity (since the presence of free-floating algae can increase turbidity), and/or BOD within the water column (as organic particles are often a substantial contributor to turbidity). Turbidity is typically reported in Nephelometric Turbidity Units (NTU), a measure of how much light is scattered when a beam of light called a nephelometer shines through water.

Elkhorn Slough has been listed by the CCRWQCB for sedimentation/siltation due to impacts from agriculture within the watershed (CCRWQCB 2011). In Elkhorn Slough, turbidity appears to be primarily controlled by weather events, though algae production may contribute to late-summer/early fall turbidity spikes. Large storms wash sediment-laden runoff into the slough, and high winds can re-suspend settled sediments.

While Elkhorn Slough is listed by the CCRWQCB for sediment impairment, in the vicinity of the site, the system is functionally impaired by the relative lack of sediment compared to its pre-European-settlement conditions. Lack of sediment limits the ability of local marshes to accrete in response to higher water levels and ongoing sea level rise.

3.4.6 Contaminants

A recent history of intense land use within the Elkhorn Slough watershed and along the slough’s mouth has increased the amounts and types of contaminants in slough waters. These contaminants can cause both short-term and long-term impacts to the survival, growth, and reproduction of biological communities within and around the slough. Most contaminants within the slough system fall into one of three categories: pesticides, microbial contaminants (pathogens), and contaminants associated with harbor operations (Caffrey 2002b). Elkhorn Slough is a CWA 303(d) listed water body for pathogens and pesticides (CCRWQCB 2011); these are discussed in greater detail below.

The primary source of pesticides to slough waters and sediments is likely the greater Elkhorn Slough watershed area (ABA Consultants 1986), and in particular the Old Salinas River Channel which drains extensive agricultural areas (Phillips 1998). A Hazard Rating Coefficient (HRC) analysis initiated by NOAA in 1992 indicated that the newer pesticides of concern within the watershed are methamsodium, thiram, dicofol, malathion, and chlorpyrifos (Phillips et al. 2002). Current application rates of these chemicals within the Parsons watershed are unknown.

There are two primary pathogens of concern within Elkhorn Slough: coliform bacteria, and *Toxoplasma gondii*, a parasitic protozoa. Within Elkhorn Slough, contamination by coliform bacteria has been a known problem since the 1960s (ABA Consultants, 1986), and the slough is 303(d) listed as impaired for coliforms by the CCRWQCB (CCRWQCB 2011). A 1985 study of coliforms throughout Elkhorn Slough found that most coliforms in the system were not human, and that levels were highest in areas with freshwater inputs (ABA Consultants 1986). *Toxoplasma gondii* is a pathogen of humans and terrestrial animals that is highly correlated with mortality in sea otters. In a 2002 study by Miller et al, 79 percent
of the otters in the area tested positive for *T. gondii*, with high levels of exposure to freshwater flow from the Elkhorn Slough watershed as the primary reason. Within the Elkhorn Slough watershed, both domestic and feral cats are likely sources of *T. gondii* (Miller et al. 2002).
4 Geology and Soils

4.1 Regional Geology and Seismicity

The Monterey Bay region, including the Elkhorn Valley, is located within the region of California referred to by geologists as the Coast Ranges geomorphic province. The Coast Ranges have experienced a complex geological history characterized by Late Tertiary folding and faulting that has resulted in a series of northwest-trending mountain ranges and intervening valleys.

More specifically, the site is located within a composite continental terrane referred to as the Salinian block that extends along coastal California from Santa Barbara to Point Reyes (Figure 8). The basement rocks of the Salinian block comprise Cretaceous granitic plutons that intruded Paleozoic and Precambrian metamorphic rocks. Surficial geologic deposits in the vicinity of the site generally comprise sands of the early Pleistocene Aromas formation, Pleistocene alluvial fans, and late Pleistocene and early Holocene marine terrace deposits and dune sands.

Since early Miocene, the Salinian Block has undergone northward translation along the active transform plate boundary between the Pacific and North American tectonic plates. The relative motion between the two plates is described as dextral (right-lateral) strike-slip. This motion is accommodated throughout a broad zone of faults and folds, but is most highly concentrated along the seismically active San Andreas Fault located northeast of the site. The USGS seismic hazard program estimates a slip rate of up to 3.4 cm/year along segments of the San Andreas fault (USGS 2008).

Exploratory drilling near the mouth of Elkhorn slough in the 1940s revealed the presence of an extensive canyon eroded into the Salinian Block at depths of up to 2.5 km below the surface (Schwartz 1983). This feature, known as the Pajaro Gorge, was cut during the late Oligocene period; some geologists consider it to be the ancient drainage location of California’s Central Valley. The gorge was filled with extensive sedimentary deposits during the early Miocene and Pliocene periods as plate tectonics moved it northwest along the California coast. Elkhorn Valley, the headward, on-land extension of the Monterey Submarine Canyon, subsequently eroded into these deposits in the early Pleistocene (Schwartz 2002). The valley was subsequently inundated by rising Holocene sea levels, causing progressively finer sediments to deposit in the relatively low-energy (pre-harbor) slough. These sediments, from a combination of littoral (coastal) and fluvial (Pajaro and Salinas River) sources, are the basis on which the dendritic tidal marshes of Elkhorn Slough formed over the past 5,000 years (Schwartz 2002).

The project area is not located within an Alquist-Priolo Earthquake Fault Zone and there is no known evidence of active or potentially active faults crossing the project area (URS et al. 2010). Based on the 2008 USGS National Seismic Hazard Maps, the nearest active faults to the project area are the Zayante-Vergeles Fault located approximately 6.2 miles northeast of the site, the Rinconada fault located approximately 9.1 miles to the northeast, and the Northern San Andreas fault located approximately 9.8 miles to the northeast (Figure 9). Other active faults located near the site include the Monterey Bay Tularcitos fault located approximate 12.7 miles to the southwest, the Calaveras fault located approximately 19 miles to the northeast, and the San Gregorio fault located approximately 21 miles to the southwest.
The Uniform California Earthquake Rupture Forecast (UCERF 2008) evaluated the 30-year probability of a M6.7 or greater earthquake occurring on the known active fault systems in the Bay Area, including the San Andreas fault. The UCERF generated an overall probability of 63 percent for the Bay Area as a whole, and a probability of 21 percent for the N. San Andreas fault, 7 percent for the Calaveras, and 6 percent for the San Gregorio fault.

4.2 Surficial Geologic Deposits

The distribution and characteristics of surficial deposits within Elkhorn Slough are driven by the history of local parent material, transport of littoral sediment from the Pacific coast into Elkhorn Slough, transport of fluvial sediments into the slough from the Pajaro and Salinas rivers, sedimentation from the slough’s local watershed, and the development of tidal marsh within the slough.

Surficial Quaternary geologic deposits are mapped in Figure 10 (Wagner, 2002). Sediments within the slough are primarily derived from heterogenous sands of the Aromas Formation, which are composed of interbedded aeolian (wind-driven) sands, stream deposits from the Pajaro and Salinas rivers as well as other tributaries, lake deposits, and nearshore marine sands (from littoral drift along the Pacific coast) (Schwartz 1983). According to Wagner (2002), surficial deposits at the location of the proposed stockpile areas are probable Pleistocene marine terrace deposits consisting of gravel, sand, silt, and clay.

Multiple studies have attempted to characterize the sediments within Elkhorn Slough. Schwartz (1983) and Hornberger (1991) hand-drilled 14 shallow (mostly < 10 ft deep) cores along the main Elkhorn Slough channel and within Parsons Slough (Figure 11). In general, cores collected in the “midslough” area (similar landscape context to the restoration sites) contained approximately 1-foot deep layers of organic root mats on top of clay; some locations had shallow layers of peat in between the root mat and clay layers (Figure 12). In general, cores closer to the mainstem channel had relatively higher clay content, while cores farther from the channel had higher organic peat contents. Core 19, within the present-day Seal Bend restoration area, was unique in that it consisted entirely of sand. More recently, sediment cores were collected near the UPRR bridge as part of the planning effort for the Parsons Slough sill (Vinnedge 2010). In both borings the top layer contained clayey silt from the surface down to 62 feet below the ground surface (bgs), and the second layer comprised clayey sand from 62 to 89 feet bgs. Two referenced cores collected during their study of the Elkhorn Slough site are detailed by Watson et al (2011). The reference core from the Azevedo coring site encountered approximately 8½ feet of silty clay marsh soil over sand. The reference core from the Yampah coring site encountered over 16½ feet of clayey silt marsh over mudflat soil; the clay and silt content of the mudflat soil in the Yampah reference core was not reported.

A geotechnical field study conducted for this project collected samples at four locations in Minhoto and Hester’s Marsh (Figure 13). Field vane shear, mini vane, and consolidation tests were conducted on all samples and descriptions of sediment texture and color were recorded for three of the four samples (Table 3). In general, the upper 1 to 2 feet of soil is generally very soft, highly organic clay. Below this layer the soil becomes medium stiff to stiff. Tidal channels and adjacent areas were much softer than areas closer to uplands. These cores did not encounter the sand layer observed in the Yampah coring site described above, but this may be due to the limited depth of exploration.
Table 3. Soil Characteristics in Minhoto Marsh

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Depth (ft)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 – 0.75</td>
<td>Clay (CH), dark gray, very soft, wet, organic odor</td>
</tr>
<tr>
<td></td>
<td>0.75 – 1</td>
<td>Peat, orange brown, organics</td>
</tr>
<tr>
<td></td>
<td>1 – 10</td>
<td>Clay (CH), bluish gray, soft, wet</td>
</tr>
<tr>
<td>2a</td>
<td>0 – 3</td>
<td>Sandy clay (CH), black, wet, very soft to soft</td>
</tr>
<tr>
<td></td>
<td>3 – 6</td>
<td>Clay (CH), bluish gray, wet, stiff</td>
</tr>
<tr>
<td>3</td>
<td>0 – 1</td>
<td>Peaty clay, black, organic odor, soft, wet</td>
</tr>
<tr>
<td></td>
<td>1 – 10</td>
<td>Clay (CH), bluish gray, stiff to 3 ft then soft to medium stiff</td>
</tr>
</tbody>
</table>

4.3 Soils

The uppermost portions of the Pleistocene surficial deposits described above have subsequently weathered to form soil horizons with distinct physical and chemical properties (Los Huertos and Shennan 2002, Buol 1997). The weathered Aromas sands break down into silt and clay particles that make local soils particularly suitable for agriculture and plant growth (Los Huertos and Shennan 2002). Less common parent materials in the Slough include uplifted marine terraces, granitic outcrops, and metamorphic materials from higher in the Elkhorn watershed (Cook and Butler 1978, Isgrig 1969 in Los Huertos and Shennan 2002). The development of tidal marsh in Elkhorn Slough over the past 5,000 years has driven the formation of an organic peat layer that forms a cap on top of mineral sediments.

According the USDA web soil survey, the restoration areas (low lying tidal marshes) are underlain by a soil map unit designated the Alviso silty clay loam (Ac) (Figure 14). The Ac is generally described as a very poorly drained hydrologic soil group D soil with a profile that generally comprises silty clay loam (0-14 inches), silty clay (14-45 inches), and very fine sand (45-60 inches). Proposed stockpile areas located to the west of the marsh are designated as Santa Ynez fine sandy loam (ShC, ShD and ShE depending on percent slope of existing ground surface). The Santa Ynez soils are generally described as moderately well drained hydrologic soil group D soils with a profile that generally comprises fine sandy loam (0-18 inches), clay loam (18-43 inches) and sandy clay loam (43-61 inches). However, soil sampling within the Minhoto Marsh indicates that existing soils at the Minhoto site are black muck (silt), with a near 50-50 split between silt and clay and only 1-3% sand (Torrent 2013). The soils are very fine-grained, with an average $D_{50}$ of 0.0026 mm (ibid).

4.4 Sediment Quality

Stockpiled Pajaro River sediments and Minhoto upland sediments are intended for use as marshplain fill in restoration. Preliminary sediment acceptability criteria for sediment chemistry were developed as part of the Project (Moffat & Nichol, 2013). Guidelines for material reuse in wetland restoration have not been established for Elkhorn Slough, so the project criteria are based on NOAA national guidelines, screening levels developed for San Francisco Bay beneficial reuse projects, and ambient levels in Elkhorn Slough areas.
Slough. The Pajaro River Excavation areas and Minhoto Marsh restoration site were sampled and tested to establish ambient constituent concentrations. The results were discussed with the Central Coast RWQCB and the Environmental Protection Agency (EPA), who agreed that the Project may reasonably base sediment suitability criteria on the NOAA guidelines and ambient site concentrations. Sediment horticultural suitability criteria were also developed and focus on managing invasive species and creating a soil environment that encourages establishment of native marsh plants (H.T. Harvey, 2013). The sediment horticultural suitability criteria specify: clay and rich silt soil, 7-30% organic matter, pH of 5.5 to 8.0, soil salinity less than 45 ppt, and Boron concentrations less than 4.5 ppm.

**Minhoto Marsh Soils.** UC Davis, with assistance from ESNERR staff, collected approximately 20 surficial sediment samples at each of five representative locations in Minhoto Marsh in February 2013. Sediment samples were collected by hand at approximately 5 cm depth. Table 4 presents the average constituent levels in the Minhoto Marsh samples.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Pajaro Site Weighted Average</th>
<th>Minhoto Marsh Ambient Average Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals (mg/kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.8</td>
<td>2.6</td>
</tr>
<tr>
<td>Cadmium</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Chromium</td>
<td>61</td>
<td>51.6</td>
</tr>
<tr>
<td>Copper</td>
<td>21</td>
<td>25.8</td>
</tr>
<tr>
<td>Lead</td>
<td>6.8</td>
<td>8.8</td>
</tr>
<tr>
<td>Mercury</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Nickel</td>
<td>81</td>
<td>58.4</td>
</tr>
<tr>
<td>Selenium</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Silver</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Zinc</td>
<td>47</td>
<td>51.4</td>
</tr>
<tr>
<td>Organochlorine Pesticides/PCBs (ug/kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDTs, sum</td>
<td>15</td>
<td>8.8</td>
</tr>
<tr>
<td>Chlorinated, sum</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Hexachlorocyclohexane, sum</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Hexachlorobenzene</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>PCBs, sum</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Polyaromatic Hydrocarbons (ug/kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAHs, total</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Low molecular weight PAHs, sum</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>High molecular weight PAHs, sum</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>1-Methylnaphthalene</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>2,3,5-Trimethylbenzene</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

As mentioned earlier, the Minhoto soils are fine-grained soils classified as black muck (silt). Metal levels in these sediments were below all Effects Range – Low (ERL) levels with the exception of nickel, which was above both ERL and ERM (Effects Range – Medium) levels but below the observed ambient levels in San Francisco Bay marsh soils. Only one organochlorine pesticide (DDT) was detected above ERL levels (all other pesticides were below detection levels). However, DDT levels were still below ambient levels

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3 Average measured nickel at Minhoto was 58.4 mg/kg; ERL = 20.9 mg/kg, ERM = 51.6 mg/kg, and SF Bay ambient level = 92.9 mg/kg.

4 Average measured DDT at Minhoto was 8.8 ug/kg; ERL = 1.58 ug/kg, ERM = 46.1 ug/kg, and SF Bay ambient level = 2.8 ug/kg. (Anderson 2013)
observed in SF Bay marsh soils (ESA PWA 2013). DDT levels in the Minhoto sediments likely reflects the history of agricultural use of DDT in the watershed prior to its banning in the early 1970s. PAH levels in these soils were below detection limits.

**Pajaro Bench Sediments Stockpiled Onsite.** The Pajaro River Bench Excavation Project generated approximately 300,000 cubic yards of material while excavating the levee benches of the lower Pajaro River (see Appendix C). The Pajaro River Bench Excavation Project is flood control initiative of the Santa Cruz County Department of Public Works (SCCDPW) and delivered sediment for use in the Elkhorn Slough Tidal Wetland Restoration Project in Summer 2013. While initially was thought that approximately 192,000 cubic yards would be available for the Restoration Project’s use (Appendix C), the actual amount received is estimated at 50,000 cubic yards (M. Fountain, pers. comm.). This material is currently stockpiled on the fields adjacent to the Minhoto-Hester’s Restoration Site and will be used in the first phase of construction.

SCCDPW collected samples at multiple depths at 17 different locations throughout the Pajaro Bench. Table 4 presents the average constituent levels in the Pajaro Bench samples, compared with the Minhoto Marsh levels. Similar to the Minhoto soils, metals, organochlorine pesticide, and PAH levels at the Pajaro Bench are below either detection limits or all established limits with the exception of DDT, which is above the ERL, the Minhoto level, and the ambient values in SF Bay soils (ESA PWA 2013). As with DDT levels in the Minhoto soils, the elevated DDT levels in Pajaro Bench soils likely reflect the valley’s history of DDT agricultural use. Pajaro River sediments that tested highest for Nickel and DDT were not accepted for use at Elkhorn Slough. In general, soils from the bench were much sandier than native Minhoto soils, with sand, silt and clay fractions of 42%, 44%, and 13%, respectively. The relatively coarser nature of these sediments may necessitate a design approach that incorporates finer-grained native soils, to make them more suitable for tidal marsh plant colonization (HT Harvey and Associates 2013). One Pajaro site, 5R3, had elevated levels of Zinc and slightly elevated levels of Barium and DDT. This section was not transported to the Elkhorn restoration site. Additionally, areas with invasive plant species were either not transported to the site or sprayed to control weeds prior to transport.

**Minhoto Upland Areas.** The volume of soil delivered from the Pajaro Bench Excavation leaves a deficit of approximately 90,000 cubic yards for restoration of the proposed Phase 1 project. Therefore, additional sediment may be supplied by excavating sediment from the adjacent hillside within the existing permitted stockpile area (Figure 2). Since these fields were farmed in the past, there is a potential for pesticide contamination. These sediments have not been tested for sediment chemistry or horticultural suitability, so this testing will need to be conducted prior to making a final decision as to whether or not they can be used as marsh fill. As mapped in the USDA soil survey (Figure 14), these soils may be coarser than those found in the marsh.

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5 “Limits” for the Pajaro Bench soils are defined as either the ERL, the Minhoto ambient level (in the case of nickel, for which both Minhoto and Pajaro Bench soils were above the ERM (Effects Level – Medium), or the SF Bay ambient level (for constituents for which there is no ERL or ERM). See ESA PWA (2013) for additional details about sediment suitability.

6 Average measured DDT at the Pajaro Bench was 15 ug/kg. (Anderson 2013)
Biological and Ecological Communities

This chapter describes the biological and ecological communities found on or adjacent to the project site, as well as those whose needs must be considered during the restoration design process. H.T. Harvey and Associates’ methods for assessing these communities are described in Appendix D.

4.5 Biotic Habitats

The following section provides a description of the biotic habitats found within the project site and their functions and values. Habitat types were developed using a combination of described habitats and vegetation alliances as per Holland (1986), Sawyer et al. (2009), and Kutcher (2008). The habitat types are based upon hydrology, land use, and vegetation, and are consistent with those previously described for Elkhorn Slough (Zimmerman and Caffrey 2002, ESTWPT 2007). Habitats are considered sensitive if they support vegetation alliances listed as sensitive on the California Department of Fish and Wildlife’s (CDFW) List of Vegetation Alliances and Associations (CDFW 2010).

