APPENDIX A.
GOALS AND OBJECTIVES, OPPORTUNITIES AND CONSTRAINTS
Appendix A

Ballona Wetlands Restoration Plan
Goals and Objectives,
Opportunities & Constraints

The purpose of this document is to identify key characteristics of the project area that present opportunities for achieving the restoration planning goals and objectives as well as those that may limit (or place constraints on) the achievement of those goals and objectives. The ideas listed below tend to be generalized, this document is an effort to take information about the existing conditions of the area and assess what that information tells us about achieving the project’s goals and objectives.

This table does not evaluate the relative importance of specific opportunities or constraints and there are internal inconsistencies among the opportunities and constraints identified. Inherent in some of the opportunities are preferences, priorities and approaches to wetland restoration and because of these differences, some conflict with one another. The purpose of this document is not to resolve these potential conflicts, but rather to be sure there is a common understanding of the project area’s potential for achieving the fullest range of goals.
Goal 1: Ecosystem Restoration: Restore, enhance, and create estuarine habitat and processes in the Ballona Ecosystem to support a natural range of habitat and functions, especially as related to estuarine dependent plants and animals.

Sub-goal 1. Habitat: Preserve, restore, enhance, and create a variety of functional wetland, estuarine and other habitats representative of the Ballona Ecosystem.

Objectives:

a. Support existing and future habitat based on identified regional needs

b. Create spatial connectivity within the site

c. Create appropriate edge habitat and connectivity to adjacent areas of the Ballona Ecosystem

d. Provide landscape-level function at a regional scale addressing habitat/landscape patches, corridors, connectivity and mosaics landscapes. Provide habitat for migratory birds, fish nurseries, etc.

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preserve, restore, enhance, and create multiple habitats historically associated with both the Ballona Wetlands and the region.</td>
<td>Because the size of the site is limited, it may not be possible to incorporate large enough patches of all historic habitat types to ensure their viability.</td>
</tr>
<tr>
<td>Restore and create fully tidal wetland habitat</td>
<td>Habitats are fragmented by the existing roads, infrastructure and surrounding development</td>
</tr>
<tr>
<td>Preserve and enhance seasonal ponding areas</td>
<td>Existing habitats on site could be displaced by future enhancement, such as the restoration of tidal inundation</td>
</tr>
<tr>
<td>Create regional habitat linkages and corridors</td>
<td>Site has been filled, existing soil types may not be appropriate for reestablishment of all historic habitats</td>
</tr>
<tr>
<td>Incorporate adjacent upland habitats along with transitional habitats linking wetlands and uplands.</td>
<td></td>
</tr>
<tr>
<td>Restore diverse habitats based upon gradients of elevation, hydroperiod and salinity</td>
<td></td>
</tr>
</tbody>
</table>
**Sub-goal 2. Biodiversity:** Preserve and increase the native biodiversity of the Ballona Ecosystem. Identify and protect multiple levels of diversity (e.g. species, habitats, biogeographic provinces and trophic structure).

**Objectives:**
- *a.* Increase diversity and populations of rare and endangered plant and animal species.
- *b.* Establish and maintain diverse native plant communities, including vascular plants, algae, and diatoms.
- *c.* Support a diverse complement of species including: birds, fish, amphibians, reptiles, native aquatic and terrestrial invertebrates.

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restore biodiversity historically associated with the region, including common, rare and locally extirpated species.</td>
<td>Implementation of restoration efforts will entail impacts to existing species to some degree and may need to be mitigated in some way.</td>
</tr>
<tr>
<td>Strategically design habitat to ensure recruitment and survival of targeted species.</td>
<td>Site may too small and isolated to support some species.</td>
</tr>
<tr>
<td>Restore microhabitats that support various life stages of species.</td>
<td>May become a biological sink as a result of invaders, predators or other impacts.</td>
</tr>
<tr>
<td></td>
<td>Restricted tidal connection could limit the species of fish that can be established.</td>
</tr>
</tbody>
</table>
Sub-goal 3. Physical/Chemical Processes: Maintain and establish physical and chemical processes consistent with the restoration goals.

Objectives:

a. Improve tidal circulation and enlarge the amount of area that is tidally inundated.

b. Manage surface and subsurface freshwater inflows to support desired on-site habitats.

c. Establish and maintain a sediment transport regime that supports the desired wetland functions.

d. Re-establish a dynamic range of hydrologic conditions (intensity and duration) to support natural ecosystem processes.

e. Establish and maintain biogeochemical processes representative of natural wetland ecosystems.

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase tidal flow into the site</td>
<td>Flood conveyance in Ballona Creek Channel needs to be maintained</td>
</tr>
<tr>
<td>Improve tidal connectivity within the site by enlarging existing channels and</td>
<td>Existing tidal connections are insufficient to create and maintain a</td>
</tr>
<tr>
<td>culverts, and creating new channel networks</td>
<td>significant area of natural tidal wetland</td>
</tr>
<tr>
<td>Improve management of tide gates to create a muted tidal system</td>
<td>Elevations are too high, fill disposal will be difficult</td>
</tr>
<tr>
<td>with long-term management of water levels</td>
<td></td>
</tr>
<tr>
<td>Change the roads and berms to improve habitat connections, reduce flood</td>
<td>Existing infrastructure may limit hydrologic connections within the site</td>
</tr>
<tr>
<td>hazards and accommodate sea-level rise</td>
<td></td>
</tr>
<tr>
<td>Include distributary channels in the bluff deltas for coarse sediment</td>
<td>Urban watershed negatively impacts sediment supply, water quality and</td>
</tr>
<tr>
<td>distribution where feasible</td>
<td>hydrograph of potential freshwater sources</td>
</tr>
<tr>
<td>Restore a more natural tidal slough system linking freshwater areas to tidal</td>
<td>Natural channel formation may be limited due to lack of tidal scour, high</td>
</tr>
<tr>
<td>marsh</td>
<td>elevations, soil type and absence of antecedent channel network</td>
</tr>
<tr>
<td>Enhance historic Centinela Creek in Area B by increasing freshwater flows.</td>
<td>Limited supply of fine sediments to the site may limit march evolution over</td>
</tr>
<tr>
<td>Reduce current flooding problems around the project area</td>
<td>time</td>
</tr>
<tr>
<td>Daylight outlet culvert of the Freshwater Marsh</td>
<td>Low-lying properties around the periphery of the site may need to be</td>
</tr>
<tr>
<td></td>
<td>protected from flooding</td>
</tr>
<tr>
<td></td>
<td>The upstream reach of Centinela Creek has been diverted.</td>
</tr>
</tbody>
</table>
### Physical/Chemical Processes, continued

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modify Ballona Creek levees by realignment or changing the form of the bank</td>
<td></td>
</tr>
<tr>
<td>Coordinate the management of tide gates in the Ballona Ecosystem (Del Rey Lagoon, Ballona Lagoon &amp; Ballona Wetlands)</td>
<td></td>
</tr>
</tbody>
</table>
**Sub-goal 4. Sustainability:** Facilitate the conservation and restoration of natural resources in a manner that maintains and improves the ecological integrity, function, diversity and productivity for future generations.

**Objectives:**

- *a.* Accommodate potential sea level rise for transitional habitat provide appropriate elevations to accommodate habitat shifts
- *b.* Use self-sustaining, low maintenance systems where possible
- *c.* Minimize future adverse effects of nuisance species, including non-native, invasive species, feral predators and disease vectors.
- *d.* Protect the wetlands from adverse impacts caused by contaminants in influent water or sediment.
- *e.* Plan for the long term management of the site

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accommodate rising sea level by using site slope to allow habitat migration</td>
<td>Future development of surrounding areas</td>
</tr>
<tr>
<td>Provide sufficient tidal flow to maintain channel system</td>
<td>Maintenance and management resources have not been identified</td>
</tr>
<tr>
<td>Incorporate principles of adaptive management in restoration design to phase</td>
<td>Some sources of water and sediment to the site may be contaminated, those</td>
</tr>
<tr>
<td>implementation and test different methods</td>
<td>contaminants may accumulate in the restoration area</td>
</tr>
<tr>
<td>Utilize (or employ) existing organizations to maintain and implement</td>
<td>Accumulation of contaminants or pollutants on the site: including trash and</td>
</tr>
<tr>
<td>stewardship activities at the site</td>
<td>aerial deposition</td>
</tr>
<tr>
<td>Use low maintenance processes to improve water quality of urban runoff</td>
<td>Site vulnerable to invasive species, onsite and from local area</td>
</tr>
<tr>
<td>entering the wetlands</td>
<td></td>
</tr>
<tr>
<td>Design site to minimize the impacts of streetlights, traffic noise and other</td>
<td>Rising sea level may inundate low lying areas</td>
</tr>
<tr>
<td>urban characteristics on habitat values</td>
<td></td>
</tr>
<tr>
<td>Reduce management costs associated with tide gates</td>
<td>Infrastructure, such as gas facilities, needs to be maintained</td>
</tr>
</tbody>
</table>
**Goal 2: Social and Socioeconomic Values:** Create opportunities for aesthetic, cultural, recreation, research and educational use of the Ballona Ecosystem that are compatible with the environmentally sensitive resources of the area.

**Sub-goal 1. Public Access:** Design enhanced access to and within the Ballona Ecosystem consistent with ecosystem preservation and restoration values in a safe, consistent, coherent and functional manner.

**Objectives:**
- Develop gateway entrances that attract, welcome and inform ecosystem visitors.
- Phase-out inappropriate or uncontrolled access points.
- Create public outreach, education and interpretive opportunities for visitors, organizations and institutions.
- Develop appropriate signage that enhances visitor understanding of wetland restoration efforts; increase public awareness of local biological and physical resources present within Ballona Wetlands.
- Develop overlooks and connections accessible to pedestrian, bike and bus users and provide the appropriate signage to facilitate such access.
- Provide potential opportunities for the public to participate in restoration and monitoring efforts.

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop parking areas and designated entry points for the public on currently disturbed or developed areas.</td>
<td>Informal access points and associated unauthorized and uncontrolled uses</td>
</tr>
<tr>
<td>Develop interpretative components to educate the public on the values of wetland functions and habitat, build on existing educational programs</td>
<td>Public access areas reduce the area available for restoration</td>
</tr>
<tr>
<td>Design access with buffers between people and sensitive habitat areas</td>
<td></td>
</tr>
<tr>
<td>Install facilities to serve visitors of the site</td>
<td></td>
</tr>
<tr>
<td>Improve overlook points. For example, potential to use sediment material onsite to create high points</td>
<td></td>
</tr>
<tr>
<td>Install consistent signage</td>
<td></td>
</tr>
</tbody>
</table>
Public Access, continued

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide access that serves people with disabilities</td>
<td></td>
</tr>
<tr>
<td>Incorporate educational and stewardship activities into the Little League program</td>
<td></td>
</tr>
</tbody>
</table>

Sub-goal 2. Cultural Access and Preservation: Initiate formal and informal consultation with representatives of the Gabrielino/Tongva Tribal Council to develop guidelines that contribute to the preservation of sacred and cultural sites.

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide access for cultural use of the site by native people</td>
<td>Protection of cultural resources on site may constrain site design</td>
</tr>
<tr>
<td>Preserve cultural resources onsite</td>
<td></td>
</tr>
<tr>
<td>Educate the public regarding archaeological and historic resources</td>
<td></td>
</tr>
</tbody>
</table>
Sub-goal 3. Recreational Use: Design site to accommodate an appropriate level of fishing, boating, walking, and other activities consistent with the Ecological Reserve Designation and ecosystem restoration values.

Objectives:

a. Provide public trails and viewing areas around the perimeter of the wetlands with interpretive displays at selected locations.

b. Concentrate potentially incompatible human activities in non-sensitive areas

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop a recreational plan compatible with the Ecological Reserve designation</td>
<td>Existing unauthorized uses, such as BMX use and dog walking, may be incompatible with Ecological Reserve designation</td>
</tr>
<tr>
<td>Integrate existing trails, features and disturbed areas into the designated trail network</td>
<td></td>
</tr>
<tr>
<td>Integrate trail network with local and regional trails, bikeways and transportation systems</td>
<td></td>
</tr>
</tbody>
</table>
Sub-goal 4. Public Safety and Security: Design public access so that the wetlands are a safe place to visit.

Objectives:

a. Design access to minimize maintenance costs

b. Provide access points at locations responsive to the needs of law enforcement.

c. Create and maintain access points in a manner that minimizes safety concerns and hazards.

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide for a safe visitor experience through site design</td>
<td>Major roadways cross the site, fast moving traffic, limited places for parking</td>
</tr>
<tr>
<td>Consolidate Gas Company facilities, separate from habitat areas and public access</td>
<td>Poorly secured site, hard to control all unauthorized access in an urban setting</td>
</tr>
<tr>
<td>Improve traffic-related safety concerns through crosswalks, walkways and safe parking areas</td>
<td>Unknown extent of methane or other potentially harmful substances</td>
</tr>
<tr>
<td>Improve emergency access to the site</td>
<td>Need to protect public health by limiting disease vectors (such as mosquitos)</td>
</tr>
</tbody>
</table>
APPENDIX B.
HABITAT DESCRIPTIONS FOR RESTORATION ALTERNATIVES
I. INTRODUCTION

The Ballona Wetlands Restoration Project seeks to restore ecosystem structure, function, and processes at Ballona Wetlands, in particular those related to the support of biodiversity. A method of organizing biological diversity information for the Ballona Wetland Restoration Project is to group plants and animals by the “habitat” in which they are most likely to be sustained under improved conditions. One measure of progress toward achieving habitat restoration goals, therefore, is a determination of whether or not these targeted organisms are supported by the manipulated habitats to a measurable and acceptable level of sustained occurrence. Performance criteria can be established to measure establishment of species populations in these habitats. Physical parameters of the environmental also can be monitored and compared against data from reference sites or expected conditions to determine if the restored areas are performing within a range of anticipated values.

The following are generalized groups of habitats (organized by category and type) with information regarding characteristics such as structural feature, ecosystem function, and landscape process as well as dominant or characteristic plant species, characteristic animal species, and presumed extirpated or rare or endangered species that could be candidates for translocation and recovery experiments or goals within the Ballona Ecosystem.

The categories and subcategories of habitats are arranged from estuarine deepwater habitats and wetlands to palustrine wetlands, followed by uplands within the Ballona Ecosystem and within the estuarine category from subtidal (deepwater) and intertidal open water and non-vegetated types of habitats to vegetated types, generally going from lower elevation and hence more frequently flooded types to less frequently flooded types, an important distinction when assessing habitat characteristics. Habitat restoration design as it relates to the potential for significant sea level rise due to global climate change is an important consideration for the Ballona Wetland Restoration Science Advisory Committee during the evaluation of restoration alternatives for the Ballona Ecosystem.
II. LIST OF HABITAT CATEGORIES AND TYPES

Habitat Category I – Estuarine Open Water: Non-vegetated Habitats and Flooded Substrates:

1. Deepwater Habitats (mud and sand substrates) – Open Water Subtidal Conditions

2. Deepwater Subtidal and Wetland Intertidal Channels (cobble/gravel and riprap substrates) – Open Water Subtidal, Intertidal, and High Tide Conditions

3. Intertidal Wetland Habitats (sand and mud substrates) – Intertidal and High Tide Conditions

Habitat Category II - Estuarine Non-vegetated Intertidal Wetland Habitats

4. Intertidal Margins, Beds, Banks, and Benches (mud and sand substrates) - Low Tide Conditions

5. Intertidal Channels (cobble/gravel and riprap substrates) - Low Tide Condition

6. Mudflats

7. Hyperhaline Salt Flats

Habitat Category III - Estuarine Vegetated Wetlands:

8. Aquatic Bed Wetlands

9. Cordgrass (Low) Marsh

10. Marsh Plain (Middle Marsh)

11. High Marsh (clay/mud or sand/loam substrates)

12. High Marsh Transition Zone (including Euryhaline and Hyperhaline Habitats)

13. Brackish Marsh (an associated Open Water Habitat)
Habitat Category IV - Palustrine Nontidal Wetlands:

14. Transitional Emergent Wetlands (delta distributaries and margins of estuaries)

15. Freshwater Marsh

16. Seasonal Palustrine Wetlands (including Haline Vernal Wetlands)

17. Palustrine Scrub/Shrub Wetland (= DFG “Riparian Scrub”)

18. Palustrine Forested Wetland (= DFG “Riparian Woodland”?)

Habitat Category V - Upland Habitats:

19. Grasslands (= DFG Non-native Herbaceous Vegetation)

20. Coastal Scrub (including Coastal Bluff Scrub)

21. Coastal Dune Scrub and Dune Herbs (including Foredunes)

22. Forests, Woodlands, Groves, and Tree Rows (including DFG “Eucalyptus Grove”)

III. HABITAT DESCRIPTIONS

Habitat Category I –

Estuarine Open Water: Non-vegetated Habitats and Flooded Substrates:

In the estuarine system, deepwater habitats are characterized by the subtidal water regime and wetlands are characterized by various non-storm-influenced intertidal water regimes including irregularly exposed, regularly flooded, and irregularly flooded regimes.

