ALTERNATIVES ANALYSIS REPORT
PHASE 2 STUDY
COLORADO LAGOON RESTORATION PROJECT

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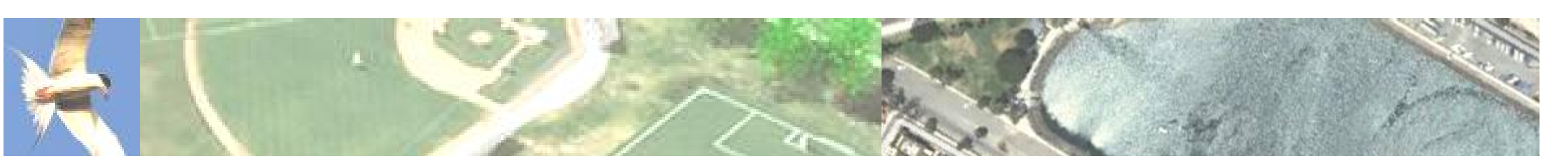

EXECUTIVE SUMMARY

The Colorado Lagoon is a tidal water body in an urban setting in the City of Long Beach. It is currently connected to the ocean tides, via Marine Stadium / Alamitos Bay, by an underground culvert. This culvert restricts the tidal flows to the lagoon and thus impacts the lagoon's water and habitat quality.

An overall Colorado Lagoon restoration project is planned and is to be implemented in two phases. Phase 1 of the project is for improvements (e.g. storm drain treatments, dredging, planting, perimeter trail) to be done at the Colorado Lagoon site and cleaning of the underground culvert. Phase 2 of the project is for further improvements to the tidal connection between the lagoon and Marine Stadium and is the subject of this report.

The purpose of the Phase 2 study is to identify and analyze various alternatives to improve the tidal connection. Four basic alternatives were identified and developed. One alternative is to create a second underground culvert parallel to the existing underground culvert. The other three alternatives are various configurations and combinations of earthen open channel and underground culverts. Two of the alternatives involve construction of bridges.

Each alternative was evaluated relative to project objectives, geomorphology, hydrodynamics, habitat, construction cost, maintenance requirements, and other considerations.

All alternatives met project objectives, although to varying degrees. All alternatives met hydrodynamic performance objectives (e.g. tidal range, tidal inundation, and flooding). All alternatives would improve existing habitat (via water quality improvements) and add new habitat at Colorado Lagoon (by tidal range increases). The open channel alternatives would create new wetland habitat, which would actually be a restoration of habitat where it once existed historically.

The open channel habitat would be created by conversion of Marina Vista Park grass areas currently used for active and passive recreational activities. The open channel footprints would occupy approximately 12 to 15% of the total park area and require relocation of baseball and soccer fields to other areas of the park. The second underground culvert alternative would not impact Marina Vista Park, except for temporary disruption during the construction period.

Construction costs for each alternative, based on conceptual designs, were developed and ranged from \$5.8M to \$9.4M. A preliminary estimate of maintenance and monitoring costs was also developed to understand the long-term costs associated with each alternative and to adequately weigh the alternatives based on both the short-term and long-term costs.

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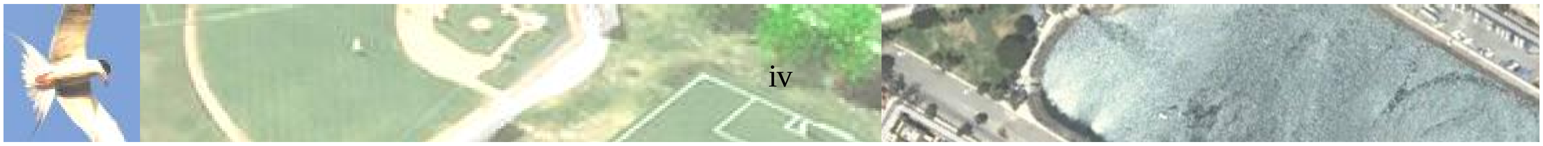


1.0 INTRODUCTION

The Colorado Lagoon is a tidal water body in an urban setting in the City of Long Beach (Figure 1-1). It is currently connected to the open ocean tides, (via the Marine Stadium and Alamitos Bay), by an underground culvert (Figure 1-2). However, this culvert restricts the tidal flows and impacts the water and habitat quality in the lagoon. This Phase 2 study is to identify and analyze various alternatives to improve the lagoon's tidal connection with the Marine Stadium (ocean).

The purpose of this report is to:

- Document and integrate information gathered as part of previous tasks;
- Present the alternatives and describe the changes needed to implement them; and
- Analyze and compare the alternatives.

This report includes a detailed description of potential alternatives and comparisons of the alternatives based on hydrodynamic performance, geomorphic context, habitat improvement, impacts, and cost.

1.1. Scope of Work

The scope of work for this Phase 2 study includes the following tasks:

1. Define study objectives and identify alternatives;
2. Perform hydrodynamic modeling/analysis of the alternatives;
3. Perform geomorphic studies of the alternatives;
4. Develop conceptual designs of the alternatives;
5. Coordinate with the resource agencies in regards to habitat improvements;
6. Analyze / compare alternatives;
7. Perform topographic survey of Marina Vista Park area;
8. Perform project management.

This report is the deliverable for task 6. The deliverables for tasks 1, 5, 7, and 8 have been provided previously under separate cover. The deliverables associated with tasks 2, 3, and 4 are provided herein as separate appendices.

Figure 1-1. Site Location

Figure 1-2. Project Site

1.2. Background Information

The overall Colorado Lagoon restoration project is to be implemented in two phases. Phase 1 of the project is for improvements to be done at the Colorado Lagoon site (e.g. storm drain treatments, dredging, planting, perimeter trails) and cleaning of the underground culvert. Final engineering of the Phase 1 components is in progress and some construction work has already begun. Phase 2 of the project is for further improvements to the tidal connection between Colorado Lagoon and Marine Stadium and is the subject of this study.

An Environmental Impact Report (EIR) for the Colorado Lagoon Restoration Project was certified by the Long Beach City Council on October 14, 2008. The Colorado Lagoon EIR included both Phases 1 and 2. The EIR-proposed Phase 2 project was an open channel through Marina Vista Park, which would replace the existing underground culvert. Upon certifying the EIR, the City Council requested that staff take a closer look at project alternatives that would achieve the same goal of improving tidal flushing between Colorado Lagoon and Marine Stadium, such as constructing a parallel underground culvert instead of an open channel or modifying the alignment of the proposed open channel to optimize the use of Marina Vista Park. As a result, this Phase 2 study was initiated. Further CEQA analyses, if necessary, will be completed as a future effort.

Colorado Lagoon was once a part of the vast historic Los Cerritos Wetlands (Figures 1-3 and 1-4). In 1923, the low-lying tidelands of Alamitos Bay were dredged to form the lagoon and Marine Stadium (Figure 1-5). The 1932 Los Angeles Olympic Committee chose the lagoon for diving trials and Marine Stadium for rowing events. To prepare for these diving trials, the lagoon was separated from Marine Stadium by land fill (Figure 1-6) and a short underground culvert and tide gate were installed to maintain adequate diving depth in the lagoon. In the late 1960s, the water area of the north end of Marine Stadium was filled and the existing underground box culvert was constructed, thereby further separating the lagoon from Marine Stadium. This was done as part of the construction for the then proposed Pacific Coast Freeway. This “filled” area is now Marina Vista Park, as shown in Figure 1-7.

A key aspect for any project is the ability to fund the project. One source of funding is from compensatory mitigation, i.e. if the project meets certain criteria, it can serve as compensatory mitigation for another project and thus it would be paid for by the other project’s owner. Examples of wetlands restoration projects that have been funded by compensatory mitigation programs include Bolsa Chica Lowlands, Batiquitos Lagoon, San Dieguito Lagoon, and Huntington Beach Wetlands. In the case of this Phase 2 study, a goal was to evaluate the alternatives relative to their ability to meet compensatory mitigation criteria. This will be further discussed in Section 3.3.

Figure 1-3. 1872 U.S. Coast Survey Map (brown lines) Overlaid on 2007 Aerial Photograph

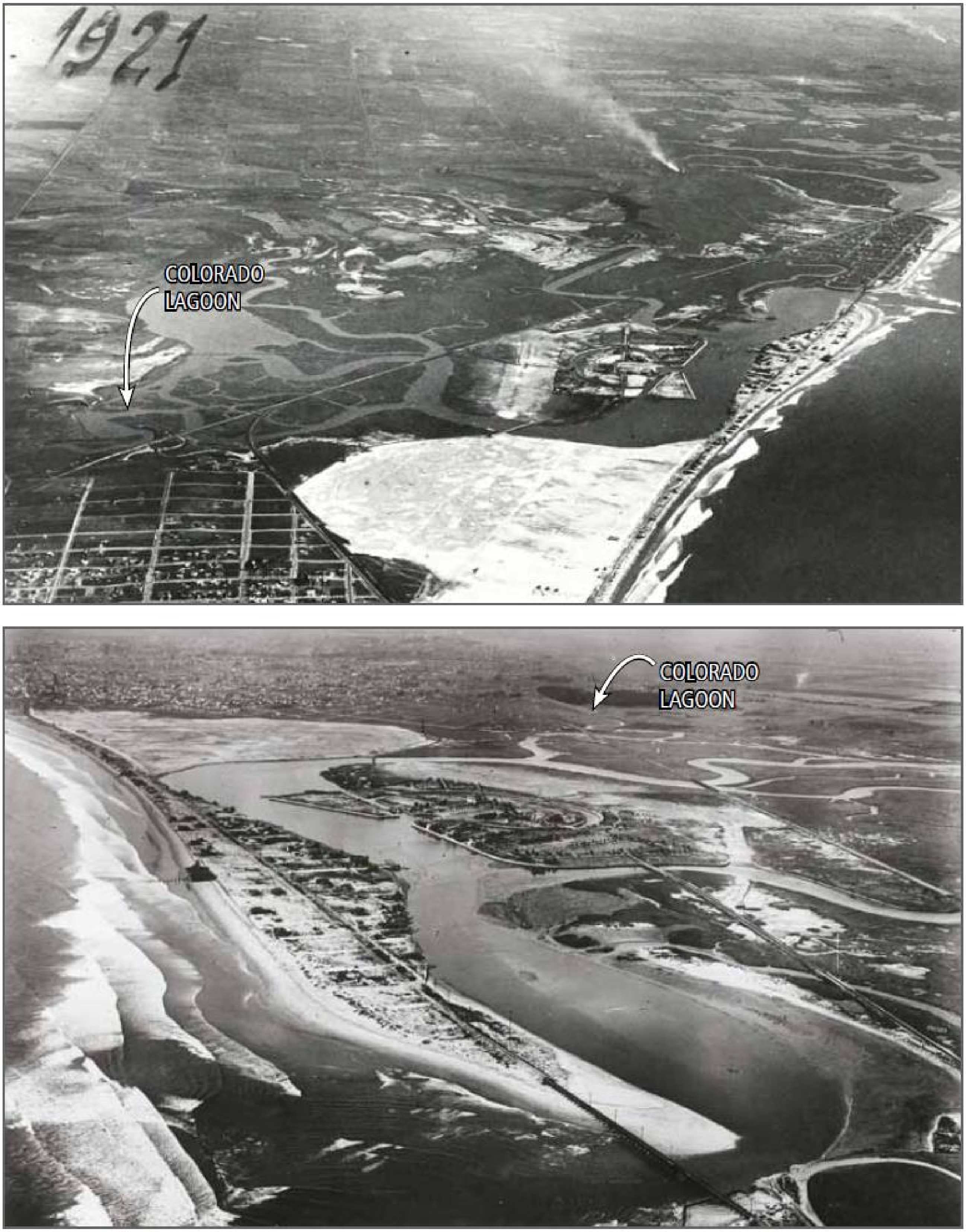


Figure 1-4. Historic Aerial Photograph of Alamitos Bay and Los Cerritos Wetlands, 1921

Figure 1-5. Historic Aerial Photograph, 1928

Figure 1-6. Historic Aerial Photograph, 1947

Figure 1-7. Current Aerial Photograph, 2008

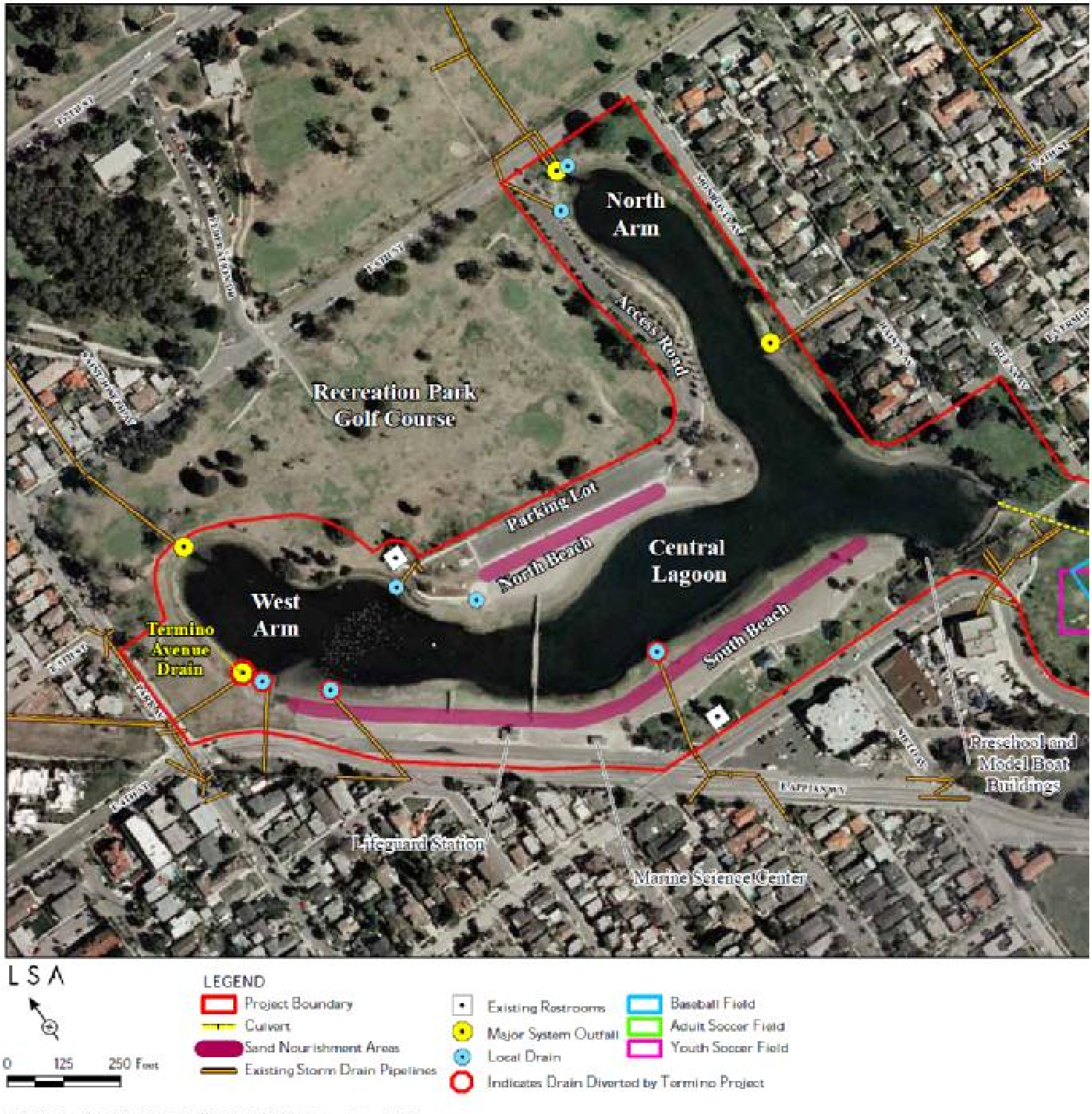
1.3. Existing Site

The Phase 2 project site is primarily within Marina Vista Park. Marina Vista Park is an open grassy area located to the southeast of the lagoon, on the south side of Colorado Street (Figure 1-2). The tidal culvert is under this park. The park overlooks the water of Marine Stadium to the south and provides the following amenities: two soccer fields, a baseball diamond, tennis courts, play equipment, picnic areas, and restrooms. Additionally, Marina Vista Park is the site of municipal band concerts in the summer.

The benefits of the Phase 2 project are primarily for the Colorado Lagoon. The deteriorated ecological health of Colorado Lagoon has been well established. The lagoon is listed on California's 303(d) list of impaired water bodies due to elevated levels of: a) lead, zinc, chlordane, and polycyclic aromatic hydrocarbons (PAHs) in the sediment, b) chlordane, DDT, dieldrin, and polychlorinated biphenyls (PCBs) in fish and mussel tissue, and c) indicator bacteria in the water. The lagoon waters frequently exceed California State Assembly Bill (AB)411 standards for bacterial contamination related to human health and the lagoon has appeared on Heal-the-Bay's "Top 10" (of the state) "Beach Bummers" list due to high bacteria levels. Algal blooms occur during the Spring months, and periodically during other times of year. The degraded sediment and water quality affect both habitat and recreational opportunity (swimming).

The sediment and water quality problems are caused by two primary factors: 1) the eleven storm drains which discharge into the lagoon (Figure 1-8), and 2) reduced tidal flushing from the existing underground culvert. The former problem is being addressed as part of the Colorado Lagoon Phase 1 project (Figure 1-9) and the latter is to be addressed by this Phase 2 study, (as well as by culvert cleaning to be done as part of Phase 1).

The existing underground culvert is a concrete box structure, approximately 880 feet (ft) long. The culvert cross-section transitions from 12 ft wide by 8 ft high on its Marine Stadium end to 14 ft wide by 7 ft high on its lagoon end. Measured tide data shows that spring low tides in the lagoon are perched above those of Marine Stadium and the ocean by approximately 3 feet, i.e. the lagoon's low tides do not get as low as those of the adjacent Marine Stadium. This indicates that something in the culvert or the culvert's as-built invert elevation restricts the low tide elevation from dropping below a certain level. There is also a tidal time lag (nearly three hours at low tides) between the Marine Stadium and the lagoon, which further indicates a reduced tidal exchange.



SOURCE: Air Photo USA (2007), Moffat & Nichol (2007), Thomas Bros. (2007).

Figure 1-8. Existing Storm Drains at Colorado Lagoon

Figure 1-9. Storm Drain Improvements at Colorado Lagoon, Phase 1 Project

The existing culvert has not been cleaned since it was built in the 1960s. Because of this, the culvert is impeded by sediment that has accumulated on the bottom, extensive marine growth that has accumulated on the sides and ceiling, and debris that is trapped within the trash rack screens at both ends of the culvert. The culvert will be cleaned and cleared of flow impediments as part of Phase 1 and the tide range will increase by approximately one foot, but the cleaned culvert is still not capable of providing a full tide range in Colorado Lagoon. Thus, there is a need for further improvements to the lagoon’s tidal connection and this Phase 2 study.

Despite its degraded condition, Colorado Lagoon currently hosts a variety of biological resources, including a diverse bird population, fish nursery, benthic organisms, and marsh vegetation. Further information on the biology of the lagoon can be found in the Colorado Lagoon Restoration Project EIR (LSA 2008), Biological Resources section.

1.4. Project Objectives

Project objectives were established in consultation with City staff and per inputs from a public meeting hosted by the City on March 12, 2009 at Lowell Elementary School to solicit feedback on the parameters of this study. These objectives are listed below:

1. Improve water quality for recreational swimming within Colorado Lagoon by increasing tidal circulation, as measured by maximum tidal range and reduced pollutant residence time in Colorado Lagoon.
2. Improve and expand habitat by:
   a. Increasing tidal circulation in Colorado Lagoon, via modification of the tidal connection, for reduced algal blooms, improved benthic habitats (such as eelgrass and benthic invertebrates) and fish utilization;
   b. Increasing tidal range in Colorado Lagoon via modification of the tidal connection; and
   c. Developing practical/feasible alternatives for creating new (restoring former) wetland habitat areas.
3. Accommodate safe recreation at Marina Vista Park, while retaining existing functionality of active sports uses.
4. Accommodate existing public and private infrastructure and services in the project area, including: flood protection and storm water drainage, (accounting for projected sea level rise over the next 50 years), utilities, traffic, and emergency services.
5. Minimize long-term maintenance requirements/costs.

These objectives, along with the information gathered from previous tasks, are the bases of the alternatives to be presented and compared in the following sections.