The six biotic habitats found within the project site are: subtidal, intertidal mudflat, intertidal salt marsh, diked salt marsh, diked brackish marsh/willow thicket, and cultivated field/ruderal grassland. The distribution of habitats within the project site is shown in Figure 15, and their approximate acreages are summarized in Table 5. Habitats at the project site are described in more detail below.

Table 5. Existing Biotic Habitats and Land Use Types

<table>
<thead>
<tr>
<th>Biotic Habitat</th>
<th>Area (ac) at Project Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtidal</td>
<td>13.4</td>
</tr>
<tr>
<td>Intertidal Mudflat</td>
<td>52.1</td>
</tr>
<tr>
<td>Intertidal Salt Marsh</td>
<td>30.8</td>
</tr>
<tr>
<td>Diked Salt Marsh</td>
<td>5.2</td>
</tr>
<tr>
<td>Diked Brackish Marsh/Willow Thicket</td>
<td>0.7</td>
</tr>
<tr>
<td>Cultivated Field/Ruderal Grassland</td>
<td>43.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>145.4</strong></td>
</tr>
</tbody>
</table>

4.5.1 Subtidal/Aquatic

Subtidal channels occupy 13.4 ac within the Seal Bend and Minhoto/Hester’s Marsh restoration areas. These channels connect to the main channel of Elkhorn Slough and provide tidal exchange to intertidal mudflats and intertidal salt marsh at the site. Subtidal channel habitats occur below the elevation of the low tidemark or Mean Lower Low Water (MLLW) where the substrate is continuously submerged. Tidal creeks form networks that serve an important function of water conveyance and drainage onto and off of mudflat and marsh surfaces as well as the transfer of sediment and nutrients between marshes and the main estuarine channel (ESTWPT 2007). The corresponding NERRS classification for the Subtidal habitat type is Estuarine Subtidal Haline Unconsolidated Bottom Mud.
Elkhorn Slough channel habitats have substrates largely composed of material such as organic matter, mud, sand, and gravel. The fine-grained materials are often cohesive, as a result of unconsolidated material eroding away over several decades. Channel depth averages about 9.8 ft (ESTWPT 2007). As discussed above, salinity in the main channel just west of Seal Bend was recorded as ranging from 5-10 parts per thousand (ppt) in the rainy season to 32-35 ppt in the summer (ESTWPT 2007). Water temperatures range from 10 to 22 °C, with an average temperature of approximately 13.5 °C (MBARI LOBO data).

As discussed in-depth in Section 3.2.5, recent water quality assessments indicate that channels in the estuary overall are moderately eutrophic, indicating excessive nutrient enrichment (Johnson 2010, Hughes et al. 2011). Elkhorn Slough is surrounded by intensely cultivated/chemically fertilized farmlands and the estuary receives substantial agricultural run-off. Nitrate concentrations in the estuary often exceed values found in the nutrient-rich waters of Monterey Bay by nearly 20-fold (Johnson 2010). Dissolved oxygen concentrations fluctuate much more widely in Elkhorn Slough than in most other estuaries, likely attributable to the high rates of primary productivity induced by external inputs of nitrogen. Degraded water quality is strongly affecting environmental conditions for organisms dwelling in subtidal habitats in Elkhorn Slough (Wasson et al. 2012).

Many of the slough channels onsite have a natural, sinuous form, however there are also numerous linear human-constructed channels as well (e.g., borrow ditches). The constructed channels reduce slough channel topographic complexity relative to the natural marsh condition and thereby likely reduce plant and animal community diversity. The forthcoming restoration plan will consider measures to restore natural slough channel form and reduce the surface area and drainage influence of the constructed channels.

4.5.1.1 Vegetation

Subtidal macroalgal species in Elkhorn Slough include Ulva lactuca, U. expansa, and U. lobata. Floating macroalgal mats occur in the water column, dominated primarily by U. intestinalis, but also include Rhizoclonium riparium and Chaetomorpha sp. High concentrations of nutrients may have contributed to increased macroalgal abundance and higher phytoplankton densities in the water column (Hughes et al. 2010).

Eelgrass (Zostera marina) is the dominant seagrass species in Elkhorn Slough. It grows in shallow, protected waters, rooted in unconsolidated sediments. Plants can spread through vegetative rhizomatous expansion and sexual seed production. Eelgrass at Elkhorn Slough has been previously described and mapped by Palacios (2010) and Hammerstrom and Grant (2012). Dense eelgrass beds occur in only a few areas along the lower main channel, with the largest bed located near Seal Bend (Palacios 2010). Once plentiful, eelgrass cover declined dramatically in the 1950s after the opening of a permanent harbor mouth at Moss Landing (Van Dyke and Wasson 2005). Declines continued until the 1980s, when a shoal formed in the Seal Bend region of Elkhorn Slough and was colonized by eelgrass. The shoal expanded in 1995, with subsequent increases in eelgrass cover (Hammerstrom and Grant 2012). This eelgrass bed, which has increased in cover over time, is located on the north side of the channel approximately 375 ft north of the Seal Bend restoration site (Figure 24). On the south side of
the channel, a smaller patch occurs about 150 ft from the Seal Bend Restoration site. Although located outside of the project site, eelgrass at this location was mapped and described here since we plan to assess any potential for indirect impacts to this sensitive resource that might result from the proposed restoration (Figure 1). Sediment at Seal Bend is fine-grained and high in organic content. Growing on the shoal at the Seal Bend site, eelgrass forms patchy beds interspersed with bare areas of up to 50 ft across. Small patches of Ulva and small aggregations of red algae from the family Gracilariaceae are found interspersed with the eelgrass (Hammerstrom and Grant 2012).

The ESNERR initiated a monitoring program for eelgrass in 2010, and the Seal Bend and Vierra beds were the two populations selected for sampling. General vegetation characteristics observed thus far are consistent with most seagrass ecosystems, with percent cover, flowering density, canopy height and biomass tending to be higher in summer months and lower in winter months. In contrast, shoot density increased in the winter and decreased in the summer, possibly due to density-dependent self-thinning. The ratio of aboveground to belowground biomass ratios were very high, meaning that the eelgrass is allocating more energy into production of photosynthetic tissue; a result of light limitation. Both grazing by herbivores and wasting disease (Labyrinthula zosterae) were observed at the Seal Bend eelgrass bed (Hammerstrom and Grant 2012).

In addition to the eelgrass at Seal Bend, a small amount of eelgrass has been previously mapped near the Minhoto-Hester’s Marsh in the main Elkhorn Slough channel (Palacio 2010). This eelgrass was not evident in sufficient abundance to map based on available 2010-2012 aerial imagery, but possibly could be detected by field investigation. In monitoring conducted since 2000 in Elkhorn Slough, significant inter-annual variability in the vegetation density of the beds has been evident (Palacios 2010, Hammerstrom and Grant 2012).

4.5.1.2 Wildlife

The subtidal channels in Elkhorn Slough are used by a variety of bird species that are able to forage from the air (e.g., terns) or under water (e.g., diving ducks, cormorants) and those that can swim. Generally, species that are associated with oceanic habitats, such as pelagic cormorants (Phalacrocorys pelagicus) and Brandt’s cormorants (Phalacrocorys penicillatus), can be found near the mouth of the slough whereas others, including many diving and dabbling duck species, are found more inland in shallower, calmer waters of the slough system. The abundance of most species varies seasonally, with the highest numbers occurring in fall through spring (Harvey and Connors 2002). Bird species that forage aerially by plunging into the water in search of fish include terns such as the Forster’s tern (Sterna forsteri) and Caspian tern (Sterna caspia), as well as the California least tern (Sterna antillarum browni), a federally and State endangered species that may occasionally visit Elkhorn Slough during migration. California brown pelican (Pelecanus occidentalis) also can be observed diving for fish in Elkhorn Slough and roosting on the water, as well as on adjacent slough banks. Brown pelicans occur in the slough after post-breeding dispersal from southerly breeding sites such as West Anacapa Island and Santa Barbara Island; after breeding they form communal roost sites. Seasonally, American white pelicans (Pelecanus erythrorhynchos), which forage for fish by swimming rather than diving like brown pelicans, may occur in the slough as well. Common loons (Gavia immer), as well as the less common Pacific loon (Gavia
and red-throated loon (*Gavia stellata*) also dive for fish in subtidal channels of Elkhorn Slough. Cormorants, including double-crested cormorants (*Phalacrocorax auritus*), pelagic cormorants, and Brandt’s cormorants, as well as red-breasted mergansers (*Mergus serrator*), a diving duck, will use subtidal channels in Elkhorn Slough to forage on fish. Other diving ducks such as greater scaup (*Aythya marila*), lesser scaup (*Aythya affinis*), ruddy ducks (*Anas clypeata*), buffleheads (*Bucephala albeola*), common goldeneye (*Bucephala clangula*), surf scoters (*Melanitta perspicillata*), and white-winged scoters (*Melanitta deglandi*) dive for bivalves, crustaceans, and other invertebrates in subtidal areas of the slough complex. Gulls also roost and forage on the channels of Elkhorn Slough. Western gulls (*Larus occidentalis*) are common residents in the Elkhorn Slough area, and glaucous-winged gulls (*Larus glaucescens*), California gulls (*Larus californicus*), ring-billed gulls (*Larus delawarensis*), and Bonaparte’s gulls (*Chroicocephalus philadelphia*) forage opportunistically by following other species and finding scraps of food or by finding prey in shallow water or near the surface. Dabbling ducks such as the gadwall (*Anas strepera*), cinnamon teal (*Anas cyanoptera*), northern shoveler (*Anas clypeata*), and mallard (*Anas platyrhynchos*) use the smaller, shallower channels in Elkhorn Slough to forage and roost.

The southern sea otter (*Phoca vitulina richardsi*) and harbor seal (*Phoca vitulina richardsi*) are two marine mammals that use subtidal channels in Elkhorn Slough. Sea otters, numbering approximately 100 individuals, rest and pup in Elkhorn Slough; however, they also forage on snails, mussels, and crabs (McCarthy 2010a). They typically use the lower and middle portions of the slough, although they also occur in mid-estuary habitats, in places like Parsons Slough. They rest and groom while floating on their backs either individually or in “rafts”, particularly in areas with eelgrass. Harbor seals are year-round residents in Elkhorn Slough and they number in the hundreds (McCarthy 2010b). They generally occur in the main channel, either individually or in small groups, and their numbers are highest from May through August when they are pupping and molting (Harvey and Connors 2002). Harbor seals use the slough complex primarily for stages, resting, and pupping, with most foraging occurring in Monterey Bay, but they occasionally forage in the slough on small fish (Harvey and Connors 2002). In addition to using the channels of the slough system, harbor seals use mudflats and marshes for haul-out sites (Harvey and Connors 2002; McCarthy 2010b).

### 4.5.1.3 Benthic Invertebrates

Subtidal benthic invertebrate community species dominance differs in the lower and upper slough (Wasson et al. 2002). In the lower slough, soft substrates provide habitat supporting abundant populations of burrowing species such as larger clam species (e.g., *Tresus nuttallii*), fat innkeeper worms (*Urechis caupo*), and polychaetes (Wasson et al. 2002). Epifauna including moon snails (*Polinices lewisi*), sea hares (e.g., *Aplysia californica*), and rock crabs (*Cancer antennarius*) are also abundant in the lower slough (Wasson et al. 2002). Farther up in the slough the substrate becomes softer and finer, with dominant species in subtidal habitats near the project site including the rough piddock (*Zirfaea pilsbryi*), tube-dwelling anemones (*Pachyserianthus fimbriatus*), polychaetes, and moon snails (Wasson et al. 2002).
In nearby subtidal channels of Parsons Slough, benthic infauna included polychaetes (e.g., *Exogone loureii*), crustacea (e.g., *Leptochelia dubia, Monocorophium* sp.), mollusks (e.g., *Nutricula tantilla*), and oligochaetes (e.g., *Tubificoides* sp.) (Oliver et al. 2009).

### 4.5.1.4 Fish
In subtidal habitats, the fish species most likely to occur are some of the same species found in intertidal mudflat habitats (see below section) such as surfperches (Family Embiotocidae), flatfishes (including California halibut [*Paralichthys californicus*]), bat rays (*Myliobatis californica*), clupeids (Family Clupeidae), and Pacific staghorn sculpin (*Leptocottus armatus*). Subtidal habitats are also utilized by species such as plainfin midshipman (*Porichthys notatus*), as well as several larger elasmobranchs such as leopard sharks (*Triakis semifasciata*), shovelnose guitarfish (*Rhinobatos productus*), and thornbacks (*Platyrhинодis triseriata*) (Yoklavich 2002, Carlisle and Starr 2009).

### 4.5.2 Intertidal Mudflat/Aquatic
Intertidal mudflats channels occupy 52.0 ac at the project site, and are more extensive within the Minhoto-Hester’s area then the Seal Bend area. Mudflats occur between channel and marsh habitats, typically between the elevations of MLLW and Mean High Water (MHW). Mudflats are generally inundated during high tide and exposed during low tide. Mudflats serve an important function in estuarine chemical cycles (ESTWPT 2007). The corresponding NERRS classification for the Intertidal Mudflat habitat type is Estuarine Intertidal Haline Unconsolidated Shore Mud.

#### 4.5.2.1 Vegetation
Much of the mudflats at the project site were devoid of any vegetation at the time of site reconnaissance. The Intertidal Mudflat mapping unit contains inclusions of small patches of salt marsh vegetation (i.e., pickleweed); however, overall cover by vascular plant species is less than 30% (Figure 15). Mudflat at relatively higher elevations supported macroalgae. Peak months of macroalgal productivity are in the summer, when blooms can completely cover intertidal mudflats in Elkhorn Slough. Dense macroalgal blooms are an indicator of high nutrient loading and eutrophication, which can facilitate microbial decomposition, cause hypoxic and anoxic conditions, and lead to an overall loss in biodiversity. Eutrophication may also play an important role in driving marsh loss mechanisms at Elkhorn Slough. Macroalgal species documented on intertidal mudflats in Elkhorn Slough include *U. lactuca, U. intestinalis, R. riparium, Chaetomorpha sp.*, and *Gracilariopsis andersonii* (Hughes et al. 2010).

#### 4.5.2.2 Wildlife
Mudflats in Elkhorn Slough are used by a wide variety of shorebirds, particularly during migration periods in the spring and fall when there can be up to 20,000 individuals in the slough complex (Ramer et al. 1991). The mudflats are used primarily for foraging and shorebirds generally roost (resting and preening) when they are not foraging. Many mudflat specialists roost on the upper flats after initially foraging on the receding tide, then fly to alternate habitats to roost as the mudflats flood. Shorebirds are very flexible and opportunistic in their diets, with considerable dietary overlap among species and
foraging guilds (Skagen and Oman 1996). They often take prey in accordance with availability, concentrating where prey is most dense (Goss-Custard 1970; Goss-Custard 1977; Goss-Custard 1979). These birds often concentrate at the edge of the receding tideline, where worms, crustaceans, and bivalves occur close to the surface. Thus, the hydrologic regimes and ecosystem processes that maintain abundant invertebrate populations are more important than the specific invertebrate taxa available. Near the waterline, shorebird microhabitat use typically depends on each species’ leg length, as well as the size and shape of their bills. For example, the very shortest-billed semipalmated plovers (Charadrius semipalmatus) and black-bellied plovers (Pluvialis squatarola) feed on recently exposed mud, small sandpipers such as western sandpiper (Calidris mauri) and least sandpipers (Calidris minuta) forage on recently uncovered mud and shallow water, mid-sized birds such as dunlin (Calidris alpina), long-billed dowitchers (Limnodromus scolopaceus), and short-billed dowitchers (Limnodromus griseus) forage in slightly deeper water, and larger shorebirds such as willets (Tringa semipalmata), long-billed curlews (Numenius americanus), and marbled godwits (Limosa fedoa) are able to probe in deeper water.

In addition to bill and leg length, sediment type can dictate where shorebird species forage. Generally, smaller shorebirds congregate in upper reaches of Elkhorn Slough, where the substrate is muddier, and larger shorebirds occur near the mouth of the slough where the sediment is coarser (Harvey and Connors 2002, Ruegg 2010). Of the species that use Elkhorn Slough mudflats, western and least sandpipers are the most abundant (Harvey and Connors 2002). As mentioned above, these shorebirds are migratory and they forage in estuaries like Elkhorn Slough and breed in other regions; however, black-necked stilt (Himantopus mexicanus), American avocet (Recurvirostra americana), western snowy plover (Charadrius alexandrinus nivosus), and killdeer (Charadrius vociferus) are shorebirds that are residents in the area. Of these species the American avocet is a common forager on mudflats, using a variety of foraging techniques with their recurved bills to forage for prey in soft substrates. Killdeer as well as the federally threatened western snowy plover, which breeds on nearby beaches and former salt ponds, may occur on Elkhorn Slough mudflats periodically.

In addition to shorebirds, wading birds such as great egrets, great blue herons, and snowy egrets (Egretta thula) will forage on the edge of mudflats for small fish in the shallow intertidal waters year-round. Harbor seals frequently use mudflats in Elkhorn Slough for haul-out sites. Seals have used various mudflat locations for haul-outs in the slough, including Seal Bend, Rubis Creek, the entrance to Parsons Slough, and tidal creeks within the Parsons Slough complex (McCarthy 2010b).

4.5.2.3 Benthic Invertebrates

Benthic invertebrate infauna and epifauna vary with distance from the mouth of Elkhorn Slough. This is in part because hydrodynamics, sediment size, and water quality vary with distance from the mouth (Wasson et al. 2002). Current speed and ocean exchange is greatest at the mouth with residence time increasing toward the head, salinity reflects the coastal marine waters at the mouth but can be fresher in the winter and more saline in the summer toward the head, and sediments are coarse beach sand at the mouth and become finer clays and silts toward the head (Wasson et al. 2002).

Intertidal benthic infauna diversity is greatest near the mouth and decreases toward the head of the slough, with bivalves, blue mud shrimp (Upogebia pugettensis) and ghost shrimp (Callianassa
Intertidal flatfishes, *C. californiensis* being more abundant in the lower slough, and more non-native infaunal invertebrates occurring in the upper slough (Wasson et al. 2002).

Intertidal benthic epifauna species also vary with distance from the mouth. Large, mobile benthic intertidal epifauna species (e.g., moon snails *Polinices lewisi*, sea hares *Aplysia californica*, sea stars, *Cancer* crabs) tend to occur closer to the mouth whereas other species (e.g., grapsid shore crabs) occur only in the upper slough or throughout the slough (Wasson et al. 2002). *Ulva* mats that are found on higher tide flats can harbor dense populations of amphipods (Wasson et al. 2002).

In nearby Parsons Slough and Pick-n-Pull marsh, invertebrate species diversity was high and reflective of the species composition expected in a “well-flushed” system (Oliver et al. 2009). In Parsons Slough, dominance and diversity changed seasonally. In the summer crustaceans accounted for 35% of the individuals, polychaetes for 33% and oligochaetes for 24%; whereas in spring crustaceans were 46%, mollusks were 26%, polychaetes were 17%, and oligochaetes were 14% of the individuals.