1. Deepwater Habitats (mud and sand substrates) – Open Water Subtidal Conditions

Narrative (refer to other open water habitats for additional information): Subtidal deepwater habitats include channels, bays, basins, and other features, which at extreme low water do not drain with the outgoing tides. The subtidal estuarine water regime results in permanently flooded habitats and permanent bodies of open water. These habitats are generally considered truly aquatic systems and are adjacent to and downslope from tidal estuarine wetlands. Estuaries with extensive deepwater habitat areas often support adjacent areas of intertidal mudflat and low marsh wetland habitats.

The “plants” of channels and creeks, both intertidal and subtidal, are generally nonvascular taxa, but under brackish conditions may include various aquatic bed and emergent vascular species. The non-vascular plants include phytoplankton (e.g., diatoms) and macroalgae, which, along with the detritus from decomposed Cordgrass (Spartina foliosa), are often direct links in the estuarine food chain (i.e., are directly consumed by higher order consumers). Benthic invertebrates are the most visible consumers of detritus, algae and plankton. Crabs and snails graze on detritus and macroalgae, while bivalve mollusks filter feed on phytoplankton. Polychaete worms inhabit the fine sediments of tidal creeks, while fish exploit the water column and substrate surface.

Fish use of subtidal habitats can be categorized by various functional groups or guilds including, for example, (1) adult and juvenile marine fish, such as Leopard Sharks (Triakis semifasciata), Grey Smoothhounds (Mustelus californicus), and Stripped Mullet (Mugil cephalus) that enter estuaries with incoming tides to forage in estuaries, (2) adult marine fish such as Round Rays that feed and mate in estuaries; (3) marine fish such as California Halibut (Paralichthys californicus) that use flooded estuarine habitats especially channels as nursery habitat for young-of-the-year juvenile populations; (4) estuarine restricted fish such as Long-jawed Mudsuckers (Gillichthys mirabilis) that spend their entire life cycle in estuaries; (5) estuarine fish such as Tidewater Gobies (Eucycloplus newberryi) that are restricted to particular types of estuaries with brackish
water but that survive under marine conditions during floods and return to estuaries under reduced runoff conditions; (6) anadromous fish such as a Steelhead Trout (*Oncorhynchus mykiss*) that live under marine conditions as adults but enter estuaries to spawn either in estuaries or in rivers and streams on adjacent watersheds. In general most estuaries do not support all of the fish guilds, but collectively, southern California estuaries as a whole provide functions for each guild.

Estuarine open water habitats such as those provided by permanently flooded conditions are important foraging areas for birds from other habitats. Of note is the endangered California Least Tern (*Sternula antillarum brownii*), which breeds on sandy habitats adjacent to marine and estuarine wetlands and forages on small fish, primarily Top Smelt (*Atherinops affinis*) and Northern Anchovy (*Engraulis mordax*) in the relatively shallow water of estuaries. Shallow water habitat also is important for foraging by wading birds [e.g., Snowy and Great Egrets (*Egretta thula*, *Casmerodias albus*), Green, Black-crown Night, and Great Blue Herons (*Butorides virescens*, *Nycticorax nycticorax*, *Ardea herodias*), wading shore birds [e.g., Willet (*Catoptrophorus semipalmatus*)], diving birds including grebes, mergansers, and many ducks. The endangered Brown Pelican (*Pelecanus occidentalis*) is a frequent forager in estuarine open water habitats such as those provided by permanently, semi-permanently flooded, and intertidal water regimes. Open waters also provide low-tide refuges for species that move on to the mudflat and marsh plain during high tide.

**Structural features:** bays, lagoons, channels.

**Deepwater habitats:** Estuarine Unconsolidated Bottom and Rocky Bottom, and Estuarine Streambed Deepwater Habitats.

**Physical processes:** estuarine hydrology including tidal hydraulics; fluvial hydrology in river and creek mouth estuaries; marine and shoreline processes associated with estuary mouth dynamics; sediment transport; biogeochemistry.

**Water regime/hydrology:** subtidal, permanently flooded (i.e., deepwater habitats).

**Salinity:** haline to mixohaline.

**Dominant/characteristic plant(s):** diatoms, algae.

**Associated plant(s):** *Zostera marina*, *Potamogeton pectinatus*, *Ruppia maritima*, *Ruppia chirrosa* in various types of Estuarine Aquatic Bed Deepwater Habitat.

**Characteristic animals:** perhaps over 35 species of fish depending on type of estuary and guild of fishes present; suites of benthic and epibenthic invertebrates including various mollusks, crustaceans, worms, etc.; wading birds; dabbling and diving waterfowl; foraging Osprey.
**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; resident and migratory bird resting and foraging habitat, source populations of marsh-plain fish species (e.g., California Killifish, Long-jaw Mudsuckers); nutrient removal (denitrification at anoxic-soil/oxic-water interface; also P removal with sediment deposition); maintain predictable environment by maintaining hydrological connectivity and reducing extremes of drought (hypersalinity) and/or freshwater flooding (hyposalinity).

**Recovery opportunities:** foraging habitat for California Least Tern (*Sterna antillarum brownii*), California Brown Pelican (*Pelecanus occidentalis californicus*), and Osprey (*Pandion haliaetus*); flat fish nursery habitat including California Halibut (*Paralichthys californicus*), Starry Flounder (*Platichthys stellatus*), and Diamond Turbot (*Hypsopsetta guttulata*).

**Management Issues:** water quality.

2. **Deepwater Subtidal and Wetland Intertidal Channels (cobble/gravel and riprap substrates) – Open Water Subtidal, Intertidal, and High Tide Conditions**

**Narrative** (refer to other open water habitats for additional information): Estuarine channels and creeks play a critical role in salt marshes as they convey tidal waters and associated nutrients and dissolved gases. They also support a complex assemblage of plants and animals, and are particularly diverse when cobble beds provide surfaces for attachment by some invertebrates (e.g., mussels, oysters, barnacles, and limpets) and protective habitats for others (e.g., crabs, gobies). This substrate differences separates this habitat type (#2) from type #3 (sand and mud substrates).

Estuarine channels and creeks are subjected to a wide variety of environmental conditions including fluctuations in salinity and depth of tidal inundation. Typically, tidal flushing is greatest at the tidal inlet and decreases with distance from the inlet. This general gradient, in turn influences, water movement, salinity, temperature, nutrients, and dissolved gases. These environmental factors influence the species composition, distribution, and population dynamics of the channel fauna.

**Structural features:** marine cobble deltas, cobble channel beds and bars, riprap.

**Deepwater Habitats and Wetlands:** Estuarine Streambed and Unconsolidated Shore and Bottom (cobble/gravel) Wetlands and Estuarine Rocky Shore and Rocky Bottom (boulder) Wetlands and Estuarine Deepwater Habitats.
**Physical processes**: estuarine hydrology including tidal hydraulics; fluvial hydrology in river and creek mouth estuaries; marine and shoreline processes associated with estuary mouth dynamics; sediment transport; biogeochemistry.

**Water regime/hydrology**: subtidal, permanently flooded (i.e., deepwater habitats); intertidal irregularly exposed, regularly flooded, irregularly flooded.

**Salinity**: haline and mixohaline.

**Dominant/characteristic plant(s)**: micro-algae (e.g., diatoms, cyanobacteria); macro-algae (e.g., *Ulva* and *Enteromorpha*).

**Associated plant(s)**: none.

**Characteristic animals**: oysters; mussels; crustaceans including Shore, Mud, and Fiddler Crabs; possibly over 70 species of invertebrates in cobble beds; wading birds; dabbling and diving waterfowl; foraging Osprey. Many estuarine fish species also use these channels depending on the type of estuary and habitat.

**Ecosystem functions**: maintenance of biodiversity; habitat for rare, endangered, and special interest species; biofiltration (e.g., bivalve filtration from mussels, oysters, etc.), nutrient cycling/biogeochemistry; N and P removal as above; carbon removal by shell forming mollusks.

**Recovery opportunities**: *Ostreola conchaphila* (native oyster) on cobble-gravel and other hard substrates; foraging habitat for California Least Tern, California Brown Pelican, and Osprey.

**Management issues**: water quality including sedimentation; loss of habitat due to dredging in some estuaries; expansion of habitat in other estuaries due to ongoing accretion of marine deltas.

### 3. Intertidal Wetland Habitats (sand and mud substrates) – Intertidal and High Tide Conditions

**Narrative** (refer to other open water habitats for additional information): Intertidal channels and creeks play a critical role in salt marshes as they convey tidal waters and associated nutrients and dissolved gases. They also support a complex assemblage of plants and animals. Estuarine channels and creeks are subjected to a wide variety of environmental conditions. Typically, tidal flushing is greatest at the tidal inlet and decreases with distance from the inlet. This general gradient, in turn influences, water movement, salinity, temperature, nutrients, and dissolved gases. These environmental factors influence the species composition, distribution, and population dynamics of the channel fauna.
Structural features: intertidal channels, creeks, basins, banks, benches, marsh plain, as well as margins of deepwater habitats in bays, lagoons and subtidal channels, natural creek levees and back-levee depressions (pools).

Wetlands: Estuarine Unconsolidated Bottom, Unconsolidated Shore, Streambed, Aquatic Bed, and Emergent wetlands.

Physical processes: estuarine hydrology including tidal hydraulics; fluvial processes in tidal river and stream channels; marine and shoreline processes in estuary mouths; sediment transport; biogeochemistry.

Water regime/hydrology: intertidal – semi-permanently flooded, irregularly exposed, regularly flooded, irregularly flooded.

Salinity: haline or mixohaline.

Dominant/characteristic plant(s): diatoms.

Associated plant(s): none or Spartina foliosa and Sarcocornia pacifica (Salicornia virginica), and other species as appropriate on flooded habitat margins and the marsh plain; channel banks provide substrate for germination of Ulva spp. spores, which then grow into blades that break free and become highly productive floating mats.

Characteristic animals: perhaps over 35 species of fish depending on type of estuary and habitat; suite of benthic and epibenthic invertebrates including Cerithidea californica (California Horn Snail) and various clam genera including Tagelus, Macoma, Protothaca; wading birds including egrets and herons; dabbling and diving waterfowl; and foraging Osprey.

Ecosystem functions: maintenance of biodiversity; habitat for rare, endangered, and special interest species; resident and migratory bird resting and foraging habitat, source populations of marsh-plain fish species (e.g., killifish, mudsuckers); nutrient cycling/biogeochemistry; N and P removal.

Recovery opportunities: flat fish habitat including California Halibut, Starry Flounder, and Diamond Turbot; foraging habitat for California Least Tern, Brown Pelican, and Osprey.

Management issues: water quality including sedimentation; loss of habitat due to dredging in some estuaries; expansion of habitat in other estuaries due to ongoing accretion of marine deltas.
**Habitat Category II**

**Estuarine Non-vegetated Intertidal Wetland Habitats**

4. **Intertidal Margins, Beds, Banks, and Benches (mud and sand substrates) - Low Tide Conditions**

**Narrative:** Within the intertidal wetland portion of estuaries and in addition to mudflat features for those estuaries that support flats, other non-vegetated structures, including channel beds, banks and benches, often occur that can have similar functions to mudflats exposed at low tide conditions. These structures are group together here when lacking aquatic bed or emergent wetland vegetation cover.

**Structural features:** bay and lagoon margins and beds, bottoms, banks, and benches of estuarine channels and creeks.

**Wetlands:** Estuarine Streambed, Unconsolidated Shore, and Unconsolidated Bottom Wetlands.

**Physical Processes:** estuarine hydrology including tidal hydraulics; biogeochemistry.

**Water regime/hydrology:** irregularly exposed, regularly flooded.

**Salinity:** haline and mixohaline.

**Dominant/characteristic plant(s):** diatoms.

**Associated plant(s):** none or *Spartina foliosa, Sarcocornia pacifica (Salicornia virginica)* on margins; channel banks provide substrate for germination of *Ulva* spp. spores, which then grow into blades that break free and become highly productive floating mats.

**Characteristic animals:** suite of benthic and epibenthic invertebrates including *Cerithidea californica* (California Horn Snail) and various clam genera including *Tagelus, Macoma, Protothaca*; wading and shore birds (foraging); polychaetes; oligochaetes.

**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; biofiltration, food chain support and nutrient cycling, N and P removal, C removal by bivalves.

**Recovery opportunities:** channel bench and similar habitat for Fiddler Crabs (*Uca crenulata*).
Management issues: water quality and sedimentation issues.

5. Intertidal Channels (cobble/gravel and riprap substrates) - Low Tide Conditions

Narrative: Estuarine channels and creeks play a critical role in salt marshes as they convey tidal waters and associated nutrients and dissolved gases. They also support a complex assemblage of plants and animals, and are particularly diverse when cobble beds provide surfaces for attachment by some invertebrates (e.g., mussels, oysters, barnacles, and limpets) and protective habitats for others (e.g., crabs, gobies). Estuarine channels and creeks are subjected to a wide variety of environmental conditions including fluctuations in salinity and depth of tidal inundation. Typically, tidal flushing is greatest at the tidal inlet and decreases with distance from the inlet. This general gradient, in turn influences, water movement, salinity, temperature, nutrients, and dissolved gases. These environmental factors influence the species composition, distribution, and population dynamics of the channel fauna.

Structural features: marine cobble deltas, cobble channel beds and bars, riprap.

Wetlands: Estuarine Unconsolidated Shore and Bottom (cobble/gravel) and Estuarine Rocky Shore and Rocky Bottom (boulder).

Physical processes: estuarine hydrology including tidal hydraulics; fluvial hydrology in river and creek mouth estuaries; marine and shoreline processes associated with estuary mouth dynamics; biogeochemistry.

Water regime/hydrology: intertidal irregularly exposed, regularly flooded, irregularly flooded.

Salinity: haline and mixohaline.

Dominant/characteristic plant(s): micro-algae (diatoms, cyanobacteria); macro-algae.

Associated plant(s): none.

Characteristic animals: oysters and mussels (hard substrates) crustaceans including Shore, Mud, and Fiddler Crabs; possibly over 70 species of invertebrates in cobble beds.

Ecosystem functions: maintenance of biodiversity; habitat for rare, endangered, and special interest species; low tide resting habitat for resident and migratory
birds and foraging habitat for shorebirds and clapper rail; biofiltration (by bivalves), nutrient cycling/biogeochemistry; food chain support.

**Recovery opportunities:** *Ostreola conchaphila* (native oyster), shore bird feeding habitat.

**Management issues:** water quality including sedimentation.

### 6. Mudflats

**Narrative:** Extensive mudflats generally occur in estuaries that have gradually sloping shorelines and are sufficiently large enough to support a extensive open water and low marsh habitats or that are flooded for long periods due to closure of the estuary mouth or reduced tidal flow, presenting development of a vegetated marsh plain. Many estuaries that lack extensive mudflat habitat support functions for shore bird foraging and maintenance of invertebrate biodiversity because tidal channel beds and banks that are exposed at low tide provide similar habitat areas.

**Structural features:** down slope from low marsh and the marsh plain.

**Wetlands:** Estuarine Unconsolidated Shore and Unconsolidated Bottom Wetlands, and Estuarine Aquatic Bed Wetland (Irregularly Exposed).

**Physical processes:** extended periods of inundation prevent vascular plant growth.

**Water regime/hydrology:** regularly (daily) flooded by high tides.

**Salinity:** haline.

**Dominant/characteristic plant(s):** micro-algae, especially diatoms (over 100 species identified at some estuaries in s. CA).

**Associated plant(s):** at lowest tides, Eelgrass (*Zostera marina*) may be exposed (Estuarine Aquatic Bed Wetland, Irregularly Exposed) if present in estuary; macroalgae (e.g., *Ulva* spp.).

**Characteristic animals:** invertebrates: crabs, shrimp, clams, etc. (some are listed above regarding intertidal creeks] and shorebirds.

**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; nitrogen fixation by microalgae, sediment accumulation (and P removal), nutrient cycling, denitrification, invertebrate habitat, shorebird foraging.
Recovery opportunities: shorebird feeding habitat.

Management issues: mudflat is a very limited in most southern California estuaries. Sedimentation elevates the mudflat to levels that can support vascular plants; once vascular plants are established, the habitat is less suitable for shorebird feeding.

7. Hyperhaline Salt Flats

Narrative: Whereas intertidal mudflats occur at low elevations, permanently hypersaline salt flats are an important part of continuum from upland to low marsh. Salt flats but generally form only when the elevational gradient of the marsh plain is sufficient low for this evaporate zone to form at the higher levels of infrequent tidal inundation. As with restoration of all tide influenced habitats, establishment of hyperhaline salt flat and adjacent euryhaline marsh habitats require careful consideration of elevation, frequency and duration of inundation, and substrate texture. Salt flats alternate between flooded and drought conditions, which prevent most plants from occurring or from developing closed canopies if they are present. The open flat, with an occasional subshrub (e.g., *Arthrocnemum (Salicornia) subterminale*), offers certain shore birds a rare habitat that allows both feeding and refuge from predators.

Structural features: shallow depressions of upper marsh plain, banks, upper tidal deltas

Wetlands: Estuarine Unconsolidated Shore (Irregularly Flooded)

Physical processes: Estuarine processes including tidal hydraulics; geochemical processes including formation of evaporate deposits; salt concentration so that soils prevent invasion by exotic plants.

Water regime/hydrology: irregularly flooded by tides; < 25% of high tide.

Salinity: hyperhaline - 200 g/L or more in dry season.

Dominant/characteristic plant(s): none; scattered *Arthrocnemum subterminale*.