2.0 DESCRIPTION OF ALTERNATIVES

Four design alternatives were defined as part of Task 1 of this study. In general, the alternatives are various configurations of underground culverts and earthen open channel. And, as a result of discussions at a meeting with the resource agencies, a fifth alternative, (a variation of Alternative 4), was identified. Detailed engineering analyses/modeling was not completed for this fifth alternative, (as was done for the original four alternatives), but this fifth alternative will be discussed and compared in general with the other alternatives.

Specifically, the identified alternatives are as follows:

- Alternative 1 – Parallel / Second Underground Culvert (Figure 2-1)
  - Second underground culvert parallel to the existing underground culvert;
  - No bridges;
  - Existing culvert left in place for use.
- Alternative 2 – Open Channel with Bridges (Figure 2-2)
  - Earthen open channel for entire connection between Colorado Lagoon and Marine Stadium;
  - Two bridges;
  - Most of the existing culvert left in place for use.
- Alternative 3 – Combination Open Channel and Culverts (Figure 2-3)
  - Earthen open channel for part of connection between Colorado Lagoon and Marine Stadium
  - Two new shorter underground culvert sections, one at each end of the open channel;
  - No bridges;
  - Existing culvert left in place for use.
- Alternative 4 - Combination Open Channel (Maximum Wetlands) and One Culvert (Figure 2-4)
  - Earthen open channel for part of connection between Colorado Lagoon and Marine Stadium; the width of this channel section was maximized for habitat potential.
  - One new shorter underground culvert section (at the lagoon end of the open channel);
  - One bridge;
  - Existing culvert demolished.

This set of alternatives was intended to provide a variety of culvert, open channel, and bridge configurations, and thus a range of resultant improvements and costs.

Figure 2-1. Alternative 1 - Second/Parallel Underground Culvert

Figure 2-2. Alternative 2 - Open Channel with Bridges

Figure 2-3. Alternative 3 - Combination Open Channel and Culverts

Figure 2-4. Alternative 4 - Combination Open Channel (Maximum Wetlands) and One Culvert

2.1. Common Design Criteria for All Alternatives

In general, all alternatives were designed to result in similar improvements to Colorado Lagoon, (i.e. similar tidal exchanges) and to provide similar sports field capabilities at Marina Vista Park. Specifically, the alternatives all need to accommodate a youth soccer field (225 ft by 135 ft), an adult soccer field (300 ft by 180 ft), and an adult softball/youth baseball field (275 ft radius from home plate) within Marina Vista Park.

The underground culvert designs were based primarily on two criteria: 1) the culvert cross-sectional size should be large enough and its elevation appropriate to provide a full tide range / tidal exchange with Colorado Lagoon; and 2) the top of the new culvert(s) should be no higher than the existing culvert so that impacts to underground utilities would not be significant. The latter assumes that all existing utilities run <u>above</u> the existing culvert; this assumption is based on limited knowledge of the existing utility depths from City of Long Beach GIS files and the existing culvert's as-built drawings.

The open channel designs for planform (channel alignment), depth, and cross-section (geometry perpendicular to flow) were driven by multiple (and sometimes conflicting) criteria. The planform intent was to align the open channel along Eliot Street so as to not divide the grassy area of Marina Vista Park into two separate parts, i.e. the goal was to retain a large contiguous grassy area for recreational sporting activities. In addition, the channel was offset to the east of Eliot Street in order to minimize the loss of mature Coral (*Erythrina*, sp.) trees along that section of Eliot Street.

The depth of the open channel was designed to be as shallow as possible so to minimize the channel's top width (and thus footprint impact to Marina Vista Park), but the channel needs to be deep enough to provide a full tide range / tidal exchange with Colorado Lagoon and have the potential to support eelgrass growth.

The cross-sectional areas of the open channel designs have to be large enough to support a full tidal exchange with Colorado Lagoon and to provide low channel velocities. (Velocity is inversely proportional to cross-sectional area for a given flow). Channel velocities are important for determining feasible vegetation and selecting channel lining materials, as well as for human safety considerations. A larger cross-section is achieved by steeper slopes, (as well as a wider bottom). In contrast, the slopes of the banks need to be shallow for stability, and to support wetland vegetation growth in appropriate elevation zones. The basic design for all open channel cross-sections, except under the bridges, was: a) a flatter sloped bottom to support eelgrass (bottom slope of 15:1 (horizontal: vertical)); b) flatter slopes (5:1 to 15:1) for the vegetated marsh zones; and c) relatively steeper slopes (3:1) for the mudflat and upland transition zones, in order to minimize the channel's top width. The open channel sections under the bridges were designed with steeper slopes (1.5:1) to minimize the channel's top width and thus minimize the length and cost of the bridge(s).

The specific features and infrastructure changes required to implement each of the alternatives are described in further detail in the sections below. These changes are based on conceptual design layouts and may need to be modified/refined upon completion of more detailed engineering plans.

2.2. Alternative 1 – Second / Parallel Underground Culvert

This alternative is to construct a second underground culvert which would be aligned parallel to the existing underground culvert.

2.2.1. General

Measured tide data show that the low tide in Colorado Lagoon is truncated ("perched") above that of the Marine Stadium by approximately 3 feet at lower water levels resulting in the lagoon never experiencing the lowest tide that occurs in the Marine Stadium. Upon completion of the Phase 1 project improvements, it is anticipated that the resultant low tides would still be muted by approximately 2 feet. This is due to the size and elevation of the existing tidal culvert. By constructing a second culvert of sufficient size and depth, the tidal exchange between Colorado Lagoon and Marine Stadium would be improved over the existing/ post-Phase 1 project condition. As opposed to the alternatives with open channel sections, this alternative would <u>not</u> alter Marina Vista Park. The conceptual plan for Alternative 1 is shown in Figure 2-1.

2.2.2. Infrastructure Changes

An approximately 880-foot long underground Reinforced Concrete Box (RCB) culvert would be constructed on the west side of the existing culvert, and in a parallel alignment with the existing culvert. The new culvert would be 20 feet wide and 8 feet high, with an invert elevation of -6.5 feet, relative to NGVD29 vertical datum. The cross-section of the new culvert, as well as the existing culvert, is provided in Appendix A. New headwalls/wingwalls at both ends of the new culvert (i.e. in Colorado Lagoon and Marine Stadium) would also be constructed.

As part of the overall park improvement, public restrooms located within Marina Vista Park to the north and south of Eliot Street would be removed and two new restrooms would be constructed in nearby locations. Approximately 15 ornamental (non-native) trees, of which 10 are palm trees, would need to be removed. New trees could be planted in other areas of the park to compensate for this loss. A storm drain along Colorado Street would need to be modified to discharge into the new culvert.

The existing culvert structure would remain in place for continued use.

Installation of the new culvert would require excavation along its alignment and would result in approximately 7,200 cubic yards (cy) of excess material. Some of this material could possibly be used to level out the sports field areas within Marina Vista Park. Following installation of the culvert, the grass at Marina Vista Park would need to be replanted.

Conceptual engineering drawings (plan view and cross-section) for Alternative 1 are provided in Appendix A.

2.3. Alternative 2 – Open Channel with Bridges

This alternative is an earthen open channel along the entire connection between Colorado Lagoon and Marine Stadium. The maximum width of the open channel is approximately 100 feet. Bridges would be constructed along both Eliot Street and Colorado Street. This alternative is similar to the design of the proposed project open channel in the EIR, except with a different channel planform alignment (along Eliot Street), and with most of the existing culvert left in place for continued use.

2.3.1. General

As discussed previously, the tidal range in the lagoon is muted even after implementation of the Phase 1 project. By constructing an open channel of sufficient size and depth, the tidal exchange between Colorado Lagoon and Marine Stadium would be improved over the existing / post-Phase 1 project condition. In contrast to Alternative 1, this alternative provides marsh habitat area within the new open channel (to be discussed further in Section 3.3 for all of the open channel alternatives). The conceptual plan for Alternative 2 is shown in Figure 2-2.

2.3.2. Infrastructure Changes

An approximately 1,160-foot long earthen open channel would be constructed between Colorado Lagoon and Marine Stadium, along the west side of Marina Vista Park, as depicted in Figure 2-2. The new channel would have a varying cross-section (varying slopes) and a bottom elevation of -6.5 feet (NGVD29). The channel lining would be clay or silt, except in the channel sections under the bridges which would have rock slope protection. The channel under the Colorado Street bridge is slightly narrower in cross section than at Eliot Street since the Colorado Street tidal and storm flows would be split between the open channel and existing culvert, whereas the Eliot Street open channel must have the capability for the entire flow volumes.

Bridges would be constructed over the channel along Eliot Street and Colorado Street. The tops of the bridges would need to be higher than the existing street elevations due to the design high water level within the channel. The FEMA base flood elevation for the area was used (+6 ft NGVD29), along with an estimated 50-year sea level rise of 1.5 feet and a freeboard of 2 feet, to calculate a bridge soffit elevation of +9.5 feet (NGVD29). With a bridge thickness of approximately 2 feet, this results in a bridge surface elevation of +11.5 feet (NGVD29), versus the existing Eliot Street and Colorado Street elevations of +6.5 feet (NGVD29), i.e. the bridge would need to be approximately five feet higher than the street. If the freeboard of 2 feet is not required, this would reduce the elevation difference to only three feet. Streets would have to be modified to rise as gradual slope approaches to each end of the bridge.

Approximately 380 feet of the south end of the existing culvert, as well as the culvert’s headwall structure at Marine Stadium, would be demolished. A new headwall would be constructed where the existing culvert intersects with the open channel.

At the top of the channel banks, where the existing elevation is below +8 feet (NGVD29), a low earthen berm/dike (one to two feet high) would be installed to protect the surrounding areas from flooding due to storm events and sea level rise. A walking trail would be constructed along the top of the channel on its east side. Preliminarily, it is assumed that this trail would be 10 feet wide to provide access for maintenance vehicles. An “aesthetically-pleasing” fence (approximately 3 to 5 feet high) and low shrub buffer would also be installed on this side of the channel, between the trail and the adjacent grassy park area. The low shrub buffer and potentially a fence would also be installed along the top of the channel on its west side.

The two existing public restrooms located within Marina Vista Park, to the north and south of Eliot Street, would need to be removed and two new restrooms would be constructed in nearby locations. Approximately 23 ornamental (non-native) trees, of which 10 are palm trees, would need to be removed. New trees could be planted in other areas of the park to compensate for this loss. The sidewalk along the northwest end of Marine Stadium, within the footprint of the open channel, would have to be re-routed to the sidewalk on the bridge.

Multiple utilities (oil, gas, sewer, water) along Colorado Street and Eliot Street would need to be re-routed on the bridges. Based on preliminary information, it is assumed that a new lift station would be needed for a sewer main line along Colorado Street. A storm drain along Colorado Street would also need to be modified to discharge into the open channel and a sewer line at the south end of the open channel would need to be re-located.

Installation of the new channel would require excavation along its alignment and would result in approximately 45,000 cubic yards (cy) of excess material. Some of this material could be used to build the earthen dike along the channel banks and possibly to level out the sports field areas within Marina Vista Park. Otherwise, it would be hauled to an appropriate off-site disposal site.

Conceptual engineering drawings (plan view and cross-sections) for Alternative 2 are provided in Appendix A.

2.4. Alternative 3 – Combination Open Channel and Culverts

This alternative is an earthen open channel along <u>part</u> of the connection between Colorado Lagoon and Marine Stadium. The maximum width of the open channel is approximately 125 feet, i.e. 25% wider than Alternative 2. The significant difference is that this Alternative 3 does not include the construction of bridges. Instead, short culvert sections would be constructed under Eliot Street and Colorado Street, at either end of the open channel section. The existing culvert would be left in place for continued use.

2.4.1. General

As discussed previously, the tidal range in the lagoon is muted even after implementation of the Phase 1 project. By constructing an open channel and culverts of sufficient size and depth, the tidal exchange between Colorado Lagoon and Marine Stadium would be improved over the existing / post-Phase 1 project condition. As is the case for Alternative 2, this alternative provides marsh habitat area within the new open channel. The conceptual plan for Alternative 3 is shown in Figure 2-3.

2.4.2. Infrastructure Changes

An approximately 650-foot long earthen open channel would be constructed between Colorado Street and Eliot Street, along the west side of Marina Vista Park, as depicted in Figure 2-3 The new channel would have a varying cross-section and a bottom elevation of -6.5 feet (NGVD29). The channel lining would be clay or silt, except at the channel sections at the culvert ends which would need to have rock lining for slope and scour protection.

New underground Reinforced Concrete Box (RCB) culverts would be constructed at either end of the open channel. The culvert at the Colorado Lagoon end would be approximately 140 feet long and the culvert at the Marine Stadium end would be approximately 180 feet long. The new culverts would each be 28 feet wide and 8 feet high, with invert elevations of -7.0 feet (NGVD29). New headwalls/wingwalls would be constructed at the ends of the new culverts (i.e. in Colorado Lagoon and Marine Stadium and at the open channel transitions).

The existing culvert would be protected in place. The only impact to the existing culvert would be the relocation/reconstruction of two storm drains which discharge into the existing culvert from its west side.

At the top of the channel banks, where the existing elevation is below +8 feet (NGVD29), a low earthen berm (one to two feet high) would be installed to protect the surrounding areas from flooding due to storm events and sea level rise. A walking trail would be constructed along the top of the channel on its east side. Preliminarily, it is assumed that this trail would be 10 feet wide to provide access for maintenance vehicles. An “aesthetically-pleasing” fence (approximately 3 to 5 feet high) and low shrub buffer would also be installed on this side of the channel, between the trail and the adjacent grassy park area. The low shrub buffer and potentially a fence would also be installed along the top of the channel on its west side.

The two existing public restrooms located within Marina Vista Park, to the north and south of Eliot Street, would be removed and two new restrooms would be constructed in nearby locations. Approximately 20 ornamental (non-native) trees, of which 10 are palm trees, would need to be removed. New trees could be planted in other areas of the park to compensate for this loss. A storm drain along Colorado Street would need to be modified to discharge into the northern culvert segment.

Installation of the new channel and culverts would require excavation along their alignment and would result in approximately 26,000 cubic yards (cy) of excess material. Some of this material could be used to build the earthen dike along the channel banks and possibly to level out the sports field areas within Marina Vista Park. Otherwise, it would be hauled to an appropriate off-site disposal site.

Conceptual engineering drawings (plan view and cross-section) for Alternative 3 are provided in Appendix A.

2.5. Alternative 4 - Combination Open Channel (Maximum Wetlands) and One Culvert

This alternative is an earthen open channel along <u>part</u> of the connection between Colorado Lagoon and Marine Stadium. The maximum width of the open channel is approximately 230 feet, i.e. over twice as wide as Alternative 2. In order to try to offset the cost of the wider channel and the impact to open space, only one bridge (along Eliot Street) was included in the concept. A short culvert section would be constructed under Colorado Street, at the north end of the open channel section. The existing culvert would be demolished.

2.5.1. General

As discussed previously, the tidal range in the lagoon is muted even after implementation of the Phase 1 project. By constructing an open channel and culverts of sufficient size and depth, the tidal exchange between Colorado Lagoon and Marine Stadium would be improved over the existing / post-Phase 1 project condition. As is the case for Alternatives 2 and 3, this alternative provides marsh habitat area within the new open channel. The conceptual plan for Alternative 4 is shown in Figure 2-4.

2.5.2. Infrastructure Changes

An approximately 850-foot long earthen open channel would be constructed between Colorado Street and Marine Stadium, along the west side of Marina Vista Park, as depicted in Figure 2-4. The new channel would have a varying cross-section and a bottom elevation of -7.0 feet (NGVD29). The channel lining would be clay or silt, except along the channel sections under the bridge and at the culvert ends which would need to have rock lining for slope and scour protection.

A new underground Reinforced Concrete Box (RCB) culvert would be constructed at the Colorado Lagoon end of the open channel. The new culvert would be approximately 135 feet long, 28 feet wide and 8 feet high, with an invert elevation of -7.0 feet (NGVD29). New headwalls/wingwalls would be constructed at both ends of the new culvert (i.e. in Colorado Lagoon and at the open channel transition).

The section of existing culvert that is within the alignment of the new channel would be demolished. The other section of the existing culvert would be either demolished/removed or capped.

A bridge would be constructed over the channel along Eliot Street. The top of the bridge would need to be higher than the existing street elevations due to the design high water level within the channel. The FEMA base flood elevation for the area was used (+6 ft NGVD29), along with an estimated 50-year sea level rise of 1.5 feet and a freeboard of 2 feet, to calculate a bridge soffit elevation of +9.5 feet (NGVD29). With a bridge thickness of approximately two feet, this results in a bridge surface elevation of +11.5 feet (NGVD29), versus the existing Eliot Street elevation of +6.5 feet (NGVD29), i.e. the top of the bridge would need to be approximately five feet higher than the existing street. If the freeboard of 2 feet is not required, this would reduce the elevation difference to only three feet. Streets would have to be modified to rise as gradual slope approaches to each end of the bridge.

At the top of the channel banks, where the existing elevation is below +8 feet (NGVD29), a low earthen berm (one to two feet high) would be installed to protect the surrounding areas from flooding due to storm events and sea level rise. A walking trail would be constructed along the top of the channel on its east side. Preliminarily, it is assumed that this trail would be 10 feet wide to provide access for maintenance vehicles. An “aesthetically-pleasing” fence (approximately 3 to 5 feet high) and low shrub buffer would also be installed on this side of the channel, between the trail and the adjacent grassy park area. The low shrub buffer and potentially a fence would also be installed along the top of the channel on its west side.

The two existing public restrooms located within Marina Vista Park, to the north and south of Eliot Street, would be removed and two new restrooms would be constructed in nearby locations. Approximately 20 ornamental (non-native) trees, of which 10 are palm trees, would need to be removed. New trees could be planted in other areas of the park to compensate for this loss. The sidewalk along the northwest end of Marine Stadium, within the footprint of the open channel, would have to be re-routed to the sidewalk on the bridge.

An oil line along Eliot Street would need to be re-routed on the bridge. A storm drain along Colorado Street would need to be modified to discharge into the northern culvert segment and storm drain along Eliot Street would need to be modified to discharge into the southern end of the open channel. A sewer line at the south end of the open channel would need to be re-located.

Installation of the new channel and culvert would require excavation along its alignment and would result in approximately 40,000 cubic yards (cy) of excess material. Some of this material could be used to build the earthen dike along the channel banks and possibly to level out the sports field areas within Marina Vista Park. Otherwise, it would be hauled to an appropriate off-site disposal site.

Conceptual engineering drawings (plan view and cross-section) for Alternative 4 are provided in Appendix A.

2.5.3. Alternative 4a

Per request at a meeting with the resource agencies, an Alternative 4a was defined. This Alternative 4a has a similar open channel to Alternative 4, except at the channel’s north end where the underground culvert is replaced with a bridge. The resultant Alternative 4a has an open channel along its entire length, a maximum open channel width of 230 feet, and two bridges. This alternative 4a would be compared at a high level with Alternative 4 to comprehend the additional habitat area gained (by the additional open channel section) versus the cost of a second bridge.

3.0 ANALYSIS OF ALTERNATIVES

Each alternative will be analyzed in terms of geomorphology, hydrodynamics, habitat improvements, general impacts, and cost in the following sections. The hydrodynamics and habitat analyses evaluate changes to the existing conditions within both Colorado Lagoon and the Marina Vista Park site for all alternatives. The geomorphology analyses are relevant only to the open channel alternatives. General impacts and costs are provided for all alternatives.

The analyses compared each alternative to each other, as well as to the existing condition of Colorado Lagoon. The "existing" condition was considered to be the lagoon in its post-Phase 1 condition, i.e. the existing culvert has been cleaned, the lagoon has been dredged and its side slopes recontoured.

3.1. Geomorphology

Geomorphology is the study of the evolution and configuration of landforms. It is relevant to the Phase 2 alternatives which include open channels, i.e. Alternatives 2, 3 and 4. An assessment was conducted to provide: (a) an interpretation of the geomorphic setting and historical conditions; (b) guidance on geomorphically-appropriate channel design and bank materials; and (d) an evaluation of long-term channel stability of the study alternatives. The findings of this assessment are summarized in this section. The full report is provided in Appendix C.

3.1.1. Channel Morphology

For this study, hydraulic geometry relationships developed from the San Francisco Bay tidal marshes (Williams et al., 2002) were applied to approximate the <u>ideal</u> cross-sectional area, depth and top width for the open channel, in the absence of other constraints/criteria. It was assumed that the hydraulic geometry relationships from the San Francisco Bay provide a suitable analog for the study area because tidal wetlands in both locations experience mixed semidiurnal tides with similar range, are formed in similar substrate (i.e., marine silts and clays), and develop climax marsh plains at an elevation approximating mean higher high water (MHHW).