### 4.5.2.4 Fish

Fish species richness and species composition declines with distance up Elkhorn Slough (Yoklavich et al. 2002). Because the lower slough is strongly influenced by coastal processes, the species composition reflects coastal marine fish species, but the upper slough becomes more euryhaline (i.e., wide range of salinities) and species composition changes. The project site is located in the mid to lower slough and is well flushed by the tides. Based on surveys conducted in similar habitats, fish species likely to occur in intertidal mudflat habitats in the project area include threespine stickleback (*Gasterosteus aculeatus*), arrow goby (*Clevelandia ios*), juvenile starry flounder (*Platichthys stellatus*), longjaw mudsucker (*Gillichthys mirabilis*), topsmelt (*Atherinops affinis*), and mullet (*Mugil cephalus*), as well as surfperches, flatfishes, bat rays, Pacific staghorn sculpin, northern anchovy (*Engraulis mordax*), and juvenile Pacific herring (*Clupea pallasii*) (Woolfolk and Labadie 2012, Ritter et al. 2008, Yoklavich et al. 2002). During H. T. Harvey & Associates’ site reconnaissance, a potential bat ray feeding pit was observed on a mudflat in the southern portion of the Minhoto restoration area.

### 4.5.3 Intertidal Salt Marsh

Approximately 30.9-ac of intertidal salt marsh occur at the project restoration sites. Marsh is more extensive in the Seal Bend restoration area compared to the Minhoto/Hester’s Marsh restoration area. In and adjacent to the project site, intertidal salt marsh habitat occurs from approximately +4 ft NAVD88 (~1 ft below MHW) to approximately +7 ft NAVD 88 (~1.3 ft above Mean Higher High Water (MHHW)). Intertidal salt marshes in Elkhorn Slough are highly saline. The corresponding NERRS classification for the Intertidal Salt Marsh habitat type is Estuarine Intertidal Haline Emergent Wetland Persistent. Cover by vascular plant vegetation is greater than 30%.

Tidal marshes have been shown to improve nutrient filtration, which provides a health benefit to the estuary’s aquatic life forms and to humans by reducing eutrophication and the transmittal of pathogens. Additionally, the unique sediment conditions of tidal salt marshes allow them to store disproportionate quantities of soil carbon and help them to remove nitrogen from the hydrosphere. Intertidal marshes in
Elkhorn Slough provide habitat for dozens of native plant species, and are used by invertebrates, fish, reptiles, birds and mammals for resting, feeding, breeding and refuge (Woolfolk and Labadie 2012).

4.5.3.1 Vegetation

Intertidal salt marsh at the project site occur on the Alviso soil series, characterized as a gray, neutral, silty clay loam typically associated with marshes (NCSS-NRCS 2013). Total vegetation cover ranges from 30-100%. The vegetation is dominated by a single native species, perennial pickleweed (Sarcocornia pacifica), as is characteristic of low elevation intertidal salt marshes in the region. Both the percent cover and the height of pickleweed are generally lower at lower elevations of the project site where the marsh transitions to mudflat. The diversity of the native plant community increases at slightly higher elevations, as on remnant interior berms, and at the upper marsh edge where a few other native species are found occurring with pickleweed; these include saltgrass (Distichlis spicata) marsh jaumea (Jaumea carnosa), alkali heath (Frankenia salina), and coast gumplant (Grindelia stricta). Tidal salt marsh vegetation provides organic matter inputs to the detrital food chain both within the vegetated marsh plain and in the adjacent intertidal mudflat and subtidal habitats of Elkhorn Slough via microbial decomposition and tidal transport of organic matter produced by tidal marsh vegetation. Pacific cordgrass (Spartina foliosa), which is a dominant species in low elevation marshes in the San Francisco Bay region, is absent from Elkhorn Slough (Caffrey et al. 2002).

Ecotones are transition zones of especially high species richness, where different plant communities overlap. The tidal salt marsh-upland ecotone is characterized by a mixture of high marsh and upland plant species. In a study of salt marsh-upland ecotones in Elkhorn Slough, Wasson and Woolfolk (2011) found that available habitat for ecotone plant species is extremely limited and highly invaded by non-native species. In most locations within the project site, the upland directly abuts the marsh, with very little or no tidal marsh-upland ecotone. For example, at its upper margin, the intertidal salt marsh at the Minhoto parcel is bordered by a cultivated field and/or ruderal grassland habitat.

4.5.3.2 Wildlife

Shorebirds that forage on mudflats during lower tides will use tidal marshes in Elkhorn Slough for roosting during high tides. Also, waders, like great egrets, snowy egrets, and great blue herons will use tidal marshes for foraging. These waders, along with larger shorebirds like long-billed curlews, marbled godwits, and willets will forage in small tidal channels and shallow marsh plain depressions for crabs, small fish, worms, and other invertebrates. Greater yellowlegs (Tringa melanoleuca), the less common lesser yellowlegs (Tringa flavipes), black-necked stilts, and American avocets will forage in a variety of habitats including salt marshes in Elkhorn Slough. Gulls, particularly smaller gulls like ring-billed gulls, Bonaparte’s gulls, and California gulls will forage in tidal channels and depressions, and these species will roost in salt marshes as well. The California clapper rail (Rallus longirostris obsoletus), a tidal marsh endemic species once occupied Elkhorn Slough marshes but is now extirpated, possibly due to loss of tidal marsh habitats; the California clapper is now restricted only to the San Francisco Bay estuary (Harding-Smith 1993). Raptors, including northern harriers (Circus cyaneus), white-tailed kites (Elanus leucurus), and red-tailed hawks also forage in tidal marshes and adjacent areas for small mammals, such as the California vole (Microtus californicus) and the Salinas harvest mouse (Reithrodontomys megalotis...
longicaudus) (this species is not a special-status species). Northern harriers nest in marshes in the area but are unlikely to nest on the project site itself due a lack of dense vegetation that is suitable for nesting. White-tailed kites and red-tailed hawks may nest in trees in adjacent upland areas. Otters have been observed hauled out in pickleweed vegetation in the Parsons Slough area (Vinnedge 2010) and may use pickleweed marshes in other locations in the Elkhorn Slough complex on occasion.

4.5.3.3 Benthic Invertebrates
California salt marshes can support dense populations of oligochaetes and polychaete worms, while the lower elevation marsh surfaces can be dominated by gastropods, amphipods, isopods, and crabs, but adjacent tidal creeks are generally more species-rich (Woolfolk and Labadie 2012). Burrows of the lined shore crab (Pachygrapsus crassipes) in Elkhorn Slough indicate their presence in lower marshes (Woolfolk and Labadie 2012). In high marshes, invertebrates also include terrestrial insects and spiders (Woolfolk and Labadie 2012).

4.5.3.4 Fish
Fish can only utilize tidal salt marshes when they are inundated at high tides. Pickleweed marsh likely provides refuge and feeding habitat at high tides for species including the threespine stickleback, arrow goby, juvenile starry flounder, longjaw mudsucker, topsmelt, and mullet (Woolfolk and Labadie 2012). Gobies may use pickleweed beds bordering tidal creeks and inland sloughs as spawning habitat (Yoklavich et al. 2002).

4.5.4 Diked Salt Marsh
A diked salt marsh occurs at the northwest side of the Minhoto/Hester’s Marsh restoration area. Historically, this was intertidal salt marsh, diked in the 1930s (Van Dyke and Wasson 2005). The diked salt marsh is approximately 5.2 ac. The corresponding NERRS classification for the Diked Salt Marsh habitat type is Palustrine Intermittent Emergent Wetland Persistent.

4.5.4.1 Vegetation
The diked marsh is enclosed by an intact levee that does not have a water control structure. The area ponds water much of the time (Woolfolk, personal communication 2013). Like the intertidal salt marsh on-site, this area is mapped as having the Alviso soil series, characterized as a gray, neutral, silty clay loam typically associated with marshes (NCSS-NRCS 2013). Presumably the soils have a residually high salinity, as most of area is dominated by a dense cover of perennial pickleweed, except where dissected by ditches, which held standing water when observed during low tide at the time of field reconnaissance. There is a fringe of brackish plants along the upper edge that is mapped and described separately as diked brackish marsh habitat.

4.5.4.2 Wildlife
The diked salt marsh provides fewer foraging opportunities for birds compared to the subtidal channels, mudflats, and tidal marshes, due to a paucity of benthic invertebrates and fishes compared to those habitats. However, shorebirds may roost in the diked marsh during high tides when intertidal areas are
flooded. Also waders, such as egrets and herons, and certain shorebirds, such as greater yellowlegs and black-necked stilts may forage in this habitat. Raptors, including white-tailed kites, northern harriers, and red-tailed hawks may forage for small mammals, including the California vole, in this habitat as well.

4.5.4.3 Benthic Invertebrates
The most likely benthic invertebrates in the diked salt marsh are chironomid fly larvae, and possibly oligochaete worms (*Paranaïs* sp.) and water boatman, a typical species assemblage for areas in Elkhorn slough with very restricted tidal input (Oliver et al. 2009). The brackish water snail, *Tryonia imitator*, tends to occur in very restricted wetland habitats that do not dry out; however, one was found in a more flushed wetland in Parsons Slough (Oliver et al. 2009). It is possible that the brackish water snail is in the project site.

4.5.4.4 Fish
Because there is no connection between Elkhorn Slough and the diked salt marsh, no estuarine fish are anticipated to be present. However, it is possible that mosquitofish (*Gambusia affinis*) could have been introduced into the area via agricultural drainage.

4.5.5 Diked Brackish Marsh/Willow Thicket
Approximately 0.7 ac of brackish marsh occurs in conjunction with the diked salt marsh. The corresponding NERRS classification for the Brackish Marsh/Willow Thicket habitat type is Palustrine Intermittent Emergent Wetland Persistent/Scrub-Shrub Wetland BLD.

4.5.5.1 Vegetation
At the upper edge of the diked salt marsh, where the levee walls are not steep and drainage pipe outflows from the adjacent agricultural field provide freshwater flow, there is a fringe of brackish/freshwater plant species. This includes a clump of willows (*Salix* sp.), cattail (*Typha* sp.), bulrush (*Schoenoplectus californicus* and *Schoenoplectus* sp.), and also an invasive plant species, pampas grass (*Cortaderia* sp.). The habitat is narrow and not well-developed.

4.5.5.2 Wildlife
The small, fringe brackish marsh/willow thicket is likely too small to provide cover for many species that typically inhabit dense riparian or brackish marsh habitats. However, the willows may be used for nesting by American robins (*Turdus migratorius*), Anna’s hummingbird (*Calypte anna*), western scrub jay (*Aphelocoma californica*), and California towhee (*Melzone crissalis*). Green herons (*Butorides virescens*) may also roost in the willows, and possibly may nest there as well. The cattails and bulrush may provide habitat to red-winged blackbirds (*Agelaius phoeniceus*), marsh wrens (*Cistothorus palustris*), common yellowthroats (*Geothlypis trichas*), and other species that commonly nest in freshwater marsh habitats. Terrestrial mammals like raccoons (*Procyon lotor*) and gray fox (*Urocyon cinereoargenteus*) may take cover and forage in this habitat as well.
4.5.5.3 Benthic Invertebrates

The most likely benthic invertebrates in the coastal brackish marsh/willow thicket are chironomid fly larvae, and possibly oligochaete worms (*Parana*is sp.) and water boatman, a typical species assemblage for areas in Elkhorn slough with very restricted tidal input (Oliver et al. 2009). The brackish water snail, *Tryonia imitator*, tends to occur in habitats that do not dry out, with restricted flows/tidal flushing; however, one was found in a more flushed wetland in Parsons Slough (Oliver et al. 2009); it is unlikely that the brackish water snail is in the project site.

4.5.5.4 Fish

Because there is no connection between Elkhorn Slough and the diked brackish marsh, no estuarine fish are anticipated to be present. However, it is possible that mosquitofish (*Gambusia affinis*) could have been introduced into the area via agricultural drainage.

4.5.6 Formerly Cultivated Field/Ruderal Grassland

Nearly the entire Minhoto stockpile/ecotone restoration area is comprised of a formerly cultivated field (now fallow), with a narrow margin of ruderal grassland occurring intermittently between the field and adjacent marshlands. Soils are described as fine sandy loam; moderately deep soils that formed in material weathered from soft sandstone (NCSS-NRCS 2013). The stockpile site is zoned CAP (CZ) – Coast Agriculture Preserve, Coastal Zone. In addition to the stockpile site, the levee surrounding the diked salt marsh is vegetated by ruderal grassland interspersed with occasional coyote brush. The corresponding NERRS classification for the Cultivated Field/Ruderal Grassland habitat type is Upland Inland Herbaceous Upland Grassland.

4.5.6.1 Vegetation

The cultivated field was under continuous agricultural production between the 1930s and 2009, at which time ESNERR acquired the property. Since acquisition, this site has been managed with the intent of using it as a soil stockpile area in conjunction with the restoration of adjacent marshlands and associated ecotone. The site has been seeded annually with sterile annual barley (*Hordeum vulgare*) as an erosion protection measure, and weeds have been controlled as needed by disking (Woolfolk personal communication 2013).

Before the cultivated field was fallowed, the area between the marsh and the crops was a road. In 2008, the road was decommissioned, disked, and planted in barley. In many places now, the field directly abuts the salt marsh. In a few areas there is a narrow fringe of ruderal grassland species including poison hemlock (*Conium maculatum*), annual grasses, and mallow (*Malva* sp.), as commonly occurs adjacent to agricultural lands in the Elkhorn Slough watershed (Wasson and Woolfolk 2011, A. Woolfolk, personal communication 2013). Within this ruderal grassland margin, the native shrub coyote brush (*Baccharis pilularis*) occurs at the north end of the stockpile site and a single small live oak tree (*Quercus agrifolia*) occurs at the south end.
4.5.6.2 Wildlife
The annual barley in the stockpile/ecotone restoration area has relatively low habitat value for wildlife species. The field is likely used for foraging by blackbirds, sparrows, finches and other birds that forage on seeds in open habitats. Western meadowlarks (Sturnella neglecta) and savannah sparrows (Passerculus sandwichensis) may nest in the barley if allowed to grow to sufficient height such that it provides cover and nesting substrate. Canada geese (Branta canadensis) likely use the field for roosting and foraging. Because the field has been tilled regularly, small mammals are likely present in low numbers, and thus raptors are less likely to forage over the site compared to nearby marsh and untilled upland areas, although they may forage there occasionally. Northern harriers are unlikely to nest in this habitat compared to other sites with taller, denser vegetation that would provide nesting cover. Small clusters of California ground squirrels (Otospermophilus beecheyi) are present in the periphery of the field and they may be preyed on by gray foxes or other predators. Western burrowing owls (Athene cunicularia hypugaea) are uncommon in the Elkhorn Slough area but they could potentially forage in the stockpile site and occupy ground squirrel burrows. The field margins where coyote brush occurs could be used by white-crowned sparrows (Zonotrichia leucophrys) and other bird species that inhabit brushy areas.

4.5.7 Eucalyptus Grove
A grove of eucalyptus and Monterey pine on the south side of the Seal Bend Restoration Area provides habitat for several sensitive wildlife species. Therefore, we provide a brief summary of the characteristics of this habitat here, although it is located outside of the project boundary (Figure 1). This grove has supported a rookery of great blue herons (Ardea herodias) and great egrets (Ardea alba). The eucalyptus trees also provide potential wintering roost sites for monarch butterflies (Danaus plexippus) and nest sites for raptors, such as red-tailed hawks (Buteo jamaicensis). Although not within the project boundary, this grove supports sensitive wildlife species that may be subject to noise and other disturbance associated with restoration activities in the Seal Bend Restoration Area, and indirect impacts to this area will be considered in the impact assessment for the project.

4.6 Special-status Plant and Animal Species
For purposes of this assessment, “special-status species” include plants and animals listed, proposed for listing, or candidates for listing as threatened or endangered under the Federal Endangered Species Act (FESA) or the California Endangered Species Act (CESA); animals listed as “fully protected” under the California Fish and Wildlife Code (Section 3511); animals designated as “Species of Special Concern” by the CDFW; and plants ranked as rare or endangered by the CNPS. An overview of special-status species regulations is provided in Appendix D.

The potential for the site to support special-status plant and wildlife species is discussed below. In addition to site reconnaissance surveys, background information was gathered to determine the potential for special-status species to occur on the project site. The information reviewed included the following:

- The California Natural Diversity Database (CNDDB 2013)
• The CNPS’s Online Inventory of Rare and Endangered Vascular Plants of California (CNPS 2013)
• The Jepson Manual (Baldwin et al. 2012)
• Changes in a California Estuary: A profile of Elkhorn Slough (Caffrey et al. 2002)
• Numerous reports in the Elkhorn Slough Technical Report Series (found at: http://www.elkhornslough.org/research/bibliography_tr.htm)
• Environmental documentation associated with the nearby Parson Slough Project, including the Final Initial Study and Mitigated Negative Declaration for the Parsons Slough Project (Vinnedge 2010)
• Personal communication with individuals, including ESNERR staff, having expertise on local habitats and special-status species

4.6.1 Special-status Plant Species and Sensitive Habitats
The following section describes special-status plant species and sensitive habitats onsite.

4.6.1.1 Special-status Plant Species
The search area defined for CNDDB (2013) and CNPS (2013) queries included the 7.5-ft topographical quadrangles in which the project site is located (Moss Landing and Prunedale), plus 5 adjacent quadrangles containing similar habitats as found on the project site (Soquel, Watsonville West, Watsonville East, Salinas, and Marina). With one additional species added from ESNERR (2006), the resulting list included 93 special-status plants occurring in the region that were evaluated for their potential to occur at the project site. Special-status plant species occurring within a 5-mi radius of the site are shown in Figure 16 (CNDDB 2013).

Many of the special-status plants that occur in the project region are associated with habitat types or soil types that did not occur on the project site historically or no longer occur on the project site due to the extensive land disturbance associated with agricultural use and hydrologic alterations at the site. Habitat types that are absent from the project site include but are not limited to: chaparral, and cismontane woodland or other forested habitat. Absent soil types include serpentine soils, gypsum, shale, and sandy dune soils. Additionally, some plant species only occur at higher elevations than the project site and/or have highly endemic ranges centered in specific areas that do not include the project site. The cultivated field/ruderal grassland at the Minhoto stockpile/ecotone restoration site is considered too disturbed/degraded to support rare plants. The few upland areas of the project site that are not cultivated annually are vegetated by tall weedy species such as poison hemlock; this tall overstory inhibits growth of the lower-statured native species (Woolfolk, personal communication 2013). The densely vegetated, ruderal grassland with coyote brush that occurs along the perimeter levee of the diked marsh is also not expected to be suitable habitat for any of the species considered. The conclusion of this assessment is that none of the 93 special-status plant species considered for occurrence within the project site are likely to occur there, as indicated in Appendix E.

4.6.1.2 Sensitive Habitats
**Tidal Wetlands.** Several sensitive habitat types are present either on-site or near the site. The *Sarcocornia pacifica* alliance is listed as a sensitive natural community by CDFW (2010), with a
global/state conservation status rank of G4 S3 (apparently secure globally, vulnerable at state level). While CNDDDB has adopted the MCV alliance-based classification for natural communities; element occurrence reports continue to include Holland (1986) natural community nomenclature. The CNDDB Element Occurrence Report generated for this project assessment includes the occurrence of Northern Coastal Salt Marsh at Elkhorn Slough as a significant occurrence of this sensitive habitat type, with a rank of G3 S3.2 (vulnerable at global and state levels) (CNDDB 2013, Figure 16). Elkhorn Slough supports one of the largest tracts of salt marsh in California outside of San Francisco Bay, and the pickleweed-dominated marshes that characterize the estuary are recognized as having significant ecological value (Woolfolk and Labadie 2012). Salt marsh habitat occurring at the project site in its current state has a lower functional capacity and lower biodiversity than other salt marshes in the estuary that have never been diked. Moreover, wetlands are considered environmentally sensitive habitat areas (ESHA) under the California Coastal Act.