Associated plant(s): none.

Characteristic animals: Staphylinid beetles; shorebirds use these areas as refugia.
**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; resting and foraging areas for migratory birds, especially during high tides when other habitats are inundated.

**Recovery opportunities:** Tiger beetles (?); Elegant Tern (*Sterna elegans*) roosting habitat.

**Management issues:** Naturally occurring salt flat habitats, such as along the margins of estuarine deltas, were often some of the first areas filled in and developed in southern California estuaries. The Ballona Ecosystem supports habitat on dredge spoil in areas that were previously lower elevation habitats on the marsh plain. Preservation of salt plat habitat and functions may require relocation of the habitat if existing conditions are altered as part of a restoration plan.

### Habitat Category III

**Estuarine vegetated wetlands:**

#### 8. Aquatic Bed Wetlands

**Narrative:** This habitat category as described herein includes a number of different types depending on the structure of the habitat and the dominant organism, such as algae, bluegreen algae, vascular plants, etc. For example, nutrient-rich, estuarine channels are likely to be dominated by floating *Enteromorpha intestinalis* whereas nutrient-rich, exposed mud flats may be characterized by *Enteromorpha clathrata*. Lagoons, channels, and flooded marsh depressions with haline salinities may support dense, submersed colonies of *Ruppia maritima*, whereas similar areas that are mixohaline are likely to be characterized by *Ruppia cirrhosa* and other vascular aquatic-bed species.

**Structural features:** depressions in marsh plain, intertidal and subtidal channels, lagoons, and bays; haline vernal wetlands.

**Wetlands:** Estuarine Aquatic Bed Algal; Estuarine Aquatic Bed Rooted Vascular.

**Physical processes:** Estuarine processes including hydraulics.

**Water regime/hydrology:** variable depending on class of wetland and type of estuarine system; includes permanently flooded, semi-permanently flooded; intermittently exposed, regularly flooded, irregularly flooded.

**Salinity:** haline; mixo-haline.
Dominant/characteristic plant(s): Algae – various species represented including Enteromorpha, Ulva, Porphyra, etc, but many examples are not large enough or provide a dense enough cover to warrant distinction as a wetland type; Rooted vascular plants – various species depending on conditions, including Ruppia maritima (haline or euryhaline) and Potamogeton pectinatus, Ruppia cirrhosa, and Zannichellia palustris (mixohaline). Floating vascular plants – e.g., Lemna gibba (mixohaline).

Associated plant(s): as noted above or various emergent species in adjacent wetlands.

Characteristic animals: food and habitat for aquatic invertebrate species and for small fish species, including Tidewater Goby (Eucyclogobius newberryi) under mixohaline conditions.

Ecosystem functions: maintenance of biodiversity; habitat for rare, endangered, and special interest species; food chain support for waterfowl such as dabbling ducks; bio-assimilation of nutrient pollution; nutrient cycling/biogeochemistry; N and P removal.

Recovery opportunities: Mixohaline (i.e., brackish) environments that support Ruppia cirrhosa are frequently habitat for populations of Tidewater Goby (Eucyclogobius newberryi), a federal endangered and state fish of concern.

Management issues: water quality.

9. Cordgrass (Low) Marsh

Narrative: Low salt marsh is regularly and daily inundated by tides and is dominated by California Cordgrass (Spartina foliosa) that forms dense monotypic stands, primarily along channel edges and adjacent to mudflats. At its lower elevation, cordgrass intergrades with mudflat habitat; at its upper elevation it intergrades with a mosaic of mid-marsh species. California Cordgrass is a highly productive species. It decomposes to form the base of the detrital food chain that supports many lower order estuarine consumers. The tall canopy provides cover for birds such as Curlew and Pintail Duck, which forage during migration.

Many of the animals of the low marsh are adapted to periods of frequent inundation. These include California horn snail, Lined Shore Crab (Pachygrapsus crassipes), Yellow Shore Crab (Hemigrapsus oregonensis), and Fiddler Crab (Uca crenulata). The best-studied animal of the low marsh is the federal and state-endangered Light-footed Clapper Rail (Rallus longirostrus levipes). This species generally nests in the cordgrass that grows in the low marsh and feeds on fishes and crustaceans in adjacent tidal creeks. It also nests in pickleweed on the marsh plain and in bulrushes in brackish marsh vegetation.
**Structural features:** lower edge of the marsh plain, tidal channel margins

**Wetlands:** Estuarine Emergent Persistent Wetland (Regularly Flooded)

**Physical processes:** Estuarine processes including tidal hydraulics; sediment accumulation.

**Water regime/hydrology:** regular (daily) flooding by tides

**Salinity:** hypersaline and saline to brackish

**Dominant/characteristic plant(s):** *Spartina foliosa*; also patches of *Batis maritima*.

**Associated plant(s):** *Salicornia bigelovii*.

**Characteristic animals:** *Pachygrapsus crassipes*; *Hemigrapsus oregonensis*; *Uca crenulata*; California Horn Snail (*Cerithidea californica*).

**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; sediment accumulation and reduced erosion along channel edges; nutrient cycling/biogeochemistry; N and P removal; C sequestration; high rates of primary productivity and food web support; invertebrate habitat; fish habitat when flooded by tide water.

**Recovery opportunities:** *Spartina foliosa* (where it previously existed or to compensate for areas where its population is declining); Light-footed Clapper Rail (Fed. & State endangered bird).

**Management issues:** potential impacts from native and introduced predators of marsh nesting birds (Light-footed Clapper Rail); excessive sedimentation.

### 10. Marsh Plain (Middle Marsh)

**Narrative:** Intermediate elevations within the salt marsh are inundated irregularly by tides but at a greater frequency than are higher elevations. As a result, the plant species that inhabit this elevation are adapted to occasional prolonged inundation. The dominant plant is Pickleweed [*Sarcocornia pacifica* (*Salicornia virginica*)] a perennial with the broadest elevation range of all salt marsh species. Other common mid-marsh species include Saltwort (*Batis maritima*), Arrow-grass (*Triglochin concinnum*), Estero Sea-blite (*Suaeda esteroa*), and Jaumea (*Jaumea carnosa*). An important feature of the marsh plain is its topographic heterogeneity, which includes creeks, creek banks, levees, and shallow depressions. The creeks provide habitat for Longjaw Mudsucker (*Gillichthys mirabilis*);
creek levees tend to support more plant species than the plain (e.g., Estero Sea-blite is especially abundant near creeks), and the shallow depressions (5-10 cm) tend to reduce biomass of perennial pickleweed. When this dominant is subdued, the annual pickleweed (*Salicornia bigelovii*) can establish and persist. Deeper depressions (>10 cm) retain tidal water and become feeding oases for the California Killifish (*Fundulus parvipinnus*); shallow depressions develop algal growths that support dense populations of invertebrates that are suitable prey for fish.

The animals of the mid-marsh are abundant and diverse. Food is abundant in the form of algae and vascular plant detritus. Animals that feed directly on algae include Ephydrid flies, amphipods, and snails such as the Olive Snail (*Melampus olivaceus*) in marsh vegetation and California Horn Snail (*Cerithidea californica*) in open flats and channels. A variety of birds forage in the mid-marsh, especially during higher tides when mudflats are under water, including Willet (*Catoptrophorus semipalmatus*), Marbled Godwit (*Limosa fedoa*), Long-billed Curlew (*Numenius americanus*), Great Blue Heron (*Ardea herodias*), and Great Egret (*Ardea alba*). The state endangered Belding’s Savannah Sparrow (*Passerculus sandwichensis beldingii*) inhabits the marsh plain where it prefers to nest in pickleweed in mid and high marsh conditions.

**Structural features:** mid-marsh plain, rivulets, tidal pools, creek-side levees and back-levee depressions.

**Wetlands:** Estuarine Emergent Persistent Wetland (Irregularly Flooded).

**Physical processes:** estuarine processes including tidal hydraulics and maintenance of sediment and elevation.

**Water regime/hydrology:** irregularly flooded by tides (ca. 50% of high tides).

**Salinity:** saline to hypersaline.

**Dominant/characteristic plant(s):** *Sarcocornia pacifica* (*Salicornia virginica*).

**Associated plant(s):** *Frankenia salina, Jaumea carnosa, Distichlis spicata, Suaeda esteroa, Triglochin concinna*.

**Characteristic animals:** *Fundulus parvipinnis* (California Killifish); *Melampus olivaceus*; polychaetes; oligochaetes.

**Ecosystem functions:** plant diversity support (the marsh plain is potentially diverse in native halophytes), habitat for rare, endangered, and special interest species; insect support, nutrient cycling/biogeochemistry; N and P removal; primary productivity and detrital food web support.
Recovery opportunities: Belding’s Savannah Sparrow (State endangered bird); Long-billed Curlew (*Numenius americanus*); Estero Seep-weed (*Suaeda esteroa*); Northern Harrier (*Circus cyaneus*).

Management issues: sedimentation (increase in elevation and loss of shallow depressions that form pools and create feeding oases, or erosion (decrease in elevation); potential impacts to marsh nesting birds (Belding’s Savannah Sparrow).

11. High Marsh (clay/mud or sand/loam substrates)

Narrative: High marsh habitats are irregularly to intermittently inundated by tidal water and generally range from saline to hypersaline conditions. Plants that comprise the high marsh include the Parish’s Glasswort [*Arthrocnemum subterminale* (*Salicornia subterminalis*)], Shoregrass (*Monanthochloe littoralis*), Alkali Heath (*Frankenia salina*), and Sea Lavender (*Limonium californicum*). The vegetation varies depending on the drainage and density of the soil (i.e., ratio of clay to sand), which often is correlated with salinity. Vegetation in dense, hypersaline (salinity greater than seawater) or euryhaline (fluctuating salinity, seasonal hypersalinity) is quite different than loose, sandy soils. The endangered Salt Marsh Bird’s Beak (*Cordylanthus maritimus* spp. *maritimus*) occurs in high marsh and is more abundant in sandy soils. Likely the open canopies of sandy areas allow seeds to germinate after rainfall while also offering roots for this hemiparasite to parasitize. High marsh vegetation provides habitat for Belding’s Savannah Sparrow, staphylinid beetles, the snail *Assiminea transluscens*, and other estuarine restricted species.

Structural features: upper marsh plain, slopes of berms and banks; upper tidal deltas.

Wetlands: Estuarine Emergent Persistent Wetland (Irregularly Flooded).

Physical processes: Estuarine processes including tidal hydraulics; also Aeolian-influenced processes if adjacent to dune systems, or fluvial-influenced if on a delta.

Water regime/hydrology: Irregularly flooded by tides (< 50% of high tides).

Salinity: saline, hyperhaline, euryhaline.

Dominant/characteristic plant(s): *Arthrocnemum subterminale*; *Monanthochloe littoralis*.

Associated plant(s): *Sarcocornia pacifica*, *Limonium californicum*, *Distichlis spicata*, *Spergularia macrotheca*, *Atriplex watsonii*, *Frankenia salina*
**Characteristic animals:** *Asiminea transluscens* (snail); Belding’s Savannah Sparrow; Cottontail; Ground Squirrels.

**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; high tide refuge for Light-footed Clapper Rail and Belding’s Savannah Sparrow.

**Recovery opportunities:** Light-footed Clapper Rail (Fed. & State endangered bird); Belding’s Savannah Sparrow (State endangered bird); Northern harrier (*Circus cyaneus*) foraging habitat; *Cordylanthus maritimus* ssp. *maritimus* (Fed. & State endangered plant)

**Management issues:** Loss of historic habitat due to filling and development. Vulnerable to invasion by many introduced invasive plant species including introduced species of *Limonium* (Sea Lavender), are less likely to invade lower elevations habitats, and introduced grass species such as Rabbit’s Foot Grass (*Polypogon monspeliensis*), Sicklegrass (*Parapholis incurva*), Italian Ryegrass (*Lolium multiflorum*) because it is rarely tidal and can have very low salinities at least seasonally.

### 12. High Marsh Transition Zone (including Euryhaline and Hyperhaline Habitats)

**Narrative:** The transition zone represents that area where the halophytic and hydrophytic salt marsh vegetation overlaps with upland communities. Storm-surge high tides may flood habitats transitional to upland habitats, including various palustrine wetlands adjacent to high marsh estuarine wetlands; however, they are generally considered to be located beyond the limits of estuarine wetlands, but within the more broadly defined “estuarine” ecosystem (e.g., the Ballona Ecosystem). At relatively undisturbed southern California estuaries, examples of Estuarine Scrub Shrub Wetland may occur in the transition zone and may include Boxthorn (*Lycium californicum*), Bush Seepweed (*Suaeda nigra*), Coast Golden Bush (*Isocoma menziesii*), Parish’s Glasswort (*Arthrocnemum subterminale*), and Quail Bush (*Atriplex lentiformis*). These overlap with the highest elevation salt marsh species including, for example, Saltgrass (*Distichlis spicata*), Alkali Weed (*Cressa truxillensis*), and Shoregrass (*Monanthochloe littoralis*). *Lycium* is a common perch for birds and various small mammals burrow under it. The fact that it is deciduous shrub that greens up whenever there is water available makes it an indicator of sewage spills or other off-season sources of water.

The animals of the higher elevations of the transition zone are primarily terrestrial species. Those associated with shrubby uplands such as portions of the transition zone include, for example, various species of snakes, lizards, small mammals and birds. Herpetofauna may include California Kingsnake (*Lampropeltis getulus californiae*), San
Diego Gopher Snake (*Pituophus melanoleucus annectens*) and side-blotched lizard (*Uta stansburiana*). Common mammals of the shrub-dominated uplands include Western Harvest Mouse (*Reithrodontomys megalotis*), Deer Mouse (*Peromyscus maniculatus*), Pocket Gopher (*Thomomys* sp.), Opossum (*Didelphis virginiana*), Striped Skunk (*Mephitis mephitis*), and California Ground Squirrel (*Spermophilus beecheyi*). The small mammals are preyed upon by a variety of birds including Short-eared Owl (*Asio flammeus*), Northern Harrier (*Circus cyaneus*), and White-tailed Kite (*Elanus caerulescens*). Ground-nesting bees that pollinate Salt Marsh Bird’s-Beak (*Cordylanthus maritimus* spp. *maritimus*) live above the high tide in this habitat. Boxthorn (*Lycium californicum*) offers a tall perch site for various birds, and its thorns can deter human intrusion.

One of the more interesting habitats is the euryhaline zone with fluctuating salinities between wet season low salinities and dry season hypersaline conditions. The habitat is characterized by winter annual plant species such as Salt Marsh Daisy (*Lasthenia glabrata* ssp. *coulteri*), Salt Marsh Sand-sperry (*Spergularia marina*), Toad Rush (*Juncus bufonius*), and Hutchinsia (*Hutchinsia procumbens*), which are adapted to the fluctuating salinities. The euryhaline zone is generally located upslope from hyperhaline salt flats and down-slope from nontidal palustrine wetland or grassland habitats and is perhaps the habitat most representative of Mediterranean climate estuarine wetlands.

The transition zone may also include nontidal palustrine habitats both salt influenced and non-saline types. Seeps from perched water tables on deltas and the toe of slopes and along dune transitions often support a variety of palustrine emergent and scrub-shrub types. Characteristic non-saline or slightly brackish species may include shrubs such as Mule Fat (*Baccharis salicifolia*) and herbaceous species such as spiny-rush (*Juncus acutus*), Willow-Dock (*Rumex salicifolia*), and Alkali Ryegrass (*Leymus triticoides*). Seasonal palustrine wetlands also occur in this area, especially in low-gradient deltaic deposits and may include salt-influenced types supporting a variety of native annual species such as Alkali Barley (*Hordeum depressum*). Belding’s Savannah Sparrows use the taller shrubs of this habitat during the non-nesting season.

**Structural features:** alluvial plain, upper deltas, banks.

**Wetlands:** Estuarine Emergent Persistent and Nonpersistent Wetland (Irregularly Flooded); Estuarine Scrub Shrub Wetland (Broadleaved Deciduous and Evergreen).

**Physical processes:** estuarine processes including tidal hydraulics; fluvial-influenced if on a delta; geochemical processes including formation of evaporate deposits.

**Water regime/hydrology:** (irregularly flooded by tides; i.e., < 20% of tides); and adjacent storm-tide influenced wetlands, palustrine wetlands, and uplands.
Salinity: fluctuating from mixohaline and saline to hyperhaline (more saline than sea water) and euryhaline (fluctuating salinity) and upslope to potentially non-haline.

Dominant/characteristic plant(s): Arthrocnemum subterminale, Monanthochloe littoralis, Lycium californicum.

Associated plant(s): winter annuals including Spergularia marina, Juncus bufonius, Hordeum depressum, Lasthenia glabrata ssp. coulteri, Hutchinsia procumbens.

Characteristic animals: (see animals discussed above regarding the high marsh habitat).

Ecosystem functions: maintenance of biodiversity; habitat for rare, endangered, and special interest species; foraging areas for upland animals; resting areas for migratory birds; high tide refuge for Light-footed Clapper Rail; pollination support.

Recovery opportunities: Lasthenia glabrata coulteri (CNPS rare); Hutchinsia procumbens (locally extirpated); Tiger beetles (?); Northern Harrier (Circus cyaneus) foraging areas.