Williams et al. (2002) provides equations to derive various components of channel geometry based on tidal prism. The potential diurnal tidal prism [i.e., volume of water between MHHW and Mean Lower Low Water (MLLW)] at the mouth of Colorado Lagoon is estimated to be 76 acre-feet. Table 3-1 provides the theoretical channel cross-sectional area, depth and top width derived from the hydraulic geometry relationships presented in Williams et al. (2002) in comparison to the dimensions of the proposed open channel alternatives.

Table 3-1. Comparison of Channel Morphology Parameters Derived from Hydraulic Geometry Relationships and Proposed Open Channel Alternatives[1]

Cross-section	Maximum Depth	Top width	Cross-sectional area
	(feet)		($feet^2$)
Theoretical channel[1]	*8.3*	*94.5*	*515*
Alternative 2 (@ Section 2a)	9.4	78	434 (channel) + 97 (culvert) = 531
Alternative 3 (@ Section 3a)	9.4	90	424 (channel) + 97 (culvert) = 521
Alternative 4 (@ Section 4a)	9.9	125	660

1. Hydraulic geometry relationships from Williams et al. 2002.
2. Based on potential diurnal tidal prism of 76 acre-feet.

Maximum channel depths for the open channel alternatives exceed the value derived from the hydraulic geometry relationships by 1 to 1.5 feet. The invert for the open channel alternatives was set at an elevation that would provide adequate tidal exchange with Colorado Lagoon, and maximize the extent of potential eelgrass habitat. By sloping the channel bed (in cross-section), considerable variability has been incorporated into the design of channel bottom to encompass the range of potential eelgrass habitat. This bed configuration is desirable from a habitat perspective, and the small differences in maximum channel depths are not likely to be problematic from a geomorphic perspective.

Top width (measured at MHHW) for Alternative 2 is somewhat less than the theoretical channel (due to this alternative's objective of minimizing the footprint within Marina Vista Park), while the top width for Alternative 4 is substantially greater than the theoretical channel (due to this alternative's objective of maximizing the amount of wetland habitat created). Top width for Alternative 3 is very similar to the theoretical channel. The cross-sectional area for Alternatives 2 and 3 (including conveyance capacity of culvert) is very similar to the theoretical channel, while the cross-sectional area for Alternative 4 is greater than the theoretical channel (again because of that alternative's objective of maximizing wetland habitat acreage).

From the perspective of this study, concern would be warranted if the channel dimensions for the proposed alternatives were substantially less than that predicted from the hydraulic geometry relationships. This would indicate that the channel would have the tendency to expand, which could result in undesirable erosion. For example, the proposed top width of Alternatives 2 is approximately 78 feet, while the theoretical channel is approximately 95 feet, suggesting that the proposed channel may have a tendency to widen. While this difference in dimensions is not at a scale that would warrant great concern, it should be considered in subsequent design phases of the open channel.

Conversely, the top width and cross-sectional area of Alternative 4 exceed the dimensions predicted from the hydraulic geometry relationships. An oversized channel would have the tendency to aggrade over time, the rate of which would be dependent on sediment supply and hydraulics. This condition would not necessarily be problematic, and a conservatively designed channel with a tendency toward aggradation, may be desirable given the study setting.

3.1.2. Channel Stability

Bank Stability

Predicted flow velocities for each of the open channel alternatives were derived from the RMA-2 model. Peak velocities, within the open channel sections, modeled for spring tide conditions range from 0.9 to 1.8 feet per second (fps); for the 50-yr storm event peak velocities range from 1.3 to 2.3 fps. Peak velocities are significantly greater at the transitions because the channel is confined in smaller cross-sections at these locations.

A literature review of permissible velocities for open channels was conducted to inform the selection the appropriate channel lining materials (See Appendix C). Permissible velocities reported in the literature for several soils types with silt or clay textures exceed the estimated peak velocities modeled for all alternatives. This suggests that the boundary of the open channel can be lined with clay or silt provided that the material is conditioned, placed and compacted in accordance with standard engineering practices. Sandier material could be placed on the channel bottom to provide better substrate for eelgrass growth. The sandier material may erode from sections of the channel where velocities are highest (e.g., outer bend of the channel meander), but the material would likely remain in place in areas of low velocity or depositional zones.

Philip Williams and Associates (PWA, 1995) provides design guidelines for slope stability of channels constructed in estuarine sediments. Very soft bay mud with shear strength of 100 lbs/ft^2 is expected to be stable at a gradient near 7:1, while well-consolidated bay mud with shear strength of 150 lbs/ft^2 will support a bank 10 ft high with a slope of 3:1. Thus, engineering design of the preferred alternative will need to consider the geotechnical properties of the proposed channel lining materials and estimates of shear stresses in the open channel to further refine calculations of bank stability and equilibrium slope angle. More robust channel lining materials, such as rock riprap, may be warranted in select areas (e.g., transitions to Colorado Lagoon and Marine Stadium) to account for confined cross-sections, steeper channel banks, and to protect infrastructure (e.g. bridges).

Long-Term Channel Stability

The primary mechanisms for large-scale adjustments (e.g., avulsion, lateral migration) in the morphology of tidal channels are changes in hydrology and sediment supply. The role these factors would play in the long-term stability of a tidal channel in the study area is discussed below.

Hydrology. The open channel alternatives have been designed to accommodate the existing tidal prism and stormwater discharge associated with Colorado Lagoon and the surrounding watershed. In the study area, tidal prism is the dominant driver of hydrology and hydraulics in the system, though inputs from large, infrequent storm events do increase peak velocities in the channel. Results from hydraulic modeling indicate maximum velocities would be relatively low (less than 2 fps) in the main portions of the open channel. Provided that the channel is constructed of suitable material, large-scale channel adjustments under the existing hydrologic regime are unlikely.

The effective tidal prism in the study area could increase as a result of sea level rise or scour in Colorado Lagoon, or decrease as a result of sedimentation in the lagoon. It is most plausible that tidal prism would increase to some degree due to sea level rise. An increase in tidal prism would likely cause the channel to widen. While widening of the channel as a result of increased tidal prism may occur, it is not anticipated to be of a magnitude that would present threats to adjacent infrastructure. Further design of the open channel must consider the impacts of sea level rise on the tidal dynamics, and the design of the selected open channel alternative must accommodate the range of projected hydrologic and hydraulic changes associated with changes in tidal prism.

Sediment Supply. Historically, large inputs of alluvial sediment to the study area were associated with the San Gabriel-Los Angeles river complex. The San Gabriel River watershed produces some of the highest sediment yields in southern California as a result of the extreme topography, rainfall patterns and granitic geology (Stein et al, 2007). With the study area separated from these influences by changes in land use and river management, the mechanism for excessive sedimentation to occur in the study area has been greatly diminished. The only remaining source of alluvial sediment is from the relatively small Colorado Lagoon watershed.

Future sediment supply from the Colorado Lagoon watershed is not anticipated to be significant because most of the watershed is developed, open space areas within the watershed are recreation facilities (primarily golf courses) that do not yield significant amounts of sediment. In addition, some of the sediment that is supplied from the watershed would bypass the channel and lagoon with the proposed re-routing of the Termino Avenue Drain (City of Long Beach, 2008). Hence, there is no longer a mechanism for large-scale channel avulsion due to sedimentation now that the study area is no longer connected to the San Gabriel River flood flows and sediment supply.

The other source of sediment to the study site would be of marine origin. Significant deposition of marine sediments in the study area is not likely because: (1) the channel has been sized to accommodate the potential tidal prism; and (2) the sediment load from marine sources is relatively low and would not result in significant accretion of tidal areas in the anticipated lifespan of the project (approximately 100 years). Thus, excessive sedimentation that would result in channel avulsion, or decrease tidal prism and cause the channel to narrow, is unlikely to occur.

3.1.3. Alternatives Comparisons Relative to Geomorphic Context

The analyses presented in the previous section indicate that, with relatively minor adjustments to channel geometry and bank materials, all of the proposed alternatives could be designed to function properly from a geomorphic standpoint. The benefits and constraints that can be distinguished among the alternatives are discussed below.

Alternatives 2 and 3. These alternatives are essentially equivalent from a geomorphic standpoint. Both of these alternatives have adequate cross-sectional area to convey the potential diurnal tidal prism assuming the capacity of the parallel culverts is maintained. If the parallel culverts were to become blocked or were not adequately maintained, the tidal channels would likely erode to accommodate the additional tidal prism. This could be problematic because the channel is highly constrained by adjacent land uses. Thus, these alternatives would require on-going maintenance of the parallel culverts. It may be feasible to “over-design” the new parallel culvert to accommodate loss of capacity due to bio-fouling, and therefore avoid the need for on-going maintenance. No additional maintenance of capacity (e.g., dredging) or bank stability is anticipated provided that the channel is constructed according to the engineer’s specifications.

Alternative 4. This alternative has the lowest flow velocities, largest cross-sectional area and shallowest slopes of the three alternatives. This indicates that it would be the least prone to erosion and would require the least amount of maintenance to maintain channel stability. Moreover, this alternative is not dependent on maintenance of the parallel culvert for conveyance capacity. The cross-sectional area and top width at the widest section exceeds the geometry predicted from empirical geomorphic relationships. An “oversized” channel would have the tendency to aggrade over time, the rate of which would be dependent on sediment supply and hydraulics. This condition would not necessarily be problematic, and a conservatively designed channel with a tendency toward aggradation, may be desirable given the study setting. Finally, of the alternatives presented, Alternative 4 provides the greatest opportunity to create a diverse wetland environment that is resilient to changes in sea level.

3.1.4. Geomorphology Summary

Colorado Lagoon is essentially a relic landform that was shaped by the complex interaction of the tides and alluvial deposition/erosion associated with the San Gabriel River. Historical maps and images provide evidence that Colorado Lagoon and the study area were historically tidal habitats with landscape features of similar dimensions to those proposed in the open channel alternatives. Thus, all of the proposed open channel alternatives present restoration concepts that closely match the historical landscape morphology at a local scale.

When restoring wetlands in southern California, Stein et al. (2007) caution against "type conversion" i.e., creating specific wetland habitats at a location where they historically did not exist. The proposed open channel provides an excellent opportunity to restore wetlands in the appropriate historical context. Further refinement of channel geometry, substrate type, slope stability and transitional habitats (e.g., alkali meadow) should be components of the subsequent phases of design. As with all restoration projects, channel morphology will need to be monitored and adaptive management measures may be warranted if adjustments exceed thresholds established for lateral erosion or sediment deposition.

3.2. Hydrodynamic Performance

Hydrodynamic modeling of each alternative, as well as the existing condition, was performed using the calibrated RMA2 two-dimensional numerical model. The model was applied to evaluate: a) tidal hydrodynamics under the dry season; b) flood hydrodynamics under the Capital Storm (50-year) event; and c) impacts of sea level rise. The results were used to determine parameters such as:

- Tidal range, muting, and tidal inundation frequencies in Colorado Lagoon and the open channel (important for habitat considerations);
- Tidal prism changes in Colorado Lagoon (measure of water quality improvement);
- Tidal residence time changes in Colorado Lagoon and one site within Alamitos Bay (measure of water quality improvement);
- Stormwater levels in Colorado Lagoon and the open channel (potential for flooding in surrounding areas);
- Flow velocities within the open channel and culverts (important for slope stability, fish passage, vegetation feasibility, and human safety).

A full report with details of the modeling and results is provided in Appendix D. A summary of the results are provided below.

3.2.1. Tidal

This section discusses the tidal hydraulics modeling results under dry season conditions. The Tidal Epoch Analysis (TEA) tide series described in Appendix D were applied in the model to predict the tidal range, tidal inundation frequency, and calculate the tidal prism for each alternative. Two modeling iterations were performed, i.e. an initial iteration was performed to assess preliminary alternatives, the alternatives were refined based on these modeling results, and a second iteration was then completed.

The tidal series in the Colorado Lagoon south end under proposed project alternatives were compared with that in the ocean (ideal condition). The gage locations (as shown in Figure 3-1), where modeling results were extracted, are fixed. The connection between the lagoon and Marine Stadium varies from alternative to alternative.

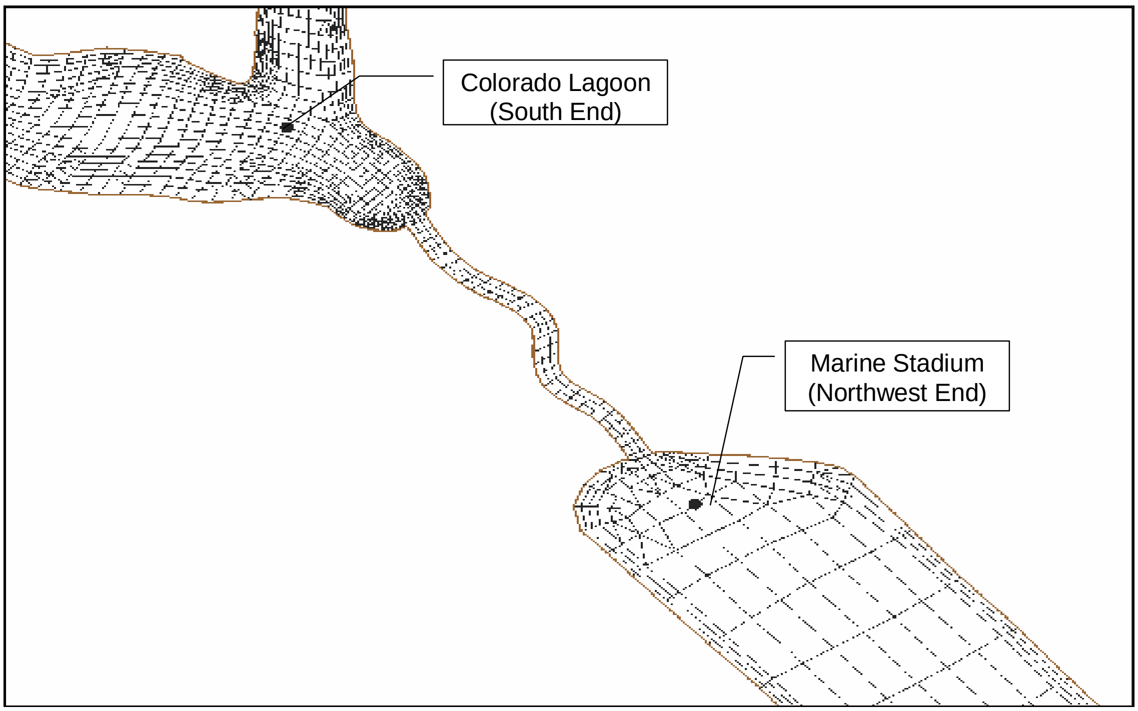


Figure 3-1. Hydrodynamic Modeling Output Gage Locations

Tidal Range and Prism Results

The tidal range and tide muting in Colorado Lagoon for all alternatives, compared with those in the open ocean and in the lagoon with the existing (post-phase-1) condition, are summarized in Figure 3-2 and Table 3-2. The Marine Stadium tidal range is nearly equivalent to that of the open ocean. The open channels in Alternatives 2, 3 and 4 would experience equivalent tide ranges as those shown for the lagoon.

Table 3-2. Tide Range Comparisons

Location / Modeling Scenario		Tidal Range (ft)	High Tide Muting (ft)	Low Tide Muting (ft)	Prism (acre-ft)
Open Ocean		*8.2*	*N/A*	*N/A*	*N/A*
Colorado Lagoon	*<u>Post</u> Phase 1 Project Condition*	*5.8*	*0.5*	*1.9*	*73.4*
	Alternative 1 - Parallel / Second Culvert	7.9	0	0.3	109.7
	Alternative 2 - Open Channel with Bridges	7.8	0	0.4	105.0
	Alternative 3 – Combo Open Channel & Culverts	8.0	0	0.2	110.7
	Alternative 4 - Maximum Wetland	8.0	0	0.2	110.7

The high tide muting is calculated by subtracting the highest ocean tide by the highest lagoon tide, and the low tide muting is calculated by subtracting the lowest lagoon tide by the lowest ocean tide. A positive number indicates the lagoon tide is muted. The modeling results indicate a significant improvement with any of the Phase 2 alternatives. There is no muting on the high tide and minor low tide muting for all alternatives. This muting is essentially insignificant; it can be considered to be within the accuracy of the model and the alternatives could be fine tuned during final engineering to achieve a full tidal range if necessary.

Table 3-2 also summarizes the spring tidal prism of the Colorado Lagoon. The spring tidal prism is the volume of water being replaced over a complete spring tidal cycle, and it serves as an indication of water quality. The spring tidal prism would increase about 50% under the post Phase 2 project condition as compared to the post Phase 1 project condition.

It is concluded that the lagoon would experience full (or nearly full) spring tides under all proposed alternatives. This is a significant improvement over the existing (post-phase 1) condition. Tidal range is not a discriminator between alternatives.

Tidal Inundation Frequency

Figure 3-3 shows tidal inundation frequency in Colorado Lagoon for the proposed alternatives versus that in the ocean and under the post-phase 1 project condition. A similar tidal inundation frequency would occur within the open channel. The inundation frequency under all proposed alternatives closely mimics the condition in the ocean, whereas the low tide is truncated under the post-phase 1 project condition. The tidal inundation frequency results were used to determine the types of habitat zones present at various elevation bands within Colorado Lagoon and within the open channel for Alternatives 2, 3 and 4. This is discussed further in Section 3.3.