**Elgrass.** Elgrass beds are considered essential fish habitat under the Magnuson-Stevens Act and environmentally sensitive habitat areas under the California Coastal Act. Seagrass meadows are one of the most productive habitats in the world. Seagrass meadows enhance biodiversity, providing nursery and feeding areas for many species of fish, shellfish, birds, and mammals. Seagrasses act as ecosystem engineers by reducing flow velocities, filtering sediment out of the water column and preventing sediment resuspension, attenuating waves, and buffering the nearshore environment from the effects of storms (van der Heide et al. 2011). Seagrass meadows cycle nutrients, serving as sinks for organic carbon and also exporting organic carbon to adjacent ecosystems (Mateo et al. 2006). Seagrass meadows worldwide are threatened by shoreline development, erosion, eutrophication, and global climate change. Shoreline development and increased wave action and storms increase sedimentation and turbidity, both of which cause greater light attenuation in the water column (Moore et al. 1997, Kirk 1994). Eutrophication may reduce water clarity by triggering increased phytoplankton abundance or decrease seagrass photosynthesis by increasing epiphyte loading on leaves (Ralph et al. 2006). In the past few decades, seagrass meadows have declined worldwide, and the pace of decline is increasing (Hammerstrom and Grant 2012).

Light availability and erosion are major factors controlling eelgrass distribution and density in Elkhorn Slough. Light availability is a function of water depth and is affected by factors such as turbidity and eutrophication. In Elkhorn Slough, eelgrass growth is generally limited to a maximum depth of approximately 6.5 ft below MLLW (Palacios 2010, Hammerstrom and Grant 2012). Eelgrass at Elkhorn Slough exhibits a high ratio of above to belowground biomass (AG/BG ratio), meaning that eelgrass is allocating more energy into production of photosynthetic tissue, presumably as a result of light limitation. This high AG/BG ratio appears to be consistent over time and is without evident seasonal variation (Hammerstrom and Grant 2012). Impacts to water clarity that significantly affect light availability could result in even higher AG/BG ratios and the potential that eelgrass may not be able to produce enough belowground rhizome material to withstand the currents in Elkhorn Slough (Hammerstrom and Grant 2012). Hammerstrom and Grant (2012) recommend research including a series of light surveys to measure photosynthetically active radiation (PAR), which would provide a better understanding of habitat characteristics and limiting factors for eelgrass in Elkhorn Slough.
At Seal Bend, most eelgrass occurs just slightly below MLLW, while at a nearby downstream site called Vierra, eelgrass grows to depths of 3.3 to 6.5 ft below MLLW, with the difference likely attributable to both light availability and erosion processes. Water clarity tends to be higher at the Vierra eelgrass bed than at the Seal Bend bed, likely due to the closer proximity to Monterey Bay and the clear water delivered to Elkhorn Slough with each incoming tide. Also, sediment grain size is larger at Vierra and therefore sediment is less likely to be resuspended and contribute to turbidity (Hammerstrom and Grant 2012). Moreover, there is active erosion of sediment on the channel-ward edges of the main eelgrass bed at Seal Bend, with a sharp-drop off at the edge of the bed in about 3 ft below MLLW, which leaves exposed rhizomes extending out into the water column where the sediment has eroded out from under the root-rhizome matrix. This steep bathymetry appears to be a limiting factor to eelgrass expansion further into the channel (Hammerstrom and Grant 2012).

### 4.6.2 Special-status Animal Species

On 18 February 2013, H. T. Harvey & Associates wildlife ecologists Ron Duke, Scott Demers, and fish ecologist Neil Kalson conducted a reconnaissance-level field survey for special-status animal species and their habitat associates on the project site. The survey method involved hiking the survey area, focusing on areas that may provide habitat for special-status species.

Prior to the site visit, the CNDDB was queried for special-status wildlife species occurring within the USGS 7.5 minute Moss Landing Quadrangle in which the project is located and within the adjacent quadrangles surrounding the project site: Soquel, Watsonville West, Watsonville East, Prunedale, Salinas, and Marina Quadrangles (CNDDB 2013). Special-status animal species occurring within a 5-mi radius of the project site are shown in Figure 17 (CNDDB 2013). In addition, we reviewed the results of previous surveys and biological studies conducted by numerous researchers and environmental planners, including the Final Initial Study and Mitigated Negative Declaration for the Parsons Slough Project (Vinnedge 2010), reports in the Elkhorn Slough Technical Report Series (found at: [http://www.elkhornsloough.org/research/bibliography_tr.htm](http://www.elkhornsloough.org/research/bibliography_tr.htm)), and other reports related to the Elkhorn Slough area. The legal status and likelihood of occurrence of these species is presented in Table 6.

The following is a list of the special-status animal species, judged to be absent because the site is outside of the known range, for which habitat at the site is not suitable, or recent records are lacking in the site vicinity. The list includes Ohlone tiger beetle (*Cicindela ohiolone*), Smith’s blue butterfly (*Euphilotes enoptes smithi*), Zayante band-winged grasshopper (*Trimerotropis infantilis*), black legless lizard (*Anniella pulchra pulchra*), coast horned lizard (*Phrynosoma blainvillii*), silvery legless lizard (*Anniella pulchra nigra*), western pond turtle (*Clemmys marmorata*), California tiger salamander (*Ambystoma californiense*), Santa Cruz long-toed salamander (*Ambystoma macrodactylum croceum*), bank swallow (*Riparia riparia*), California black rail (*Laterallus jamaicensis coturniculus*), California clapper rail (*Rallus longirostris obsoletus*), American badger (*Taxidea taxus*), and Monterey ornate shrew (*Sorex ornatus salarius*).

Several special-status species may occur on the site rarely, or only as occasional foragers or dispersants, but are not expected to breed on the site, and would not likely be affected by project implementation. These species include the central California coast steelhead DPS (*Oncorhynchus mykiss*), Central Valley...
spring-run ESU (*Oncorhynchus tshawytscha*), Central Valley fall-run Chinook salmon ESU (*Oncorhynchus tshawytscha*), Sacramento River winter-run Chinook salmon ESU (*Oncorhynchus tshawytscha*), south central California coast steelhead DPS (*Oncorhynchus mykiss*), California red-legged frog (*Rana aurora draytonii*), American peregrine falcon (*Falco peregrinus anatum*), bald eagle (*Haliaeetus leucocephalus*), California least tern (*Sternula antillarum browni*), golden eagle (*Aquila chrysaetos*), tri-colored blackbird (*Agelaius tricolor*), pallid bat (*Antrozous pallidus*), Townsend’s big-eared bat (*Corynorhinus townsendii*), and western red bat (*Lasiurus blossevillii*).

Expanded discussions are provided below for the special-status animal species that could breed on the site or for which the resource agencies have expressed particular concern in the general vicinity of the site.
<table>
<thead>
<tr>
<th>Name</th>
<th>Status*</th>
<th>Habitat</th>
<th>Potential For Occurrence On Site</th>
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<tbody>
<tr>
<td><strong>Federal or State Threatened or Endangered Species</strong></td>
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<tr>
<td>Ohlone Tiger Beetle <em>Cicindela ohlone</em></td>
<td>FE</td>
<td>Coastal prairie grasslands with poorly drained clay soils.</td>
<td><strong>Absent:</strong> No suitable grasslands with clay soils present in the project site or adjacent areas.</td>
</tr>
<tr>
<td>Smith’s Blue Butterfly <em>Euphilotes enoptes smithi</em></td>
<td>FE</td>
<td>Coastal dune and sage scrub habitats.</td>
<td><strong>Absent:</strong> No suitable dune or coastal scrub habitats with larval or adult foodplants present.</td>
</tr>
<tr>
<td>Zayante Band-winged Grasshopper <em>Trimerotropis infantilis</em></td>
<td>FE</td>
<td>Open ponderosa pine forests in the “Zayante Sandhills” region of Santa Cruz County.</td>
<td><strong>Absent:</strong> No suitable ponderosa pine habitat with sandy soils present in the project site or adjacent areas.</td>
</tr>
<tr>
<td>California Red-legged Frog <em>Rana aurora draytonii</em></td>
<td>FT, CSSC</td>
<td>Streams, freshwater pools, and ponds with overhanging vegetation.</td>
<td><strong>Unlikely:</strong> No suitable freshwater habitats occur within the project site. Low probability that individuals could disperse from freshwater sites to the southwest onto uplands stockpile area during rain events.</td>
</tr>
<tr>
<td>California Tiger Salamander <em>Ambystoma californiense</em></td>
<td>FT, CSSC</td>
<td>Breeds in vernal or temporary pools in annual grasslands, or open stages of woodlands. Uses small mammal burrows for refugia during dry season.</td>
<td><strong>Absent:</strong> No suitable freshwater pools on site. Dispersal onto upland areas is not expected due to distance and intervening unsuitable habitat between the project site and nearest breeding habitat.</td>
</tr>
<tr>
<td>Santa Cruz Long-toed Salamander <em>Ambystoma macrodactylum croceum</em></td>
<td>FT, CSSC</td>
<td>Temporary pools in coastal oak woodlands, chaparral and other habitats. Uses small mammal burrows and leaf litter in upland habitats during dry season.</td>
<td><strong>Absent:</strong> No suitable freshwater pools on site. Dispersal onto upland areas is not expected due to distance and intervening unsuitable habitat between the project site and nearest breeding habitat.</td>
</tr>
<tr>
<td>Chinook Salmon – Sacramento River Winter-run ESU <em>Oncorhynchus tshawytscha</em></td>
<td>FE, SE</td>
<td>Cool streams with suitable spawning habitat and conditions allowing migration, as well as estuarine and marine habitats.</td>
<td><strong>Unlikely:</strong> Salmonids occur in coastal waters of the Monterey Bay region and individuals could occasionally stray into Elkhorn Slough. This species and other salmonids may infrequently occur into aquatic habitats within the project site for short durations but are not expected to occur regularly or for extended periods of time.</td>
</tr>
<tr>
<td>Name</td>
<td>Status*</td>
<td>Habitat</td>
<td>Potential For Occurrence On Site</td>
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<tr>
<td>Chinook Salmon – Central Valley Spring-run ESU (Oncorhynchus tshawytscha)</td>
<td>FT, ST</td>
<td>Cool streams with suitable spawning habitat and conditions allowing migration, as well as estuarine and marine habitats.</td>
<td>Unlikely: Salmonids occur in coastal waters of the Monterey Bay region and individuals could occasionally stray into Elkhorn Slough. This species and other salmonids may infrequently occur into aquatic habitats within the project site for short durations but are not expected to occur regularly or for extended periods of time.</td>
</tr>
<tr>
<td>Coho Salmon - Central California Coast ESU (Oncorhynchus kisutch)</td>
<td>FE, SE</td>
<td>Cool streams with suitable spawning habitat and conditions allowing migration, as well as estuarine and marine habitats.</td>
<td>Unlikely: Salmonids occur in coastal waters in the Monterey Bay region and individuals could occasionally stray into Elkhorn Slough. This species and other salmonids may infrequently occur into aquatic habitats within the project site for short durations but are not expected to occur regularly or for extended periods of time.</td>
</tr>
<tr>
<td>North American Green Sturgeon – Southern DPS (Acipenser medirostris)</td>
<td>FT, CSSC</td>
<td>Spawn in freshwater tributaries of the Sacramento River and river systems farther north, forage in riverine, estuarine, and marine habitats.</td>
<td>Unlikely: Green sturgeon may occasionally occur in Elkhorn Slough as a forager, although they are less likely to use the smaller channels within the project site.</td>
</tr>
<tr>
<td>Steelhead – Central California Coast DPS (Oncorhynchus mykiss)</td>
<td>FT</td>
<td>Cool streams with suitable spawning habitat and conditions allowing migration, as well as estuarine and marine habitats.</td>
<td>Unlikely: Salmonids occur in coastal waters in the Monterey Bay region and individuals could occasionally stray into Elkhorn Slough. This species and other salmonids may infrequently occur into aquatic habitats within the project site for short durations but are not expected to occur regularly or for extended periods of time.</td>
</tr>
<tr>
<td>Name</td>
<td>Status*</td>
<td>Habitat</td>
<td>Potential For Occurrence On Site</td>
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<tr>
<td><strong>Steelhead</strong> – South Central California</td>
<td>FT, CSSC</td>
<td>Cool streams with suitable spawning habitat</td>
<td>Unlikely: Salmonids occur in streams and coastal waters in the Monterey Bay region and individuals could occasionally stray into Elkhorn Slough. This species and other salmonids may infrequently occur into aquatic habitats within the project site for short durations but are not expected to occur regularly or for extended periods of time. South Central California Coast steelhead occur in Gabilan Creek (Bougton et al. 2006), which is connected to Moss Landing Harbor via Tembladero Slough and the Old Salinas River Channel and thus individuals of this run may occur in the vicinity of Elkhorn Slough more frequently than those of other runs.</td>
</tr>
<tr>
<td>Coast DPS <em>(Oncorhynchus mykiss)</em></td>
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<td>and conditions allowing migration, as well as estuarine and marine habitats.</td>
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<tr>
<td><strong>Tidewater Goby</strong> <em>(Eucyclogobius newberryi)</em></td>
<td>FE</td>
<td>Shallow coastal bar-built lagoons and lower estuaries with minimal tidal flushing but high oxygen levels.</td>
<td>Possible: Tidewater gobies are known to occur in Moro Cojo Slough to the south and Struve Pond to the north of Elkhorn Slough, but are not known to occur in Elkhorn Slough due to high tidal flows. However, this species may occasionally disperse into Elkhorn Slough and the smaller channels in the project site in search of suitable habitat. Also, restoration activities that reduce tidal prism may facilitate occupation of Elkhorn Slough habitats by this species.</td>
</tr>
<tr>
<td><strong>Bald eagle</strong> <em>(Haliaeetus leucocephalus)</em></td>
<td>DL, SE, SP, BEGEPA</td>
<td>Occurs mainly along seacoasts, rivers and lakes; nests in tall trees or in cliffs. Feeds mostly on fish.</td>
<td>Possible: Occasional forager in aquatic habits within and adjacent to the project site. No suitable breeding habitat on the project site.</td>
</tr>
<tr>
<td><strong>Bank Swallow</strong> <em>(Riparia riparia)</em></td>
<td>ST</td>
<td>Nests in colonies on vertical banks or bluffs in alluvial soils adjacent to streams, rivers, lakes, and coastlines.</td>
<td>Absent: No suitable bank or bluff habitats occur within the project site or adjacent areas.</td>
</tr>
<tr>
<td>Name</td>
<td>Status*</td>
<td>Habitat</td>
<td>Potential For Occurrence On Site</td>
</tr>
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</tr>
<tr>
<td>California Black Rail</td>
<td>ST, SP</td>
<td>Breeds in fresh, brackish, and tidal salt marsh in coastal California including San Francisco Bay-Delta Estuary, as well as northwestern Baja California, lower Imperial Valley and Colorado River, and Sierra Nevada foothills.</td>
<td><strong>Absent:</strong> Not known to breed in the Elkhorn Slough area likely due to a lack of suitable marsh habitat with dense vegetation and shallow water.</td>
</tr>
<tr>
<td>California Clapper Rail</td>
<td>FE, SE, SP</td>
<td>Salt and brackish marsh habitat usually dominated by pickleweed and cordgrass.</td>
<td><strong>Absent:</strong> Extirpated from Elkhorn Slough. Currently restricted to San Francisco Bay estuary.</td>
</tr>
<tr>
<td>California Least Tern</td>
<td>FE, SE, SP</td>
<td>Nests along the coast on bare or sparsely vegetated flat substrates.</td>
<td><strong>Possible:</strong> Occasional forager in aquatic habitats within the project site during migration. No breeding habitat on site.</td>
</tr>
<tr>
<td>Western Snowy Plover</td>
<td>FT, CSSC</td>
<td>Nests on sandy beaches and salt pan habitats.</td>
<td><strong>Possible:</strong> No salt pan or sandy beach habitat occurs on the project site. Nests in the former salt pond complex to the north and on coastal beaches to the west. May occasionally forage in intertidal areas in the project site.</td>
</tr>
<tr>
<td>Southern Sea Otter</td>
<td>FT, MMPA, SP</td>
<td>Inhabits nearshore waters along the California coastline from San Mateo County to Santa Barbara County. Uses both rocky and soft bottom areas for foraging on a variety of marine invertebrates.</td>
<td><strong>Present:</strong> Southern sea otters occur regularly in Elkhorn Slough for foraging, resting, socializing, and pupping. Foraging, rafting, and pupping locations are generally down-slosh near Seal Bend, in areas with full tidal exchange (Maldini et al. 2010). Sea otters may occasionally forage or rest in some of the deeper channels on the project site and they may haul-out on pickleweed areas adjacent to the slough.</td>
</tr>
</tbody>
</table>