Management issues: Loss of historic habitat due to filling and development. Vulnerable to colonization by many introduced invasive plant species. This transitional habitat [and the high marsh as noted above] is highly susceptible to invasive species such as Rabbit’s Foot Grass (Polypogon monspeliensis), Sicklegrass (Parapholis incurva), Italian Ryegrass (Lolium multiflorum), and other grasses because it is rarely tidal and can have very low salinities at least seasonally, especially during unusually wet winters and in areas that receive substantial anthropogenic freshwater inputs.

13. Brackish Marsh (and associated Open Water Habitat)

Narrative: Sites where freshwater mixes with saline seawater produce brackish conditions with intermediate salinities. This phenomenon is less frequent in southern California where many estuaries are less influenced by runoff from rainfall than in more northerly latitudes. In southern California, brackish sites vary seasonally, with dilution during the wet season and concentration of salts during the dry season. Local influence from seeps and springs and seasonally impounded stream and river-mouths can produce brackish environments that support emergent vegetation characterized, for example, by Prairie Bulrush (Bolboschoenus (Scirpus) maritimus), and Southern Cattail (Typha domingensis), and aquatic bed species including (Potamogeton pectinatus) and Ditchgrass (Ruppia spp.). The biggest difference in plant composition between brackish
and salt marshes is often at the lower elevations in the marsh -- higher elevation areas of Mediterranean-climate brackish marshes tend to be similar to the mid-marsh plain or high marsh habitats of salt marshes. Tidewater Goby (Eucyclogobius newberryi), a Federal listed endangered species, occurs in systems or habitats within systems characterized by brackish water conditions.

**Structural features:** channels, depressions, basins, seeps and springs.

**Wetlands:** Estuarine Emergent Persistent and Nonpersistent Wetland (Semi-permanently Flooded); estuarine Aquatic Bed Wetland (Floating and Rooted Vascular; Algal).

**Physical processes:** Estuarine processes including tidal hydraulics; also fluvial-influenced if associated with a river channel and artesian-influenced if associated with seeps or springs from groundwater.

**Water regime/hydrology:** Tidally influenced with a wide range of tidal inundation frequencies depending on elevation and distance from the tidal inlet; seasonal dilution from surface water (runoff).

**Salinity:** brackish (mixohaline).

**Dominant/characteristic plant(s):** Prairie Bulrush [Bolboschoenus (Scirpus) maritimus]; California Bulrush, Tule [Schoenoplectus (Scirpus) californicus]; American Bulrush [Schoenoplectus (Scirpus) americanus]; Southern Cattail (Typha domingensis).

**Associated plant(s):** Salt Marsh Bulrush [Bolboschoenus (Scirpus) robustus] (unknown from Ballona?); Spiny Rush (Juncus acutus).

**Characteristic animals:** rails; bittern; wrens, Redwing Blackbird.

**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; biofiltration of freshwater runoff; nutrient cycling/biogeochemistry; N and P removal; C sequestration; sediment accumulation; very high rates of primary productivity in the lower portions of brackish and freshwater marsh areas; food web support.

**Recovery opportunities:** Light-footed Clapper Rail (Fed. & State endangered); Tidewater Goby (threatened); Brackish Water Snail (Tyonia imitator).

**Management issues:** Influence of stormwater runoff on formation of and impacts to brackish marshes; water quality; excessive sedimentation from upstream disturbances.
Habitat Category IV
Palustrine Nontidal Wetlands:

14. Transitional Emergent Wetlands (delta distributaries and margins of estuaries)

Narrative: The toe of slopes along estuary margins often provide opportunities for the formation of fresh or brackish water seeps and springs, including examples with well-developed dune fields containing freshwater lenses, deltas of rivers with shallow aquifers, and alluvial fans with artesian wells. These features can be the sites of estuarine brackish marshes and palustrine freshwater marshes. They also can support the development of palustrine emergent wetlands that are transitional in nature and similar to habitat type No 12 – High Marsh Transition Zone, but are distinctly palustrine and adjacent to estuarine habitats within coastal ecosystems.

Structural features: margins of dunes, deltas, banks, bluffs, alluvial fans and plains.

Wetlands: Palustrine Emergent Persistent Wetland.

Physical processes: Fluvial and/or groundwater hydrology.

Water regime/hydrology: (Permanently?), seasonally, temporarily, or intermittently saturated; temporarily or intermittently flooded.

Salinity: Freshwater to euryhaline. Due to brackish nature of water, salt spray, or rare storm-tide influences, or even concentration of salts by plants, soil salinity may increase during dry periods and may include formation of surface precipitates.

Dominant/characteristic Plant(s): Alkali Ryegrass (*Leymus triticoides*); Saltgrass (*Distichlis spicata*); Western Goldenrod (*Euthamia occidentalis*); Salt Marsh Baccharis (*Baccharis douglasii*).


Characteristic animals: small mammals including voles, harvest mice, field mice, gophers; herpetofauna.
Ecosystem functions: maintenance of biodiversity; habitat for rare, endangered, and special interest species; hydrology (seasonally saturated, temporarily flooded).

Recovery opportunities: foraging habitat for White-tailed Kite and other raptors; potential habitat for Ventura Marsh Milk-vetch (*Astragalus pycnostachys* var. *lanosissimus* - Fed and State listed endangered plant); Wandering Skipper (butterfly); Southern Salt Marsh Shrew (*Sorex ornatus salicornicus*).

Management issues: invasion by Giant reed (*Arundo donax*) and Myoporum (*Myoporum laetum*).

15. Freshwater Marsh

Narrative: Freshwater marshes occur in saturated, organic rich or sometime mineral soils. The dominant plants are generally emergent monocots such as cattails (*Typha spp.*) and bulrushes [e.g., *Schoenoplectus (Scirpus) californicus*], although aquatic-bed species, such as pondweeds (*Potamegeton spp.*), may also be common. Redwing Blackbirds (*Agelaius phoeniceus*) and Marsh Wrens (*Cistithorus palustris*) commonly breed in the tall, dense vegetation. Common mammals include Raccoon (*Procyon lotor*), Striped Skunk and Opossum. Freshwater marsh habitat may also support the Light-footed Clapper Rail, although this is not considered optimal breeding or foraging habitat. These marshes may provide refugia for rails and other bird species during extreme high tides and rive floods. Creation and maintenance of freshwater marsh habitat is dependent upon a continual source of freshwater. Some coastal wetland restoration plans have incorporated freshwater and brackish marshes due to historical evidence of springs adjacent to intertidal areas.

Structural features: river and stream channels; ponds; seeps and springs

Wetlands: Riverine Nonpersistent Emergent Wetland; Palustrine Emergent Persistent Wetland (Permanently or Semi-permanently Flooded, Irregularly Exposed).

Physical processes: Fluvial and/or groundwater.

Water regime/hydrology: Permanently flooded; intermittently flooded; seasonally flooded; permanently and seasonally saturated.

Salinity: fresh water to slightly brackish (groundwater conditions).

Dominant/characteristic Plant(s): Broadleaved Cattail (*Typha latifolia*); Bur-reed (*Sparganium eurycarpum*); California Bulrush (*Schoenoplectus californicus*); Southern Cattail (*Typha domingensis*).

**Characteristic animals:** Western Pond Turtle, Red-legged Frog; rails, waterfowl, Red-winged Blackbird (*Agelaius phoeniceus*); many passerine birds.

**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; nutrient cycling/biogeochemistry; N and P removal; C sequestration; sediment accumulation; high rates of primary productivity; habitat for breeding birds.

**Recovery opportunities:** Western Pond Turtle (*Clemmys marmorata*); California Red-Legged Frog (*Rana aurora draytonii*); Light-footed Clapper Rail and other rail species known to use freshwater marshes adjacent to estuaries in southern California; Least Bittern (*Ixobrychus exilis*); Northern Harrier (*Circus cyaneus*); Spiny Rush (*Juncus acutus*).

**Management issues:** excessive sedimentation; subject to shrub invasion (e.g., willow invasion). Sites that are less frequently flooded can have substantial problems with non-native grasses such as Rabbitsfoot Grass. Also, Giant Reed and Pampas Grass are large perennial grasses that can be problematic.

---

**16. Seasonal Palustrine Wetlands (including Haline Vernal Wetlands)**

**Narrative:** Seasonal wetlands are non-tidal wetlands and transitional habitats that are flooded to varying degrees by seasonal rainfall and runoff. If there are sufficient salts in the soil, the seasonal wetland may support plant species more typical of coastal salt marsh, such as Pickleweed [*Sarcocornia pacifica* (*Salicornia virginica*)], Saltgrass (*Distichlis spicata*), and Alkali Weed (*Cressa truxillensis*). If the soils do not contain salts or alkaline substances, the seasonal wetlands may support freshwater marsh species and a mixture of weedy opportunists. “Vernal pools” and saline vernal wetlands of transition zones can occur on alluvial and deltaic deposits adjacent to estuarine habitats and are known to support special concern plants and invertebrate animals (e.g., fairy shrimp species).
Seasonal wetlands can be important to a number of bird species that feed on the insects, algae and aquatic invertebrates that develop in these temporary habitats. Amphibians, such as western toad (*Bufo boreas*) and Pacific Tree Frog (*Pseudacris regilla*) have been noted to breed in this habitat. These areas also attract mammals, such as Coyote, Raccoon, Striped Skunk and Opossum. In areas where water pools deeply enough, waterfowl species such as Mallard (*Anas platyrhynchos*), Cinnamon Teal (*Anas cyanoptera*) and American Coot (*Fulica Americana*) have been observed. Seasonal wetlands may also be used by shorebirds such as Killdeer (*Charadrius vociferus*) and Black-necked Stilts (*Himantopus mexicanus*).

**Structural features:** depressions in deltas and fill deposits often associated with other palustrine wetlands adjacent to estuarine wetlands

**Wetlands:** Palustrine Emergent Wetland, persistent and non-persistent types, seasonally flooded and generally euryhaline

**Physical processes:** natural examples influenced by fluvial and coastal (storm) processes and anthropogenic effects from disturbances including infilling, dredging, grading, etc.

**Water regime/hydrology:** Seasonally flooded

**Salinity:** Fresh water or euryhaline (low salinity when flooded and higher salinity when dry)

**Dominant/characteristic Plant(s):** Haline vernal wetland examples – Alkali Barley (*Hordeum depressum*); Pickleweed (*Sarcocornia pacifica*); Salt Marsh Daisy (*Lasthenia glabrata ssp. coulteri*); Salt Marsh Sand-Sperry (*Spergularia marina*); Toad Rush (*Juncus bufonius ssp. halophilus*?). Freshwater examples – Meadow Barley (*Hordeum brachyantherum ssp. brachyantherum*).

**Associated plant(s):** Alkali Mallow (*Malvella leprosa*); Alkali Weed (*Cressa truxillensis*); Sea-Purslane (*Sesuvium verrucosum*); Horned Sea-blite (*Suaeda calceoliformis*); Seaside Heliotrope (*Heliotropium curassavicum*); Slim Aster (*Symphyotrichum subulatum*); Sticky Conyza (*Conyza coulteri*).

**Characteristic animals:** planktonic (e.g., rotifers, crustaceans including copepods, cladocerans) and macroscopic (e.g., aquatic insect larvae) invertebrates.

**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; shorebird foraging habitat.
**Recovery opportunities:** Silver Scale (*Atriplex argentea* var. *mohavensis*) (extirpated?); Hutchinsia (*Hutchinsia procumbens*) (extirpated?); Southern Tarweed (*Centromadia. parryi* ssp. *australis*); fairy shrimp species?

**Management issues:** impacts (e.g., cover and thatch) from introduced annual weeds including Brass Buttons (*Cotula coronopifolia*), Mediterranean Barley (*Hordeum marinum*), Italian Ryegrass (*Lolium multiflorum*), Rabbitsfoot Grass (*Polypogon monspeliensis*), and Sicklegrass (*Parapholis incurva*).

17. **Palustrine Scrub/Shrub Wetland (= DFG “Riparian Scrub”)**

**Narrative:** Willow scrub is characterized by dense broad-leafed, winter-deciduous riparian thickets dominated by several willow shrub and tree species (*Salix* spp.). Riparian trees also may occur with the association and may include, for example, scattered Fremont’s Cottonwood (*Populus fremontii*), and Western Sycamore (*Platanus racemosa*). Riparian woodland also may occur in small groves or in riverine corridors that drain into estuaries. As with other riparian habitats, riparian scrub supports a diverse assemblage of wildlife species, especially passerine bird species. The endangered Least Bell’s Vireo (*Vireo bellii pusillus*) and Southwestern Willow Flycatcher (*Epidonax traillii extimus*) as well as other sensitive species, such as Yellow Warbler (*Dendroica petechia brewsteri*) and Yellow-breasted Chat (*Icteria virens*) all depend on riparian woodlands for breeding. Mammal assemblages are similar to those found in freshwater marsh habitats as the two often intergrade. In an undisturbed estuarine system, willow scrub habitat would generally occur upstream of tidal influence as willows are very sensitive to salt. Like freshwater marsh, this habitat is dependent upon a constant source of freshwater.

**Structural features:** bluff and dune seeps or spring, floodplains.

**Wetlands:** Palustrine Scrub/Shrub Wetland (Broadleaved Deciduous and Evergreen).

**Physical processes:** fluvial and/or groundwater hydrology; sediment transport.

**Water regime/hydrology:** seasonally and permanently saturated; temporarily flooded; phreatophytic.

**Salinity:** fresh water.

**Dominant/characteristic Plant(s):** Arroyo Willow (*Salix lasiolepis*); Mule Fat (*Baccharis salicifolia*); Sandbar Willow (*Salix exigua*).

**Characteristic animals:** resident and migratory passerine birds, such as Common Yellowthroat (*Geothlypis trichas*) and Blue grosbeak (*Guiraca caerulea*), and those listed herein (habitat no. 18); herpetofauna and mammals of various guilds.

**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; refuges for estuarine wildlife species and wildlife corridors linking upland sites with coastal wetlands.

**Recovery opportunities:** Least Bell’s Vireo (*Vireo bellii pusillus*) and Southwestern Willow Flycatcher (*Eidonax trailli extimus*) as well as other sensitive species, such as Yellow Warbler (*Dendroica petechia brewsteri*) and Yellow-breasted Chat (*Icteria virens*).

**Management issues:** Impacts from invasive plant species including Giant reed (*Arundo donax*), Pampas Grass (*Cortaderia selloana*); Myoporum (*Myoporum laetum*).

**18. Palustrine Forested Wetland (= DFG “Riparian Woodland”?)**

**Narrative:** Palustrine Forested Wetland as discussed herein is generally characterized by isolated stands of trees or tall shrubs that occur at seeps, toe-of-slopes, ponded areas, along streams and rivers, and at other sites with shallow water tables. Arroyo Willow (*Salix lasiolepis*) is the most common representative but other native species such as additional willow species, Black Cottonwood (*Populus balsamifera* ssp. *trichocarpa*), and Western Sycamore (*Platanus racemosa*) are also represented. Riparian corridors along streams and rivers are no longer well developed due to impacts from urbanization, but portions of the original drainage of Centinela Creek still support riparian vegetation. In the riparian setting, trees in upland and wetland habitats may be included in mapped examples of this vegetation where the distinction among hydric (i.e., wetland), mesic, and xeric (i.e., upland) types of riparian vegetation are often not distinguished. A number of exotic species also may be represented including Myoporum (*Myoporum laetum*) and various species of *Eucalyptus*, especially Blue Gum (*Eucalyptus globulus*)

**Structural features:** bluff seeps, floodplains, margins of dunes and dune swales.

**Wetlands:** Palustrine Forested Broadleaved Deciduous Wetland.

**Physical processes:** fluvial and/or groundwater hydrology; sediment transport.
**Water regime/hydrology:** permanently, seasonally, temporarily, or intermittently flooded; permanently, seasonally saturated; phreatophytic.

**Salinity:** freshwater.

**Dominant/characteristic Plant(s):** Black Cottonwood (*Populus balsamifera* ssp. *trichocarpa*); Western Sycamore (*Platanus racemosa*); Arroyo (*Salix lasiolepis*).

**Associated plant(s):** Blue Elderberry (*Sambucus mexicana*); Coast Live Oak (*Quercus agrifolia*); White Alder (*Alnus rhombifolia*); Red Willow (*Salix laevigata*); Shining Willow (*Salix lucida* ssp. *lasiandra*); Black Willow (*Salix goodingii*); California Walnut (*Juglans californica*); various riparian shrubs and vine species and herbaceous plants including Stinging Nettle (*Urtica dioica* ssp. *holosericea*).

**Characteristic animals:** Passerine birds including resident and migratory birds such as those sensitive species listed below; herpetofauna; shelter and corridor for mammals including raccoon, skunk, and coyote.

**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; breeding bird habitat.

**Recovery opportunities:** Southwestern Willow Flycatcher (*Empidomax trallii extimus*); Least Bell’s Vireo (*Vireo belli pusillus*); Western Yellow Warbler (*Dendroica petechia brewsteri*); Yellow-breasted Chat (*Icteria virens*).

**Management issues:** vulnerable to invasion by Giant Reed (*Arundo donax*) and various exotic vines (e.g. Cape Ivy), shrubs (Tamarisk), and tree species (e.g., *Eucalyptus* spp.); restore connectivity of stands when appropriate and feasible.