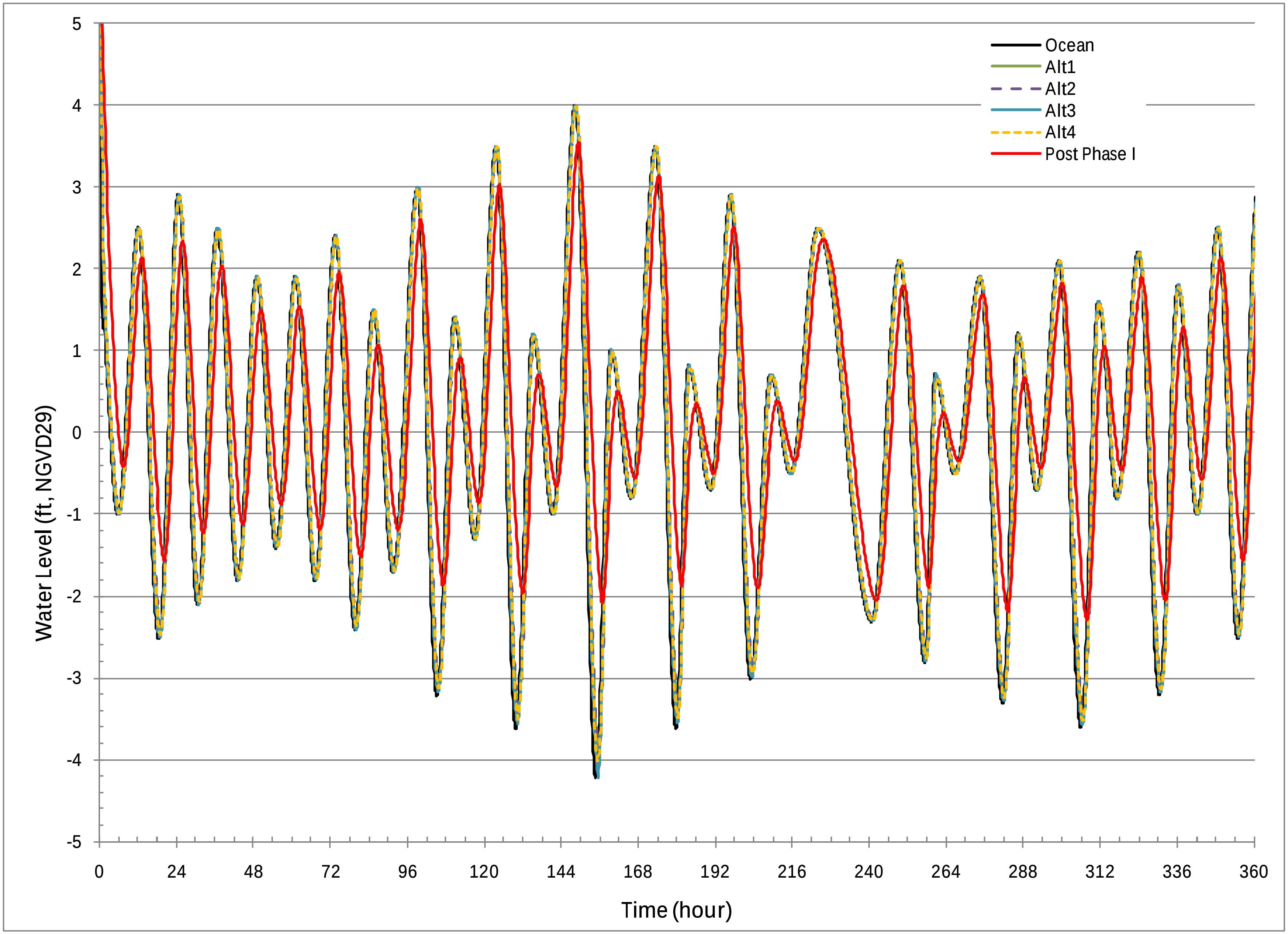


Figure 3-2. Tide Range Comparisons

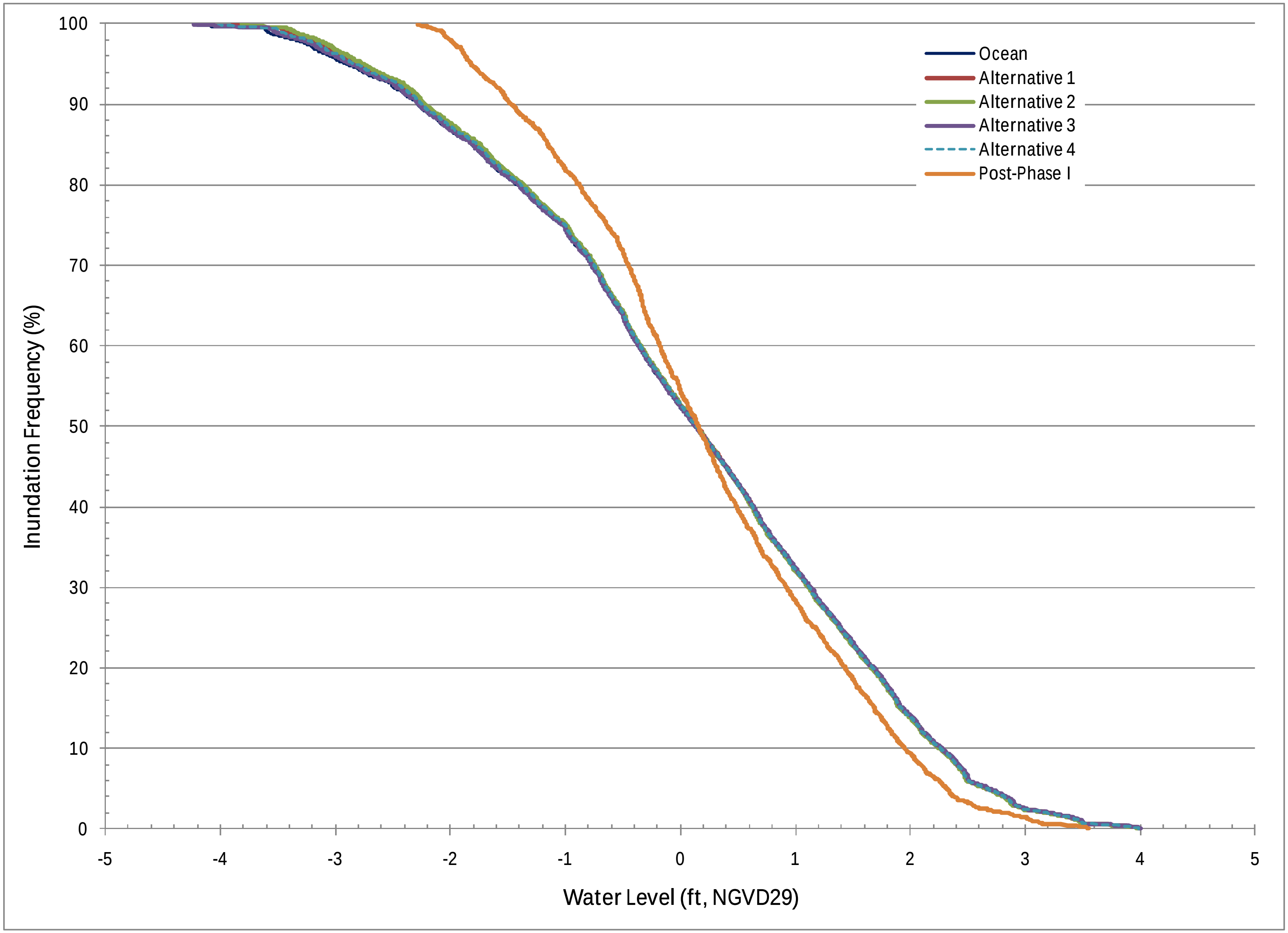


Figure 3-3. Tidal Inundation Frequency

Residence Time

Water surface elevations and current patterns simulated by the RMA2 hydrodynamic model were input to the pollutant transport RMA4 model to estimate water residence times. As there was no data and budget available for RMA4 model calibration, the modeling parameters used were based on literature and past similar project experiences. Two power plants, namely the AES power plant and Haynes power plant, intake cooling water from Alamitos Bay and discharge it into the San Gabriel River (SGR). These affects are not considered in the modeling. The residence times will vary with power plant pumping included. However, the results without pumping are considered sufficient for the purpose of alternatives comparisons.

The residence time will also vary under different tide conditions such as spring and neap tide cycles. In this study, a synthetic (PMP) tidal series, representing a long term average tidal condition was used in determining residence times. The residence times are shorter for locations relatively close to the ocean entrance and longer for areas farther upstream such as Colorado Lagoon.

The locations selected to compare residence times were the south end of the lagoon (near the culvert) and the northwest end of the Marine Stadium, as shown in Figure 3-1. Residence times at Mother's Beach (another area within Marine Stadium / Alamitos Bay) were also included in the comparison. In general, the northwest end of Marine Stadium represents the best possible condition attainable by the Colorado Lagoon. Table 3-3 summarizes residence times at these locations, with the Parametric Mean Periodic (PMP) tides, under the different connection scenarios. The residence time is shortest under the Phase 2 condition.

Table 3-3. Residence Time under PMP Tide

Modeling Scenario	Residence Time (Days) In:		
	Colorado Lagoon	Marine Stadium	Mother's Beach
Existing Lagoon and Culvert	*8.5*	*6.9*	*5.3*
Post Phase 1 Project Condition- Dredged Lagoon and Cleaned Culvert, No Open Channel	*7.7*	*6.0*	*4.9*
Alternative 1 - Parallel / Second Culvert	7.5	6.0	4.9
Alternative 2 - Open Channel with Bridges	7.2	6.0	4.9
Alternative 3-Combination Open Channel & Culverts	7.4	6.0	4.9
Alternative 4 - Maximum Wetland	7.3	6.0	4.9

The residence time difference between alternatives is small; alternatives could be fine tuned to achieve similar residence times, and thus residence time is not considered to be a discriminator between alternatives.

The residence time differences between post -Phase 1 and Phase 2 projects are relatively small, which is partially contributed to the PMP tidal series used. The PMP tidal series is the average tidal series between the MLLW and MHHW. However, the low tidal muting primarily occurs at the spring low tides for the existing connection. Under the spring tidal condition, the residence time in the lagoon under Post Phase 2 project can be improved more than the existing connection. Table 3-4 presents the residence time predictions following the spring tide series condition.

Table 3-4. Residence Time under TEA Tide

Modeling Scenario	Residence Time (Days) In:		
	Colorado Lagoon	Marine Stadium	Mother's Beach
Post Phase 1 Project Condition - Dredged Lagoon and Cleaned Culvert, No Open Channel	*7.1*	*5.0*	*3.9*
Alternative 2 - Open Channel with Bridges	6.4	5.0	3.9

3.2.2. Flooding

For the flood hydrodynamics analysis, the 50-year storm was modeled. The input hydrographs are discussed in detail in Appendix D. Input hydrographs assumed implementation of the Termino Avenue Drain Project (TADP), i.e. they represented the post-TADP condition. An extreme tidal series was vertically adjusted to match the FEMA base flood elevation of +6 ft (NGVD29) (FEMA FIRM Panel No. 0601360025C) in Alamitos Bay. The resulting tidal series are shown in Figure 3-4. The extreme high tide is +6.0 ft (NGVD29).

The modeling results show that the water level in the lagoon would reach approximately +6.4 ft (NGVD29) for all alternatives, +6.5 ft (NGVD29) for the existing post-phase-1 condition, under the joint event of a 50-year storm event and an extreme tidal condition. All alternatives provide the same efficiency in relieving floods. However, these results do not take into account sea level rise which is discussed in the following section.

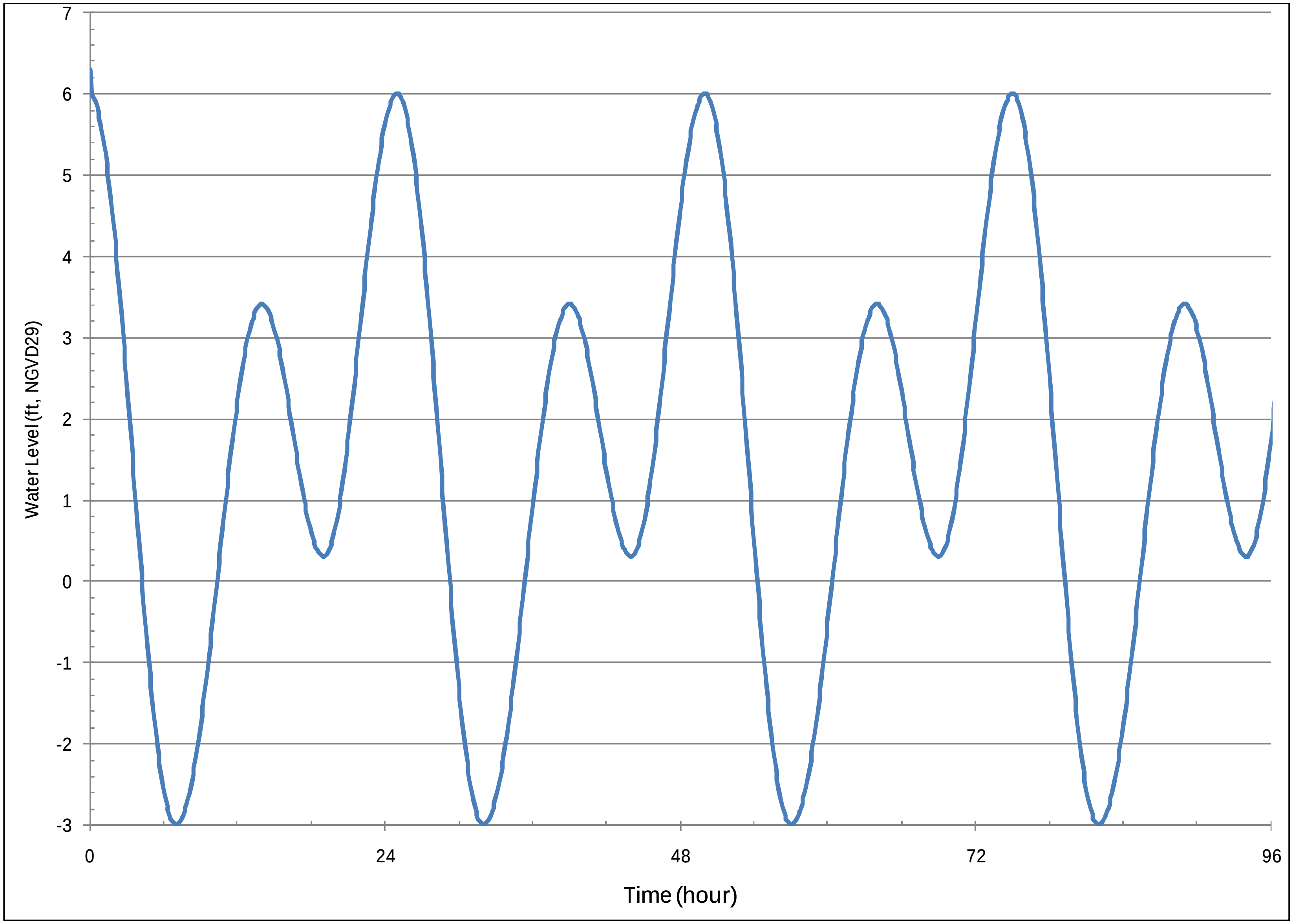


Figure 3-4. Extreme Tide Series Used for Flood Modeling (Based on FEMA Base Flood Elevation)

3.2.3. Sea Level Rise

Design of any of the alternatives must consider sea level rise, specifically relative sea level rise, which is the local rate of sea level rise relative to the land. Sea level rise primarily affects two aspects related to this study: 1) the potential for flooding and 2) the rising tide's impact on wetland habitat. The former will be addressed in this section. Regarding the latter, it is not always clear how wetland habitat will (or will not) adjust to the rising tides, but a general design objective is to develop a grading plan such that vegetation can migrate upward as sea level rise occurs. This is something that can be addressed during final design of any of the open channel alternatives.

This section will provide a brief overview of both the global sea level rise rate and local conditions specific to the Colorado Lagoon area.

Global Values and California Coastline

Sea level is rising as the result of general global warming that melts ice caps and expands the water column through heating and possibly due to decadal effects such as the El Niño Southern Oscillation and the Pacific Decadal Oscillation (M&N, 2007b). The global average rate of sea level rise is also known as the eustatic rate. A range of scenarios exist for the future global average rate and it is valuable to understand the range of scenarios. Figure 3-5 summarizes the range of projections developed by the IPCC (2007), by Rahmstorf (2006), and by the California Climate Change Center (2009). (The Rahmstorf analysis addresses possible model limitations associated with IPCC predictions of global sea level rise). These authors generally have not provided numerical tables giving the projected sea level rise at intermediate dates; the curves on this chart have been developed by Moffatt & Nichol by fitting to the published values (either tabulated or read from charts).

The gist of this chart is that the values specified by the California State Coastal Conservancy (SCC 2009) – 16 inches (40 cm) by 2050 and 55 inches (140 cm) by 2100 – represent an upper limit on the sea level rise anticipated absent any catastrophic changes (such as dramatic losses to the ice sheets). These SCC values must be considered in project planning, i.e. new construction should consider how best to counter coastal flooding given these increases. However, the SCC values are not the most likely increases to design to. For example, it would make no sense to "perch" a newly constructed wetland restoration such that the highest habitat values are obtained only after the sea level has risen by 55 inches.

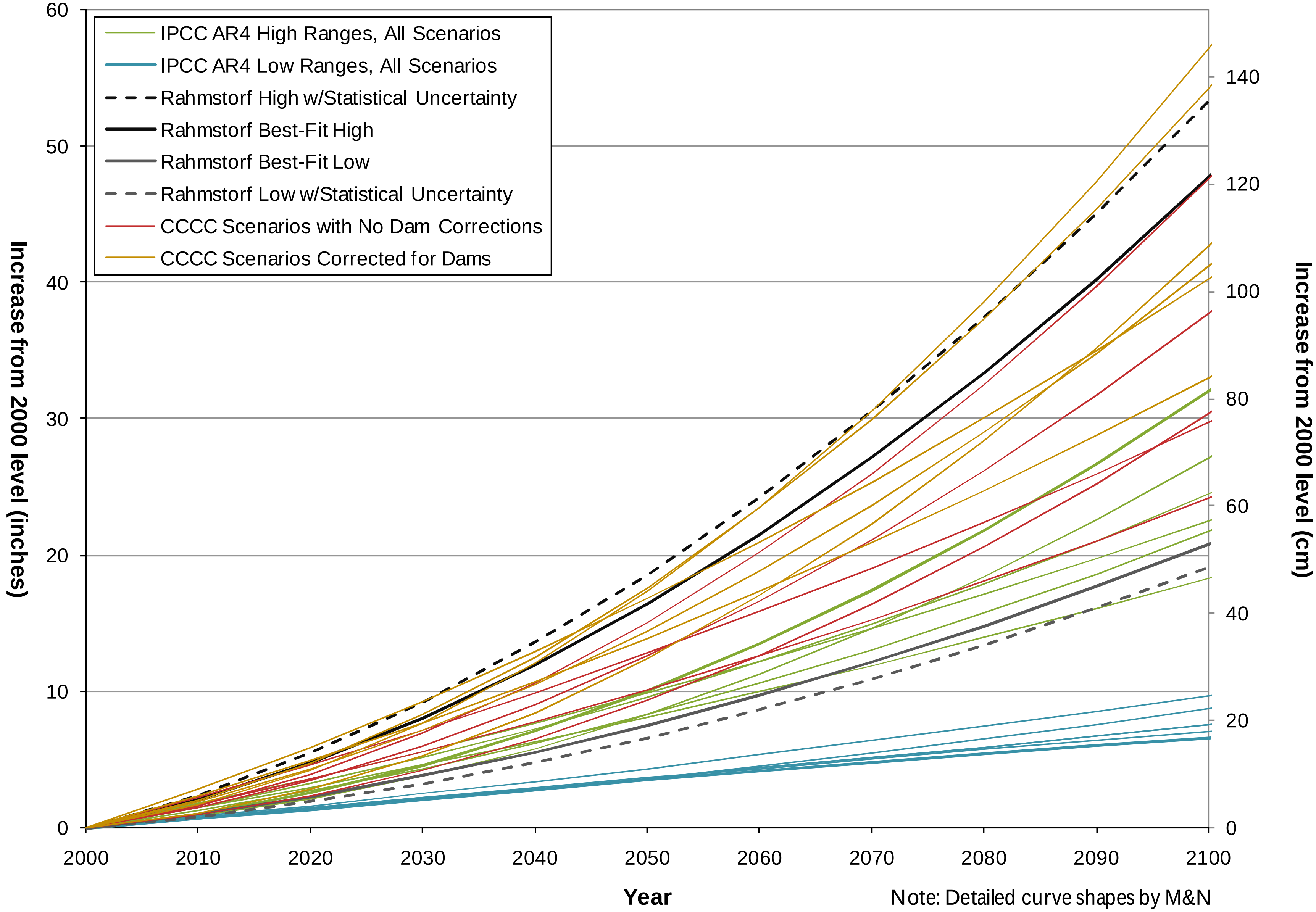


Figure 3-5. Range of Projected Increases in Sea Level Rise: California Coast Generally

Uplift at Colorado Lagoon

At a given coastal site, the rate of eustatic sea level rise is of less practical importance than the local rate of sea level rise relative to the land. This relative sea level rise is determined by local tectonic conditions (land uplift or subsidence). There is evidence, discussed below, of uplift in the vicinity of Colorado Lagoon. Consequently, the rate of relative sea level rise at Colorado Lagoon is likely to be less than the global rate.

The local conditions can be estimated by using long-term tide records. NOAA has analyzed the tide records for the tide gauge at Los Angeles, California – the nearest long-term gauge to Colorado Lagoon. NOAA estimates the rate of relative sea level rise as 0.83 ± 0.27 mm per year (3.3 ± 1.1 inches per century) at this L.A. tide gauge, based on monthly mean sea levels from 1923 to 2006 (NOAA 2008). This is lower than the historic eustatic rate of sea level rise, and suggests that the local land is rising at a rate of approximately 3 inches per century. However, even if this uplift rate is assumed to continue into the future, it is basically insignificant in the context of the future eustatic sea level rise projections.

The City of Long Beach maintains a number of benchmarks in the vicinity of Colorado Lagoon. Elevation data for three historical benchmarks (with data available since 1928) and two more recent benchmarks were provided to Moffatt & Nichol for the present analysis. The elevation data are provided relative to NGVD 29 and are tied to the Tidal 8 benchmark, which is the primary benchmark for the tide gauge at Los Angeles, California[1]. Figure 3-6 shows the five measured benchmark elevations relative to NGVD29. The benchmark elevations have varied by about one foot over the past 80 years.

Figure 3-7 shows elevations relative to arbitrary datums chosen to align the measurements for the five benchmarks. This expands the scale at which changes in the benchmark elevations are shown. The red line in this chart highlights three periods:

1. Between the 1920s and the 1960s, when the land in the vicinity of Colorado Lagoon subsided due to oil and gas extraction in the Seal Beach and Wilmington fields;
2. A brief period of rebound in the 1970s with no subsidence, in response to water injection on THUMS Oil Island Chaffee, to the south of the lagoon;
3. Since the 1970s, during which there has been essentially no vertical movement of the Long Beach benchmarks relative to the Tidal 8 benchmark at Los Angeles, California.

[1] All the elevation surveys are referenced to the USGS Tidal 8 benchmark in San Pedro. After the City of Long Beach began GPS surveying in 2002, any changes to the Tidal 8 elevation were not included in the subsequent surveys. Information from John Jepson, Long Beach Gas and Oil, City of Long Beach.