**California Species of Special Concern**

<table>
<thead>
<tr>
<th>Name</th>
<th>Status*</th>
<th>Habitat</th>
<th>Potential For Occurrence On Site</th>
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</thead>
<tbody>
<tr>
<td>Black Legless Lizard</td>
<td>CSSC</td>
<td>Sandy dunes and habitats with moist sandy soils dominated by bush lupine and mock heather.</td>
<td><strong>Absent:</strong> No suitable sandy habitats occur within the project site or adjacent areas.</td>
</tr>
<tr>
<td>Coast Horned Lizard</td>
<td>CSSC</td>
<td>Sandy washes and other open habitats with bushes for cover and loose soils with abundant insects for prey.</td>
<td><strong>Absent:</strong> No suitable habitats with sandy or loose soils occur within the project site or adjacent areas.</td>
</tr>
<tr>
<td>Name</td>
<td>Status*</td>
<td>Habitat</td>
<td>Potential For Occurrence On Site</td>
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</table>
| Silvery Legless Lizard  
(*Anniella pulchra nigra*) | CSSC | Chaparral and other habitats with sparse vegetation and sandy or loose loamy soils. | **Absent**: No suitable sandy habitat occurs within the project site or adjacent areas. |
| Western Pond Turtle  
(*Clemmys marmorata*) | CSSC | Permanent or nearly permanent fresh or brackish water in a variety of habitats. | **Absent**: No suitable permanent or nearly permanent fresh or brackish water occurs on the project site. The aquatic habitat on site consists of tidal salt water. Not expected to disperse across the site. |
| Chinook Salmon –  
Fall-run Central Valley ESU  
(*Oncorhynchus tshawytscha*) | CSSC | Cool rivers and large streams that reach the ocean and that have shallow, partly shaded pools, riffles, and runs. | **Unlikely**: Salmonids occur in coastal waters in the Monterey Bay region and individuals could occasionally stray into Elkhorn Slough. This species and other salmonids may infrequently occur into aquatic habitats within the project site for short durations but are not expected to occur regularly or for extended periods of time. |
| Loggerhead Shrike  
(*Lanius ludovicianus*) | CSSC | Nests in dense shrubs and trees, forages in grasslands, marshes, and ruderal habitats. | **Possible**: Occasional forager in tidal marshes and upland habitats within project site and adjacent upland areas, particularly during the non-breeding season. Could potentially breed in adjacent areas with suitable nesting trees and shrubs, but not likely to breed in the vicinity. |
| Northern Harrier  
(*Circus cyaneus*) | CSSC | Nests and forages in marshes, grasslands, and ruderal habitats. | **Likely**: Occasional forager in tidal marshes in the project site and adjacent upland areas and likely breeds in Elkhorn Slough. Unlikely to breed in the low-elevation tidal marshes within the project site, the annual barley crop, or other low-quality upland habitats in the stockpile area. |
| Short-eared Owl  
(*Asio flammeus*) | CSSC | Nests on ground in tall emergent vegetation or grasses, forages over a variety of open habitats. | **Possible**: Occasional forager in tidal marshes within project site and adjacent upland areas. Unlikely to breed in the low-elevation tidal marshes within the project site, and not likely to breed in the annual barley crop or other low-quality upland habitats in the stockpile area. |
<table>
<thead>
<tr>
<th>Name</th>
<th>Status*</th>
<th>Habitat</th>
<th>Potential For Occurrence On Site</th>
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</thead>
<tbody>
<tr>
<td>Tricolored Blackbird ((Agelaius tricolor))</td>
<td>CSSC</td>
<td>Breeds near freshwater in dense emergent vegetation.</td>
<td>Possible: No suitable freshwater habitat on site but may occur as occasional visitor.</td>
</tr>
<tr>
<td>Western Burrowing Owl ((Athene cunicularia hypugaea))</td>
<td>CSSC</td>
<td>Flat grasslands and ruderal habitats with low vegetation and suitable burrows.</td>
<td>Possible: Occasional forager in tidal marshes within the project site and adjacent upland areas. A low number of California ground squirrel burrows used for breeding and roosting were observed in the stockpile area and there is potential for the site to become occupied by burrowing owls.</td>
</tr>
<tr>
<td>American Badger ((Taxidea taxus))</td>
<td>CSSC</td>
<td>Grasslands, savannas, deserts and other open habitats with friable soils for excavating dens and abundant prey, including fossorial mammals.</td>
<td>Absent: No suitable open areas with friable soils occur on the project site or adjacent areas.</td>
</tr>
<tr>
<td>Monterey Ornate Shrew ((Sorex ornatus salarius))</td>
<td>CSSC</td>
<td>Moist riparian woodland habitats with dense vegetation, duff, or downed logs.</td>
<td>Absent: Suitable densely vegetated habitats do not occur on site.</td>
</tr>
<tr>
<td>Pallid Bat ((Antrozous pallidus))</td>
<td>CSSC</td>
<td>Forages over many habitats; roosts in buildings, rocky outcrops and rocky crevices in mines and caves.</td>
<td>Unlikely: May occasionally forage over the project site. No suitable roosting habitat on the project site or in adjacent areas.</td>
</tr>
<tr>
<td>Townsend’s Big-eared Bat ((Corynorhinus townsendii))</td>
<td>CSSC</td>
<td>Forages in a variety of habitats; roosts in caves and artificial structures.</td>
<td>Possible: May occasionally forage over the project site. No suitable roosting habitat on the project site; may roost on artificial structures in the project vicinity, including bridges.</td>
</tr>
<tr>
<td>Western Red Bat ((Lasiurus blasaevillii))</td>
<td>CSSC</td>
<td>Migratory species that typically breeds in old growth riverine habitats such as areas in the Central Valley. Solitary and roosts in the foliage of deciduous trees in riparian areas and sometimes orchards.</td>
<td>Unlikely: May occur as an occasional forager over the project site, but unlikely to roost on or adjacent to the site due to the absence of suitable roost sites.</td>
</tr>
</tbody>
</table>

**State Protected Species**
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<thead>
<tr>
<th>Name</th>
<th>Status*</th>
<th>Habitat</th>
<th>Potential For Occurrence On Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Peregrine Falcon</td>
<td>DL, SP</td>
<td>Forages in many habitats; nests on cliffs and similar human-made structures.</td>
<td>Possible: Occasional forager (on other birds) in the project site, primarily during migration and winter. Does not currently breed in the project site.</td>
</tr>
<tr>
<td><em>(Falco peregrinus anatum)</em></td>
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<tr>
<td>California Brown Pelican</td>
<td>DL, SP</td>
<td>Occurs in nearshore marine habitats and coastal bays. Nests on islands in Mexico and southern California.</td>
<td>Present: Known to roost in Elkhorn Slough; no breeding habitat on site. May occasionally use channels within the Project site.</td>
</tr>
<tr>
<td><em>(Pelecanus occidentalis californicus)</em></td>
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<tr>
<td>Golden Eagle</td>
<td>SP, 3EGEPA</td>
<td>Grasslands, deserts, and other open habitats with abundance of suitable prey species.</td>
<td>Unlikely: May occur as an occasional forager over marshes, the stockpile area, and adjacent upland areas. No suitable breeding habitat occurs in the project site.</td>
</tr>
<tr>
<td><em>(Aquila chrysaetos)</em></td>
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<tr>
<td>White-tailed Kite</td>
<td>SP</td>
<td>Nests in tall shrubs and trees, forages in grasslands, marshes, and ruderal habitats.</td>
<td>Possible: No suitable nesting habitat on the project site. May occasionally forage in marsh habitats on the project site or in adjacent upland habitats.</td>
</tr>
<tr>
<td><em>(Elanus leucurus)</em></td>
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<tr>
<td><strong>Species Protected by the Marine Mammal Protection Act</strong></td>
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</tr>
<tr>
<td>Harbor Seal</td>
<td>MMPA</td>
<td>Coastal waters, river mouths, estuaries, and lagoons along the Pacific Coast, typically in areas with sheltered areas that can provide haul-out areas.</td>
<td>Present: Harbor seals inhabit Elkhorn Slough year-round. Harbor seals may periodically forage near the mouth of the slough, but they typically forage offshore. There are numerous haul-out sites in the Elkhorn Slough area, including Seal Bend, Seal Point (across from Seal Bend), near the entrance to Parsons Slough, and within Parsons Slough and in tidal creeks within the Parsons Slough complex (McCarthy 2010).</td>
</tr>
<tr>
<td><em>(Phoca vitulina richardi)</em></td>
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</table>
Special-status Species Code Designations

FE = Federally listed Endangered
FT = Federally listed Threatened
SE = State listed Endangered
DL = Delisted
CSSC = California Species of Special Concern
SP = State Protected Species
BEGEPA = Bald Eagle Golden Eagle Protection Act
MMPA = Marine Mammal Protection Act

Definitions Regarding Potential Occurrence

Present: Observed on or very close proximity to the project site
Likely: Reasonably certain to occur on the site
Possible: Conditions suitable for occurrence, at least as occasional visitor
Unlikely: Conditions marginal for occurrence
Absent: Conditions unsuitable for occurrence
Tidewater Goby (*Eucyclogobius newberryi*); Federal Listing Status-Endangered; State Listing Status-None. The species was federally listed as endangered in 1994 (USFWS 1994). Critical habitat was designated in 2000, revised in 2008 (USFWS 2008), and further revised in 2013 (USFWS 2013). The current range of the species extends from Tillas Slough near the Oregon border to Cockleburrr Canyon in San Diego County. This species inhabits coastal lagoons, estuaries, and marshes during all its life stages and is rarely found in marine environments, except during breaching or storm events when individuals are flushed out to sea (USFWS 1994). This species usually selects areas within upper estuaries within the freshwater and saltwater interface but can range short distances into freshwater (USFWS 2005). Tidewater gobies are typically found in shallow (<3 ft) water and prefer sandy substrates for breeding but can be found on rocky or soft substrates as well (USFWS 2005). Tidewater gobies feed on small animals, including mysid shrimp, amphipods, and aquatic insects (Moyle 2002). This species is typically an annual species although some individuals may live longer than a year (Moyle 2002). Reproduction occurs year-round, with peaks in spawning occurring in late spring and late summer (Swenson 1999, USFWS 2005). Female gobies can lay 6 to 12 clutches per year; male gobies guard the eggs that are attached to sand grains within burrows (Swenson 1999). Tidewater gobies formerly inhabited 134 locations but have been extirpated at 23 of those sites, and between 55 and 70 of the locations have become degraded or are small enough that the long-term inhabitance of this species is uncertain (USFWS 2005).

In the Elkhorn Slough area, tidewater gobies occur in Bennett Slough, which is considered critical habitat for the species (USFWS 2013), to the north of Elkhorn Slough. They are also known to occur in the Moro Cojo Slough system to the south of Elkhorn Slough. Tidewater gobies are likely absent from the Elkhorn Slough system due to high tidal flows; however, this species may enter the system as occasional dispersants. Reduced tidal flows in tidal channels due to restoration activities may facilitate colonization of tidewater gobies in the project site.

North American Green Sturgeon Southern Distinct Population Segment (*Acipenser medirostris*); Federal Listing Status- Threatened; State Listing Status- Species of Special Concern. There are two distinct population segments (DPSs) of the North American green sturgeon, the Northern and Southern DPS. They are distinguished only by their spawning locations; otherwise they are identical and their ranges overlap (Adams et al. 2002; USFWS 2006; USFWS 2009). The Northern DPS breeds north of the Eel River and is not listed as threatened or endangered, and the Southern DPS breeds only in the Sacramento River and was federally listed as threatened in 2006 (USFWS 2006). Threats to green sturgeon include loss of spawning habitat, degradation of water quality, fisheries harvest, and poaching. Green sturgeon is a long-lived (up to 70 years), anadromous fish species that occurs along the Eastern Pacific Coast from the Bering Sea south to Ensenada, Mexico. They spend most of their lives in coastal marine waters, coastal bays, and estuaries along the Pacific coast, and Monterey Bay provides habitat for adults and sub-adults (Huff et al. 2012). Juveniles inhabit bays and estuaries for 1 to 4 years before traveling to the ocean. They spend about 15 years at sea before returning to spawn in their natal freshwater habitat, and spawn every 2 to 4 years thereafter (Moyle 2002). They spend summers in coastal waters up to 360 ft deep along California, Oregon, and Washington, migrate north in the fall to as far as southeast Alaska, and then return in the spring (Erickson and Hightower 2007; Lindley et al.)
2008). They occur on the bottom, although they can forage throughout the water column, feeding on benthic invertebrates and small fishes.

Green sturgeon have not been documented within Elkhorn Slough (Brown 2002), and although unlikely, the species could enter the Elkhorn Slough system to forage.

**California Brown Pelican (Pelecanus occidentalis); Federal Listing Status- Delisted ;State Listing Status- State Protected Species.** Pelican populations were decimated by the effects of DDT, and while the species began to recover after the chemical was banned in 1972, the California population remained threatened by other environmental contaminants, habitat loss, and human disturbance, to which they are extremely sensitive (Jacques et al. 1996, Shields 2002). The species was listed as endangered both under FESA and CESA until 2009 when the California brown pelican population was determined to have sufficiently recovered to be delisted by both the federal (74 FR 59443) and state agencies (Fish and Game Commission 2009). The California brown pelican ranges from the San Francisco bay area to Baja California. Established breeding colonies occur on West Anacapa Island, Santa Barbara Island, and at the Salton Sea; communal winter roosts occur throughout the range (Shields 2002). Pelicans are highly gregarious in all seasons, forming large communal winter roosts from which they range up to 47 mi to forage (Shields 2002). Preferred winter roost sites are comprised of estuaries, sand bars, spits, or beaches that are close to aquatic foraging grounds, allow the birds to dry off after foraging, and offer shelter from predators and the elements (Jacques et al. 1996, Shields 2002). Sites that are completely or almost completely surround by water are required for night roosts, to maximize protection from predators (Jacques et al. 1996). Pelicans forage in relatively warm brackish and ocean waters where fish are close enough to the surface to be captured by plunge-diving birds (Shields 2002).

Brown pelicans use Elkhorn Slough for roosting in open water habitats and on steep banks of the lower portions of the slough during post-breeding (i.e., July – August). This species may occasionally roost in the project site in aquatic habitats.

**Western Snowy Plover (Charadrius nivosus nivosus); Federal Listing Status- Threatened ;State Listing Status- Species of Special Concern.** The Pacific Coast population of the snowy plover (i.e., “western snowy plover”) was federally listed as a threatened species in 1993 (58 FR 12864) because of a decline in the breeding population, loss of breeding habitat, and increased depredation by non-native predators. The listed western snowy plover was recognized at the time as *Charadrius alexandrinus nivosus*, which was considered a subspecies of the Eurasian Kentish plover (*Charadrius alexandrinus*). In 2009, the American Ornithologist’s Union (AOU) received, and later accepted, a proposal to change the scientific name of the snowy plover that occurs in the Americas to *Charadrius nivosus*, with 3 subspecies including *C. nivosus nivosus* (occurring in the United States and parts of Mexico), *C. nivosus tenuirostris* (occurring in Cuba, Puerto Rico, the Caribbean, and Yucatan Peninsula), and *C. nivosus occidentalis* (occurring in South America). The USFWS accepted the AOU change in taxonomic nomenclature and now recognizes the western snowy plover as *C. nivosus nivosus* (USFWS 2012). The snowy plover is a small pale shorebird that nests on beaches and salt pans in western North America. Snowy plovers nest on barren to sparsely vegetated beaches, salt flats, dredge spoils, levees, river bars, and salt evaporation ponds (Page et al. 1995). The western snowy plover nests along the Pacific Coast from Damon Point,
Washington to Bahia Magdalena, Baja California, Mexico (USFWS 2007). Snowy plovers that nest in inland areas are not considered part of the Pacific coast population, although interior-nesting plovers will winter along the Pacific coasts. Snowy plovers consume flies, beetles, crabs, polychaete worms, amphipods, sand hoppers, moths, grasshoppers, small crustaceans, mollusks, and plant seeds (Page et al. 1995). They forage by pursuing their prey on foot, picking from the surface or probing in sand and loose soils, and will charge dense aggregations of flies, snapping their bill at those flushed (Purdue 1976, Page et al. 1995). Window surveys along the Pacific Coast indicate that the numbers of breeding snowy plovers have ranged from a low of 976 in 2000 to a high of 1,904 in 2004; in 2006 1,723 plovers were counted along the Pacific Coast (USFWS 2007).

Western snowy plovers nest on the sandy beaches near Moss Landing Harbor and in the former salt pond on the north side of the slough. Western snowy plovers are not expected to breed on the project site due to a lack of suitable sandy or salt pan areas but they may occur as an occasional forager on tidal flats.

**Southern Sea Otter (Enhydra lutris nereis) Federal Listing Status- Threatened and Protected by Marine Mammal Protection Act; State Listing Status- Protected Species.** The species was federally listed as threatened in 1977 (USFWS 1977). It also is designated as a fully protected species by California. No critical habitat has been designated for the species. The northern California coast historically was home to large numbers of southern sea otters, but they were nearly extirpated from the region by fur hunters in the 1700s and 1800s. A small population of approximately 50 individuals was discovered along the Big Sur coast; the species was subsequently protected and the population has gradually increased, although a lack of genetic diversity is a concern for the species’ recovery. The current population size is estimated at 2,800 individuals (Carretta et al. 2009). The range of the southern sea otter currently extends from just south of San Francisco Bay to just south of Point Conception, Santa Barbara County (Carretta et al. 2009). A small translocated population remains near San Nicholas Island off southern California. Sea otters forage on sea urchin and abalone in rocky areas and burrowing infauna like the Pismo clam and butter clam is soft sediment areas (McCarthy 2010a). Sea otters use estuaries for resting, pupping, and foraging, where they rest and groom while floating on their backs either individually or in rafts. They often congregate in areas where they can anchor to eelgrass or other materials.

Sea otters frequently use Elkhorn Slough and the population in this area has reached 100 individuals after being extirpated in the early 1900’s and returning in the 1980’s (McCarthy 2010a). Sea otters rest and pup in Elkhorn Slough but also forage on snails, mussels, and crabs (McCarthy 2010a). Within the slough, otters are typically located in areas of full tidal exchange and tend to be located in the lower and middle portions of the slough, although they occur upstream in subtidal mudflats and tidal channels in Parsons Channel. Otters have been observed hauled out in pickleweed vegetation in the Parsons Slough area (Vinnedge 2010) and may use pickleweed marshes in the project site on occasion. Individuals at Moss Landing Harbor, at the mouth of Elkhorn Slough, are comprised mainly of males (ranging from juvenile to adult), whereas otters occupying the slough itself tend to consist of juvenile, sub-adult, adult females, some with pups, and small numbers of reproductive/territorial males (K. Mayers pers. comm., as cited in McCarthy 2010a). Sea otters are also known to occur in Yampah Marsh and Parsons Slough in proximity to the Minhoto/Hester’s Marsh restoration area (Eby and Scoles 2010).
Harbor Seal (*Phoca vitulina richardsi*); Federal Listing Status- Protected by Marine Mammal Protection Act; State Listing Status- None. Harbor seals are widely distributed throughout the northern Atlantic and Pacific Oceans along coastal waters, river mouths, and bays (Burns 2008; Lowry et al. 2008). Despite the species’ continuous distribution, there is significant genetic variation throughout the range, and they are divided into five subspecies, with two occurring in the Pacific Ocean (O’Corry-Crowe et al. 2003; Westlake and O’Corry-Crowe 2002). The Eastern North Pacific (ENP) subspecies ranges from Baja California, Mexico, to the Pribilof Islands, Alaska (Carretta et al. 2009; Westlake and O’Corry-Crowe 2002), and is the subspecies that occurs in the Elkhorn Slough area. Harbor seals do not undergo extensive seasonal migrations and show strong site fidelity throughout their lives. Several management stocks that differ in these characteristics are defined within the ENP subspecies, including the California stock, the Oregon/Washington coastal stock, and the inland Washington stock (Carretta et al, 2009). Aside from occasional dispersing individuals, harbor seals within the Elkhorn area are part of the California stock. In northern California, pupping peaks in June and lasts about 2 weeks; pups are weaned in 4 weeks (Burns 2008). A seasonal molt occurs in June and July, after pupping. Mating occurs in the water after weaning. The larger males defend territories near female haul-outs and return to these sites in successive years. Harbor seals consume a variety of prey, but small fishes predominate in the diet (Tallman and Sullivan 2004). Foraging occurs in a variety of habitats, from streams to bays to the open ocean, and harbor seals can dive to depths of almost 500 m (Eguchi and Harvey 2005). The primary predators of harbor seals are killer whales (Ford et al. 1998) and great white sharks (Anderson et al., 2008). The harbor seal population in California grew rapidly following the passage of the Marine Mammal Protection Act in 1972; however, growth has slowed and the population has remained relatively constant since 1990 (Carretta et al. 2009; Lowry et al. 2008). The estimated minimum population size in California waters is 31,600 seals, and it is unknown if an optimal sustainable population has been attained is unknown (Carretta et al. 2009).