---

**Habitat Category V**

**Upland Habitats:**

**19. Grasslands (= DFG Non-native Herbaceous Vegetation)**

**Narrative:** Grasslands are illustrated on historic maps of the Ballona region and are likely to have occurred on alluvial deposits on the periphery of the coastal wetland ecosystem, mixed with various forms of coastal scrub. DFG recently used the designation “non-native herbaceous” for the category of vegetation that represents the existing conditions of “grassland”, “meadow”, or “prairie” vegetation within the Ballona Ecosystem. In a restored state, the vegetation could include native grass species and a diverse number of native herbaceous and sub-shrub species as noted above, with small
Ballona Wetland Restoration Project: Draft: 06-22-07
Habitat Descriptions for Restoration Alternatives

colonies and scattered individuals of coastal scrub species to provide perches and shelter for animals that characterize grassland and adjacent scrub and wetland habitats.

**Structural features:** upland alluvial deposits, graded spoil deposits,

**Physical processes:** potentially a fire-maintained community.

**Dominant/characteristic Plant(s):** in an upland context - California Barley (*Hordeum brachyantherum* ssp. *californicum*); Purple Needlegrass (*Nassella pulchra*); Salt Grass (*Distichlis spicata*); Alkali Ryegrass (*Leymus triticoides*).


**Characteristic animals:** resident and migratory grassland bird species including Horned Lark; herpetofauna including lizards and snakes, such as California King Snake and Gopher Snake; and small mammals including voles, mice, shrews, and moles.

**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; host plants for butterfly larvae including the Wandering Skipper Monarch (*Danaus plexippus*) butterflies; habitat for native small mammals; foraging habitat for raptors such as White-tailed Kite and Northern Harrier and egrets (Great Egret) and herons (Great Blue Heron).

**Recovery opportunities:** South Coast Marsh Vole (*Microtus californicus stephensi*); San Diego Black-tailed Jackrabbit (*Lepus californicus bennettii*); California Horned Lark (*Eremophila alpestris*); White-tailed Kite (*Elanus caeruleus*); Northern Harrier (*Circus cyaneus*).

**Management issues:** Maintenance of grassland habitat to prevent it becoming coastal scrub (using fire, grazing, or mowing techniques?); control of invasive plant species.
20. Coastal Scrub (including Coastal Bluff Scrub)

Narrative: The general category “coastal scrub” includes a number of shrub-dominated plant communities in the context of a variety of land forms. Coyote Brush and California Sage Brush form colonies on alluvial and disturbed soils and can occur within the context of grassland and other herbaceous vegetation. Upland delta scrub can be quite rich in shrub species and occurs in alluvium adjacent to wetland forms of delta scrub often dominated by Mulefat (Baccharis salicifolia). Coastal Bluff Scrub is limited to coastal bluffs where salt tolerant species including Wooly Sea-Blite (Suaeda taxifolia) and Quail Bush (Atriplex lentiformis) are characteristic but occurs in different forms depending on proximity to salt spray. Within the bluff community, sparsely-vegetated areas or areas with low vegetation also can support a wide variety of herbaceous species, some of which are also associated with coastal dunes. Coastal Dune Scrub is treated separately herein. No Maritime Chaparral occurs in the Ballona Ecosystem.

Other forms of upland coastal scrub include, for example, Delta Scrub and Baccharis Scrub, which can be transitional to wetland scrub types.

A variety of terrestrial animals, including amphibians, reptiles, mammals and birds are supported by coastal scrub habitat. For instance, Coastal Sage Scrub is the preferred breeding habitat of the coastal California Gnatcatcher (Pilipoptila californica californica).

Structural features: alluvial deposits, berms and banks; coastal bluffs.

Physical processes: fluvial, erosional, (and anthropogenic).

Dominant/characteristic Plant(s): Coyote Brush (Baccharis pilularis); California Sagebrush (Artemisia californica); Mugwort (Artemisia douglasiana); Quail Bush (Atriplex lentiformis); Douglas’ Nightshade (Solanum douglasii); Lemonade Berry (Rhus integrifolia); Seacliff or Dune Buckwheat (Eriogonum parvifolium).

Associated plant(s): Laurel Sumac (Malosma laurina); Cliff Aster (Malacothris saxatilis); Deerweed (Lotus scoparius); Black Sage (Salvia mellifera); Wild Morning-glory (Calystegia macrostegia); Melic Grass (Melica imperfecta); Foothill Needlegrass (Nassella lepida); California Brome (Bromus carinatus); Mock Heather (Ericameria ericoidea); Bladderpod (Isomeris arboreus); Elderberry (Sambucus mexicanus); Wild Cucumber (Marah macrocarpus); Giant Ryegrass (Leymus condenstatus); California Encelia (Encelia californica); Suffrutescent Wallflower (Erysimum insulare ssp suffrutescens); Coastal Prickly Pear (Opuntia littoralis); California Buckwheat (Eriogonum fasciculaum); Milk Vetch (Astragalus trichopodus); Branching Phacelia (Phacelia ramosissima var.

austrolittoralis); Bush Mallow (Malacothamnus fasciculatus); Lewis’ Evening Primrose (Camissonia lewisii); Toyon (Heteromeles arbutifolia); Chaparral Nightshade (Solanus xanti); Wooly Sea-blite (Suaeda taxifolia).

**Characteristic animals:** Loggerhead Shrike (Lanius ludovicianus) perching; California Gnat Catcher (Polioptila californica californica) endangered; resident and migratory passerine birds including Luzuli Bunting (Passerina amoena) and Blue Grosbeak (Guiraca caerulea); small mammals.

**Ecosystem functions:** maintenance of biodiversity; habitat for rare, endangered, and special interest species; breeding bird habitat; refuge for resident estuarine birds.

**Recovery opportunities:** Pacific Pocket Mouse (Perognathus longimembris pacificus); Loggerhead Shrike (Lanius ludovicianus) perching; California Gnat Catcher (Polioptila californica californica) breeding habitat; Suffrutescent Wallflower (Erysimum insulare ssp. suffrutescens); Lewis’ Evening Primrose (Camissonia lewisii); Coastal Dunes Milkvetch (Astragalis tener var. ttit).

**Management issues:** plan for connectivity among sites; invasive species such as Pampas Grass.

### 21. Coastal Dune Scrub and Dune Herbs (including Foredunes)

**Narrative:** Dune habitat represents a form of transition zone between the land and the sea and includes Coastal Dune Scrub and Dune Herb vegetation. Coastal dune habitats have been largely lost due to development in southern California. Prior to development, plant species such as dune lupine (Lupinus chamissonis), Mock Heather (Ericameria ericoideis), dune primrose (Camissonia cheiranthifolia), sand verbena (Abronia maritima) and dune ragweed (Ambrosia chamissonis) stabilized the loose sand, and the dunes where thereby anchored. Following human disturbance, many of the native plants were eliminated and exotics, such as sour-fig (Carporotus edulis) and sea rocket (Cakile maritima) invaded or were planted.

Dunes are important habitats for several species of rare insects including Globose Dune Beetle (Coelus globosus), the Sandy Beach Tiger Beetle (Coelus hiticollis gravida), and Sand Dune Tiger Beetle (C. latesignata latesignata). The San Diego Horned Lizard and Silvery Legless Lizard (Anniella pulchra pulchra) were once common; the later still occurs within the Ballona Ecosystem. The endangered California Least Tern (Sterna antillarum browni) and Western Snowy Plover (Charadrius alexandrinus nivosus) are associated with dune habitat but generally nest in the upper beach environment, which is no longer connected to the dunes.
Structural features: coastal dunes

Physical processes: aeolian transport and deposition of sands; storm influenced.

Dominant/characteristic Plant(s): Dune Lupine (*Lupinus chamissonis*); Dune Buckwheat (*Eriogonum parvifolium*); Beach Bur (*Ambrosia chamissonis*); Beach Evening Primerose (*Camissonia cheiranthifolia*); Common Sand Verbena (*Abronia umbellata*).

Associated plant(s): California Croton (*Croton californicus*), Tall Stephanomeria (*Stephanomeria virgata*), Mock Heather (*Ericameria ericoides*), Yellow Pincushion (*Chaenactis glabriuscula*), California Sun Cup (*Camissonia bistorta*), Lewis’ Evening Primrose (*Camissonia lewisii*), Miniature Sun Cup (*Camissonia micrantha*), Coastal Dunes Milkvetch (*Astragalus tener var. titi*).

Characteristic animals: Silvery Legless Lizard (*Anniella pulchra pulchra*); Globose Dune Beetle (*Coelus globosus*); Ciliated Dune Beetle.

Ecosystem functions: maintenance of biodiversity; habitat for rare, endangered, and special interest species; source of freshwater seeps along interface with salt marsh habitat.

Recovery or protection opportunities: Silvery Legless Lizard (*Anniella pulchra pulchra*); El Segundo Blue Butterfly (*Euphilotes battoides allyni*); Dorothy’s El Segunda Dune Weevil (*Trigonoscuta dorothea dorothea*); Globose Dune Beetle (*Coelus globosus*); Lande’s El Segundo Dune Weevil (*Onychobaris langei*); Suffrutescent Wallflower (*Erysimum insulare ssp. suffutescens*); Beach Spectaclepod (*Dithyrea maritima*), Lewis’ Evening Primrose (*Camissonia lewisii*).

Management issues: Remnant dunes are disjunct from coastal processes that formed them hence no natural disturbance regime, and beach related habitats are missing from the complex. Vulnerable to introduced invasive plant species.

22. Forests, woodlands, groves, and tree rows (including DFG “Eucalyptus Grove”)

Narrative: Oak woodlands, characterized by Coast Live Oak (*Quercus agrifolia*), are characteristic along slopes, bluffs, and banks adjacent to various estuaries in southern California but may not have been located within or in proximity to the Ballona Ecosystem. Nonetheless, Coast Live Oaks may have been in the more xeric portions of riparian forests that included stands of Western Sycamore (*Platanus racemosa*). Current conditions include a number of groves and stands of planted or naturalized, largely exotic trees (e.g., Blue Gum, *Eucalyptus globulus*) within the Ballona Ecosystem. Some of these sites have important ecosystem functions such as nesting areas for great Blue Herons,
whereas others (e.g., Myoporum and Acacia) may be less important depending on the site and role in the ecosystem.

**Structural features:** cultivated areas; roadsides; yards; banks and bluffs.

**Physical processes:**

**Dominant/characteristic Plant(s):** *Eucalyptus* spp.; Myoporum (*Myoporum laetum*).

**Associated plant(s):** numerous species of planted and naturalized trees including Acacia (*Acacia baileyana*); California Walnut (*Juglans californica*); Peruvian and Brazilian Pepper Trees (*Schinus molle* and *S. terebinthifolia*); Canary Island Date Palm (*Phoenix canariensis*); Slender Fan Palm (*Washingtonia robusta*); Carob (*Ceratonia siliqua*); Sweet Gum (*Liquidambar styraciflua*); Olive (*Olea europea*); Velvet Ash (*Fraxinus velutina*); Fremont Cottonwood (*Populus fremontii*); Chinese Elm (*Ulmus parvifolia*).

**Characteristic animals:** resident and migratory passerine birds; roosting and possibly nesting raptors; roosting and nesting herons.

**Ecosystem functions:** habitat for rare, endangered, and special interest species; perches for raptors.

**Recovery opportunities:** Preservation/expansion of Great Blue Heron rookery; potential for Monarch Butterfly over-wintering habitat in groves of Blue Gum (*Eucalyptus globulus*).

**Management issues:** Monarch Butterflies use exotic Eucalyptus trees as winter roosts. Need to retain butterfly habitat (if Eucalyptus trees are targeted as butterfly habitat at Ballona), while not encouraging spread of exotic tree species.
Hydrodynamic modeling was conducted in support of the development and evaluation of restoration alternatives for the Ballona Wetlands Restoration Project. The Environmental Fluid Dynamics Code (EFDC) hydrodynamic model was selected because of its capacity to model the relevant physical processes, its compliance with regulatory standards, and its availability in the public domain at no cost.

This appendix documents the development, calibration, and alternative implementation of the EFDC model. It also provides supporting documentation for specific model results discussed in the Feasibility Report. This appendix is not a stand-alone report and should be reviewed in conjunction with Section 3.3 (Hydrology) of the Feasibility Report.

Because the EFDC model uses metric units, some of the model results in this appendix are presented using metric units. However, the discussion in the Feasibility Report uses English units to follow local convention. As a result, this appendix presents some results in metric units and some in English units.

Sections C-1 and C-2 were prepared as stand-alone memos. Section C-1 discusses the EFDC model development and calibration. Section C-2 discusses the representation of marsh channel networks within the model. Section C-3 shows overview plots of model bathymetry for each alternative. Section C-4 provides supporting documentation for model results discussed in Section 3.3 (Hydrology) of the Feasibility Study.
C-1. LOWER BALLONA CREEK MODELING – EFDC MODEL DEVELOPMENT AND CALIBRATION

1. INTRODUCTION

This section presents the calibration process for the Environmental Fluid Dynamics Code (EFDC) hydrodynamic model developed for the Ballona Creek Wetland Restoration Project. The EFDC model was configured such that predicted water levels accurately replicate observed water levels from a two-week calibration period. Typically, predicted water levels agree to within 5 cm of the observed water levels. Having calibrated the EFDC model, it is ready to characterize the hydrologic response of the proposed restoration actions for feasibility assessment purposes.

This section includes details of the model development and calibration. The section on model development describes the EFDC model in general and summarizes how the model was configured to represent the Lower Ballona Wetland system. The section on calibration describes the calibration approach and compares model predictions and field observations.

2. MODEL DEVELOPMENT

The EFDC model was chosen to simulate the Lower Ballona Wetland system after discussion between the Project Management Team, the Science Advisory Committee and the LA District, Corps of Engineers. Benefits of this model include its capacity to model the relevant physical processes, its compliance with regulatory standards, and its availability in the public domain at no cost.

After briefly describing EFDC’s general characteristics, this section describes the application of the model to the Lower Ballona Wetland system, including the model’s domain, boundary conditions, initial conditions and model execution. The linked Lower Ballona Wetland system includes lower Ballona Creek; Ballona Wetland Restoration Areas A, B, and C; Marina Del Rey; Del Rey Lagoon; Ballona Lagoon; the Grand Canal; and a portion of Santa Monica Bay. The uncertainties with respect to the model predictions are discussed.

2.1. MODEL DESCRIPTION

EFDC is a numerical model designed for simulating flows in open water systems. The model was originally developed at the Virginia Institute of Marine Science and receives continuing support from the U.S. EPA. A complete description of the model assumptions, governing equations and approximations, including the space discretization, time integration, and numerical solution methods is presented in Hamrick (1992). Tetra Tech (2002) provides guidance in using the model as well as references to successful applications of EFDC for a variety of tidally-influenced systems.

The physical processes represented in the model include important aspects of the Lower Ballona Wetland system:

- unsteady tidal flow,
• boundary wetting and drying, and
• hydraulic control structures.

EFDC solves the physical equations for fluid flow on a staggered, finite-difference grid. The modeling domain is defined by a curvilinear flexible mesh, enabling the grid to follow dominant terrain features. At present, the model has been configured to predict two-dimensional (2D) depth-averaged flow. Although not implemented for this study, the model can be extended to simulate three-dimensional (3D) flows and the transport of salt, sediment, and/or contaminants.

2.2. MODEL DOMAIN

The model domain defines the portion of the physical environment that is included in the model. Its extent should include the system’s relevant components and processes between these components. Additionally, the boundaries of the system should be sufficiently far from the region of interest such that boundary conditions do not overly constrain flow in the region of interest. When constructing the model’s horizontal grid that defines the domain, these factors must be balanced against model execution time. The vertical component of the model domain is defined by the system’s bathymetry. Further information about the physical setting within the model domain can be found in PWA (2006).

2.2.1. Model extent

The model domain extends from where Ballona Creek passes under Sawtelle Boulevard to Santa Monica Bay, as shown in Figure 1. The upstream boundary is beyond the range of tidal influence and coincides with a discharge monitoring station. Placing the downstream boundary within Santa Monica Bay provides ample distance and tidal volume between the specified tidal boundary condition and the region of interest. Between the upstream and downstream boundaries, the model domain includes:

- lower Ballona Creek;
- Ballona Wetland Restoration Areas A, B and C;
- Marina Del Rey, including Oxford Basin;
- Del Rey Lagoon;
- Ballona Lagoon, including the Grand Canal downstream of Washington Boulevard; and
- a portion of Santa Monica Bay roughly 1.3 km by 2.5 km.

2.2.2. Horizontal grid generation

EFDC employs a curvilinear orthogonal grid to represent the physical domain. The grid is analogous to a rubber sheet of graph paper. Its curvilinear aspect allows the grid to be stretched and transformed so that it aligns with the major topographic features of the model domain. However, orthogonality requirements dictate that the grid maintains nearly perpendicular intersections at cell boundaries.

The grid generation tools available within the EFDC modeling environment are somewhat limited in their functionality. Instead, DELFT3D’s grid generation software (WL | Delft Hydraulics, 2006b) was used to create the grid. DELFT3D’s graphical user interface provides robust tools for grid orthogonalization,
manipulation, and merging. After creating the grid with the DELFT3D software, the grid files were converted to EFDC format using MatLab programs. The grid cell sizes average 10 m across in most of the model domain, resulting in approximately 42,000 active cells within the domain.