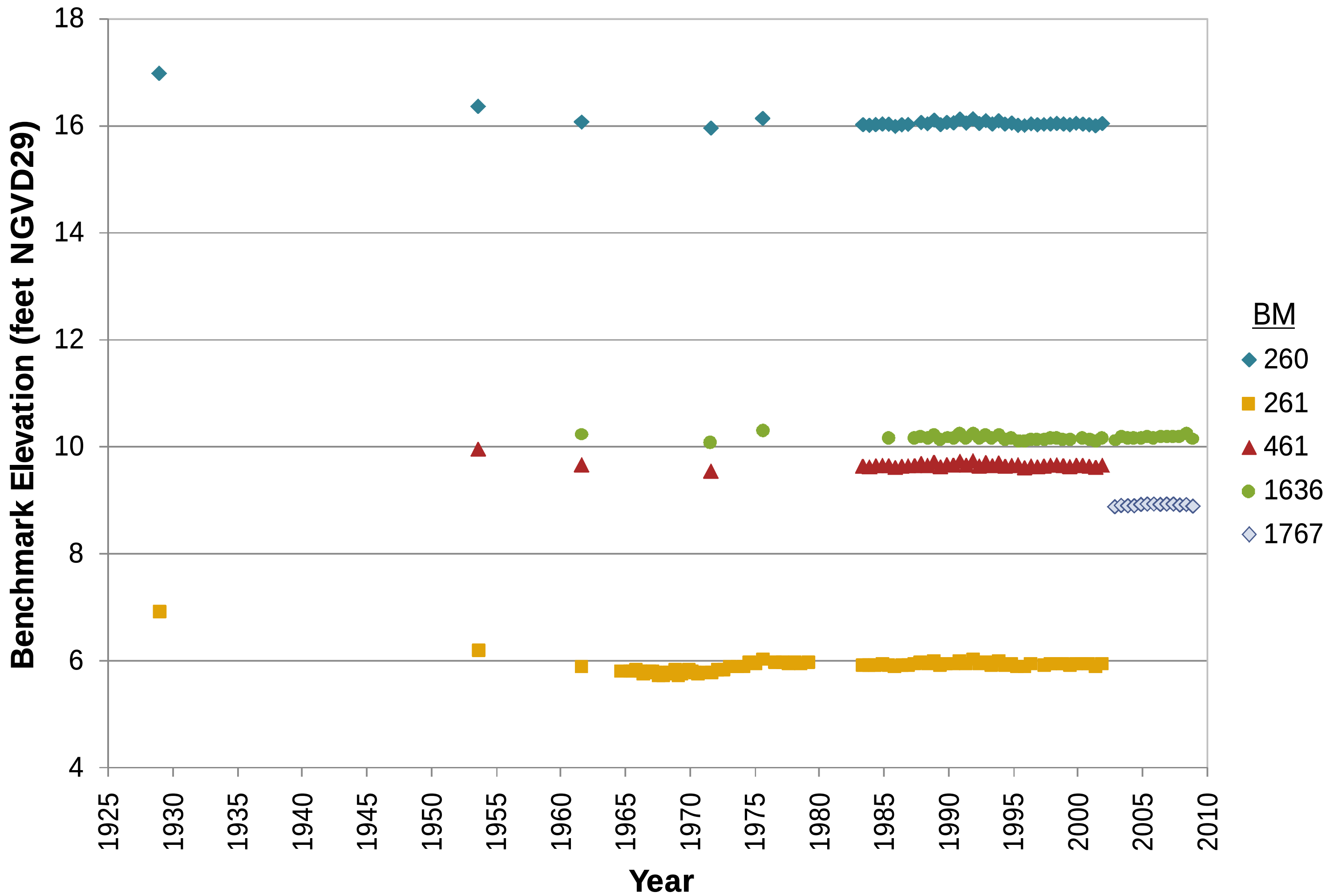


Figure 3-6. Benchmark Elevations in the Vicinity of Colorado Lagoon: <u>Absolute</u> Values

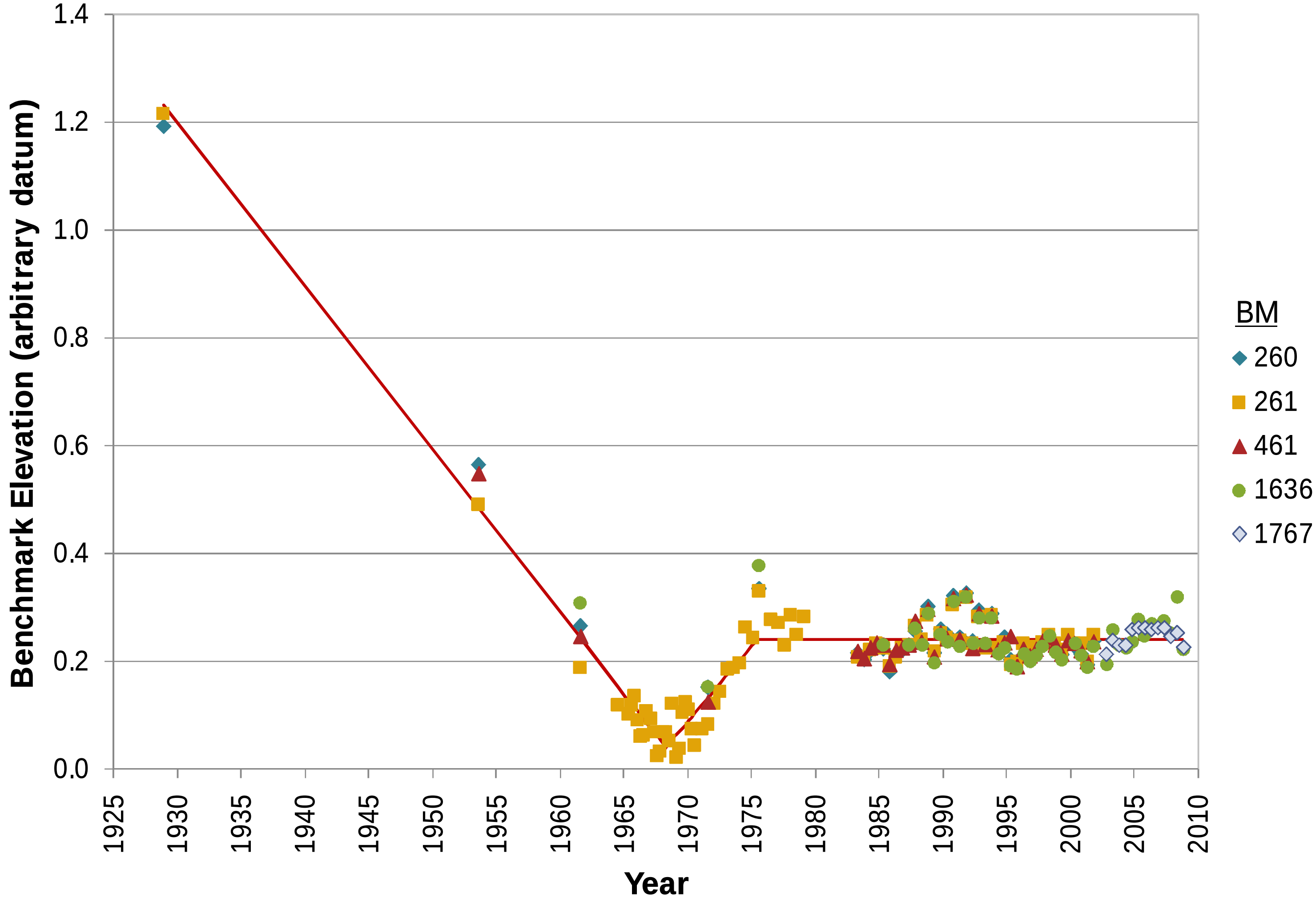


Figure 3-7. Benchmark Elevations in the Vicinity of Colorado Lagoon: Aligned to Arbitrary Datum to Expand Scale and Visualize Trends

Over the past 30 years, vertical land movements in the vicinity of Colorado Lagoon have been similar to the vertical land movements (uplift) at the Los Angeles tidal gauge – approximately 3.3 inches per century. This uplift rate is likely to continue, but is basically insignificant relative to the much greater eustatic sea level rise projections.

Summary of Relative Sea Level Rise in Colorado Lagoon Area

Three plausible scenarios can be identified for future sea level rise (through 2100). The values given below take into account the localized uplift at Colorado Lagoon, (such that the lagoon sea level rise is approximately 3.3 inches per century lower than the projected increase in global sea levels).

- <u>Low rate of increase</u>: Sea level rise continues at the average of low sea level rise projections for different emissions scenarios given in the *2007 IPCC Report* (IPCC 2007). Relative to the value in 2000, the sea level rises 2 inches by 2050 and 9 inches by 2100.
- <u>Likely high rate of increase</u>: Sea level rises according to the mid-range of predictions from the recent *California 2008 Climate Change Scenarios Assessment* (CA Climate Change Center 2009). This is similar to the mid-range of Rahmstorf's projections and is above the highest values given in the *2007 IPCC Report*. Relative to the value in 2000, the sea level rises 12 inches by 2050 and 37 inches by 2100.
- <u>Highest rate of increase</u>: As specified by the California State Coastal Conservancy (SCC 2009) and based on the highest predictions from the recent *California 2008 Climate Change Scenarios Assessment* (CA Climate Change Center 2009), the sea level rises 16 inches by 2050 and 52 inches by 2100.

Table 3-5 gives intermediate values for the three scenarios, together with the final (100-year, to 2100) projection. Sea level rise is given relative to the year 2000.

Table 3-5. Recommended Sea Level Rise Scenarios
(Includes Localized Uplift in Colorado Lagoon Area)

Scenario	Sea Level Rise, Relative to Year 2000, in Future Years (Inches)					
	2010	2020	2030	2040	2050	2100
Low Rate	0	1	1	2	2	9
Likely High	1	3	6	9	12	37
Highest Rate	2	4	7	11	16	52

More rapid scenarios have been discussed in the scientific literature, particularly in the light of possible nonlinear effects such as instability of the Antarctic and Greenland Ice Sheets. However, it seems very unlikely that these will significantly increase sea level rise in a 50-year time frame.

Los Angeles Area Tidal Range Changes

It should also be noted that the tidal range measured at the Los Angeles tide gauge has increased measurably during the 20th century (Flick, et al, 2003). This means, for example, that the elevation of Mean Higher High Water (MHHW) is rising more rapidly than the mean sea level discussed elsewhere in this section. Based on measurements at Los Angeles from 1923 to 1999, the tidal range (MHHW-MLLW) is increasing at a rate of 0.25 mm per year (1 inch per century).

The mechanisms causing this increase in tidal range are not known, and it is not known whether the rate of increase will increase, decrease, or remain constant. This potential increase in tidal range is small compared to the general level of uncertainty in future sea level rise. Consequently, it does not seem necessary to account for the increase in tidal range in most planning activities.

Impacts/Considerations of Sea Level Rise on Phase 2 Study

The design life analyzed for this study was 50 years, i.e. out to the year 2060. Based on a non-linear interpolation of the 2050 and 2100 highest rate values in the table above, a projected sea level rise of 1.5 ft (18 inches) by 2060 was approximated. This means that the base flood elevation of +6.0 ft (NGVD29) today will become +7.5 ft by 2060 due to the sea level rise.

As discussed in Section 3.2.1, the lagoon would receive a full ocean tide range under all proposed alternatives. Therefore, the extreme high tide in the lagoon is projected to reach +7.5 ft (NGVD29) by 2060 (with sea level rise) with any of the proposed tidal connections between the lagoon and Marine Stadium. Under a joint event of a 50-year storm and extreme high tide, the predicted water level in the lagoon would reach +7.8 ft (NGVD29) with sea level rise. Although the post-phase-1 extreme high tide is slightly lower than that with the phase 2 alternatives (because the culvert mutes the high tide), the lagoon condition with the joint-event case is basically the same for post-phase-1 and post-phase 2. In other words, implementation of any of the phase 2 alternatives does not improve or worsen the flood scenario at Colorado Lagoon, with or without sea level rise.

In order to mitigate the flood risk in Marina Vista Park for the alternatives with open channels, an earthen berm would be constructed along the top of the banks of the channel where the existing elevation is below +8 ft (NGVD29). However, it should be noted that the adjacent Marine Stadium and Colorado Lagoon have perimeter areas below this elevation and thus would be still be at risk of flooding during extreme events.

3.2.4. Flow Velocities

Flow velocities for each alternative were analyzed to determine: a) suitable material for lining of open channel slopes, b) viability of proposed vegetation, e.g. eelgrass, c) stability of open channel planform, d) sedimentation potential, and e) human safety. Three types of velocities were determined for each alternative: 1) peak tide velocities under daily average tidal condition due to tidal exchange currents, 2) the peak tide velocities under bi-weekly spring tidal condition, and 3) the maximum velocities during a 50-year storm event and peak ebb tide. Table 3-6 below provides estimates, based on modeling results, of the flow velocities.

Table 3-6. Representative Velocities within Open Channel and/or Culverts

Modeling Scenario	Location	Peak Average Tide Velocity (fps)	Peak Spring Tide Velocity (fps)	Peak Storm Velocity (fps)
Post Phase 1 Condition - Cleaned Culvert and Dredged Lagoon	*Existing Culvert*	*1.8*	*3.8*	*4.3*
Alternative 1 - Parallel / Second Culvert	Existing Culvert	0.7	1.5	2.1
	New Culvert	0.9	1.6	2.3
Alternative 2 - Open Channel with Bridges	Culvert	1	2.2	2.8
	Colorado Bridge	0.7	1.3	1.8
	Channel Midway	0.6	1.2	1.9
	Eliot St. Bridge	0.9	1.7	2.4
Alternative 3 - Combination Open Channel and Two Culverts	Existing Culvert	0.5	1.0	1.8
	Colorado Culvert	0.7	1.5	2.0
	Channel Midway	0.7	1.8	2.0
	Eliot St. Culvert	0.8	1.6	2.2
Alternative 4 – Combination Open Channel (Max Wetland) and One Culvert	Colorado Culvert	0.9	1.7	2.5
	Channel Midway	0.5	0.9	1.3
	Eliot St. Bridge	0.9	1.6	2.3

These values provide a basis of design for all alternatives. For all alternatives and cases, the velocities are lower than for the existing/post-Phase 1 project culvert conditions.

3.2.5. Summary of Alternatives Comparisons Relative to Hydrodynamics

All alternatives provide nearly identical hydrodynamic performance, i.e. full tidal ranges within Colorado Lagoon, ocean-equivalent tidal inundation frequencies for the lagoon and open channel (for the alternatives with open channels), and similar flood levels. Although hydrodynamics is not a discriminator between alternatives, it does indicate that implementation of any of the Phase 2 alternatives would be an improvement over post-Phase 1 conditions.

3.3. Habitat Improvements

The Colorado Lagoon Phase 2 project represents an opportunity to restore the Colorado Lagoon and adjacent areas to similar habitat which once existed. This restoration would occur at the Colorado Lagoon (for all alternatives) and within the open channel (for Alternatives 2, 3 and 4). The Phase 1 project also provides an opportunity for mitigation credits to be established for projects elsewhere.

The following sections discuss the potential mitigation credit opportunities for the purpose of understanding the potential funding opportunities and for discussion with the agencies. Three specific opportunities exist: 1) the enhancement of existing resources within Colorado Lagoon through a functional improvement in habitat; 2) the restoration/creation of new habitat within Colorado Lagoon by an increased tide range; and 3) the restoration/creation of new habitat in the new open channel for Alternatives 2, 3 and 4. Both sites (Colorado Lagoon and the open channel) have benefits that may qualify for mitigation credits, assuming that the conditions established meet the criteria set forth in the mitigation policy and that regulatory agencies responsible for approving such mitigation are in agreement on the acceptability of the lagoon for mitigation.

3.3.1. Relevant Mitigation Credit Policy

Mitigation credits refer to the benefits that may accrue to a project sponsor or funder who is preserving, enhancing, or creating habitat types that are required or in demand to satisfy environmental and regulatory requirements set by federal and state agencies. In particular, wetland mitigation is an established practice that is embodied in federal and state policies and is used to off-set damages to the same or similar habitats elsewhere.

Recently, the Corps of Engineers and U.S. Environmental Protection Agency have issued a Final Rule on “Compensatory Mitigation for Losses of Aquatic Resources” (Federal Register Vol 72, No. 70 April 2008). This policy provides for a number of mechanisms to achieve “no net loss” of the function and value of wetlands and other aquatic habitats. As defined by the policy, compensatory mitigation “means the restoration (re-establishment or rehabilitation), establishment (creation), enhancement, and/or in certain circumstances preservation of aquatic resources for the purpose of offsetting unavoidable adverse impacts which remain after all appropriate and practicable avoidance and minimization has been achieved". The policy also encourages mitigation options which provide habitat prior to or concurrent with impacts.

Restoration actions are given preference by the policy and because the lagoon was part of a historic tidal area, actions to improve habitat in the lagoon can be considered as mitigation. While the lagoon currently qualifies as a wetland habitat by federal and state agencies, it functions have been diminished by the untreated stormwater flows and reduced tidal action. Actions taken to reduce these environmental stressors would result in a functional "lift" of the habitat quality and quantity in the lagoon. Quantification of this improvement can be made using functional assessment methodologies such as the Habitat Evaluation Procedure, the California Rapid Assessment Method (CRAM), or other procedures that may be relevant to estuarine habitats.

The federal mitigation policies require greater accountability on those parties who are seeking to use properties for mitigation purposes. Well-defined enhancement and restoration plans, long term management and maintenance, protection under conservation easements, and financial assurances are elements of an acceptable project that provides mitigation for adverse impacts elsewhere. In addition, acceptable mitigation sites are often in close proximity to or affect similar species and habitats as present at the impact site. Federal and state agencies must pre-approve both the mitigation site as well as the type of activities that can be mitigated using the site.

3.3.2. Habitat at Colorado Lagoon

Following completion of the Phase 1 project, (e.g. culvert cleaning and side slope recontouring), approximately 18.2 acres of aquatic habitat will exist at Colorado Lagoon. A summary of the habitat type acreages is provided in Table 3-7.

Table 3-7. Habitat Enhanced at Colorado Lagoon as a Result of Phase 1 and/or Phase 2 Improvements

Habitat Type	Acres per Habitat Type	Total Enhanced Aquatic Habitat (Acres)
Tidal Vegetated Wetland	4.3	
Intertidal Mudflat	2.2	18.2
Subtidal / Eelgrass Habitat	11.7	

Both the Phase 1 and Phase 2 actions would result in habitat enhancement (functional lift) over the entire 18.2 acres of tidal habitat at the lagoon. The Phase 1 improvements would remove contaminated sediments, improve water quality, and propagate native wetlands vegetation. All of the proposed Phase 2 alternatives, as discussed in Section 3.2.2, would improve the lagoon by: (a) increasing the tidal range within the lagoon, and (b) increasing the tidal circulation and exchange in the lagoon. These tidal hydraulic changes could result in subsequent changes in habitat distribution and quality in the lagoon itself in a number of ways, e.g.:

- Additional vegetated wetland habitat and intertidal mudflat would become established within the lagoon under any of the Phase 2 alternatives due to the increased tidal range. The extent of vegetated tidal wetlands is likely to increase in certain areas, especially in the arms of the lagoon where beach areas are not present. The increase in habitat is dependent upon the slopes of the areas where tidal vegetation can become established and the condition of those slopes. It is expected that the high marsh habitat would be able to extend up approximately 0.5 feet higher on the shoreline, (related acreage amounts discussed in next paragraph).

- It is estimated that approximately 1.6 acres of additional intertidal habitat and 0.2 acres of tidal marsh habitat would be created, whereas subtidal habitat would be reduced by approximately 1.3 acres. This gives a net increase of 0.5 acres of additional tidally-influenced habitat. The decrease in subtidal habitat is due entirely to the increased tide range resulting in greater mudflat areas at low tide, which is probably more akin to the historic condition of the lagoon, and would likely lead to improved foraging habitat for fish as the mudflats would likely support more benthic invertebrates. A portion of the intertidal area, estimated as approximately 15%, is maintained beach and therefore the total new habitat created at the lagoon would be approximately 0.42 acres. These numbers provide a good approximation of new habitat acreage potential, but it should be noted that these numbers could change upon final design of Phase 1, (specifically the dredging and side slope recontouring plans).

- Another potential benefit is the possibility that Pacific cordgrass, *Spartina foliosa,* may become established as a low marsh habitat in areas that are not maintained for beach uses[2]. Cordgrass does not establish and spread well in muted tidal regimes so the increase in tidal range may create suitable conditions for its establishment. It would need to be planted in

[2] Under the Phase 1 plan, the north beach area will be allowed to revert to natural habitat types and the south beach maintained area will be restricted to the area between the pedestrian bridge and the buoy line. The remainder of the south beach area will also be allowed to revert to native habitat types.

order for it to establish and pilot plantings in conjunction with the planting in the open channel area would be the most effective way to establish this species in the lagoon. Following implementation of the Phase 2 project, Colorado Lagoon would have approximately 1.4 acres of low marsh area (potential cordgrass area).