Harbor seals, numbering in the hundreds, are year-round residents in Elkhorn Slough. They occur in individually or in small groups in the main channel and often haul-out on channel banks and mudflats, especially at Seal Bend (Harvey and Connors 2002). The slough is mainly used for staging, resting, and pupping, with most foraging occurring in Monterey Bay, but they occasionally forage in the slough (McCarthy 2010b). Foraging in the slough is mostly on small fish (Harvey and Connors 2002). Elkhorn Slough began to be used for breeding in 1989 after the human access to haul-out sites near Seal Bend was limited, and pupping now occurs up-sloough on various mudflats including in Rubis Creek and Parsons Slough (Harvey and Connors 2002; McCarthy 2010b). Haul-out sites have varied in the slough, with Seal Bend being the most frequented historically, and other sites being used as well, including mudflat use at Rubis Creek, the entrance to Parsons Slough, and tidal creeks within the Parsons Slough complex (McCarthy 2010b; Eby and Scoles 2010).

### 4.6.3 Special-status Bird Species

**Raptors.** The tidal marsh and upland portions of the project site represent potentially suitable habitat for several special-status raptor species, including the northern harrier (*Circus cyaneus*), short-eared owl (*Asio flammeus*), western burrowing owl (*Athene cunicularia hypugaea*), and white-tailed kite (*Elanus caeruleus*). The northern harrier nests in marshes and grasslands, usually those with tall vegetation and
moisture sufficient to inhibit accessibility of nest sites to predators. This species forages, primarily on small mammals and birds, in a variety of open grassland, ruderal, and agricultural habitats. Northern harriers may nest in the project site, although the tidal marshes are likely too low in elevation and too sparsely vegetated to support nesting by this species, and they are unlikely to nest in the upland stockpile area due to insufficient vegetation density; however they are likely to forage on the site at least occasionally.

Short-eared owls occur in open habitats such as grasslands, wet meadows, and marshes. They require tules or other tall grasses for nesting or daytime refuge. They may occur in the project site as an occasional forager but are unlikely to breed in Elkhorn Slough.

Western burrowing owls prefer annual and perennial grasslands, typically with sparse or nonexistent tree or shrub canopies. In California, burrowing owls are found in close association with California ground squirrels; owls use the burrows of ground squirrels for shelter and nesting. Burrowing owls occur infrequently in Elkhorn Slough and are unlikely to use the project site for breeding. However, there are small numbers of California ground squirrel burrows around the edges of the stockpile area and there is potential for owls to use that portion of the site.

White-tailed kites can be found in association with the herbaceous and open stages of a variety of habitat types, including open grasslands, meadows, emergent wetlands, and agricultural lands. Nests are constructed in dense stands located adjacent to foraging areas. Stick nests are often built near the top of a dense willow, oak, or other tree stands. White-tailed kites are not expected to nest on the project site due to a lack of nesting habitat although they may nest in the vicinity and forage on the site on occasion.

**Nestling Migratory Birds.** In addition to the species described above, all native non-game birds are protected under the federal Migratory Bird Treaty Act (MBTA). This protection prohibits direct take of birds and the destruction of nests or eggs. A variety of common birds, such as western meadowlarks (*Sturnella neglecta*) and savannah sparrows (*Passerculus sandwichensis*) could potentially nest within the project area, particularly in upland areas within and adjacent to the stockpile area. Although take of these relatively common species would not be considered a significant impact under the CEQA, it would be in violation of federal and state laws. Appendix D provides an overview of the MBTA.
5 Conceptual Model of Habitat Restoration

The historic record indicates that prior to European colonization, Elkhorn Slough sustained a healthy tidal marsh community (Van Dyke and Wasson 2005). As shown in Figure 18a, historic conditions likely consisted of a relatively flat marsh plain with an elevation close to the Slough’s MHHW tidal datum. However, since these historic conditions, the marsh plain has been subject to multiple stressors which have caused marsh vegetation dieback (Figure 18b).

A panel of marsh and estuarine experts convened by the ESNERR TWP reviewed Elkhorn Slough physical and biological data to assess likely causes of marsh dieback. The panel found that the increased frequency and duration of tidal inundation is a primary driver of marsh dieback (Callaway et al. 2012). Tidal marsh vegetation is adapted to a relatively narrow range of inundation characteristics; when these characteristics shift to more frequent and longer periods of inundation, the marsh plants are stressed and may even die. Increased inundation occurs in Elkhorn Slough due to an increase in tide range and decrease in marshplain elevation relative to historic conditions (Figure 18b). In combination, these two factors mean that marsh vegetation (primarily pickleweed) is subject to longer and more frequent periods of inundation.

Before European colonization, the Elkhorn Slough system (including Temblader), Moro Cojo, and Bennett Sloughs) contained broad extents of tidal marsh and mudflat habitats. Historic accounts as well as data from the late 1800s describe a system with a full (or nearly full) tidal range and a subtidal sandbar at the joint Slough-Salinas River outlet. As significant portions of the Slough were diked and drained (e.g. Parsons, Temblader, and Moro Cojo Sloughs), the tidal prism of the system significantly decreased. Around the same time, the Salinas River was diverted from the Slough. The combined effects of the decreased tidal prism and reduced riverine inflows led to the development of extensive sand shoals at the mouth, which can be seen in aerial photographs from the harbor construction period in the mid-1940s. The extensive shoaling likely muted the tides relative to their historic range, and may have also perched the tides. The effects of this shoaling were permanently reversed with the construction of the Moss Landing Harbor, which exposes the mouth of Elkhorn Slough to the full range of oceanic tides.

Widespread diking and draining of tidal marsh directly eliminated tidal marsh communities by blocking tidal flows and subjecting tidal communities to competition from upland communities. The diking and draining throughout the Slough also led to subsidence in diked areas as organic marsh peat soils oxidized. In healthy marshes, a network of marsh channels develops in equilibrium with the marsh’s tidal prism (PWA 1995). Therefore, once the subsided areas were restored to tidal action, the resulting increase in tidal prisms led to scour of tidal channels, as they adjusted to accommodate the larger tidal prisms. The increased size of these tidal channels has enabled ocean tides to propagate to their full range and even very slightly amplify along the length of the Slough. In addition to the effects of Harbor construction, the tide range within the Slough has also increased due to global sea level rise. In past

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7 Watson et al. 2011 notes that European colonization may have increased the extent of tidal marsh within the Slough through increased sedimentation driven by local land use. In other words, it’s possible that some areas of tidal marsh that were present in the Slough post-European were mudflat pre-European.
decades, the rate of sea level rise has been approximately 2 mm/yr (see Section 3.2.1), which is similar to factors affecting bed elevation, as discussed below.

In order for marshes to avoid drowning/dieback, their bed elevations must be able to keep pace with their inundation regimes. The bed elevations of tidal marshes in the Slough are influenced by multiple factors. Factors that increase bed elevation include the deposition of sediment on the marsh plain (accretion), and development of below-ground biomass from plant growth (peat generation). Factors that decrease bed elevations include the previously discussed diking and draining, erosion of marsh sediments off the marsh plain, and shallow/deep subsidence. Shallow subsidence refers to decreases in elevation due to a net loss of organic matter in the top 15 ft of the soil column. Multiple factors are thought to contribute to shallow subsidence, but the relative importance of these factors is not well understood. These factors likely include the cumulative effects of eutrophication (Deegan et al. 2012), reduced freshwater inputs, and invertebrate activity (Callaway et al. 2012). Subsidence results because these factors likely cause lowered rates of organic matter production and/or increased rates of organic matter decomposition (oxidation).

Since the sediment supply to the Slough has likely been drastically curtailed by the diversion of the Salinas River, and, to a lesser degree, by diking along the Pajaro River, the Slough has been subject to a substantial sediment deficit for many decades. As a result, there is insufficient sediment available for accretion to cause net accretion of bed elevation. Although accretion is still occurring on the marsh plain, the accretion rate of 3.9 mm/yr is countered by the shallow subsidence of 2.9 mm/yr, resulting in a slight net gain in marsh elevation of 1 mm/yr (Van Dyke 2012). This slight net gain in marsh elevation is exceeded by the rate of mean sea level rise in the past few decades of approximately 2 mm/yr. As a result, accretion has been inadequate to allow previously diked, subsided areas to establish elevations suitable for the recovery of tidal marsh. This low rate of accretion has also been inadequate to sustain tidal marsh in areas that were not previously diked and drained, as percent cover by salt marsh vegetation in these areas has declined from an average of 90% in 1931 to an average of 46% in 2003 (Van Dyke and Wasson 2005). In other words, even for areas that were not diked and drained, the combined effects of the current inundation regime, river diversions, and shallow subsidence has been enough to drive tidal marsh dieback. As a result, the already-low marsh plain continues its historic trend of a net loss of elevation relative to the tides. With the anticipated future acceleration of sea level rise, marsh viability is expected to worsen in the upcoming decades.

The proposed project is projected to reverse the trend of increasing tidal inundation and its detrimental effects on marsh vegetation by placing soil fill on the marsh plain (Figure 18c). By elevating the marsh plain, the marsh vegetation will be inundated by the tide less frequently, at shallower depths, and for shorter periods. Although the existing marsh vegetation is likely to be eliminated by fill placement, the Slough’s existing seed bank is expected to regenerate healthy marsh vegetation within several years. The decreased tidal prism from fill placement may also encourage siltation in the tidal channels, as they shrink to accommodate smaller tidal prisms. Design criteria for the placed fill, including avoiding fill in the tidal channels, will be addressed during later phases of the project.
Report Preparers
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**Personal Communication**

Fountain, M., Tidal Wetland Project Director for ESNERR. Phone call between Fountain and Michelle Orr regarding volume of sediment delivered to the restoration site from the Pajaro River Bench Excavation. November 2013.

Gentzler, S., Hydrology and Hydraulics Group Manager. Email correspondence between Gentzler, URS Corporation, and April Zohn, Lux Environmental Consulting, regarding updated tidal prism and habitat estimates (Tables 7-1 and 7-2 in DU 2010) based on revised tidal datums. March 2, 2010.

VanDyke, E., GIS Specialist. Email communication between VanDyke, ESNERR, and Christina Toms. December 2009.

Figure 1
Regional Map
Elkhorn Slough Tidal Marsh Restoration Project. D120505.00

Figure 2
Site Map
Figure 3
Excerpt from 1854 US Coast Survey T-sheet

SOURCE: US Coast and Geodetic Survey
Figure 4
August 1946 Aerial Photograph of Harbor Construction

SOURCE: US Geological Survey
Figure 5
July 1952 Aerial Photograph of Restoration Areas

SOURCE: US Geological Survey
Figure 6

Site Topography

Key
- Marsh Restoration Areas
- Minhoto Stockpile Area

Elevation
feet NAVD88
-0.4 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 3
3.1 - 4
4.1 - 5
5.1 - 6
6.1 - 8
8.1 - 10
10.1 - 12
12.1 - 18
18.1 - 24
24.1 - 30
30.1 - 36
36.1 - 42
Inland water (no LiDAR)
Limits of LiDAR

Sources:
- NAIP 2010 (air photo)
- CA Coastal Conservancy 2009-2011 (DEM)

Notes: LiDAR for this area was flown in Sept 2010. Horizontal accuracy is 50 cm RMSE or better. Vertical accuracy in flat, non-vegetated areas is 9 cm RMSE.
Spot Elevations at Habitat Transitions

- Upland to Ecotone (ave = 8.4 ft NAVD88)
- King Tide (Jan 2013, ave = 7.5 ft NAVD88)
- Ecotone to 100% Pickleweed (ave = 7 ft NAVD88)
- 100% Pickleweed to <100% Pickleweed (ave = 5.5 ft NAVD88)
- Sparse Pickleweed to Mudflat (ave = 4 ft NAVD88)

Example of multiple habitat transitions on the eastern side of Hester’s Marsh. Photo by Gavin Archbald.
Elkhorn Slough Tidal Marsh Restoration Project.D120505.00

Figure 8
Regional Geologic Map

EXPLANATION

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qs</td>
<td>DUNE SAND</td>
</tr>
<tr>
<td>Qal</td>
<td>ALLUVIUM</td>
</tr>
<tr>
<td>Qt</td>
<td>QUATERNARY NONMARINE TERRACED DEPOSITS</td>
</tr>
<tr>
<td>Qc</td>
<td>PLEISTOCENE NONMARINE</td>
</tr>
<tr>
<td>Pml</td>
<td>MIDDLE PLIOCENE MARINE</td>
</tr>
<tr>
<td>Mv</td>
<td>MIocene VOLCANIC</td>
</tr>
<tr>
<td>Mi</td>
<td>LOWER MIocene MARINE</td>
</tr>
<tr>
<td>φ</td>
<td>OLIGOCENE MARINE</td>
</tr>
<tr>
<td>gr</td>
<td>MESOZOIC GRANITIC ROCKS</td>
</tr>
<tr>
<td></td>
<td>FAULT, DASHED WHERE APPROXIMATELY LOCATED</td>
</tr>
</tbody>
</table>

SOURCE: Jennings 1959 (Reprint)
Elkhorn Slough Tidal Marsh Restoration Project.

Figure 10
Site Geologic Map

EXPLANATION
Qe  EOLIAN SAND
Qb  BASIN DEPOSITS, SILTY CLAY
Qod OLDER DUNE SAND
Qfa FAN DEPOSITS OF ANTIOCH
Qt  UNDIVIDED TERRACE DEPOSITS
Qtw WATSONVILLE TERRACE DEPOSITS
Qmt MARINE TERRACE DEPOSITS

SOURCE: Wagner 2002

SOURCE: Wagner 2002

Figure 10
Site Geologic Map
The locations of CALTRANS boreholes (blue squares), the marsh transect hand-driven cores (green squares), and other single Elkhorn cores (yellow squares and red squares) collected by Schwartz (1983) and Hornberger (1991) are depicted above. The cores are displayed over a merge of multibeam bathymetry processed, archived, and distributed by SFML CSUMB and NOAA LIDAR data. Descriptions of the CALTRANS cores are in Figure 4. The marsh transect and other Elkhorn cores are described in Figures 5 and 6.
Sediment cores collected by Schwartz (1983) and Hornberger (1991) are ordered from left to right from Seal Bend to Elkorn’s Backslough. Parsons Slough cores are shown on the far right. Descriptions of the cores include a range of possible grain-size diameters in microns. Elevations from the DEM in Figure 3 were applied to the surface of the cores to orient the data in relation to Mean Lower Low Water (MLLW).
Figure 13
2013 Sediment Core Locations

SOURCE: ENGEO 2013
Elkhorn Slough Tidal Marsh Restoration Project.

**EXPLANATION**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ac</td>
<td>ALVISO SILTY CLAY LOAM</td>
</tr>
<tr>
<td>Ad</td>
<td>ALVISO SILTY CLAY LOAM, DRAINED</td>
</tr>
<tr>
<td>CnC</td>
<td>CROPLEY SILTY CLAY, 2-9% SLOPES</td>
</tr>
<tr>
<td>DdD</td>
<td>DIABLO CLAY, 9-15% SLOPES</td>
</tr>
<tr>
<td>DdE</td>
<td>DIABLO CLAY, 15-30% SLOPES</td>
</tr>
<tr>
<td>EdB</td>
<td>ELKHORN FINE SANDY LOAM, 2-5% SLOPES</td>
</tr>
<tr>
<td>OaD</td>
<td>OCEANO LOAMY SAND, 2-15% SLOPES</td>
</tr>
<tr>
<td>ShC</td>
<td>SANTA YNEZ FINE SANDY LOAM, 2-9% SLOPES</td>
</tr>
<tr>
<td>ShD</td>
<td>SANTA YNEZ FINE SANDY LOAM, 9-15% SLOPES</td>
</tr>
<tr>
<td>ShE</td>
<td>SANTA YNEZ FINE SANDY LOAM, 15-30% SLOPES</td>
</tr>
<tr>
<td>W</td>
<td>WATER</td>
</tr>
<tr>
<td>Xc</td>
<td>XERORTHENTS, LOAMY</td>
</tr>
</tbody>
</table>

**SOURCE:** USDA Web Soil Survey 2/17/2012

**Figure 14**

UDSA Soil Map
Figure 15
Biotic Habitats Map
A. Pre European Colonization

- Healthy pickleweed and brackish marsh vegetation
- Slough tide range large

B. Existing Conditions

- Marshplain subsidence in response to past diking
- Increase in MHHW with harbor opening and main channel scour
- Vegetation die back due to increased inundation
- Channel scour in response to re-introduced tides
- Slough-wide sediment deficit precludes net accretion through deposition

C. Restored Conditions

- Marshplain raised with imported fill
- Healthy pickleweed regeneration
- Channel may experience siltation in response to decreased tidal prism
- Ecotone planting with native vegetation
Appendix A

2013 FIELD DATA COLLECTION MEMO
memorandum

date February 4, 2013
to Monique Fountain
from Elena Vandebroek and Michelle Orr
subject Field Data Collection Review for Field Day #1, January 15, 2013
project D120505.00 – Elkhorn Slough Tidal Marsh Restoration Project

This memorandum summarizes field data collection efforts for the Elkhorn Slough Tidal Marsh Restoration Project. Fieldwork was conducted on January 15, 2013, by Elena Vandebroek (ESA PWA, leading elevation survey) and Gavin Archbald (H.T. Harvey & Associates, leading habitat survey). Data collection included transects, spot elevations, and characteristics of vegetation at various locations at the proposed restoration sites and a nearby reference site (Figure 1). The upper limit of a recent king tide\(^1\) event was also surveyed at multiple locations along the Minhoto Marsh.

Field data were collected to support restoration planning for the ~135 acre project site, with emphasis on the likely locations of Phase 1 implementation.

**Fieldwork Objectives**

- Develop representative transects overlaying habitat data and elevations.
- Identify approximate elevation bands corresponding to vegetation categories at the proposed restoration site and reference marsh for input to design elevations.
- Compare survey data for multiple ground cover types to recent LiDAR data collection to identify/flag major LiDAR biases or inaccuracies.
- Collect a few water surface elevations for comparison with water level data collectors currently deployed in the Slough.

**Topographic Methods**

*Horizontal and Vertical Control and Equipment*

All data were surveyed relative to the control network established in January 2011 by a licensed surveyor (Van Dyke, 2012). Horizontal and vertical benchmark coordinates were provided to ESA PWA by ESNERR. The

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\(^1\) King tides are the highest and lowest predicted tides of the year at a given location. They are above the highest water level reached at high tide on an average day. At Elkhorn Slough they occur in November/December and January/February.
horizontal datum is UTM Zone 10N meters and the vertical datum is NAVD88 meters. The horizontal coordinates were converted to California State Plane Zone 4 feet (NAD83) using the US Army Corps of Engineers’ CORPSCON 6. Table 1 contains coordinates for the two benchmarks referenced. All surveys were completed using a Leica System 1200 RTK-GPS rover unit receiving corrections via cellular connection to the Leica SmartNet North America control network.

Table 1 - Benchmark Coordinates

<table>
<thead>
<tr>
<th>Benchmark Identifier</th>
<th>Coordinates provided by ESNERR</th>
<th>Coordinates converted by ESA PWA to California State Plane, imperial units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Easting UTM Z10</td>
<td>Northing UTM Z10</td>
</tr>
<tr>
<td>9413631 J</td>
<td>611616.746</td>
<td>4074523.608</td>
</tr>
<tr>
<td>9413631 K</td>
<td>611484.988</td>
<td>4074625.922</td>
</tr>
</tbody>
</table>

Representative Transects
Nine transects (#1, 2, 3, 4, 5, 8, 9, 10, 11, and 12) were surveyed in the restoration site, one transect across the stockpile (#6), and one transect at the Yampah Marsh reference site (#7). The survey included elevation data for all transects as well as habitat classifications along seven transects (#1, 2, 3, 4, 7, 8, and 10). The purpose of transects without habitat classifications was to compare surveyed elevations to recent LiDAR elevation data to inform volume estimates for construction.