2.2.3. **Bathymetry**

The bathymetry, or spatial map of surface elevations, is represented in the model as a single elevation value at the center of each grid cell. Multiple sources of bathymetric data were compiled to cover the entire model domain. The sources of bathymetry data for each region are listed below:

- **Ballona Creek**: Channel centerline elevations and width from the channel’s design drawings (Los Angeles County Flood Control District, 1959).


- **Marina Del Rey**: Elevations in the main stem of the marina from unpublished USACE dredging surveys in March 2006 and elevations in the mooring basins extrapolated from the adjacent main channel elevations.

- **Del Rey Lagoon**: Spot elevations from bathymetric survey drawings (City of Los Angeles, 2003) interpolated across the lagoon.

- **Ballona Lagoon and the Grand Canal**: Elevations from cross section surveys (Coastal Frontiers Corporation, 1989) and Ballona Lagoon Enhancement Project design drawings (City of Los Angeles, 1997).

- **Santa Monica Bay**: Bathymetric survey data from the National Oceanic and Atmospheric Administration (1997).

All elevation data were converted to the same horizontal datum (UTM Zone 10N) and vertical datum (NAVD88) using Corpscon software (U.S. Army Corps of Engineers, 2004). The data sets were then imported into the DELFT3D bathymetry generation software (WL | Delft Hydraulics, 2006a) and smoothly interpolated at the boundaries between data sets. The compiled bathymetric surface was converted into EFDC-specific input files using the EFDC_Explorer graphical user interface (Criag, 2004). To refine features such as wetland channels and elevated road bed that have widths on the order of the 10 m grid cell size, a MatLab program was used to inscribe these features into the bathymetry. This procedure ensures that these features are hydraulically contiguous, but yields a stair-step appearance as the features traverse diagonally across the grid. The compiled bathymetry for the model extent is shown in Figure 1. Figure 2 displays a portion of the bathymetry within the western portion of Area B that includes wetland channels and road bed. This figure demonstrates the implementation of these features as contiguous sets of grid cells.
2.3. BOUNDARY AND INITIAL CONDITIONS

Boundary and initial conditions describe the external forcing applied to the model and starting values for the predicted variables, respectively. Boundary conditions consist of:

- the tidal boundary within Santa Monica Bay,
- the freshwater inflows from the Ballona Creek watershed,
- culvert discharges, and
- bed roughness.

Initial conditions must be specified for the water surface elevation and velocity field when the model begins a simulation.

2.3.1. Tidal boundary

Comparison between the NOAA continuous tide gauge station at the Port of Los Angeles (Station ID 9410660) and water surface measurements in Ballona Creek collected by Nearshore and Wetland Surveys (2006) show good agreement with minimal amplitude differences or phase lag. For example, observations in Ballona Creek (Nearshore and Wetland Surveys, 2006) and at the Port of Los Angeles are shown in Figure 3. Because of the agreement between the two data sets, the Port of Los Angeles water surface elevation data was applied as the open tidal boundary condition at the model’s western edge in Santa Monica Bay. This tide station is well established and it can provide boundary condition data for a wide range of time periods. The northern and southern boundaries of the model grid in Santa Monica Bay are linked by a periodic boundary condition. This type of boundary condition minimizes the influence of these boundaries on model results.

2.3.2. Freshwater inflow

The primary freshwater inflow into the Lower Ballona system comes from Ballona Creek itself. The upstream model boundary coincides with the County of Los Angeles, Department of Public Work’s discharge station at Sawtelle Blvd (Station ID F38C-R). Observations from this station were used as a discharge boundary condition into the model.

2.3.3. Culvert and gate discharges

Culverts and gates regulate flow into and out of the Area B wetland, Fiji Ditch, Del Rey Lagoon, and Ballona Lagoon. Culvert flow is represented in the model as water-level-dependent discharge between a pair of grid cells. Discharges through all but one culvert are implemented in the EFDC model through an input file that specifies the discharge as a function of the difference in water levels at the ends of each culvert.

A slightly more complex specification was used for the gate that conveys water from Ballona Creek to the Area B wetland. Flow through this gate is governed by a self-regulating tide gate that closes automatically once the water level in Ballona Creek reaches a predetermined level. For this culvert, the discharge was
modeled as a function of both the upstream and downstream water levels and the discharge was set to zero when the upstream water level in Ballona Creek equal or exceeds the water level which triggers gate closure.

Observed water levels within the Area B wetland (Nearshore and Wetland Surveys, 2006) slowly increase even after the self-regulating tide gate has closed. This increase may result from leakage through either of the tide gates and/or seepage from the headlands to the south of the wetland. The exact source remains a point of discussion. To replicate these slowly increasing water levels, a constant discharge of 0.16 m$^3$/s was added as a source to the wetland. This rate was estimated from the observed rate of water level increase after the self-regulating tide gate has closed (Figure 5) and the area of inundated wetland during higher high water. If future investigation clarifies and quantifies the source of this water level increase, it can be more explicitly included in the model.

2.3.4. Bed roughness

Bed roughness relates the flow velocity to the frictional loss of momentum as the flow moves over the bed. EFDC parameterizes the bed friction’s effect on flow through a roughness height, $z_0$, based on the assumption of a logarithmic velocity profile. A typical, constant $z_0$ value of 0.002 m was applied across the entire domain (Blumberg and Mellor, 1987). Sensitivity analysis of water levels to variations in $z_0$ confirms that water levels are relatively insensitive to this parameter.

2.3.5. Initial conditions

Model start times were selected to coincide with slack tide when current speeds can be initialized to zero. Initial water levels throughout the model domain were set to a uniform value equal to the open boundary condition. The model was spun up for four days of simulation time to remove initial transients from the model results and enable water levels and velocities to equilibrate to the prescribed boundary conditions.

2.4. MODEL EXECUTION

For the model configuration described above, model testing indicates that stable and accurate predictions are achieved with a time step of two seconds. With this time step, simulations execute on a 3.6 GHz PC workstation at speeds approximately eight times faster than real time.

2.5. MODEL UNCERTAINTY

EFDC is a widely used modeling tool for estuarine simulations and has been validated in numerous studies (Tetra Tech, 2002). However, numerical models inherently rely on approximations that introduce sources of uncertainty in the model results. Uncertainties may be present both spatially and temporally, and may result from a variety of factors, including:

- physical characteristics of the model domain,
- specification of boundary conditions, or
- limitations in the model’s numerical formulation.
For the specific application of a hydrodynamic model of the Lower Ballona system, it is important to assess the modeling uncertainties and assumptions made in applying the model to understand the extent to which these uncertainties affect model predictions.

The largest uncertainties affecting model performance for the Lower Ballona model are the accuracy and resolution of available bathymetry and the grid resolution used in the model to resolve this bathymetry. To the extent possible, the model has made use of the most recent and best available bathymetric data and datum conversion tools (Section 2.2.3). However, when the bathymetric data is sampled onto the model grid, additional filtering of the bathymetric data occurs which limits the capacity of the model to resolve small-scale bathymetric features. The grid resolution for the model was selected to be as fine as possible, subject to the computation time restraints. The nominal grid cell size of 10 m prevents the model from accurately resolving the bathymetry in the smallest channels. However, since the volume of these small channels represents a small fraction of the overall domain, their exclusion is not likely to significantly alter the model’s predictions.

The model solves the 2D depth-averaged approximation of the hydrodynamic flow equations. The use of 2D simulations significantly reduces the computational time required for the model simulations but also introduces additional model uncertainty in the hydrodynamic predictions. This uncertainty is constrained because the wetland’s shallow depths and limited freshwater inputs minimize the impact of 3D flow effects.

Model uncertainties are also introduced through the specification of boundary conditions and model parameterizations, such as bed roughness. Additionally, any field data used either to force the model or to calibrate the model has some associated uncertainty due to instrument calibration and errors, instrument location, field corrections, and data noise.

3. MODEL CALIBRATION

The model was calibrated to observed water levels, primarily by adjustment of culverts and gate discharge rates. As presently calibrated, the model predicts water levels to within 5 cm of observations for nearly all of the calibration period. The sections below describe the calibration approach, summarize the observation data, compare predicted and observed water levels, and outline future refinements to the model.

3.1. CALIBRATION APPROACH

Calibrating a model involves adjusting model parameters or model formulation in order to match model predictions and field observations at known locations. Initially, the calibration process can verify that each of the specified model inputs and boundary conditions are working properly. Subsequent iterations of the calibration process enhance agreement between model predictions and observations. The model is run for a known set of input conditions, and its output is compared to a known set of observations. The discrepancies between the model predictions and the observation data help determine which aspects of the
model are not adequately capturing the physical processes. This may lead to adjusting some model parameters to improve agreement between predictions and observations.

Adjustments to model parameters are made until the model’s response to the specified inputs replicates the field measurements as closely as possible. The goal of the calibration process is to identify the areas and processes of highest interest, and maximize the model’s predictive capability in those areas, while ensuring reasonable behavior in the rest of the model predictions.

The model was calibrated to optimize agreement between observations and predictions of water levels. Calibration to water levels indicates that the model is correctly predicting the volumes of water that are exchanged between each region of the model. Calibration of Ballona Creek water levels required no adjustments to model parameters beyond the model setup described above in Section 0. To calibrate water levels at the other four observation stations, all of which are upstream of culverts, a coefficient scaling the discharge through the culverts was adjusted. Comparison between this calibrated discharge and the discharge estimated by the U.S. Geological Survey Culvert Analysis Program (CAP; Fulford, 1998) exhibit good agreement.

3.2. OBSERVATION DATA

The water level observations used for calibration were collected by PWA and Nearshore and Wetland Surveys (2006) in July and August, 2006. A representative spring-neap cycle from July 5 to July 20 was selected from this observation record as the calibration period to simulate. The five locations at which water levels were observed are shown in Figure 1. In addition to water levels in Ballona Creek, which is directly exposed to the tidal action, the other four stations are located in regions where the tidal flows are controlled by flow through gates and culverts.

3.3. WATER LEVEL COMPARISON

Time series of predicted water levels at five stations and the corresponding observed water levels are plotted in Figure 4 to Figure 8. For most of the two-week simulation period, these time series demonstrate agreement within 5 cm between the model predictions and observations. Differences larger than 5 cm between predictions and observations are typically caused by mechanisms beyond the scope of the model that are insignificant in comparison to the changes expected from restoration. Explanation for these larger differences between observations and predictions are discussed below:

- During several of the lowest tides in the middle of the simulation period, the observations bottom out at constant values that are above the predicted values (Figure 4 to Figure 7). This is because the instruments were mounted such that water levels during these lowest tides fell below their sensors and exposed the sensors to the atmosphere during these periods.
- As discussed above in Section 2.3.3, an unknown water source causes water levels to rise in the Area B wetland after the tide gates between Ballona Creek and the wetland close. The observed water levels consist of a rapidly rising section while the tide gate is open and then a slowly rising section once the tide gate closes (Figure 5). In the absence of data, the unknown source was modeled as a constant discharge to the wetland. This approximation of the source is sufficient to
reproduce the typical rising water levels during high tides. However, the source’s actual discharge rate probably varies in time, causing the differences between the observed and the modeled water levels.

- In Fiji Ditch (Figure 6), high frequency oscillations in the water level observations are consistent with the 6 to 8 second water level oscillations observed visually during instrument installation. It is hypothesized that these water level oscillations result from ocean swell that propagates through the marina and culvert. The model does not include the physical processes which create this type of water level oscillation since this process does not transport significant amounts of water.
- Below 0.25 m NAVD, predicted water levels in Del Rey Lagoon fall more rapidly than observed water levels (Figure 7). This difference may be the result of the representation of the lagoon’s bathymetry in the model, which was created by interpolation from relatively few spot elevations. Since the predictions at all other times and locations otherwise demonstrate good agreement with the observed water levels and the lagoon is only a small feature located outside the project area, the current implementation is sufficient for assessment of the restoration alternatives. If specific questions regarding circulation within the lagoon are of interest, the model’s representation of the lagoon’s bathymetry should be improved.
- The tide gates regulating flow into Ballona Lagoon (Figure 8) are manually adjusted to restrict flow during spring tides, e.g. from July 7 to July 14. This operational practice prevents flooding upstream of the gates. Since records of the actual gate settings are not maintained (Mariposa Landscaping, personal communication), no attempt was made to model the Lagoon’s water levels during this period. Hence, during the spring tides, the predicted water level continues to span nearly the full range of water levels in Ballona Creek while the observed water level within Ballona Lagoon was muted.

3.4. FUTURE WORK

Although the model is sufficiently calibrated to provide a feasibility assessment of the proposed restoration alternatives, additional calibration should be conducted for future stages of alternative design or evaluation of more complex processes, such as sediment transport or water quality. These additional steps include:

- Calibration to observed current velocity data
- Calibration to observed salinity data
- Validation to water levels during high Ballona Creek discharge

4. REFERENCES


5. FIGURES

Figure 1 Model Bathymetry, Full Extent
Figure 2 Model Bathymetry, Area B Wetland
Figure 3 Port of Los Angeles and Ballona Creek Observed Water Levels
Figure 4 Predicted vs. Observed Water levels, 2006 – Ballona Creek
Figure 5 Predicted vs. Observed Water levels, 2006 – Area B Wetland
Figure 6 Predicted vs. Observed Water levels, 2006 – Fiji Ditch
Figure 7 Predicted vs. Observed Water levels, 2006 – Del Rey Lagoon
Figure 8 Predicted vs. Observed Water levels, 2006 – Ballona Lagoon
Figure 1

Lower Ballona Modeling

Model Bathymetry, Full Extent


PWA Ref#: 1793.01
Figure 2

Lower Ballona Modeling

Model Bathymetry, Area B Wetland


PWA Ref# 1793.01

P:\Projects\1793_Ballona_Wetlands\1793.01_Modeling\Reporting\Model calib memo\Figs\Model calibration report figs v1.doc
Source: NOAA (Station ID 9410660) and Nearshore and Wetland Surveys (2006)

*Lower Ballona Modeling*

*Port of Los Angeles and Ballona Creek Observed Water Levels*
Source: USACE field observations and EFDC model predictions

Predicted vs. Observed Water levels, 2006 – Ballona Creek

PWA Ref# 1793.1

P:\Projects\1793_Ballona_Wetlands\1793.01_Modeling\Reporting\Model calib memo\Figs\ballona_wse_creek.pdf
Source: USACE field observations and EFDC model predictions

Figure 5

Lower Ballona Modeling

Predicted vs. Observed Water levels, 2006 – Area B Wetland

PWA Ref# 1793.1
Source: PWA field observations and EFDC model predictions

Figure 6
Lower Ballona Modeling

Predicted vs. Observed Water levels, 2006 – Fiji Ditch

PWA Ref# 1793.1

P:\Projects\1793_Ballona_Wetlands\1793.01_Modeling\Reporting\Model calib memo\Figs\ballona_wse_fiji.pdf
Figure 7

Lower Ballona Modeling

Predicted vs. Observed Water levels, 2006 – Del Rey Lagoon

Source: PWA field observations and EFDC model predictions

PWA Ref# 1793.1
Source: PWA field observations and EFDC model predictions

Figure 8

Lower Ballona Modeling

Predicted vs. Observed Water levels, 2006 – Ballona Lagoon

PWA Ref# 1793.1

P:\Projects\1793_Ballona_Wetlands\1793.01_Modeling\Reporting\Model calib memo\Figs\ballona_wse_BLagoon.pdf
C-2. MARSH CHANNEL REPRESENTATION IN LOWER BALLONA EFDC MODEL

1. INTRODUCTION

This section outlines the methodology implemented to represent tidal channel morphology and layout in the Lower Ballona Wetlands EFDC numerical model. The purpose of the numerical model is not to model fine scale hydrodynamics or velocities in the tidal channels (existing or future), but to describe the hydraulic characteristics and flushing of each restoration parcel. The procedure is based on the methods presented in the “Design Guidelines for Tidal Channels in Coastal Wetlands,” prepared by PWA in January 1995 for the U.S. Army Corps of Engineers. The guidelines present empirical relationships between morphologic characteristics of marsh channels (channel top width, depth, and cross sectional area) and diurnal tidal prism. Characteristics of marsh morphometry (channel order, length, sinuosity, drainage density, etc.) are also tabulated. The tidal prism dataset includes sites from San Diego Bay (Chula Vista) and San Francisco Bay (Novato, Corte Madera, and Newark Slough). The marsh morphometry dataset includes a more extensive analysis of sites from southern California, north San Francisco Bay, and south San Francisco Bay.

The approach taken to implement the appropriate channel characteristics in the model was to first determine what the detailed tidal channel characteristics would be, and then to aggregate these for inclusion into the model, given the grid cell size limitations. A general outline of the procedure is presented below:

1. Approximate channel order, length, and number of channels based on channel morphometry relationships with marsh area (Section 2).
2. Approximate channel geometry (width and thalweg depth) based on tidal prism using hydraulic geometry relationships (Section 3).
3. Aggregate channel morphology and morphometry for inclusion into the model (Section 4).

2. CHANNEL MORPHOMETRY

Marsh morphometry refers to the plan view features of tidal marshes, such as channel length, sinuosity, channel order, and density of channels. The general outline presented in the Design Guidelines is reproduced below:

1. Determine the order of the drainage system that can be accommodated within the site based on the marsh area.
2. Calculate the total channel length based on an assumed drainage density (typically 0.01-0.02 ft/ft²).
3. Estimate the number of channels of each order.
4. Partition the length among the different order channels.