- Additional tidal flushing may also improve water quality within the lagoon, reducing algal growth (both phytoplankton as well as benthic algae), and thereby providing more suitable habitat for eelgrass colonization. Eelgrass is currently absent from the lagoon due to algal matting along the bottom, salinities which are slightly lower than optimal, and poor water clarity. Tidal flushing would increase water exchange and bottom currents and, coupled with the storm water quality improvements in Phase 1, may result in more suitable conditions for eelgrass colonization. Following implementation of the Phase 2 project, Colorado Lagoon would have approximately 11.7 acres of subtidal area (potential eelgrass area).

- Fish and avian habitat is also likely to improve in diversity and abundance with the improved tidal flushing. Fish which may not be able to currently pass through the long culvert would benefit from the open channel design and would be able to move freely in and out of the lagoon. It is possible that juvenile halibut could utilize the lagoon to a greater extent. Fish and invertebrates may currently be limited by either reduced salinities in the winter or by algal mats in the summer. Open channels convey the entire water column that benefits fish and larvae. Culverts convey a smaller portion of the water column and limit transmission of species between the lagoon and Marine Stadium.

- Special status species may also benefit if suitable management actions are taken after restoration of the open channel. With the potential for improved water quality and greater vegetated habitat, it is possible there would be some limited benefits to special status bird species. Least terns may be able to forage more frequently within the lagoon on smaller bait fish, and Belding's savannah sparrows may be able to utilize an expanded marsh habitat. These opportunities, however, would be constrained by the ongoing human uses of the lagoon and the presence of human associated predators, e.g. cats, raccoons, etc. In addition, continued control of invasive weeds would also need to be undertaken to allow for natural habitat establishment along the fringes of the lagoon.

The actual mitigation credit amount for the Colorado Lagoon enhancement is dependent upon a functional analysis. But, if this was on the order of a 10 - 30% improvement in habitat, then Phase 1 and/or Phase 2 actions could possibly result in a 1.8 to 5.5 acre mitigation credit.

In order to further determine the benefit or "credits" that may be accrued from these habitat enhancements, a quantitative analysis of the before condition using existing data compared to expected future conditions following the Phase 2 (and Phase 1) improvements could be completed. Another approach is to use existing data to establish the current baseline condition and then assess the lagoon after the Phase 1 and Phase 2 projects are completed, determine the improved condition, if any, and then determine credits based on those improved conditions. A methodology such as the Habitat Evaluation Procedure (HEP) or the California Rapid Assessment Methodology (CRAM, augmented with HEP) may be used for such an approach; however, the methodology to be used will need to be set forth by the agencies that will approve the use of these enhancement credits.

3.3.3. Habitat within the Open Channel

Within the open channel, a number of habitat types are possible based on the frequency of inundation by tides. While there are limited areas of natural tidal wetlands nearby, the project team investigated the occurrence and elevational ranges of typical habitats. The elevation data in Table 3-8 below were determined from reference sites located at Los Cerritos Lagoon, detailed tidal inundation studies at San Dieguito Lagoon, and from eelgrass distributions in Marine Stadium and Lower Newport Bay.

Table 3-8. Predicted Elevation for Various Habitat Types (Feet, Relative to NGVD29)

Habitat Type	Low	High	Percent Time Exposed
Transition Zone (salt grass, uplands)	3.9	4.5	>99%
High Marsh (pickleweed, jaumea)	2.8	3.9	96-99%
Mid Marsh (pickleweed)	1.6	2.8	82-96%
Low Marsh (cordgrass)	0.7	1.6	65-82%
Intertidal	-4.0	0.7	0-65%
Subtidal	-30.0	-4.0	0%
Eelgrass	-10.0	-3.5	0%

Tidal inundation frequency curves developed by Moffatt and Nichol were then used to predict ranges where plant communities would be found. These estimates for the range of various habitat types were developed by Dr. Michael Josselyn at WRA, Inc. The specific elevations where plants may occur would depend upon actual tidal ranges that occur after the project is constructed and may vary based on currents, water salinity, soil conditions, algal growth, and water clarity (esp. for

eelgrass). Tidal vegetated wetlands consist of the high, mid, and low marsh; intertidal mudflats occur within the range between low marsh and subtidal; and eelgrass can be found in nearby areas up to a depth of 10 feet below NGVD29, but is generally between -3.5 and -6.0 ft (NGVD29). The graphics in Appendix B show the habitat distribution, based on these tidal zones, for each of the alternatives, in both plan view and cross-section.

Assuming that the created habitats meet the performance criteria that are set forth in the final Habitat Monitoring and Management Plan (HMMP) approved by the agencies, the determination of credits is usually based on the number of acres of habitat that are created from non-habitat upland areas. Each of the open channel alternatives has been designed in sufficient detail to calculate acreage of the habitat types created. All of the habitats below the High Tide Line are considered to be wetlands under the Clean Water Act as well as the California Coastal Act and could therefore be utilized for mitigation on projects requiring permits from federal and state agencies. Table 3-9 provides a summary of the mitigation credits that may be available for each alternative, based on the conceptual designs.

Table 3-9. Habitats Created Within Each of the Open Channel Alternatives

Alternative	Habitat Type	Acres per Habitat Type	Total Created Aquatic Habitat (Acres)
2	Tidal Vegetated Wetland	0.54	1.98
	Intertidal Mudflat	0.45	
	Subtidal - Eelgrass Habitat	0.92	
	Subtidal – Rocky Habitat	0.07	
3	Tidal Vegetated Wetland	0.53	1.47
	Intertidal Mudflat	0.32	
	Subtidal - Eelgrass Habitat	0.59	
	Subtidal - Rocky Habitat	0.03	
4	Tidal Vegetated Wetland	0.72	2.21
	Intertidal Mudflat	0.52	
	Subtidal - Eelgrass Habitat	0.96	
	Subtidal - Rocky Habitat	0.01	

A habitat mapping was not done for Alternative 4a, but using the numbers above, it is assumed that approximately 2.4 acres of new habitat could be created with Alternative 4a.

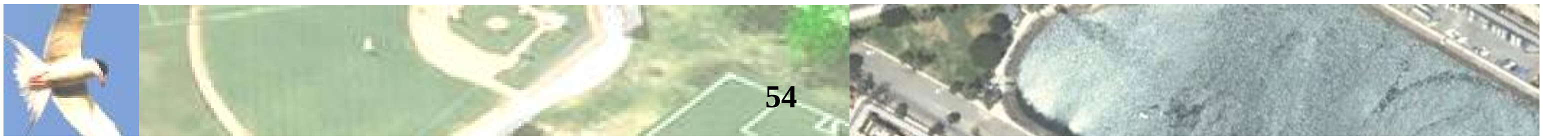
These numbers provide a good approximation of new habitat acreage potential with the open channel alternatives, but it should be noted that these numbers could change upon more detailed engineering of the Phase 2 open channel designs.

The open channel habitat types created would have a number of benefits for species found within the vicinity of the project as described below:

- Tidal Vegetated Wetland: This habitat type is lacking within the vicinity as the areas suitable for tidal vegetation surrounding Marine Stadium are largely rip-rapped and the Colorado Lagoon has been highly maintained for beach use and grassed areas for open space. The nearest area of significant tidal vegetation is the Los Cerritos wetlands. These wetlands were used as a reference site for the type of vegetation that could become established within the open channel area. It is expected that some pioneering species such as pickleweed would readily colonize over time; however, other species such as Pacific cordgrass would need to be planted in the low marsh. Both species are the dominants in this community; however, other species such as marsh jaumea, alkali heath, saltgrass, and shoregrass would be planted or may colonize this habitat.

  Given the relatively small size of the habitat area and the few areas of similar habitat nearby, the tidal wetland area is not likely to be significant in terms of support for sensitive bird species such as Belding's savannah sparrow or light footed clapper rail. However, it would provide valuable habitat for benthic invertebrates and smaller fish may forage in the tidal marsh areas during high tides. Egrets and herons are likely to utilize this area for foraging and cover especially during higher tides. When inundated, waterfowl may also forage within the vegetation for smaller invertebrates and insects. The greatest value of the tidal vegetated wetland at this location would be in shoreline stabilization, nutrient removal, and the potential to provide seed sources for other areas adjacent to the channel such as the Colorado Lagoon which may support greater tidal vegetation following improvement in tidal range and flushing.

- Intertidal mudflat: This habitat type is most important to colonization by benthic invertebrates and foraging by shorebirds. Benthic invertebrates consist of those species which burrow into the mud such as worms and mollusks as well as more mobile species such as crustaceans and epibenthic mollusk species. The increased tidal flow through this



channel would result in an abundance of filter feeders (e.g. invertebrates that feed on particles suspended in the water column) which should increase the diversity and density of species in the mudflat. During high tides when it is inundated, demersal fish would have access to the mudflat for foraging and this may attract fish eating birds such as herons and egrets. At low tide, shorebirds are likely to forage throughout the mudflat area. The mudflat also supports benthic algae; some of which would be exported to Marine Stadium during ebb flows and can support filter feeders within that area.

For those portions of the non-vegetated intertidal where hard surfaces are present (i.e. rip-rap and culvert bottoms and sides), attached invertebrates such as mussels and barnacles are likely to become established. These species are also filter feeders and provide valuable functions in removing algae from the water column; thereby improving water clarity.

- Eelgrass habitat: This habitat is important for a variety of fish species—both as habitat for escape from predators and breeding and as a potential foraging area. It is likely that eelgrass would colonize the open channel eventually given the nearby populations in Marine Stadium and the likely suitable conditions (low turbidity and good tidal flushing) within the channel; however, transplanting may be required to initiate establishment. The most likely distribution would be a series of eelgrass patches with open areas in-between—such habitats have been found to be very beneficial to epibenthic crustaceans such as crab and shrimp which in term attract fish species. Smaller juvenile fish would find shelter within the eelgrass blades as well as potential prey items.

  While eelgrass beds are less likely to provide as extensive a foraging base as mudflats, a number of larger shorebirds such as blue herons and snowy egrets may forage in these areas during low tide and terns would forage over them during high tides when fish may leave the eelgrass beds to search for food in the intertidal areas.

Overall, the channel habitat coupled with the Phase 1 improvements would re-establish a more natural and native plant and animal community in this area. While it is important not to overstate the benefits of this relatively small area to Marine Stadium and Alamitos Bay, it is equally important that the benefits be considered in light of the trajectory of change anticipated for these larger habitats. It is hoped that success here will continue to stimulate actions that will expand and improve tidal habitats elsewhere, including Los Cerritos wetlands, and to reduce the amount of hardscape within the estuary as a whole.

3.3.4. Habitat within the Alternative 1 Culvert

Alternative 1 would increase tidal circulation but would not create the open water habitat that would provide the type of habitat mitigation credits described above. There is a potential for greater surface area for colonization by mussels and barnacles on the culvert walls and bottom. While these species have been implicated in reducing tidal flows within the existing culvert, it is expected that the addition of another culvert (lower flow velocities) would reduce this problem.

Mussels and barnacles filter the water; removing algae and other particulates. This feeding mode can also lead to bio-accumulation of contaminants, as has been observed within Colorado Lagoon, as reported by Kinnetic Laboratory (2004). While these species (mussels and barnacles) are not harvested by the public for food, they can be consumed by epibenthic invertebrates and eventually fish and thereby increase bioavailability of some contaminants. It is assumed that the Phase 1 project would reduce contamination within Colorado Lagoon such that this issue is minimized. Mussels and barnacles produce abundant meroplankton (juvenile free-swimming stages) when they reproduce which can be a food source to plankton and small fish.

3.3.5. Fish Passage through Culverts (for Alternatives 1, 3 and 4)

Another consideration in regards to habitat improvement is fish passage through the culvert segments, both for the longer Alternative 1 culvert (approximately 880 feet long), as well as the shorter culverts in Alternatives 3 and 4 (up to 180 feet long). Potential impedances to fish passage were investigated based on culvert flow velocities, shading, and other considerations.

Flow Velocities

Primary considerations for fish passage through culverts focuses on the velocities and the length of the culvert. As velocity and length increase, the ability of fish to pass through those culverts decreases. Of course, variability in individual species swimming modes, swim rates, and their size affect their ability to move through culverts.

As shown in Table 3-6 above, <u>average</u> tidal velocities within the culverts of the proposed alternatives range from 0.5 to 0.9 feet per second (fps) and <u>maximum tidal</u> velocities are up to 2.2 fps (approximately half of the existing culvert's maximum tidal velocity).

Warren and Pardew (1998) conclude that maximum water velocities of 1 to 1.3 fps for a 100-m-length culvert would allow passage of most mature migratory fish species. They also suggest that problematic water flow velocities in culverts for non-migratory small stream fishes are likely to be lower than those suggested for migratory fish species. It is assumed that this recommendation would hold true for non-migratory estuarine fish species as well.

Fish species known to inhabit Colorado Lagoon include: Topsmelt (Atherinops affinis), Jacksmelt (Atherinops californiensis), Arrow Goby (Clevelandia ios), Longjaw Mudsucker (Gillicthhys mirabilis), Pacific Staghorn Sculpin (Leptocottus armatus), Diamond Turbot (Hypsopetta guttulata), California Halibut (Paralichthys californicus), Striped Mullet (Mugil cephalus), Round Sting Rays (Urobatis halleri) and Grey Smoothhounds (Mustelus californicus). These species are relatively common species in the region; however, little swim speed and passage data is available for these estuarine species. Swim data for those fish species known to occur in Colorado Lagoon (or analogous species) is presented in Table 3-10 below.

Table 3-10. Swim Data of Fish Species Known to Occur in Colorado Lagoon

Species Known to Occur in Colorado Lagoon (or analogous species)	Prolonged Swim Speed	Burst Speed	Time to Exhaustion at Prolonged Swim Speed
Topsmelt, Jacksmelt (Delta Smelt)	1 fps	X	10 minutes
Surfperch	X	5.7 to 8.2 fps	X
Pacific Staghorn Sculpin	X	8.2 to 9.8 fps	X
Striped Mullet (juvenile)	1.1 to 2.7 fps	1.7 to 4.2 fps	30 seconds

The swim speeds listed above are only a fraction of the potential fish assemblage in Colorado Lagoon; however, they do provide a general snapshot of the potential swim speeds in relation to the potential water velocities associated with each alternative. The swim speeds listed above appear to be adequate to compensate for the short term maximum water velocities calculated for each of the four alternatives. In addition, the difference in water velocity between Alternative 2 (open channel) at 2.2 fps and Alternative 4 (with culverts) at 1.7 fps appears to be negligible.

Shading

In addition to changes in flow dynamics, culverts may also modify light regimes. As culvert size decreases or its length increases, the light levels within the culvert would also decrease. Light levels would influence a variety of ecological conditions within the culvert including reduction in submerged vegetation and algae, changes in benthic communities, and behavioral changes in foraging, breeding, and movement of animals. In addition, culverts are considered an impediment to movement of mobile species such as fish.

While flow and culvert configuration are most often the focus in designing “fish friendly” passage; consideration of shading as it affects fish behavior is also an issue. Most fish depend upon vision for feeding and schooling behaviors.

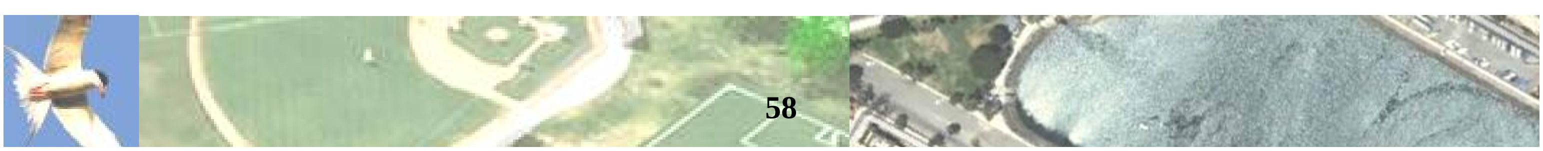
Nightengale and Simenstad (2001) found that several species of salmon had optimal ranges for schooling and feeding behaviors within a range of light conditions equivalent to a “clear new moon” night to a “cloudy” day.   Thus, foraging efficiency could be disrupted when passing through a culvert. On the other hand, the darkness of the culvert would protect species from being preyed upon by larger fish.   It would be expected that passage through a culvert would be fairly rapid so that lower light conditions might not have a significant effect on the energy budget for a species based solely on loss of foraging time.

Few studies have actually looked at the effect of shading on fish behavior when approaching a culvert.   Pearson et al. (2005) used a test bed that allowed them to adjust light levels in a culvert system. They found that most juvenile salmon passed through culverts during the night time and there was no difference whether the culvert was shaded or not. There was a decrease in successful passage during daylight hours for culverts that were shaded; however, this effect was not statistically significant due to the fewer fish using the culvert in the day. For most larval forms, it is likely that the lower light levels in the culvert would not significantly affect their behavior and that they would simply pass through with the water flow.

Dark culverts may present some advantages in providing escape from visual predators.   In addition, species that are active at night may not be affected by the culvert darkness as was shown by Pearson et al (ibid).   However, larger species that actively forage during the day may have reduced opportunities when moving through culverts.

For the Colorado Lagoon Phase 2 project, the longer the culvert the more likely to be the affect of shading.   For the longest culvert alternative, species may avoid entering the culvert if there is limited light as their opportunity for foraging would be reduced, and for species that have schooling behaviors, they may not be able to maintain their school.   For those alternatives with large and relatively short culverts, the ability of light to enter either end of the culvert will reduce the lowering of ambient light levels. While light levels are lower, they may still be within the natural range of the species visual acuity.

The Anaheim Bay Mitigation Project, constructed by the Port of Long Beach in 1990 involved the use of culverts to provide tidal flows to three of the four constructed tidal wetlands.   This project provides a good example to the Colorado Lagoon project and what might be expected in terms of fish abundance after tidal flows are improved.   A five year monitoring program was completed by



MEC Analytical (1995) that documented fish use within the mitigation areas compared to a reference site without culvert restrictions. Current meters within the culverts of the mitigation sites recorded mean velocities of 0.4 to 1.5 ft/sec with peak flows of 2.7 to 5.9 ft/sec. These mean velocities are similar to or slightly higher than those expected under the various Colorado Lagoon alternatives. The fish abundance and species richness data for the five sites studied were based on sampling using beach seines, beam trawls, enclosures, and gillnets. Fish use of the mitigation areas was rapidly achieved after the tidal flow was introduced through the culverts though there was some trend over time for increased use by pelagic fish such as anchovies, queenfish, sargo, shiner surfperch, spotted sand bass, and white croaker. All the mitigation sites had somewhat higher mean abundances of fish compared to the reference site; however, there was no significant difference at the end of the five year monitoring period. A total of 50 taxa were collected. The mitigation sites exhibited a significantly higher species richness than the reference site with the highest abundance consisting of juvenile Gobiidae, arrow goby, juvenile Engraulidae, and topsmelt. Interestingly, there was also a higher abundance of pelagic species in the mitigation sites than the reference site, perhaps due to the deeper water habitat created by dredging within the mitigation sites.

Fish Passage Summary / Conclusion

The size of the box culvert is also an advantage to fish moving through this channel. The large size and the likelihood of the sides and bottom to be colonized by attached aquatic organisms would result in a variation in flow over the culvert cross-section. This would allow for some smaller fish to avoid areas with higher velocities.

A criticism of narrow culverts is that they direct fish to locations where predators may wait for fish to pass through. Either birds or predatory fish may sometimes wait at culvert openings to snag fish. The proposed Phase 2 culverts are wide and should not provide a “pin point” location that would be targeted by predators. Also, the depth of the culvert would allow most fish to escape fish-eating wading birds. The type of bottom within the culvert also affects passage; those culverts that have natural bottoms and baffles that allow for fish to find refuge while passing through are more successful in promoting fish migration. The Phase 2 culverts would likely be concrete boxes.

In general, the data support the conclusion that culverts that are properly designed to minimize velocities do not appear to hinder fish colonization of tidally influenced basins. While it is possible that culvert length and darkness may have an effect on fish survival or rates of passage, this phenomenon does not result in any diminishment of abundance or diversity within the connected areas, e.g. the Colorado Lagoon.

3.4. Other Considerations

This section is not intended to cover environmental impacts as addressed by CEQA, but simply to acknowledge general impacts and other considerations for each of the alternatives.