Spot Elevations
Spot elevations were collected in a variety of locations throughout the Minhoto, Hester, and Yampah marshes. Measurements were mainly focused on the transition zone between upland and marsh. Most of the spot elevations were accompanied by notes describing the habitat classification (e.g. upland, ecotone, marsh, mudflat, pickleweed) and sometimes modifiers describing where in a particular habitat zone the point was measured (e.g. upper limit, lower limit). Between 19 and 50 points were collected along the perceived breakpoint between each habitat zones.

King Tide Markers
ESNERR staff marked the upper limit of the December 12, 2012 king tide with flags at a series of locations along the western side of Minhoto marsh. During the fieldwork day, elevation data were collected at sixteen of these flags (Figure 1).

Habitat Classification Scheme
Many of the representative transects and spot elevations were accompanied with habitat classifications, described as follows:

**Ecotone**: where pickleweed and non-tidal marsh plants co-occur.

**Lower edge of ecotone**: where vegetation became 100% pickleweed

**Marsh**: Where pickleweed cover exists. These areas were further classified by percent cover: 100%, 50 – 100%, and less than 50% pickleweed cover. When the percent cover was not available, a simple description of “pickleweed” was noted.

**Mudflat**: 0% pickleweed (bare mud)
Results and Discussion

Figure 2 shows each of the surveyed transect elevations compared to recent LiDAR data collection. Spot elevations are summarized by vegetation category in Figure 3. Figure 3 also includes the king tide marker elevations, which averaged 7.5 feet NAVD88 (approximately 1.7 feet above Mean Higher High Water). The corresponding king tide elevation at the NOAA Monterey tide gage (#9413450) was 7.48 feet NAVD88 (NOAA, 2012a).

Comparison with LiDAR Digital Elevation Model

Figure 2 shows the surveyed profile elevations compared with the LiDAR elevations from the 2009 – 2011 California Coastal Conservancy LiDAR Project Hydro-flattened Bare Earth DEM (NOAA, 2012b). The LiDAR data in Elkhorn Slough were collected in September and October 2010. The published metadata reports that in flat, non-vegetated areas, at least 95% of the data had an error less than or equal to 18 cm (0.6 feet).

The elevations surveyed in Elkhorn Slough on Jan 15, 2013, generally fall below LiDAR elevations. The extent of this bias depends heavily on the type of ground cover. In general, elevations of bare mud, upland areas, and the stockpile area (e.g. Transect 6, end of Transects 1 and 3) fall within the rated LiDAR accuracy. There is no consistent LiDAR bias apparent in the limited upland measurements. Areas with approximately 50 – 100% pickleweed cover showed approximately 0.3 to 0.4 feet bias, with ground survey elevations below LiDAR elevations. Not enough data were collected in the sparsely vegetated marsh to quantify an average bias. Some heavily vegetated areas (e.g. middle of Transects 1 and 7, Transects 5 and 12) show a strong vegetation bias, up to 1.5 feet above ground elevation.

Habitat Zone Elevation Ranges

The habitat transition elevations are summarized in graphical and tabular form in Figure 3. Based on these very limited data, there is no significant difference between the habitat zone transitions at the proposed restoration site and the Yampah Marsh reference site. Ecotone was observed over a fairly wide elevation range, from approximately 6.4 to 10.0 feet NAVD88. High marsh was found between 5.1 and 7.3 feet NAVD88. The transition from mid to high marsh occurs, on average, at 5.5 feet NAVD88. The upper limit of mudflat was observed at an average elevation of 4 feet NAVD88. Table 2 reports the tidal datum elevations for comparison.

The surveyed mid and high marsh measurements are generally higher than those observed at the Rubis Creek marsh (across the main Elkhorn Slough channel from the project site) (Van Dyke, 2012). Rubis Creek marsh elevations averaged at 5.02 feet NAVD88 and ranged from 4.4 to 5.6 feet NAVD88 (the range observed in the current fieldwork was approximately 4.0 to 7.3 feet NAVD88). This difference may be attributed to the higher elevation focus of the January 15, 2013, fieldwork (as stated in the objectives); the Van Dyke 2012 study collected more points at each site (75 to 100), the measurement locations were randomized within the marsh area, and the study was not focused primarily on habitat transitions.
Table 2 – Tidal Datum

<table>
<thead>
<tr>
<th>Tidal Datum</th>
<th>Elevation NAVD88, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Higher High Water</td>
<td>5.784</td>
</tr>
<tr>
<td>Mean High Water</td>
<td>5.075</td>
</tr>
<tr>
<td>Mean Tide Level</td>
<td>3.261</td>
</tr>
<tr>
<td>Mean Low Water</td>
<td>1.444</td>
</tr>
<tr>
<td>Mean Lower Low Water</td>
<td>0.417</td>
</tr>
<tr>
<td>NAVD88</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Van Dyke, 2012

List of Figures

Figure 1 - Field Data Collection: January 15, 2013
Figure 2 - Surveyed Transects with Comparison to Recent LiDAR
Figure 3 - Spot Elevations at Habitat Transitions

References


Figure 1
Field Data Collection: January 15, 2013

Key
- Restoration Areas
- Stockpile Area

Survey Locations
- Benchmark
- King Tide Marker
- Spot Elevation
- Transects

Sources:
NAIP 2009 (air photo)
ESA PWA 2013 (survey)
Transect 1 - South Minhoto Marsh (M1)

SOURCE: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).
Figure 2-2

Transect 2 (Site M1)

SOURCE: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).
Transect 3 (M3)

Elevation (feet NAVD88) vs. Location along Transect (feet)

Figure 2-3
Transect #3

SOURCE: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).
Transect 4 - High Berm Crest (dividing M2 and M3)

SOURCE: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).
Transect 5 - Transect in area with heavy pickleweed (M2)

SOURCE: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).
SOURCE: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).
Figure 2-7
Transect #7

SOURCE: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).
Transect #8 - Hester's Marsh (H1)

SOURCE: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).
Transect 9 - Short Transect, North Minhoto (M4b)

Source: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).
Transect 10 - LiDAR Check, North Minhoto (M4b)

SOURCE: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).
Transect 11 - LiDAR Check, Diked Area (M6)

SOURCE: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).

Elkhorn Slough Tidal Marsh Restoration Project. D120505.00

Figure 2-11
Transect #11
Transect 12 - LiDAR Check, Diked Area, Dense Vegetation (M6)

SOURCE: ESA PWA 2013 (Figure, Survey Data), NOAA 2012 (Airborne LiDAR, collected in Sept/Oct 2010), Van Dyke 2012 (Tidal Datum).
Spot Elevations at Habitat Transitions (Sorted)

- Upper Limit of Ecotone
- King Tide Marker
- Upper Limit of High Marsh (Lower Limit of Ecotone)
- Upper Limit of Mid Marsh (Lower Limit of High Marsh)
- Upper Limit of Mudflat (Lower Limit of Low Marsh)

**Habitat Transition (High to Low)**

<table>
<thead>
<tr>
<th>Habitat Transition</th>
<th># of points</th>
<th>Mean Elevation (feet NAVD88)</th>
</tr>
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<tbody>
<tr>
<td>Upland to Ecotone</td>
<td>19</td>
<td>8.4</td>
</tr>
<tr>
<td>Ecotone to High Marsh</td>
<td>22</td>
<td>7.0</td>
</tr>
<tr>
<td>High Marsh to Mid Marsh</td>
<td>26</td>
<td>5.5</td>
</tr>
<tr>
<td>Low Marsh to Mudflat</td>
<td>9</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Example of multiple habitat transitions on the eastern side of Hester's Marsh. Photo by Gavin Archbald.
Appendix B. Water Quality

This appendix presents detailed water quality background for Elkhorn Slough.

List of Figures
Figure B-1. Dissolved Oxygen in the Main Channel, 2011
Figure B-2. Dissolved Oxygen in the Main Channel, Aug 2011
Figure B-3. Nitrate in the Main Channel, 2011
Figure B-4. Nitrate in the Main Channel, Aug 2011
Figure B-5. Turbidity in the Main Channel, 2011
Figure B-6. Organochlorine Pesticides in the Elkhorn Slough System, 1982-1993


1. Temperature
Temperatures in Elkhorn Slough demonstrate an expected seasonal pattern, with warmest temperatures (15-20°C) in the late summer and fall and coolest temperatures (< 10°C) during the winter and early spring (ESNERR data). In deeper areas closer to the slough mouth, tidal forcing can affect temperature by moving cold marine waters into the Slough on a flood tide, and out of the Slough on an ebb tide. Like many shallow estuaries, temperature stratification (warmer temperatures near the top of the water column, and cooler temperatures near the bottom) typically occurs during slack low tides in shallower (less than 1 meter deep) areas of the slough, especially in the summer. Significant stratification is unlikely during the winter-spring months due to the mixing effects of watershed inputs and strong winds and rains from winter storms.

2. Salinity
Typically, salinity in Elkhorn Slough is near-marine, averaging approximately 30 parts per thousand (ppt) (ocean salinity is typically about 35 ppt) (ESNERR data). However, salinity temporarily decreases in response to freshwater inputs from the watershed, and during particularly significant winter storm events can dip well below 20 ppt and even (very rarely) approach freshwater values (ESNERR data, Moffatt & Nichol 2008). On ebb tides, more saline waters draining from shallow marsh and mudflat areas (due to evapotranspiration) mix with cooler, less saline waters from the mainstems of Elkhorn and Parsons Sloughs, causing a semi-diurnal increase in salinity that can be observed during both warm and cool months (Caffrey and Broenkow 2002).

3. Dissolved Oxygen and Eutrophication
In its recent updates to the Clean Water Act (CWA) 303(d) list of impaired water bodies, Elkhorn Slough was listed by the Central Coast Regional Water Quality Control Board (CCRWQCB) as impaired for low
DO, a decision supported by ESNERR scientists (ESNERR 2009). Monitoring data from within Elkhorn Slough demonstrates that the system typically has DO levels within acceptable ranges, but episodic events can drive extreme increases or decreases in DO (LOBO data, Moffatt & Nichol 2008). Extreme increases in DO (up to DO supersaturation, or DO levels above 100 percent saturation) are usually induced by primary production in the water column or along the benthos – e.g., the oxygen produced during the day through photosynthesis by algae (both free-floating and filamentous) and other submerged aquatic plants such as eelgrass. Elkhorn Slough monitoring data sets all contain frequent instances of DO saturation of well over 100 percent (supersaturation); these events do not seem to be limited to a particular seasonal set of conditions (Figure B-1). However, it is possible that many of these events are tied to low-turbidity conditions, as photosynthesis is a light-dependent process. During times of algal blooms (sudden population increases triggered by eutrophication, see below), DO can increase to supersaturated levels during the day, and then suddenly crash to hypoxic or even anoxic levels once the sun sets and the algae turn to respiration, which consumes DO in the water column (Figure B-2).

Tidal flows can also influence DO concentrations on a semi-diurnal cycle by transporting high-DO water from Monterey Bay into the slough on a flood tide, and removing lower-DO water from the slough into Elkhorn Slough and eventually the Bay on an ebb tide.

In Elkhorn Slough, severe low DO events are frequent during the summer and early fall, when nighttime DO crashes become cumulatively worse as the system accumulates both respiring algae and decomposing organic material due to summertime productivity and eutrophication. Sudden decreases in DO can also occur when there is turbulence in the water column, which can re-suspend organic material with high biological oxygen demand (BOD) from the benthos and cause a corresponding decrease in DO. Water quality data collected by ESNERR and MBARI indicates that eutrophication in Elkhorn Slough is a concern, especially in tidally restricted areas (Hughes et al. 2011, ESF 2012). Aerial photography of the Minhoto restoration site indicates frequent periods of time in the summer when eutrophic conditions prevail, and lower-elevation areas are covered in extensive, bright green beds of the macroalga *Ulva* and its allies.

The extensive beds of macroalgae constitute a major source of highly labile organic material (material subject to aerobic decomposition) within Elkhorn Slough, and may also impact the persistence of eelgrass beds within the system (ESNERR 2009). When algae and other organic material decompose in the slough, flushing action within the slough system generally prevents the development of severely hypoxic and anoxic waters (with the exception of the tidally restricted areas mentioned above). In these areas of poor tidal circulation, high hydraulic residence times exacerbate eutrophication and attendant low DO levels by prolonging the period of time that water is in contact with high-BOD bottom sediments. This lowers DO levels in the water column at these locations even further. Under periods of exceptionally poor circulation, bottom waters can become anoxic, which can induce the release of nutrients such as ammonium (NH$_4^+$) and orthophosphate (PO$_4^{3-}$) from the benthos in a process called “internal nutrient loading.” Such loading can induce a positive-feedback loop that further exacerbates eutrophication and lowers DO levels throughout the water column.

Recent research by Deegan et al. (2012) indicates that eutrophication can be a primary driver of tidal marsh in nutrient-enriched estuaries such as Elkhorn Slough. Their work was conducted in East Coast salt marshes, which contain plant species that can grow relatively lower in the tidal frame than
pickleweed, such as smooth cordgrass (*Spartina alterniflora*) and saltmeadow cordgrass (*Spartina patens*). Conceptually, therefore, East Coast marshes should be relatively more resistant to marsh loss mechanisms than Elkhorn marshes, because plant root systems can stabilize sediments across a broader range of tidal depths. Nevertheless, their research demonstrated that:

“...nutrient levels commonly associated with coastal eutrophication increased above-ground biomass, decreased the dense, below-ground biomass of bank-stabilizing roots, and increased microbial decomposition of organic matter. Alterations in these key ecosystem properties reduced geomorphic stability, resulting in creek-bank collapse with significant areas of creek-bank marsh converted to unvegetated mud. This pattern of marsh loss parallels observations for anthropogenically nutrient-enriched marshes worldwide, with creek-edge and bay-edge marsh evolving into mudflats and tidal creeks.” (Deegan et al. 2012)

It can be expected that sea level rise, with its attendant increases in tidal prisms and wave energy, will further exacerbate this and other marsh loss mechanisms within the Slough. This new research indicates that efforts by local farmers and farming organizations to manage nutrient loading can complement the efforts of scientists working with the Slough to help restore tidal marsh habitats.

### 4. Nutrients

The primary inorganic nutrients of interest within Elkhorn Slough are nitrogen and phosphorus. Both are necessary for the growth of algae and other plants, and as such are important components of a productive marsh food web. However, in excessive quantities, such as are found under anthropogenically-altered conditions, these same nutrients can negatively impact water quality and ecosystem health within the slough. As mentioned earlier, high levels of nutrients can induce the formation of eutrophic conditions within the estuary, which can decrease DO levels and limit habitat suitability for aquatic organisms. The primary source of external nutrients to the Elkhorn Slough system is runoff from the system’s watershed, especially from agricultural operations (e.g., fertilizers, manure); relatively smaller inputs include atmospheric deposition and bacterial fixation (Caffrey 2002b).

Nutrient levels, and particularly nitrate levels, throughout the entire Elkhorn Slough system have increased dramatically over the past 60 years, primarily in response to increases in the proportion of agricultural land within the slough’s watershed (Caffrey 2002b). Nitrate levels in Elkhorn Slough, which were once within the range of those measured within Monterey Bay, are now among the highest of any coastal estuary. Nitrate-nitrite levels of up to 2000 µM$^1$ and phosphate levels of up to 50 µM have been measured within the slough; these concentrations are orders of magnitude higher than those commonly encountered in San Francisco Bay or Tomales Bay (Caffrey 2002b). To address these elevated nutrient levels, ESNERR scientists have requested that Elkhorn Slough be listed as a CWA 303(d) impaired water body for nitrate, ammonia, and phosphate. As of the most recent update (2010, approved in 2011), however, the system is not yet listed by the CCRWQCB as impaired for these constituents.

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1 Micromolar (µM) is a term commonly used to describe concentrations in a solution. A solution with a molarity of one M contains one mole of a compound in one liter of solution. A solution with a molarity of one µM contains $10^{-6}$ moles of a compound in one liter of solution.
Runoff from the surrounding watershed is the primary source of nutrients to the Elkhorn Slough system (Caffrey 2002b). Inorganic nitrate concentrations in the slough peak during the spring, when storm events transport sediment and associated nitrogen loads from the watershed into the basin (Figure B-3). These concentrations then decrease throughout the summer as inputs decrease and the nitrate is converted to organic nitrogen and other inorganic forms of nitrogen (Caffrey 2002b). While relatively less is known about phosphorus within the Elkhorn system, it is known that approximately 90 percent of the system’s phosphorus is in a dissolved, inorganic form (Caffrey et al., 1997), and that phosphate flux between the benthos and the water column are low and not directly related to primary productivity or diffusion across the sediment-water interface (Caffrey 1996). Concentrations of both nitrogen and phosphorus with the slough system can exhibit diurnal or semi-diurnal patterns: both nutrients are taken up by primary producers during the day, and tidal flushing can dilute slough water with water from Monterey Bay, which contains relatively lower levels of nutrients (Caffrey 2002b). Figure B-4 displays an example of these diurnal changes in nitrate concentrations.

5. **Turbidity and Suspended Sediment**

Turbidity is a measure of the amount of material suspended in the water column, and is a commonly measured water quality constituent along with temperature and salinity. In tidal systems, turbidity monitoring can often help indicate the relative amounts of sediment that are entering a site on flood tides and leaving on ebb tides. Turbidity can also be an indicator of other water quality constituents, such as primary productivity (since the presence of free-floating algae can increase turbidity), and/or BOD within the water column (as organic particles are often a substantial contributor to turbidity). Turbidity is typically reported in Nephelometric Turbidity Units (NTU), a measure of how much light is scattered when a beam of light called a nephelometer shines through water.

Elkhorn Slough has been listed by the CCRWQCB for sedimentation/siltation due to impacts from agriculture within the watershed (CCRWQCB 2011). In Elkhorn Slough, turbidity appears to be primarily controlled by weather events, though algae production may contribute to late-summer/early fall turbidity spikes. Large storms wash sediment-laden runoff into the slough, and high winds can re-suspend settled sediments. Data from 2011 illustrate spikes in turbidity from winter storms as well as summer algae blooms (Figure B-5).

It is important to note that while Elkhorn Slough is listed for sediment impairment, this listing is primarily due to the beneficial uses attributed to the Slough by the RWQCB. The system is functionally impaired by the relative lack of sediment compared to its pre-European-settlement conditions to raise marshplain elevations in response to higher water levels and ongoing sea level rise.

6. **Contaminants**

A recent history of intense land use within the Elkhorn Slough watershed and along the slough’s mouth has increased the amounts and types of contaminants in slough waters. These contaminants can cause both short-term and long-term impacts to the survival, growth, and reproduction of biological communities within and around the slough. Most contaminants within the slough system fall into one of three categories: pesticides, microbial contaminants (pathogens), and contaminants associated with
harbor operations (Caffrey 2002b). Elkhorn Slough is a CWA 303(d) listed waterbody for pathogens and pesticides (CCRWQCB 2011); these are discussed in greater detail below.