The results for Area B East Wetland are presented below as an example of the methodology and assumptions used in the analysis.
1. For a given marsh area of approximately 35 acres, Figure 7.1-4 of the design guidelines was used to select a maximum channel order of 4 for the parcel.

2. Drainage densities at numerous California marshes tend to fall between 0.01-0.02 ft/ft$^2$. A drainage density of 0.01 ft/ft$^2$ was selected to minimize construction costs and allow for natural evolution of the site. From this drainage density, a total length of channels of 15,250 ft was determined.

3. The number of channels of each order was determined assuming a bifurcation ratio of 3.5. This ratio predicts 1 fourth-order channel, 4 third-order channels, 12 second-order channels, and 43 first-order channels, although not all orders can be represented in the model due to grid cell size limitations.

4. Table 7-6 and Figure 7.3-1 of the Design Guidelines give typical channel distributions for California marshes. The following distribution of channel length was assumed for the 4th through 1st order channels: 10%, 15%, 30%, and 45%. The total length of channels was used with the channel order distributions to determine the length of each order channel.

3. HYDRAULIC GEOMETRY

The term hydraulic geometry refers the empirical relationships between channel discharge and channel geometry. The hydraulic geometry relationships presented in the Design Guidelines relate diurnal tidal prism with channel width, depth, and cross sectional area. A predicted tidal prism of 25 acre-ft was determined to represent the diurnal tidal prism for the 35-acre Area B East Wetland parcel using Figure 5.2-1. The top width and depth of the 4th order channel were determined assuming this tidal prism. For the lower order channels, the total tidal prism was distributed incrementally based on the bifurcation ratio, after subtracting out the intertidal storage volume of the next higher order channel. The partitioned tidal prism was used in the hydraulic geometry relationships for each channel order.

4. IMPLEMENTATION OF CHANNEL MORPHOLOGY IN MODEL BATHYMETRY

For each channel order, the predicted top width was compared to the grid cell size of the EFDC model grid, nominally equal to 9 m (29.5 ft). The predicted top widths of the 3rd and 4th order channels were 28 ft and 54 ft, roughly equivalent to one and two cell widths, respectively. The model tidal prism was calculated as the total intertidal channel storage volume for a diurnal tide range of 5.49 ft (LA tide gage, #9410660). The resulting tidal prism was 19 acre-ft, 24% less than the predicted tidal prism of 25 acre-ft. This is due to the lack of first and second order channels in the model. To account for the remaining 6 acre-ft, 4 of the 12 second-order channels were implemented at a width of one grid cell. The number of grid cells for each channel order was determined by dividing the length per channel by the nominal grid size. An idealized channel layout was then overlaid on the existing topography grid based on the widths, depths, and lengths determined from the Design Guidelines. The bed elevation of the highest-order channel is constant along its length. Along-channel bed elevations of lower-order channels were linearly interpolated from the channel junction to the channel end (i.e., from the predicted elevation of the higher-order channel to the predicted elevation of the lower-order channel). Elevations of the future marshplain (non-channel regions within the wetland footprint) were set at MHHW (1.61 m NAVD).
The channel layout was adjusted iteratively to correctly reproduce the expected future tidal prism for the marsh restoration parcel. The model tidal prism was confirmed by comparing the total intertidal channel storage volume to the predicted diurnal tidal prism for the given marsh area. Future model refinement could be to develop a more detailed bathymetry grid in the region of tidal channels.
C-3. LOWER BALLONA EFDC MODEL – ALTERNATIVES BATHYMETRY

Sections C-1 and C-2 above describe the model development and calibration procedures. Figure 9 through Figure 14 show the model bathymetries for each alternative.

Figures

Figure 9. Existing Conditions (No Action) Bathymetry
Figure 10. Alternative 1 – Muted Tidal Bathymetry
Figure 11. Alternative 2 – Partial Tidal Bathymetry
Figure 12. Alternative 3 – Full Tidal Bathymetry
Figure 13. Alternative 4 – Area A Subtidal Bathymetry
Figure 14. Alternative 5 – New Creek Bathymetry
Figure 9

Ballona Wetlands Restoration Project

Existing Conditions (No Action) Bathymetry

Source: EFDC model setup.
Notes: Bottom elevations shown in meters NAVD.

PWA Ref# 1793
Figure 10

Ballona Wetlands Restoration Project

Alt 1 – Muted Tidal Bathymetry

Source: EFDC model setup.
Notes: Bottom elevations shown in meters NAVD.
Figure 11

Ballona Wetlands Restoration Project

Alt 2 – Partial Tidal Bathymetry

Source: EFDC model setup.
Notes: Bottom elevations shown in meters NAVD.

PWA Ref# 1793
Ballona Wetlands Restoration Project

Alt 3 – Full Tidal Bathymetry

Source: EFDC model setup.
Notes: Bottom elevations shown in meters NAVD.

PWA Ref# 1793

Figure 12

Bottom Elev (m)

-2 0 2 4 6 8 10
Ballona Wetlands Restoration Project

Alt 4 – Area A Subtidal Bathymetry

Source: EFDC model setup.
Notes: Bottom elevations shown in meters NAVD.

Figure 13

PWA Ref# 1793
Source: EFDC model setup.
Notes: Bottom elevations shown in meters NAVD.

Ballona Wetlands Restoration Project

Alt 5 – New Creek Bathymetry

PWA Ref# 1793
C-4. SUPPORTING DOCUMENTATION FOR SECTION 3.3 HYDROLOGY

Section 3.3 of the Lower Ballona Creek Restoration Feasibility Study discusses the expected hydrology for each proposed alternative. The text and figures below provide supporting documentation for the specific model results discussed in the report as well as related model results not explicitly discussed in the Feasibility Study. The section numbers below correspond to the relevant subsections of Section 3.3 (Hydrology).

Section 3.3.1 - Muted Tidal System versus Full Tidal System
Inundation regime is the percentage of time that a given water level is exceeded during a neap-spring tidal cycle. It is a useful parameter for characterizing the tidal inundation at a particular location with a specific elevation. The inundation frequency curves corresponding to Table 3-7 are shown in Figure 15.

Section 3.3.2 - Tidal prism
Tidal prism is the volume of water passing through a channel cross section on each tide (ebb or flood). Tidal prism was evaluated for each restoration area at four cross sections: (1) mouth of Ballona Creek, (2) mouth of Marina Del Rey, (3) Basin H entrance, and (4) Marina del Rey above Basin H. Tidal prism was estimated by integrating the discharge time series at each cross section for each tide (flood or ebb). The mean tidal prism of all floods and all ebbs was estimated for all runs that spanned the full spring-neap cycle. The results are shown in Table 1.

Section 3.3.3 – Connections

Area B southwest wetland SRT and culvert connection
Figure 16 shows a sample water level comparison for the culvert sizing and SRT optimization for the Area B southwest wetland. Two culvert geometries are tested: (1) 2 x 5 ft culverts and (2) 3 x 5 ft culverts. Three elevations are tested for the SRT: 3.6 ft, 4.9 ft, and 6.6 ft NAVD. Increasing the culvert area increases the tide range within the wetland and improves drainage from the wetland to Ballona Creek. The effect of the SRT in limiting high water within the site is seen once the Ballona Creek water levels reach the closure elevation.

Area B southeast wetland, Area A small marsh, Area A large marsh, Area A subtidal
Figure 17 illustrates the procedure adopted to size the culvert connections to each wetland. The number of culverts was increased until the tide range within the wetland approximately matched that of Ballona Creek. As can be seen in Figure 17, once the number of culverts increases beyond six 5-ft culverts, there are very small incremental gains in tide range for relatively large increases in culvert cross sectional area. The same procedure was followed to size the culverts for the small and large marshes and subtidal portion of Area A, shown in Figure 18, Figure 19, and Figure 20, respectively.

Area B southwest breach

J:\1793_Ballona_Wetlands\1793.01_Modeling\Reporting\Modeling appendix\Technical Appendix\1793_Modeling_Appendix_v3.doc
The Area B breach was sized with a similar objective to the culvert sizing described above. The breach was sized to allow full conveyance of the tidal signal to the wetland (i.e. no tidal damping or muting). A sample water level comparison is shown in Figure 21.

Section 3.3.4 - Channel Network

Section 3.3.4 of the Feasibility Report discusses the expected channel network characteristics for each alternative. See Appendix C-2 (Marsh channel representation in Lower Ballona EFDC model) for a more detailed explanation of the methodology used to develop the channel networks.

Section 3.3.6 - Excursion Length

Section 3.3.6 of the Feasibility Report provides a qualitative discussion of tidal excursion lengths and implications for hydraulic connectivity and mixing in Ballona Creek. Excursion length was examined at the same cross sections locations as for the tidal prism analysis: (1) mouth of Ballona Creek, (2) mouth of Marina del Rey, and (3) Entrance to Basin H. For this application, excursion length was calculated by integrating the velocity time series over each tidal cycle to obtain the tidal excursion for each flood or ebb tide. The median tidal excursion lengths for flood and ebb were then tabulated for each model run. The results are shown in Table 2.

Section 3.3.7 – Flooding

50-yr hydrograph

The Ballona Creek Ecosystem Restoration Feasibility Study Hydrology Appendix (USACE 2008) presents results of a flood frequency analysis and rainfall-runoff model for the Ballona Creek watershed. A discharge-frequency relationship for Ballona Creek at Sawtelle Boulevard for the period 1928-2005 was developed to predict the hydrograph for the 50-yr discharge event (Figure 22). Ballona Creek hydrographs for the 50-year event were provided to PWA by the USACE. PWA then used these hydrographs to estimate the discharge from Sepulveda Channel and from Centinela Channel. These estimates were used as boundary conditions for the model.

50-yr flood water levels

The restoration alternatives were evaluated under flood conditions by using the EFDC model to predict water levels resulting from the 50-yr flood. The predicted peak water levels near the SRT for existing conditions (Figure 23) compare well with the USACE predictions at the same location. Overall changes to the system under Alternative 1 and Alternative 2 are minimal, resulting in nearly identical water level predictions in Ballona Creek as for Existing Conditions (Figure 24, Figure 25). Because of flow through the culverts is limited, water levels within the southeast wetlands peak at lower values than within Ballona Creek and also take longer to drain off with the falling flood water levels (Figure 25). Alternative 3’s peak water levels in Ballona Creek were lower than the Existing Conditions peak because the large expanse of wetlands in this alternative provides storage for the flood waters (Figure 26). For floods under Alternatives 1-3, predicted water levels in Area A are not altered since these wetlands are not connected to Ballona Creek. Therefore, Alternative 4, which is identical to Alternative 3 except for the subtidal region of Area A, was not modeled with flood conditions. For Alternative 5, water levels
were assessed both upstream near Area C and at the SRT. While the upstream water levels are higher as a consequence of the channel and water surface slope, Alternative 5’s upstream water levels are below that of existing conditions (Figure 27). This suggests that flood hazard is unlikely to increase with restoration.

**Storm Surge Analysis**

Water levels at the Port of Los Angeles were examined using an event selection approach to identify typical storm surge events (super-elevation of water levels above astronomical tides). Events were selected based on events identified in the Ballona Creek Ecosystem Restoration Feasibility Study Hydrology Appendix (USACE 2008), since coastal storms often exhibit high precipitation and storm surge. Typical surges ranged from 0.5 to 1.5 ft above astronomical tides, with a maximum of 1.65 ft during the 1997-1998 El Niño winter. Storm surge events lasted approximately 3-7 days. Table 3 shows a summary of the event-based analysis.

**Additional Model Runs**

Additional model runs were conducted for each alternative to inform the culvert sizing, SRT closure elevations, and other aspects of the model setup. The full run catalog is shown in Table 4.

**Figures**

Figure 15. Annual inundation frequency, Area B southwest SRT
Figure 16. Culvert sizing and SRT optimization, Area B southwest
Figure 17. Culvert sizing, Area B southeast
Figure 18. Culvert sizing, Area A small marsh
Figure 19. Culvert sizing, Area A large marsh
Figure 20. Culvert sizing, Area A subtidal
Figure 21. Culvert sizing, Area B southwest breach
Figure 22. Ballona Creek 50-yr hydrograph at Sawtelle Boulevard
Figure 23. Existing Conditions: Water Levels, 50-yr Flood
Figure 24. Alt. 1: Water Levels, 50-yr Flood
Figure 25. Alt. 2: Water Levels, 50-yr Flood
Figure 26. Alt. 3: Water Levels, 50-yr Flood
Figure 27. Alt. 5: Water Levels, 50-yr Flood
Source: EFDC model predictions

Figure 15

Lower Ballona Wetlands

Inundation frequency, Area B Southwest SRT
Source: EFDC model predictions

Figure 16
Lower Ballona Wetlands

Culvert sizing and SRT optimization, Area B southwest

PWA Ref# 1793.1
Source: EFDC model predictions

Figure 17
Lower Ballona Wetlands
Culvert Sizing, Area B SE Marsh

Source: EFDC model predictions
Figure 18
Lower Ballona Wetlands

Culvert Sizing, Area A Small Marsh

Source: EFDC model predictions

C:\m.brennan\Projects\1793_Ballona\Modeling\Alternatives\Analysis\Culvert sizing\compare_culverts_AreaA_small_marsh.m
Source: EFDC model predictions

Figure 19

Lower Ballona Wetlands

Culvert Sizing, Area A Large Marsh

PWA Ref# 1793.1

C:\m.brennan\Projects\1793_Ballona\Modeling\Alternatives\Analysis\Culvert sizing\compare_culverts_AreaA_large_marsh.m
Figure 20
Lower Ballona Wetlands

Culvert Sizing, Area A Subtidal

Source: EFDC model predictions

- Blue: Basin H
- Green: Area A subtidal, 8 x 5' culverts (Alt 4 Prod v1)
- Red: Area A subtidal, 12 x 5' culverts (Alt 4 Prod v2)
- Teal: Area A subtidal, 2x(12 x 5') culverts (Alt 4 Prod v5)
- Pink: Area A subtidal, 2x(12 x 5') culverts @ Via Venetia (Alt 4 Prod v6)
Figure 21
Lower Ballona Wetlands

Source: EFDC model predictions

Culvert Sizing, Area B Southwest Breach
Figure 22

Ballona Wetlands Restoration Project

Ballona Creek 50-yr hydrograph at Sawtelle Blvd

Source: Ballona Creek Ecosystem Restoration Feasibility Study Hydrology Appendix

J:\1793_Ballona_Wetlands\1793.01_Modeling\Reporting\Modeling appendix\Flooding\plot_50yr_hydrograph.m
Figure 23

Lower Ballona Wetlands

Existing Conditions: Water Levels, 50-yr Flood

Source: EFDC model predictions

PWA Ref# 1793.1

C:\m.brennan\Projects\1793_Ballona\Modeling\Alternatives\Analysis\Flooding\plot_alt0_flood.m
Lower Ballona Wetlands

Alt. 1: Water Levels, 50-yr Flood

Source: EFDC model predictions

PWA Ref# 1793.1
Figure 25

Lower Ballona Wetlands

Alt. 2: Water Levels, 50-yr Flood

Source: EFDC model predictions

PWA Ref# 1793.1
Source: EFDC model predictions

Figure 26

Lower Ballona Wetlands

Alt. 3: Water Levels, 50-yr Flood

PWA Ref# 1793.1

C:\m.brennan\Projects\1793_Ballona\Modeling\Alternatives\Analysis\Flooding\plot_alt3_flood_2.m
Source: EFDC model predictions

Figure 27

Lower Ballona Wetlands

Alt. 5: Water Levels, 50-yr Flood

PWA Ref# 1793.1

C:\m.brennan\Projects\1793_Ballona\Modeling\Alternatives\Analysis\Flooding\plot_alt5_flood.m
<table>
<thead>
<tr>
<th>Model Run*</th>
<th>Mouth of Ballona Creek</th>
<th>Mouth of Marina del Rey</th>
<th>Entrance to Basin H</th>
<th>Marina del Rey above Basin H</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean flood</td>
<td>mean ebb</td>
<td>mean flood</td>
<td>mean ebb</td>
</tr>
<tr>
<td>Alt 0 Prod v1</td>
<td>231</td>
<td>-243</td>
<td>1291</td>
<td>-1400</td>
</tr>
<tr>
<td>Alt 1 Prod v1</td>
<td>235</td>
<td>-279</td>
<td>1402</td>
<td>-1287</td>
</tr>
<tr>
<td>Alt 2 Prod v1</td>
<td>267</td>
<td>-314</td>
<td>1384</td>
<td>-1343</td>
</tr>
<tr>
<td>Alt 2 Prod v2</td>
<td>274</td>
<td>-306</td>
<td>1348</td>
<td>-1383</td>
</tr>
<tr>
<td>Alt 2 Prod v3</td>
<td>277</td>
<td>-405</td>
<td>1221</td>
<td>-1418</td>
</tr>
<tr>
<td>Alt 2 Prod v7</td>
<td>284</td>
<td>-331</td>
<td>1281</td>
<td>-1385</td>
</tr>
<tr>
<td>Alt 3 Prod v1</td>
<td>386</td>
<td>-416</td>
<td>1404</td>
<td>-1362</td>
</tr>
<tr>
<td>Alt 3 Prod v2</td>
<td>390</td>
<td>-419</td>
<td>1409</td>
<td>-1367</td>
</tr>
<tr>
<td>Alt 3 Prod v4</td>
<td>396</td>
<td>-427</td>
<td>1477</td>
<td>-1438</td>
</tr>
<tr>
<td>Alt 4 Prod v1</td>
<td>391</td>
<td>-421</td>
<td>1625</td>
<td>-1488</td>
</tr>
<tr>
<td>Alt 4 Prod v2</td>
<td>392</td>
<td>-421</td>
<td>1701</td>
<td>-1651</td>
</tr>
<tr>
<td>Alt 4 Prod v5</td>
<td>392</td>
<td>-421</td>
<td>1765</td>
<td>-1714</td>
</tr>
<tr>
<td>Alt 4 Prod v6</td>
<td>392</td>
<td>-421</td>
<td>1764</td>
<td>-1713</td>
</tr>
<tr>
<td>Alt 5 Prod v1</td>
<td>599</td>
<td>-627</td>
<td>1400</td>
<td>-1284</td>
</tr>
</tbody>
</table>