3.4.1. Marina Vista Park Usage

The three alternatives with open channels (Alternatives 2, 3, and 4) would permanently impact Marina Vista Park. The total area of Marina Vista Park (not including the grass area south of Eliot Street) is 17.8 acres. (This area is outlined in light green in Figure 1-2). The Marina Vista Park footprints of each of the Phase 2 alternatives (including the trail and shrub buffer areas along the top of the channel banks) are shown in Table 3-11 below.

Table 3-11. Open Channel Footprints on Marina Vista Park

	Open Channel Footprint Within MV Park (including trail and shrub buffer areas), Acres	Percent of Total MV Park Site Occupied by Open Channel Footprint
Alternative 2	2.3	13%
Alternative 3	2.2	12%
Alternative 4	2.7	15%

The Marina Vista Park area impacted by the open channel alternatives is existing grassy open space, generally used for a variety of active and passive recreational activities (e.g. baseball, soccer, volleyball, flag football, cricket, picnicking, kite-flying, etc.). The sports activities would need to be relocated to other areas of Marina Vista Park for Alternatives 2, 3 and 4. Potential new locations of the youth and adult soccer fields and the youth baseball/adult softball field are shown in Figures 2-2, 2-3, and 2-4 and in the plan view drawings provided in Appendix A. The area on the east side of Marina Vista Park, east of the tennis courts, is a potential area to provide an additional youth soccer field.

The open channel alternatives would provide passive recreational opportunities, e.g. walking, nature-watching, as well as educational opportunities for local schools. Although not included in the construction costs, educational signage and/or benches could be installed along the perimeter trail. Many examples of tidal channels being adjacent to sports fields and recreational parks can be found in the San Francisco Bay area. Photographs of these sites are shown in Figure 3-8.

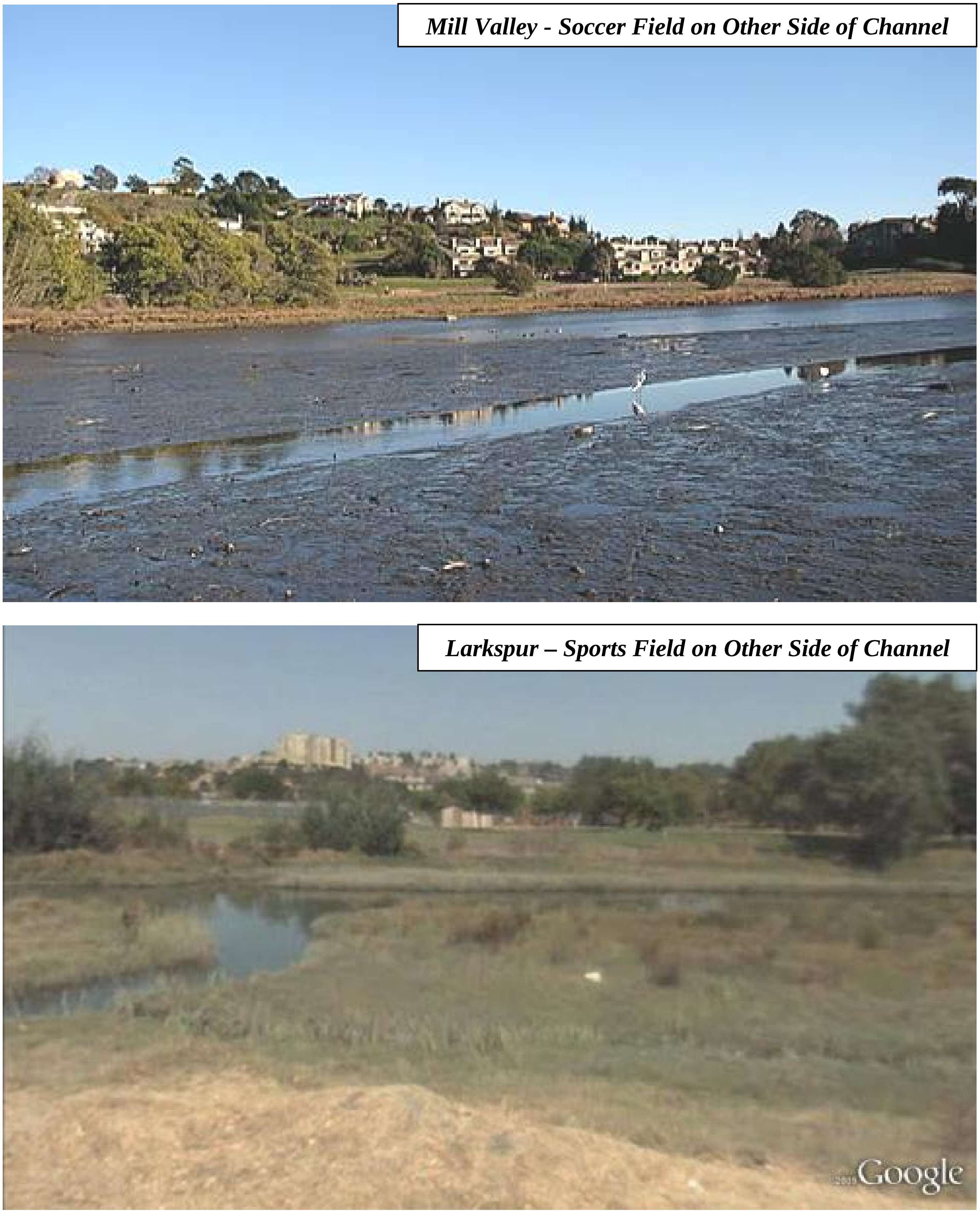


Figure 3-8. Examples of Tidal Channels Alongside Recreational Parks (San Fran Bay area)

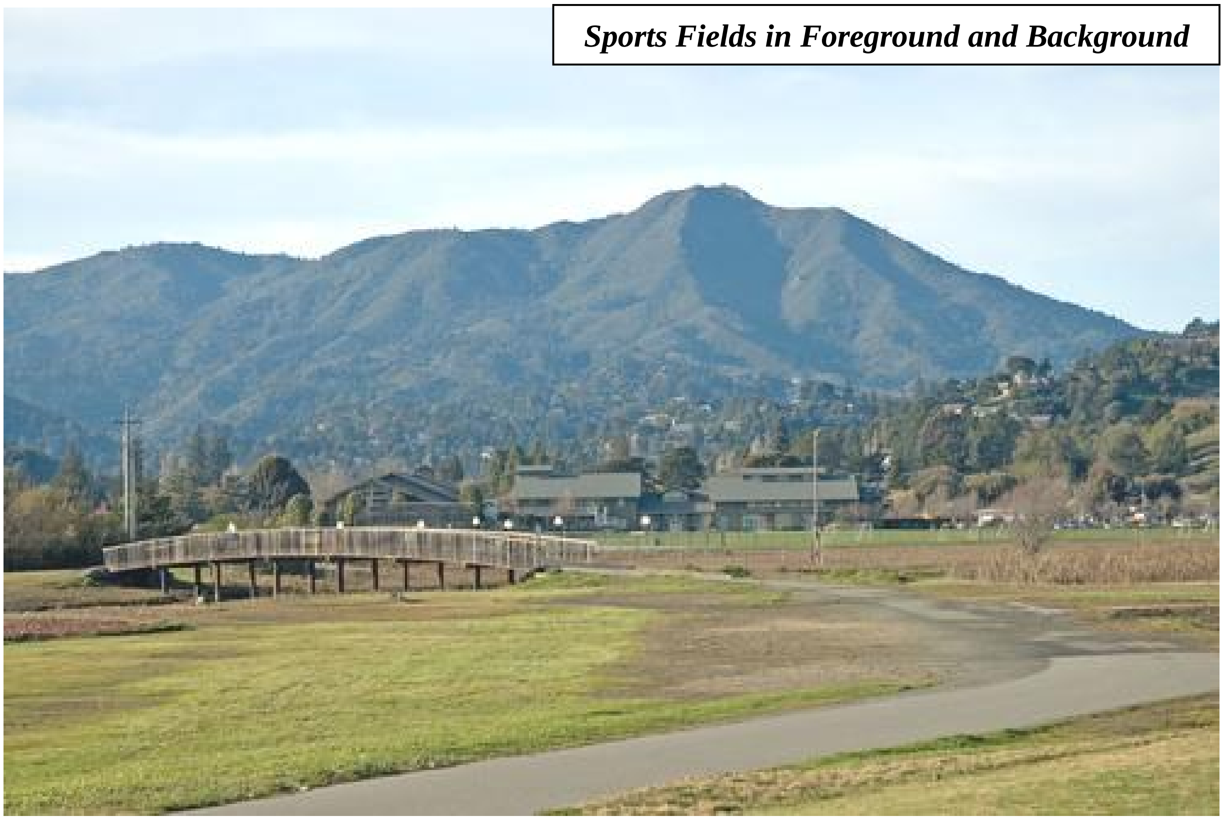


Figure 3-8 (continued). Examples of Tidal Channels Alongside Recreational Parks (San Fran Bay area)

3.4.2. Human Safety

During previous public meetings, concerns were raised regarding the potential for people, in particular young children, to fall into the open channel. This aspect could be considered to be a downside of the open channel alternatives (Alternatives 2, 3 and 4), i.e. Alternative 1 would be a lower risk. In this regards, the following information is provided:

- Water depth in channel during high tides (Mean Higher High Water): ~10 feet;
- Water depth in channel during low tides (Mean Lower Low Water): ~5 feet;
- Peak average tidal velocities: 0.9 feet per second (fps);
    - With a 1,160 foot long channel, this would mean it would take an object approximately 21 minutes to float the length of the channel.
- Maximum (peak Spring) tidal velocities (in narrower sections under bridges): 1.8 feet per second (fps):
    - With a 1,160 foot long channel, this would mean it would take an object approximately 11 minutes to float the length of the channel.
- Maximum/peak storm velocities: 2.4 fps (for Alternative 2):
    - With a 1,160 foot long channel, this would mean it would take an object approximately 8 minutes to float the length of the channel.
- For comparison, the maximum/peak storm velocities <u>for the existing culvert</u> is 4.3 fps:
    - With the 880 foot long culvert, this would mean it would take an object approximately 3 minutes to float the length of the culvert.

Although other water bodies in the adjacent areas do not have perimeter fences, a natural-looking fence could be installed along the top of the east bank of the open channel (side where sporting activities occur) and potentially along the west bank to mitigate the risk for the three alternatives which include open channels. In addition, low shrubbery would be installed along both sides of the lagoon to provide a further buffer between the grassy park area and the open channel.

3.4.3. Construction Impacts

During construction of any of the alternatives, construction equipment would temporarily impact noise, air quality, traffic and parking. Construction of any of the alternatives would require closure of the western half of Marina Vista Park (west of the tennis courts) and the small grassy area to the south of Eliot Street. Thus, there would be an impact to the recreational usage of the park during the construction period. For Alternatives 2 and 4, the existing culvert would need to be closed during part of the construction period when the south end of the open channel is constructed. During this time, no tidal exchange with the lagoon would occur and thus water quality would likely be temporarily degraded and swimming in the lagoon would not be allowed.

For construction of Alternative 2, road closures would be required on both Eliot Street and Colorado Street, although not simultaneously, for construction of the bridges. For construction of Alternative 4, road closure would be required on only Eliot Street for construction of the bridge. For all alternatives, some temporary road or lane closures may be required, but for shorter periods than that required for bridge construction.

3.4.4. Project Funding

A consideration for selection of an alternative is the potential for grant (or other) funding for the various types of alternatives. This grant funding would likely come from federal or state agencies. The various agencies have different criteria for their various grants. A summary of potential grant funding sources and any known information about the grant (e.g. funding amount, local agency matching requirements, criteria) is provided in Table 3-12.

The last two columns of the table provide an assessment of the potential applicability of each grant to either the parallel underground culvert alternative (Alternative 1) or the alternatives involving an open channel (Alternatives 2, 3, and 4). Although the underground culvert alternative, (as well as the open channel alternatives), expands and improves habitat in Colorado Lagoon, some grants would be more likely to fund the restored tidal connection and creation of new habitat associated with the open channel. Thus, the wetlands restoration related grants are considered to be of low likelihood for Alternative 1. However, grants related to water quality improvements would be applicable to Alternative 1, as well as the open channel alternatives.

Table 3-12. Potential Funding Sources

Source	Agency	Approx Annual Funding Total	Matching Reqt	Eligible Applicant	Project Element / Criteria	Potential to Obtain Funding for: Open Channel Alts	Potential to Obtain Funding for: Parallel Culvert Alt
FEDERAL FUNDING							
National Coastal Wetlands Conservation Grant Program 2011	U.S. Fish & Wildlife Service	$16 million total - awards typically range from $200,000 to a max of $1 million.	25%	Governor designated State agency/cies, generally a State natural resource or fish and wildlife agency.	Restoring wetland hydrology by plugging drainage ditches, installing water control structures or re-establishing historic connections with waterways.	Good	Poor
Wetland Program Development Grant	U.S. EPA, Region 9	$1,975,300 - awards likely range from $50,000 to $350,000	no	States, tribes, local government agencies, interstate agencies.	Build or refine state/tribal/local government wetland programs	Good	Poor
Wetlands Reserve Enhancement Program (voluntary conservation program of the Natural Resources Conservation Service)	U.S. Dept of Agriculture			For 2011, there is a set list of 41 watersheds in 12 key states eligible for monies - CA is not one of them but check for future listings.		Fair	Poor
Federal Clean Water Act Section 319 Nonpoint Source Grant Program	State Water Resources Control Board	$3.5 million total - minimum $250,000; max $1milllion	25% of total project cost		Implementation projects - actions to restore impaired surface waters by controlling NPS pollution and achieve quantifiable water quality load reductions identified in TMDLs	Good	Good
Nationwide and Regional funding opportunities for fisheries and ocean related projects	National Oceanic and Atmospheric Association (NOAA)					Good	Poor
Coastal Impact Assistance Program	Dept of the Interior	LA County (a CPS) has been allocated $300,000 for FY 2010	TBD	Allocations made to an oil or gas producing State or coastal political subdivision (CPS)	Authorizes funds to be distributed to Outer Continental Shelf (OCS) oil and gas producing states to mitigate the impacts of OCS oil and gas activities. Projects and activities for the conservation, protection, or restoration of coastal areas, including wetlands, are eligible.	Good	Poor

Source	Agency	Approx Annual Funding Total	Matching Reqt	Eligible Applicant	Project Element / Criteria	Potential to Obtain Funding for:	
						Open Channel Alts	Parallel Culvert Alt
STATE FUNDING							
Clean Water State Revolving Fund. These are low interest loans and not grants.	State Water Resources Control Board			1. Publicly owned wastewater treatment facilities, 2. Nonpoint source projects (publicly or privately owned), 3. Estuary management projects (publicly or privately owned) - wetlands projects typically fall under approved state nonpoint source management plans or are included in national estuary management plans.		Good	Good
Competitive Grants	Ocean Protection Council					Fair	Poor
Unsolicited proposals	Ocean Protection Council				Proposals must be consistent with the OPC program priorities: governance, research and monitoring, ocean and coastal water quality, physical processes and habitat structure, ocean and coastal ecosystems, and education and outreach. More info at http://www.opc.ca.gov/webmaster/ftp/pdf/docs/opc_program_priorities_2008_2010.pdf	Fair	Poor
OTHER							
Compensatory Mitigation	Companies/ agencies seeking to fulfill mitigation obligations					Good	Poor

3.5. Construction Costs

Preliminary construction cost estimates, based on conceptual designs for each of the alternatives, including alternative 4a, are provided in Table 3-13. The construction costs include mobilization/demobilization of construction equipment, excavation, installation of culverts, construction of bridges, relocation of utilities, construction of new restrooms, landscaping, relocation of sports fields (as applicable to each alternative) and construction management.

In summary, the preliminary estimated construction costs for each alternative are:

- Alternative 1 - Second/Parallel Underground Culvert: $6.8M
- Alternative 2 - Open Channel with Bridges: $9.0M
- Alternative 3 - Combination Open Channel and Culverts: $5.8M
- Alternative 4 - Combination Open Channel (Max Wetlands) and One Culvert: $7.3M
- Alternative 4a - Combination Open Channel (Max Wetlands) and Two Bridges: $9.4M

Table 3-13 provides a breakout of these costs by the major elements of each alternative.

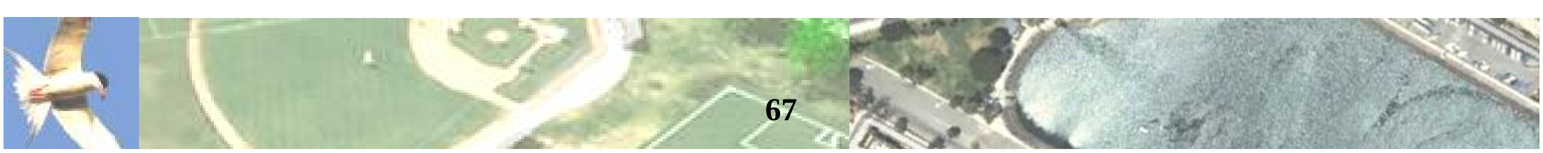


Table 3-13. Construction Cost Estimates for Phase 2 Alternatives

Alternative 1 - Second/Parallel Underground Culvert				
	Mobilization	$K	425	
	Install New Culvert	$K	3,750	
	Relocate Utilities	$K	63	
	Replace Grass	$K	322	
	Construct New Restrooms (2)	$K	953	
	Other Work	$K	155	
	Construction Management and Contractor Markup	$K	1,133	
	Total	**$K**		**6,800**
Alternative 2 - Open Channel with Bridges				
	Mobilization	$K	675	
	Construct Channel	$K	2,103	
	Construct Bridges (2)	$K	2,496	
	Relocate Utilities	$K	688	
	Channel Landscaping and Sports Fields Reconfiguration	$K	313	
	Construct New Restrooms (2)	$K	953	
	Other Work	$K	276	
	Construction Management and Contractor Markup	$K	1,501	
	Total	**$K**		**9,004**
Alternative 3 - Combination Open Channel and Culverts				
	Mobilization	$K	363	
	Construct Channel	$K	1,135	
	Construct Culverts (2)	$K	1,831	
	Relocate Utilities	$K	63	
	Channel Landscaping and Sports Fields Reconfiguration	$K	276	
	Construct New Restroom (2)	$K	953	
	Other Work	$K	195	
	Construction Management and Contractor Markup	$K	963	
	Total	**$K**		**5,778**

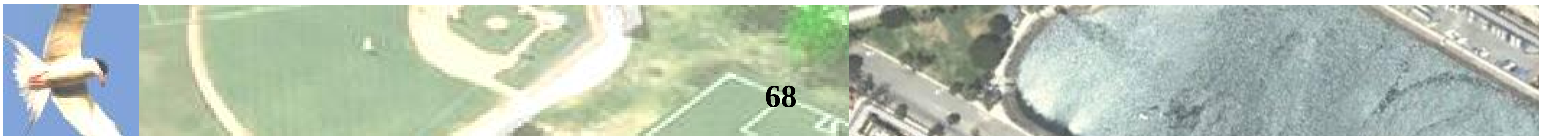


Table 3-13 (continued). Construction Cost Estimates for Phase 2 Alternatives

Alternative 4 - Combination Open Channel (Max Wetlands) and One Culvert				
	Mobilization	$K	519	
	Construct Channel	$K	1,729	
	Construct Culvert (1)	$K	817	
	Construct Bridge (1)	$K	1,240	
	Relocate Utilities	$K	63	
	Channel Landscaping and Sports Fields Reconfiguration	$K	302	
	Construct New Restrooms (2)	$K	953	
	Remove Existing Culvert	$K	341	
	Other Work	$K	144	
	Construction Management and Contractor Markup	$K	1,221	
	Total	**$K**		**7,329**
Alternative 4a - Combination Open Channel (Max Wetlands) and Two Bridges				
	Mobilization	$K	695	
	Construct Channel	$K	2,211	
	Construct Bridges (2)	$K	2,496	
	Relocate Utilities	$K	688	
	Channel Landscaping and Sports Fields Reconfiguration	$K	312	
	Construct New Restrooms (2)	$K	953	
	Remove Existing Culvert	$K	341	
	Other Work	$K	144	
	Construction Management and Contractor Markup	$K	1,568	
	Total	**$K**		**9,408**

It should be noted that these are estimates of construction costs based on conceptual designs. Although a design contingency factor has been included in the numbers above, these costs may change upon development of final engineering plans. It should also be noted that these costs do not include engineering design, permitting, or environmental documents.

3.6. Maintenance / Monitoring Considerations and Costs

Each of the alternatives has various types of required maintenance and monitoring. The activities are primarily associated with the maintenance of the open channel segments, the culverts, and the bridges, as well as post-construction monitoring required by regulatory agencies. These potential maintenance and monitoring activities and a preliminary estimate of the associated long-term costs are discussed herein.