Pesticides. Extensive research of pesticide contamination in and around Elkhorn Slough indicates that though there was likely a past history of direct application of pesticides such as DDT to soils immediately adjacent to the slough (Blankinship and Evans 1993), the primary source of pesticides to slough waters and sediments is likely the greater watershed area (ABA Consultants 1986), and in particular the Old Salinas River Channel which drains extensive agricultural areas (Phillips 1998). Within the Elkhorn Slough watershed, commercial agriculture is the largest contributor of pesticides to the environment; residential use likely contributes a much smaller fraction (Phillips et al. 2002). Extensive studies by the California State Mussel Watch Program (CSMWP) have detected lower DDT concentrations during wetter years than in dryer years, and higher concentrations in locations near the Old Salinas River and Moro Cojo Slough than in the center of Elkhorn Slough (Phillips 1998).

The CSMWP is one of the more extensive data sets of the many studies that describe toxic contaminants throughout Elkhorn Slough (see Phillips et al. 2002 for a useful bibliography). The CSMWP monitored contaminants from 1977 through 2000, at times monitoring as many as 10 locations throughout the slough (only one was monitored toward the end of the program). Two of the more frequently monitored sites were Elkhorn Slough at the Highway 1 bridge (station 403.0), and Sandholdt Bridge within the south Moss Landing harbor (station 404.0). Data from the CSMWP describing concentrations of total DDT and total chlordane\(^2\) levels in parts per billion of grams (ppb/g) of lipid weight\(^3\) are presented in Figure B-6. While ecological health standards for organochlorine concentrations have not been established within Elkhorn Slough, a similar mussel monitoring program in coastal Massachusetts set “caution levels” of 205 ppb/g lipid weight for chlordane, and 483 ppb/g lipid weight for DDT (Werme and Hunt, 2002). In the CSMWP dataset, levels of total chlordane and total DDT both varied, though levels within Elkhorn Slough were consistently lower than those in the southern portion of the Moss Landing harbor. Relative differences between constituent concentrations on different dates were fairly consistent, indicating that regional processes (and not site-specific ones) likely drive pesticide dynamics in the Slough. Almost all of the CSMWP samples exceeded the Massachusetts standards, indicating that the persistence of these pollutants was and is likely to remain a concern within the Elkhorn Slough system.

Aside from the importance of regional processes, the forces governing contaminant dynamics within Elkhorn Slough are not well understood. However, anecdotal evidence may shed some light on these pollutants. In 1995, multiple organochlorines were linked to the sudden collapse of a nesting colony of Caspian Terns (Sterna caspia) within South Marsh in Parsons Slough (upstream of the project site). Research by ESNERR scientists indicated that levels of DDE (a metabolite of DDT), toxaphene, and PCBs (polychlorinated biphenyls, a common industrial pollutant) in eggshells and the bodies of dead birds

\(^2\) DDT and chlordane have multiple chemical forms; the use of the word “total” indicates that the data describe the sum of their respective different forms.

\(^3\) Organochlorine pesticides bioaccumulate in organisms because they are highly lipophilic. Therefore, organochlorine concentrations in tissue samples are often presented in ppb wet weight, dry weight, and lipid weight. The latter is being increasingly used as monitoring standard in water quality management programs.
were much higher in 1995 than in samples collected in 1994. The scientists came to the preliminary conclusion that the 1995 flooding of the Pajaro River transported contaminated sediments from the Pajaro agricultural basin into Elkhorn Slough; the subsequent movement of these contaminants into the food chain was likely what led to the failure of the nesting colony (ESNERR 2008).

Since the banning of many of the most persistent pesticides in the 1970s, the potential movement of newer, acutely toxic yet rapidly-degrading agricultural chemicals from the Elkhorn Slough watershed into the basin is poorly understood. In order to assess which newer pesticides might cause adverse impacts within the basin, in 1992, NOAA initiated a Hazard Rating Coefficient (HRC) analysis for the slough. The HRC analysis considered fish and crustacean toxicity, bioconcentration factors, and soil half-life, assigned an HRC to each pesticide, and then multiplied each HRC by the quantity of the pesticide used in the Elkhorn watershed at the time. The analysis indicated that the newer pesticides of concern within the watershed are metham sodium, thiram, dicofol, malathion, and chlorpyrifos (Phillips et al. 2002). Current application rates of these chemicals within the Parsons watershed are unknown.

**Pathogens.** There are two primary pathogens of concern within Elkhorn Slough: coliform bacteria, and *Toxoplasma gondii*, a parasitic protozoa. Within Elkhorn Slough, contamination by coliform bacteria has been a known problem since the 1960s (ABA Consultants, 1986), and the slough is 303(d) listed as impaired for coliforms by the CCRWQCB (CCRWQCB 2011). A 1985 study of coliforms throughout Elkhorn Slough found that most coliforms in the system were not human, and that levels were highest in areas with freshwater inputs (ABA Consultants 1986). The latter was confirmed by another study in 1994 and 1995, which also found only moderate coliform levels near harbor seal haul-out sites and dairies (Young 1996).

*Toxoplasma gondii* is a pathogen of humans and terrestrial animals that is highly correlated with mortality in sea otters. A 2002 study by Miller et al. described Elkhorn Slough and its environs as an epicenter for infection; 79 percent of the otters in the area tested positive for *T. gondii*, and otters within 10 kilometers of the slough were 1.5 times more likely to be infected. Miller and her colleagues performed a series of analyses to conclude that the primary reason for the high infection rate within Elkhorn Slough is the high levels of exposure to freshwater flow from the Elkhorn Slough watershed. Within the Elkhorn Slough watershed, both domestic and feral cats are likely sources of *T. gondii* (Miller et al. 2002). The Monterey Regional Storm Water Management Program (MRSWMP) has implemented a program to identify and reduce sources of *T. gondii* infection within the County, including the Elkhorn Slough watershed (MRSWMP 2007).
Figure B-1
2011 Dissolved Oxygen in Main Channel (LOBO Station LO1)

SOURCE: Monterey Bay Aquarium Research Institute

NOTE: SURF = 0.5 m below water surface
Figure B-2
Aug 2011 Dissolved Oxygen in Main Channel (LOBO Station LO1)

SOURCE: Monterey Bay Aquarium Research Institute
NOTE: SURF = 0.5 m below water surface
Figure B-3
2011 Nitrate in Main Channel
(LOBO Station LO1)

SOURCE: Monterey Bay Aquarium Research Institute
NOTE: SURF = 0.5 m below water surface
Figure B-4
Aug 2011 Nitrate in Main Channel (LOBO Station LO1)

SOURCE: Monterey Bay Aquarium Research Institute
NOTE: SURF = 0.5 m below water surface
Figure B-5
2011 Turbidity in Main Channel
(LOBO Station LO1)

SOURCE: Monterey Bay Aquarium Research Institute
NOTE: SURF = 0.5 m below water surface
Selected Pesticides at Parsons Slough: CSMWP Data


SOURCE: California Mussel Watch Program
NOTE: Data is from Parsons Slough, upstream of the Minhoto-Hester’s and Seal Bend sites
Appendix C

PAJARO BENCH EXCAVATION
Appendix C. Pajaro Bench Excavation

Table C-1 below describes the anticipated volumes of sediment to be excavated from the Pajaro floodplain bench and used in tidal wetland restoration at Elkhorn Slough. Figure C-1 on the next page displays the locations of the excavation areas.

<table>
<thead>
<tr>
<th>Excavation Site</th>
<th>Material Volume (CY)</th>
<th>Off Haul Volume* (CY)</th>
<th>Off Haul Distance (mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4L</td>
<td>16,583</td>
<td>18,241</td>
<td>12</td>
</tr>
<tr>
<td>5R</td>
<td>35,769</td>
<td>39,346</td>
<td>4.7</td>
</tr>
<tr>
<td>5.5R</td>
<td>6,285</td>
<td>6,914</td>
<td>5.2</td>
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<tr>
<td>6R</td>
<td>84,833</td>
<td>93,316</td>
<td>6</td>
</tr>
<tr>
<td>7R</td>
<td>5,588</td>
<td>6,147</td>
<td>7.4</td>
</tr>
<tr>
<td>8R</td>
<td>25,324</td>
<td>27,856</td>
<td>9.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>174,382</strong></td>
<td><strong>191,820</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Off haul volume assumes 10% swelling of excavated material

Source: Santa Cruz County 2012
Figure C-1

Pajaro Bench Excavation Areas

SOURCE: Santa Cruz County 2012
Appendix D

BIOLOGICAL AND ECOLOGICAL COMMUNITIES: REGULATORY OVERVIEW
Appendix D. Biological and Ecological Communities: Regulatory Overview and Discussion of Assessment Methods

Special-status Species Regulations Overview

Federal and state endangered species legislation gives several plant and animal species known to occur in the vicinity of the site special status. In addition, state resource agencies and professional organizations, whose lists are recognized by agencies when reviewing environmental documents, have identified as sensitive some species occurring in the vicinity of the site. Such species are referred to collectively as “species of special-status” and include: plants and animals listed, proposed for listing, or candidates for listing as threatened or endangered under the Federal Endangered Species Act (FESA) or the California Endangered Species Act (CESA), animals listed as “fully protected” under the California Fish and Game Code, animals designated as “Species of Special Concern” by the CDFG, and plants listed as rare or endangered by the CNPS in the Inventory of Rare and Endangered Plants of California (2001).

Federal Endangered Species Act provisions protect federally listed threatened and endangered species and their habitats from unlawful take. “Take” under FESA includes activities such as “harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any of the specifically enumerated conduct.” The U.S. Fish & Wildlife Service’s (USFWS) regulations define harm to mean “an act which actually kills or injures wildlife.” Such an act “may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering” (50 CFR § 17.3). Activities that may result in “take” of individuals are regulated by the USFWS. The USFWS produced an updated list of candidate species September 19, 1997 (USFWS 1997; 50 CFR Part 17). Candidate species are not afforded any legal protection under FESA; however, candidate species typically receive special attention from federal and state agencies during the environmental review process.

Provisions of CESA protect state-listed threatened and endangered species. CDFG regulates activities that may result in “take” of individuals (i.e., “hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill”). Habitat degradation or modification is not expressly included in the definition of “take” under the California Fish and Game Code. The CDFG, however, has interpreted “take” to include the “killing of a member of a species which is the proximate result of habitat modification . . . “. Additionally, the California Fish and Game Code contains lists of vertebrate species designated as “fully protected” (California Fish & Game Code §§ 3511 [birds], 4700 [mammals], 5050 [reptiles and amphibians], 5515 [fish]). Such species may not be taken or possessed without a permit.

The CDFG has also produced 3 lists (amphibians and reptiles, birds, and mammals) of “species of special concern” that serve as “watch lists.” Species on these lists either are of limited distribution or the extent of their habitats has been reduced substantially, such that threat to their populations may be imminent. Thus, their populations should be monitored. They may receive special attention during environmental review.
Plants listed as rare or endangered by the CNPS (2001), but which have no designated status under state endangered species legislation, are defined as follows:

- **List 1A.** Plants considered by the CNPS to be extinct in California.
- **List 1B.** Plants rare, threatened, or endangered in California and elsewhere.
- **List 2.** Plants rare, threatened, or endangered in California, but more numerous elsewhere.
- **List 3.** Plants about which we need more information - A review list.
- **List 4.** Plants of limited distribution - A watch list.

**The Migratory Bird Treaty Act Overview**

The Federal Migratory Bird Treaty Act (MBTA; 16 U.S.C., §703, Supp. I, 1989) prohibits killing, possessing, trading, or other forms of take of migratory birds except in accordance with regulations prescribed by the Secretary of the Interior. “Take” is defined as the pursuing, hunting, shooting, capturing, collecting, or killing of birds, their nests, egg or young (16 U.S.C. §703 and §715n). This act encompasses whole birds, parts of birds, and bird nests and eggs. The MBTA does not protect non-native species.

**California State Fish and Game Code**

Native migratory birds are also protected by the State of California. California Fish and Game Code §3503 emulates the MBTA and protects native birds’ nests and eggs from all forms of take. The Fish and Game Code goes further than the MBTA in protecting eggs and young, in that disturbance that causes nest abandonment resulting in the loss of eggs or young may be considered take by the CDFW. Nesting raptors (birds of prey) are specifically protected under CDFG Code §3503.5. Section 3503.5 states that it is “unlawful to take, possess, or destroy any birds in the order Falconiformes or Strigiformes (birds of prey) or to take, possess, or destroy the nest or eggs of any such bird except as otherwise provided by this code or any regulation adopted pursuant thereto.” To avoid take, the CDFW typically recommends buffers between active nests and new human activities that were not present at the onset of nesting. During the breeding season, the CDFW typically recommends a minimum buffer of 50-100 ft around active nests of non-raptors and a minimum buffer of 300 ft around active nests of raptors.

**U.S. Army Corps of Engineers Jurisdiction**

Areas meeting the regulatory definition of “Waters of the U.S.” (jurisdictional waters) are subject to the jurisdiction of the USACE under provisions of Section 404 of the Clean Water Act (1972) and Section 10 of the Rivers and Harbors Act (1899). These waters may include all waters used, or potentially used, for interstate commerce, including all waters subject to the ebb and flow of the tide, all interstate waters, all other waters (intrastate lakes, rivers, streams, mudflats, sandflats, playa lakes, natural ponds, etc.), all impoundments of waters otherwise defined as “Waters of the U.S.,” tributaries of waters otherwise defined as “Waters of the U.S.,” the territorial seas, and wetlands (termed Special Aquatic Sites) adjacent to “Waters of the U.S.” (33 CFR, Part 328, Section 328.3). Wetlands on non-agricultural lands are identified using the [Corps of Engineers Wetlands Delineation Manual](https://www.envlab.corps.gov/wetlands/delineation/) (Environmental Laboratory
1987). In addition, the *Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Arid West Region* (Regional Supplement; USACE 2006) was followed to document site conditions relative to hydrophytic vegetation, hydric soils and wetland hydrology. The Regional Supplement is designed to be used with the current version of the Corps Manual; where differences in the 2 documents occur; the Regional Supplement takes precedence over the Corps 1987 Manual.

Construction activities within jurisdictional waters are regulated by the USACE. The placement of fill into such waters must comply with permit requirements of the USACE. No USACE permit will be effective in the absence of state water quality certification pursuant to Section 401 of the Clean Water Act. The State Water Resources Control Board is the state agency (together with the Regional Water Quality Control Boards) charged with implementing water quality certification in California.

**Biological and Ecological Community Assessment Methods**

H. T. Harvey & Associates’ plant, wildlife, and fish ecologists Annie Eicher, Scott Demers, Ron Duke, and Neil Kalson assessed biotic conditions for the project site via a review of existing information, supplemented with a reconnaissance-level survey of the project site conducted on 18 January 2013. Specifically, the information review and reconnaissance survey was conducted to 1) characterize existing aquatic, wetland, and terrestrial habitats; 2) identify sensitive habitats including coastal salt marsh habitat; and 3) assess the site for its potential to support special-status plant and animal species and their habitats. In accordance with our scope, species-specific surveys were not conducted. Additionally, it is our understanding that ESA PWA is scoped to conduct a jurisdictional wetland delineation. Therefore, we did not conduct a jurisdictional wetlands assessment or delineation during our reconnaissance-level survey. Our plant ecologist prepared a map of the existing biotic habitats within the project site in Geographic Information System (GIS) format, based on existing GIS mapping (H. T. Harvey and Associates 2008, NERRS 2009), review of National Wetlands Inventory mapping, aerial imagery (NAIP 2009, World Imagery-dated 8 May 2010, GoogleEarth Imagery dated 5 May 2012), and site reconnaissance. Per our scope, the habitat map is approximate and sufficient for CEQA documentation; the map is based principally upon the existing GIS mapping and interpretation of recent aerial imagery with limited ground-truthing.

The boundary of H. T. Harvey & Associates’ site description and associated biotic habitat map was defined by the project site boundary provided by ESA PWA in a GIS shapefile on 17 January 2013 (with subsequent amendments per consultation with ESA PWA staff). The site boundary included 2 proposed tidal marsh restoration areas and an upland soil stockpile area. The Minhoto-Hester’s Marsh restoration area is 80.3 acres (ac) and the Seal Bend restoration area is 25.7 ac. The 41.2-ac stockpile/ecotone restoration area is located on the Minhoto parcel adjacent to the restoration area. The project will restore all or at least the marsh-ward portion of the stockpile area to marsh-upland ecotone habitat.

Additionally, we included eelgrass beds at Seal Bend in our mapping and site description; eelgrass beds with greater than approximately 30% cover were mapped using GoogleEarth imagery (dated 5/5/2012). Although located outside the project boundaries, we intend to assess the possible indirect impacts of the project on this sensitive resource in the forthcoming impact assessment as part of the project’s
Initial Study. Also outside the project boundary is a grove of eucalyptus (*Eucalyptus* spp.) and Monterey pine (*Pinus radiata*) on the south side of the Seal Bend Restoration Area (Figure 1) that provides habitat for sensitive wildlife species. Therefore, this habitat is discussed below.

The California Natural Diversity Database (CNDDB 2013) and the California Native Plant Society’s (CNPS) Online Inventory of Rare and Endangered Plants (CNPS 2013) were queried for information on the local distribution of special-status species. Additional information was obtained from technical publications, the California Consortium of Herbaria (CCH 2013), The Jepson Manual, Second Edition (Baldwin et al. 2012), and personal communication with individuals, including Elkhorn Slough National Estuarine Research Reserve (ESNERR) staff, who have expertise on local habitats and special-status species. Soils mapping data from the Web Soil Survey prepared by the National Cooperative Soil Survey, Natural Resources Conservation Service (NCSS-NRCS 2013) was used to identify any soils on-site with the capacity to support special-status plants with specific edaphic requirements.
Appendix E

SPECIAL-STATUS PLANT SPECIES CONSIDERED BUT REJECTED FOR OCCURRENCE
Appendix E. Special-Status Plant Species Considered but Rejected for Occurrence at the Elkhorn Slough Tidal Marsh Restoration Project Site

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Lack of Serpentine Soils</th>
<th>Suitable Habitat Type Not Present</th>
<th>Microhabitat Features Not Present</th>
<th>Other Edaphic Requirements</th>
<th>Outside the Elevation Range</th>
<th>Highly Endemic Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acanthomintha lanceolata</td>
<td>Santa Clara thorn-mint</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acanthomintha obovata ssp. cordata</td>
<td>heart-leaved thorn-mint</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acanthomintha obovata ssp. obovata</td>
<td>San Benito thorn-mint</td>
<td>X</td>
<td>X</td>
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<td>Pinus radiata</td>
<td>Monterey pine</td>
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<tr>
<td>Piperia yadonii</td>
<td>Yadon's rein orchid</td>
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<tr>
<td>Plagiobothrys chorisianus var. chorisianus</td>
<td>Choris' popcorn-flower</td>
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<td>Plagiobothrys diffusus</td>
<td>San Francisco popcorn-flower</td>
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<td>Rosa pinetorum</td>
<td>pine rose</td>
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<td>Trifolium buckwestiorum</td>
<td>Santa Cruz clover</td>
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<tr>
<td>Trifolium hydrophilum</td>
<td>saline clover</td>
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