* See run catalog for more detailed description of model setup for each run.
Table 2. Median tidal excursions lengths

1793.01 Ballona Wetlands Restoration Project

<table>
<thead>
<tr>
<th>Model Run*</th>
<th>Ballona Creek flood (mi)</th>
<th>ebb (mi)</th>
<th>Marina del Rey flood (mi)</th>
<th>ebb (mi)</th>
<th>Basin H Entrance flood (mi)</th>
<th>ebb (mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt 0 - No action Prod v1</td>
<td>0.63</td>
<td>-0.71</td>
<td>0.75</td>
<td>-0.52</td>
<td>0.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>Alt 1 - Muted tidal Prod v1</td>
<td>0.64</td>
<td>-0.72</td>
<td>0.67</td>
<td>-0.57</td>
<td>0.01</td>
<td>-0.02</td>
</tr>
<tr>
<td>Alt 2 - Partial tidal Prod v1</td>
<td>0.69</td>
<td>-0.76</td>
<td>0.69</td>
<td>-0.58</td>
<td>0.04</td>
<td>-0.03</td>
</tr>
<tr>
<td>Alt 2 - Partial tidal Prod v2</td>
<td>0.71</td>
<td>-0.82</td>
<td>0.69</td>
<td>-0.58</td>
<td>0.06</td>
<td>-0.02</td>
</tr>
<tr>
<td>Alt 2 - Partial tidal Prod v7</td>
<td>0.79</td>
<td>-0.83</td>
<td>0.69</td>
<td>-0.58</td>
<td>0.04</td>
<td>-0.02</td>
</tr>
<tr>
<td>Alt 3 - Full tidal Prod v1</td>
<td>1.03</td>
<td>-0.95</td>
<td>0.70</td>
<td>-0.59</td>
<td>0.07</td>
<td>-0.05</td>
</tr>
<tr>
<td>Alt 3 - Full tidal Prod v2</td>
<td>1.03</td>
<td>-0.95</td>
<td>0.70</td>
<td>-0.59</td>
<td>0.12</td>
<td>-0.04</td>
</tr>
<tr>
<td>Alt 3 - Full tidal Prod v4</td>
<td>1.03</td>
<td>-0.95</td>
<td>0.70</td>
<td>-0.59</td>
<td>0.11</td>
<td>-0.04</td>
</tr>
<tr>
<td>Alt 4 - Area A subtidal Prod v1</td>
<td>1.03</td>
<td>-0.95</td>
<td>0.78</td>
<td>-0.65</td>
<td>0.37</td>
<td>-0.10</td>
</tr>
<tr>
<td>Alt 4 - Area A subtidal Prod v2</td>
<td>1.03</td>
<td>-0.95</td>
<td>0.81</td>
<td>-0.69</td>
<td>0.41</td>
<td>-0.18</td>
</tr>
<tr>
<td>Alt 4 - Area A subtidal Prod v5</td>
<td>1.03</td>
<td>-0.95</td>
<td>0.85</td>
<td>-0.72</td>
<td>0.47</td>
<td>-0.20</td>
</tr>
<tr>
<td>Alt 4 - Area A subtidal Prod v6</td>
<td>1.03</td>
<td>-0.95</td>
<td>0.84</td>
<td>-0.72</td>
<td>0.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>Alt 5 - New creek Prod v1</td>
<td>1.52</td>
<td>-1.43</td>
<td>0.67</td>
<td>-0.57</td>
<td>0.01</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

* See run catalog for more detailed description of model setup for each run.

Note: mi = miles
<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
<th>Storm Dates</th>
<th>Peak Surge (ft)**</th>
<th>Date/Time***</th>
<th>Approx. Duration (days)****</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Series of winter storms tracked eastward from North Pacific</td>
<td>27 February - 3 March 1938</td>
<td>0.76</td>
<td>3/2/38 15:40</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Winter storm, combination of warm Pacific cyclone and cold coastal storm</td>
<td>21-23 January 1943</td>
<td>1.35</td>
<td>1/22/43 21:10</td>
<td>3.5</td>
</tr>
<tr>
<td>3a</td>
<td>Low-latitude north Pacific cyclone</td>
<td>3-4 March 1943</td>
<td>0.54</td>
<td>3/3/43 18:00</td>
<td>2.5</td>
</tr>
<tr>
<td>3b</td>
<td></td>
<td></td>
<td>0.75</td>
<td>2/22/43 20:00</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Combination of cold low pressure system moving down coast and subtropical cyclone</td>
<td>19-21 November 1967</td>
<td>0.64</td>
<td>11/21/67 19:10</td>
<td>4</td>
</tr>
<tr>
<td>5a</td>
<td>Series of unusually intense low latitude Pacific storms</td>
<td>18-26 January 1969</td>
<td>0.86</td>
<td>1/21/69 5:00</td>
<td>4.5</td>
</tr>
<tr>
<td>5b</td>
<td></td>
<td></td>
<td>0.80</td>
<td>1/25/69 7:00</td>
<td>5.5</td>
</tr>
<tr>
<td>6</td>
<td>Pacific cyclone cold front</td>
<td>3-4 December 1974</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Persistent series of warm, subtropical Pacific storms from SW</td>
<td>5-13 February 1978</td>
<td>1.58</td>
<td>2/10/78 1:30</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>Persistent series of warm, subtropical Pacific storms from SW</td>
<td>27 February - 5 March 1978</td>
<td>1.32</td>
<td>3/1/78 2:00</td>
<td>7</td>
</tr>
<tr>
<td>9a</td>
<td>1982-83 El Nino Winter</td>
<td>1982-83 Winter</td>
<td>1.64</td>
<td>3/2/83 1:20</td>
<td>7</td>
</tr>
<tr>
<td>9b</td>
<td></td>
<td></td>
<td>1.23</td>
<td>2/2/83 15:30</td>
<td>7</td>
</tr>
<tr>
<td>10</td>
<td>High storm event in SF Bay</td>
<td>3 December 1983</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
<th>Storm Dates</th>
<th>Peak Surge (ft)**</th>
<th>Date/Time***</th>
<th>Approx. Duration (days)****</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Series of winter storms tracked eastward from North Pacific</td>
<td>27 February - 3 March 1938</td>
<td>0.76</td>
<td>3/2/38 15:40</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Winter storm, combination of warm Pacific cyclone and cold coastal storm</td>
<td>21-23 January 1943</td>
<td>1.35</td>
<td>1/22/43 21:10</td>
<td>3.5</td>
</tr>
<tr>
<td>3a</td>
<td>Low-latitude north Pacific cyclone</td>
<td>3-4 March 1943</td>
<td>0.54</td>
<td>3/3/43 18:00</td>
<td>2.5</td>
</tr>
<tr>
<td>3b</td>
<td></td>
<td></td>
<td>0.75</td>
<td>2/22/43 20:00</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Combination of cold low pressure system moving down coast and subtropical cyclone</td>
<td>19-21 November 1967</td>
<td>0.64</td>
<td>11/21/67 19:10</td>
<td>4</td>
</tr>
<tr>
<td>5a</td>
<td>Series of unusually intense low latitude Pacific storms</td>
<td>18-26 January 1969</td>
<td>0.86</td>
<td>1/21/69 5:00</td>
<td>4.5</td>
</tr>
<tr>
<td>5b</td>
<td></td>
<td></td>
<td>0.80</td>
<td>1/25/69 7:00</td>
<td>5.5</td>
</tr>
<tr>
<td>6</td>
<td>Pacific cyclone cold front</td>
<td>3-4 December 1974</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Persistent series of warm, subtropical Pacific storms from SW</td>
<td>5-13 February 1978</td>
<td>1.58</td>
<td>2/10/78 1:30</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>Persistent series of warm, subtropical Pacific storms from SW</td>
<td>27 February - 5 March 1978</td>
<td>1.32</td>
<td>3/1/78 2:00</td>
<td>7</td>
</tr>
<tr>
<td>9a</td>
<td>1982-83 El Nino Winter</td>
<td>1982-83 Winter</td>
<td>1.64</td>
<td>3/2/83 1:20</td>
<td>7</td>
</tr>
<tr>
<td>9b</td>
<td></td>
<td></td>
<td>1.23</td>
<td>2/2/83 15:30</td>
<td>7</td>
</tr>
<tr>
<td>10</td>
<td>High storm event in SF Bay</td>
<td>3 December 1983</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

| Average Surge | 1.1 |

* Events were selected based on the COE Ballona Creek Ecosystem Study Appendix F3 Hydrology.
* Peak surge determined from the max residual between observed and predicted water level at NOAA Station #9410660 Los Angeles
** Dates and times are given in local standard time (LST)
*** Approximate storm durations were determined by visually examining the residual time series for each event

J:\1793_Ballona_Wetlands\1793.01_Modeling\Reporting\Modeling appendix\Technical Appendix\Tables\Table 3 Storm Surge Analysis.xlsResults Summary
<table>
<thead>
<tr>
<th>Restoration alternatives</th>
<th>Run name</th>
<th>Status</th>
<th>Tide or Flood</th>
<th>Run period, days</th>
<th>Project area configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Action</td>
<td>Calibration v1</td>
<td>C</td>
<td>Tide</td>
<td>0.1-19.1</td>
<td>Area B: Existing SRT (2x5' culverts)</td>
</tr>
<tr>
<td></td>
<td>Alt 0 - Prod v1</td>
<td>C</td>
<td>Tide</td>
<td>10.88-28.88</td>
<td>Area B: Existing SRT (2x5' culverts)</td>
</tr>
<tr>
<td></td>
<td>Alt 0 - Prod fld v6</td>
<td>C</td>
<td>Flood</td>
<td>5.86-7.36</td>
<td>Area B: Existing SRT (2x5' culverts)</td>
</tr>
<tr>
<td>Alt 1 - Muted tidal</td>
<td>Alt 1 - Prod v1</td>
<td>A</td>
<td>Tide</td>
<td>10.88-28.88</td>
<td>Area B: Existing SRT (2x5' culverts, cutoff at 1.1 m NAVD)</td>
</tr>
<tr>
<td></td>
<td>Alt 1 - Prod v2</td>
<td>A</td>
<td>Tide</td>
<td>10.88-21.1</td>
<td>Area B: Existing SRT (2x5' culverts, cutoff at 2.25 m NAVD)</td>
</tr>
<tr>
<td></td>
<td>Alt 1 - Prod fld v2</td>
<td>R</td>
<td>Flood</td>
<td>5.28-6.78</td>
<td>Area B: Existing SRT (2x5' culverts, cutoff at 1.1 m NAVD)</td>
</tr>
<tr>
<td></td>
<td>Alt 1 - Prod fld v3</td>
<td>R</td>
<td>Flood</td>
<td>5.86-7.36</td>
<td>Area B: Existing SRT (2x5' culverts, cutoff at 1.1 m NAVD)</td>
</tr>
<tr>
<td>Alt 2 - Partial tidal</td>
<td>Alt 2 - Prod v1</td>
<td>A</td>
<td>Tide</td>
<td>10.88-28.88</td>
<td>Area B: Modified SRT (2x5' culverts, cutoff at 1.5 m NAVD)</td>
</tr>
<tr>
<td></td>
<td>Alt 2 - Prod v2</td>
<td>A</td>
<td>Tide</td>
<td>10.88-28.88</td>
<td>Area B: Modified SRT (2x5' culverts, cutoff at 2.0 m NAVD)</td>
</tr>
<tr>
<td></td>
<td>Alt 2 - Prod v3</td>
<td>A</td>
<td>Tide</td>
<td>21.8-24.6</td>
<td>Area B: Modified SRT (2x5' culverts, cutoff at 2.0 m NAVD)</td>
</tr>
<tr>
<td></td>
<td>Alt 2 - Prod v4</td>
<td>A</td>
<td>Tide</td>
<td>21.8-24.8</td>
<td>Area B: Modified SRT (2x5' culverts, cutoff at 2.0 m NAVD)</td>
</tr>
<tr>
<td></td>
<td>Alt 2 - Prod v5</td>
<td>A</td>
<td>Tide</td>
<td>21.8-24.8</td>
<td>Area B: Modified SRT (2x5' culverts, cutoff at 2.0 m NAVD)</td>
</tr>
<tr>
<td></td>
<td>Alt 2 - Prod v6</td>
<td>A</td>
<td>Tide</td>
<td>21.8-24.7</td>
<td>Area B: Modified SRT (2x5' culverts, cutoff at 2.0 m NAVD)</td>
</tr>
<tr>
<td></td>
<td>Alt 2 - Prod v7</td>
<td>A</td>
<td>Tide</td>
<td>10.88-28.88</td>
<td>Area B: Modified SRT (2x5' culverts, cutoff at 2.0 m NAVD)</td>
</tr>
<tr>
<td></td>
<td>Alt 2 - Prod fld v2</td>
<td>C</td>
<td>Flood</td>
<td>5.28-6.78</td>
<td>Area B: Modified SRT (2x5' culverts, cutoff at 2.0 m NAVD)</td>
</tr>
<tr>
<td></td>
<td>Alt 2 - Prod fld v3</td>
<td>C</td>
<td>Flood</td>
<td>5.86-7.36</td>
<td>Area B: Modified SRT (2x5' culverts, cutoff at 2.0 m NAVD)</td>
</tr>
<tr>
<td>Alt 3 - Fully tidal</td>
<td>Alt 3 - Prod v1</td>
<td>A</td>
<td>Tide</td>
<td>10.88-28.88</td>
<td>Area B: Breach to Creek</td>
</tr>
<tr>
<td></td>
<td>Alt 3 - Prod v2</td>
<td>A</td>
<td>Tide</td>
<td>10.88-28.88</td>
<td>Area B: Breach to Creek</td>
</tr>
<tr>
<td></td>
<td>Alt 3 - Prod v3</td>
<td>A</td>
<td>Tide</td>
<td>21.8-24.7</td>
<td>Area B: Breach to Creek</td>
</tr>
<tr>
<td></td>
<td>Alt 3 - Prod v4</td>
<td>A</td>
<td>Tide</td>
<td>9.88-28.88</td>
<td>Area B: Breach to Creek</td>
</tr>
<tr>
<td></td>
<td>Alt 3 - Prod fld v4</td>
<td>C</td>
<td>Flood</td>
<td>5.86-7.36</td>
<td>Area B: Breach to Creek</td>
</tr>
<tr>
<td>Alt 4 - Subtidal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-----------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alt 4 - Prod v1</td>
<td>A</td>
<td>Tide 10.88-28.88</td>
<td>Area B N: Breach to Creek Area B NE: 2x5' culverts Area B SE: 6x5' culverts Area A: 6x5' culverts, Dock 52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alt 4 - Prod v2</td>
<td>A</td>
<td>Tide 10.88-28.88</td>
<td>Area B N: Breach to Creek Area B NE: 2x5' culverts Area B SE: 6x5' culverts Area A: 12x5' culverts, Dock 52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alt 4 - Prod v3</td>
<td>A</td>
<td>Tide 10.88-11.2</td>
<td>Area B N: Breach to Creek Area B NE: 2x5' culverts Area B SE: 8x5' culverts Area A: 8'(12x5' culverts), Dock 52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alt 4 - Prod v4</td>
<td>A</td>
<td>Tide 10.88-11.2</td>
<td>Area B N: Breach to Creek Area B NE: 2x5' culverts Area B SE: 6x5' culverts Area A: 4'(12x5' culverts), Dock 52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alt 4 - Prod v5</td>
<td>A</td>
<td>Tide 10.88-28.88</td>
<td>Area B N: Breach to Creek Area B NE: 2x5' culverts Area B SE: 8x5' culverts Area A: 2'(12x5' culverts), Dock 52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alt 4 - Prod v6</td>
<td>C</td>
<td>Tide 10.88-28.88</td>
<td>Area B N: Breach to Creek Area B NE: 2x5' culverts Area B SE: 8x5' culverts Area A: 2'(12x5' culverts), Via Venetia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alt 5 - New creek</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alt 5 - Prod v1</td>
<td>C</td>
<td>Tide 10.88-28.88</td>
<td>Phase 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alt 5 - Prod fld v4</td>
<td>P</td>
<td>Flood 5.86-7.36</td>
<td>Phase 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SLR / Storm surge**