3.6.1. Open Channel Segments (Alternatives 2, 3, 4 and 4a)

The Phase 2 open channel segments would not have significant ongoing maintenance costs once the plant communities are established. Initial costs would be necessary to cover weed removal, especially in the higher portions of the channel, and replanting. Long-term maintenance costs for the open channel areas would include trash removal, weed removal, replanting, maintenance of fencing, and occasional repairs to slope protection measures. The annual long-range costs are usually determined through estimating life cycle costs for the various structural features (e.g. fencing, paving, culverts) and dividing the replacement cost by the life of the feature. In addition, routine maintenance such as trash removal can be estimated based on lump sum estimates. These calculations were not performed as part of this study, but it is expected that such costs would not exceed $25,000 annually.

There would also be costs associated with annual monitoring and reporting under the permits issued by federal and state agencies. There may be some additional monitoring costs associated with any assurances that the channel is meeting the performance criteria necessary to provide mitigation credits to other projects. These initial monitoring program costs are likely to occur over a five year period and would probably be on the order of $50,000 per year. This monitoring effort would involve:

- Basic description of the vegetation (including eelgrass) and its establishment and growth within the channel accompanied by vegetation maps;
- Basic observational data on birds and fish that may be using the channel area—two to three site visits or compilation of volunteer collected data;
- Standard and repeatable photograph stations;
- Success of the site in relation to performance standards that may be set by agencies;
- Recommendations on any remedial actions necessary;
- Report preparation and submittal.

The ultimate scope and costs will be dependent upon the final Habitat Monitoring and Mitigation Plan to be submitted and approved by the U.S. Army Corps of Engineers, and any other long-term monitoring requirements imposed by regulatory agencies.

3.6.2. Culvert Segments (All Alternatives Except 4a)

As is known, based on the condition of the existing culvert, the culverts can become partially blocked over time if not properly maintained. This occurs as a result of sedimentation on the floors and bio-fouling on the inside walls. It is assumed that sediment load into the lagoon would decrease in the future and thus sedimentation of the culvert would be minimal, but mussel and barnacle growth would still occur and thus both the new and existing culverts would need to be cleaned periodically. To determine the need for cleaning, tide gages could be deployed in the Colorado Lagoon and the northwest end of the Marine Stadium periodically (on the order of every three to five years). Any tidal condition differences between the two sites would be indicative that muting is occurring within the culvert and thus the need for cleaning. It is difficult to speculate how frequent cleaning would be required, but it could be as often as every ten years. (In contrast, the existing culvert was never cleaned in the 40+ years since it was constructed). During the cleaning period, there would be a need to close the culvert from tidal flows and thus this feature would need to be incorporated into the design of the culverts.

Maintenance would be most critical for Alternative 1 which has the longest new culvert, as well as the existing culvert left in place, and for Alternatives 3 and 4 which have short culvert segments. The existing culvert is left in place for Alternative 2, but it is not critical to the tidal exchange with Colorado Lagoon.

3.6.3. Bridges (Alternatives 2, 4, and 4a)

The bridge(s) would have to obtain a federal bridge log number. As part of this program, periodic (likely on the order of every three years) inspections of the bridge would be required. For concrete bridge structures and railing, minimal, if any, maintenance would be required assuming the bridge was designed for a 50 to 100 year life. For any steel structures, there would likely be a need for periodic painting.

3.6.4. Lift Station (Alternatives 2 and 4a)

Assuming a sewer lift station is required for alternatives 2 and 4a, there would be a need to maintain the lift station in accordance with the pump supplier instructions. The lift station would be designed to operate autonomously, but there would be general operations monitoring needed.

3.6.5. Preliminary Estimate of Long-Term Maintenance Costs for Each Alternative

Based on the conceptual design of the alternatives and assumptions for the amount of maintenance required, preliminary cost estimates were developed for the maintenance and monitoring required for each alternative over a 50-year period. These costs include a yearly escalation factor.

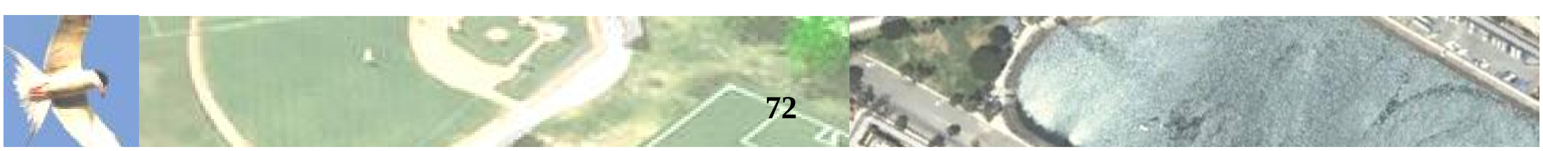
- Alternative 1 - Second/Parallel Underground Culvert: $8.4M
- Alternative 2 - Open Channel with Bridges: $4.7M
- Alternative 3 - Combination Open Channel and Culverts: $7.1M
- Alternative 4 - Combination Open Channel (Max Wetlands) and One Culvert: $5.0M
- Alternative 4a - Combination Open Channel (Max Wetlands) and Two Bridges: $4.0M

Alternative 1 has the highest overall maintenance costs because of the long-term costs of cleaning the culverts, based on an assumed need for cleaning the new culvert five times over the 50 year period and cleaning the existing culvert once over the 50 year period. Alternative 4a is the least cost because this alternative has no culverts to clean. Alternative 3 has higher maintenance costs than Alternatives 2 and 4 because of its additional culverts. The present value for these estimates ranges from $1.3M to $2.0M, assuming an annual interest rate of 6%. (The present value is the cash amount necessary to invest now in order to pay for the long-term (50 year) maintenance costs.)

3.7. Cost Per Habitat Acre

Relative to project objective 2.c, (developing practical/feasible alternatives for creating new / restoring former wetland habitat areas), it is useful to compare the alternatives on a cost-per-habitat-acre basis. This cost-per-habitat-acre calculation is especially important in the context of the availability of mitigation credits associated with this project. Table 3-14 shows the dollars-per-acre calculations for each of the alternatives for the following four cases:

1) based on the amount of habitat area created within the open channel and at Colorado Lagoon, using only short-term (construction) costs;
2) based on the amount of habitat area created within the open channel and at Colorado Lagoon <u>and</u> habitat area enhanced at the lagoon, using only short-term (construction) costs;
3) based on the amount of habitat area created within the open channel and at Colorado Lagoon, using both short-term (construction) costs <u>and</u> long-term (maintenance and monitoring) costs; and
4) based on the amount of habitat area created within the open channel and at Colorado Lagoon <u>and</u> habitat area enhanced at the lagoon, using both short-term (construction) costs <u>and</u> long-term (maintenance and monitoring) costs.



In Table 3-14, the highest cost-per-habitat-acre values for each of the four cases are highlighted in red font and the lowest cost-per-habitat-acre values are highlighted in green font.

Table 3-14. Cost Per Habitat Acre Estimates

	Based on Only Short-Term (Construction) Costs		Based on Both Short-Term and Long-Term Costs	
	Cost per Habitat Acre Created	**Cost per Habitat Acre Created and Enhanced**	**Cost per Habitat Acre Created**	**Cost per Habitat Acre Created and Enhanced**
Alternative 1	$17.0M	$1.2M	$37.9M	$2.6M
Alternative 2	$3.8M	$1.1M	$5.7M	$1.7M
Alternative 3	$3.0M	$0.8M	$6.8M	$1.7M
Alternative 4	$2.8M	$0.9M	$4.7M	$1.5M
Alternative 4a	$3.4M	$1.1M	$4.8M	$1.6M

Alternative 1 is clearly the least cost-effective from a cost-per-habitat-acre basis. It is interesting to note that the inclusion of long-term maintenance and monitoring costs changes the relative ranking of the most cost-effective alternatives, e.g. Alternative 3 is the most cost-effective alternative if considering only construction costs, but Alternative 4 is the most cost-effective if considering both long-term and short-term costs. This is because of the additional long-term maintenance costs associated with the additional culverts in Alternative 3. In general though, Alternatives 2, 3 and 4 have similar cost-per-acre values, considering the fidelity of the cost estimates.

3.8. Comparisons to Project Objectives

This section evaluates how well each alternative satisfies the Phase 2 project objectives. Although this is a relatively subjective evaluation and some objectives may be more important than others, it is a valuable exercise.

Color coding has been used for summarization and clarity. In order of ranking, blue is the best (excellent / very good), followed by green (good), with yellow (fair) being the poorest. In some cases, a slight variation of this definition was used to signify slight differences between

alternatives. Additionally, the post-phase 1 condition has been included in this assessment as a reference comparison.

1. Improve water quality for recreational swimming within Colorado Lagoon by increasing tidal circulation, as measured by maximum tidal range and reduced pollutant residence time in Colorado Lagoon.
    - Alternative 1 - Excellent - provides maximum possible tidal improvements to Colorado Lagoon
    - Alternative 2 - Excellent - provides maximum possible tidal improvements to Colorado Lagoon
    - Alternative 3- Excellent - provides maximum possible tidal improvements to Colorado Lagoon
    - Alternative 4 - Excellent - provides maximum possible tidal improvements to Colorado Lagoon
    - Post-Phase 1 Condition - Good - culvert cleaning provides improved tidal conditions, but not to maximum extent possible.

2. Improve and expand habitat by:
    a. Increasing tidal circulation in Colorado Lagoon, via modification of tidal connection, for reduced algal blooms, improved benthic habitats (such as eelgrass and benthic invertebrates) and fish utilization;
        - Alternative 1 - Excellent - provides maximum possible tidal improvements to Colorado Lagoon
        - Alternative 2 - Excellent - provides maximum possible tidal improvements to Colorado Lagoon
        - Alternative 3- Excellent - provides maximum possible tidal improvements to Colorado Lagoon
        - Alternative 4 - Excellent - provides maximum possible tidal improvements to Colorado Lagoon
        - Post-Phase 1 Condition - Good - culvert cleaning provides improved tidal conditions, but not to maximum extent possible.

b. Increasing tidal range in Colorado Lagoon via modification of tidal connection;

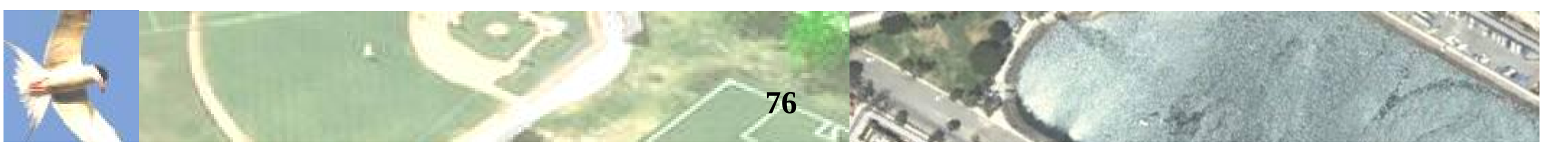
- Alternative 1 - Excellent - provides maximum possible tidal improvements to Colorado Lagoon
- Alternative 2 - Excellent - provides maximum possible tidal improvements to Colorado Lagoon
- Alternative 3- Excellent - provides maximum possible tidal improvements to Colorado Lagoon
- Alternative 4 - Excellent - provides maximum possible tidal improvements to Colorado Lagoon
- Post-Phase 1 Condition - Good - culvert cleaning provides improved tidal conditions, but not to maximum extent possible.

c. Developing practical/feasible alternatives for creating new wetland habitat areas.

- Alternative 1 - Fair - only provides new wetland habitat at Colorado Lagoon
- Alternative 2 - Good/Fair - provides new habitat both at Colorado Lagoon and within the open channel - provides the second most amount of new habitat of the alternatives, but at the highest construction cost.
- Alternative 3- Very good - provides new habitat both at Colorado Lagoon and within the open channel - provides a substantial amount of new habitat and at the lowest construction cost.
- Alternative 4 - Excellent - provides new habitat both at Colorado Lagoon and within the open channel - provides the most new habitat of any of the alternatives.
- Post-Phase 1 Condition - Fair - culvert cleaning (and resultant expanded tide range) provides new marsh habitat at Colorado Lagoon and at a low cost, but no new net habitat.

3. Accommodate safe recreation at Marina Vista Park, while retaining existing functionality of active sports uses.
    - Alternative 1 - Excellent - existing sports fields unaffected.
    - Alternative 2 - Good - although the open channel impacts the Marina Vista Park recreational uses, the existing functionality of active sports uses (i.e. soccer and baseball fields) are retained.
    - Alternative 3- Good - although the open channel impacts the Marina Vista Park recreational uses, the existing functionality of active sports uses (i.e. soccer and baseball fields) are retained.
    - Alternative 4 - Good - although the open channel impacts the Marina Vista Park recreational uses, the existing functionality of active sports uses (i.e. soccer and baseball fields) are retained.
    - Post-Phase 1 Condition - Excellent - existing sports fields unaffected.

4. Accommodate existing public and private infrastructure and services in the project area, including: flood protection and stormwater drainage, (accounting for projected sea level rise over the next 50 years), utilities, traffic, and emergency services.
    - Alternative 1 – Excellent/Very good - existing infrastructure unaffected, with relatively minor exceptions.
    - Alternative 2 - Fair - although all of the existing public and private infrastructure and services are ultimately provided, implementation of this alternative requires modification of two public streets, relocation of restrooms, relocation of utilities, and potentially a new sewer lift station.
    - Alternative 3- Good - implementation of this alternative requires only a relatively minor modification of public infrastructure, i.e. relocation of a restroom.
    - Alternative 4 - Good - implementation of this alternative requires some modification of public infrastructure, i.e. modification of a public street, relocation of a restroom, and relocation of utilities. Ultimately though, all existing public and private infrastructure and services are provided.
    - Post-Phase 1 Condition - Excellent - existing infrastructure unaffected.



5. Minimize long-term maintenance requirements/costs.

   - Alternative 1 - Fair - it is assumed that sediment load into the lagoon would decrease and thus sedimentation of the culvert would be minimum, but mussel and barnacle growth would still occur and thus both the new and existing culverts would need to be cleaned periodically. Alternative 1 has the highest long-term maintenance costs.
   - Alternative 2 - Good - maintenance requirements are associated with preventing invasive species into the marsh habitat, clearing the open channel of debris, periodically cleaning the existing culvert, and maintaining/operating the sewer pump station (assuming the pump station is need).
   - Alternative 3- Fair - maintenance requirements are associated with preventing invasive species into the marsh habitat, clearing the open channel of debris, and periodically cleaning the short culvert segments. Alternative 3 has the second highest long-term maintenance costs because of its additional culverts.
   - Alternative 4 - Good- maintenance requirements are associated with preventing invasive species into the marsh habitat, clearing the open channel of debris, and periodically cleaning the short culvert segment.
   - Post-Phase 1 Condition - Fair - the existing culvert would continue to need to be maintained clear of sediment, debris and bio-fouling.

A summary of the evaluations above is provided in Table 3-15.

Table 3-15. Summary Comparison of Alternatives to Project Objectives

	Alt 1	Alt 2	Alt 3	Alt 4	Post-Phase 1
1. Improve water quality for recreational swimming within Colorado Lagoon by increasing tidal circulation, as measured by maximum tidal range and reduced pollutant residence time in Colorado Lagoon.	Exclnt	Exclnt	Exclnt	Exclnt	Good
2a. Improve and expand habitat by increasing tidal circulation in Colorado Lagoon, via modification of the tidal connection, for reduced algal blooms, improved benthic habitats (such as eelgrass and benthic invertebrates) and fish utilization.	Exclnt	Exclnt	Exclnt	Exclnt	Good
2b. Improve and expand habitat by increasing tidal range in Colorado Lagoon via modification of the tidal connection.	Exclnt	Exclnt	Exclnt	Exclnt	Good
2c. Improve and expand habitat by developing practical/feasible alternatives for creating new (restoring former) wetland habitat areas.	Fair	Good/ Fair	Very Good	Exclnt	Fair
3. Accommodate safe recreation at Marina Vista Park, while retaining existing functionality of active sports uses.	Exclnt	Good	Good	Good	Exclnt
4. Accommodate existing public and private infrastructure and services in the project area, including: flood protection and storm water drainage, (accounting for projected sea level rise over the next 50 years), utilities, traffic, and emergency services.	Exclnt/ Very Good	Fair	Good	Good	Exclnt
5. Minimize long-term maintenance requirements/costs.	Fair	Good	Fair	Good	Fair

All of the Phase 2 alternatives meet the project objectives to some extent and provide improvement over the Phase 1 project. Alternative 1 was fair in meeting the objectives of creating new habitat in a cost-effective manner and relative to minimizing long-term maintenance requirements. Alternative 2 was fair for objectives 2.c and 5, due to a higher construction cost and the amount of impact to public infrastructure. Alternative 3 was fair for objective 5 due to the maintenance requirements of the culverts in this alternative. Alternative 4 was good or excellent relative to all objectives.

4.0 CONCLUSION

The goal of this Phase 2 study was to identify and analyze various alternatives to improve the Colorado Lagoon's tidal connection with the Marine Stadium (and thus the open ocean). Four basic alternatives related to this tidal connection were identified and developed as part of the study. One alternative was to create a second underground culvert parallel to the existing underground culvert. The other three alternatives were various configurations of earthen open channel and underground culverts. Two of the alternatives involved construction of bridges.

Each alternative (as applicable) was evaluated relative to geomorphology, hydrodynamics, habitat, construction cost, maintenance requirements, and other considerations. All alternatives met project objectives, although to varying degrees.

All alternatives met hydrodynamic performance objectives (e.g. tidal range, tidal inundation, and flooding) and resulted in significant improvements from the post Phase 1 condition. In comparison to the post Phase 1 condition, all alternatives increased the tidal range in Colorado Lagoon by approximately 2 feet, increased tidal prism by about 50%, and decreased residence time, resulting in increased water quality for recreational swimming, as well as for habitat. All alternatives accommodated storm events and sea level rise. Hydrodynamics performance was considered to not be a discriminator between alternatives

All alternatives would improve existing habitat (via water quality improvements) and add new habitat at Colorado Lagoon (by tidal range increases). The improvements to tidal exchange, even under Alternative 1, would benefit the lagoon's existing tidally-influenced habitats (approximately 18.2 acres), as water quality for marine organisms would be improved. The increased tidal exchange would likely improve the lagoon's benthic community diversity and thereby provide greater food sources for demersal fish and migratory shorebirds. It is also possible that eelgrass could become established under these improved conditions. This improvement in habitat quality could result in enhancements that could be determined by a comparison of post-project conditions to the baseline environmental data. The increased tidal range, while decreasing the permanently inundated (subtidal) areas, would also result in a net creation/restoration of approximately 0.4 acres of additional intertidal habitat at the lagoon (a distribution probably akin to the lagoon's historic condition).

Three of the alternatives would create new wetland habitat within earthen open channels, which would actually be a restoration of habitat where it once existed. As noted in the geomorphology analyses, the open channel alternatives provide an excellent opportunity to restore wetlands in the "appropriate historical context", i.e. where wetlands historically existed as seen in historic aerial photographs. The maximum amount of new wetland habitat created within the open channel was

2.4 acres for Alternative 4a (a variation of Alternative 4). The new habitat for all open channel alternatives includes subtidal/eelgrass, intertidal/mudflat and marsh within the channel.

The total additional/restored wetland habitat in the open channel and at Colorado Lagoon for each alternative is:

- Alternative 1: +0.4 acres
- Alternative 2: +2.4 acres
- Alternative 3: +1.9 acres
- Alternative 4: +2.6 acres
- Alternative 4a: +2.8 acres

The open channel habitat would be created by conversion of Marina Vista Park grass areas currently used for active and passive recreational activities. The open channel footprints (Alternatives 2, 3 and 4) would occupy approximately 12 to 15% of the total park area and require relocation of baseball and soccer fields to other areas of Marina Vista Park. Alternative 1 would not impact Marina Vista Park, except for temporary disruption during the construction period.

Construction costs for each alternative, based on conceptual designs, were:

- Alternative 1: $6.8M
- Alternative 2: $9.0M
- Alternative 3: $5.8M
- Alternative 4: $7.3M
- Alternative 4a: $9.4M

Alternative 3 (combination open channel and culverts) is the least expensive alternative to construct, primarily because it does not include any bridges.

A preliminary estimate of maintenance and monitoring costs was also developed to understand the long-term costs associated with each alternative and to adequately weigh the alternatives based on both the short-term and long-term costs. While Alternative 4a was the most expensive alternative to construct, it had the lowest long-term maintenance and monitoring costs because it does not have culverts to maintain.

The overall costs per habitat acre were calculated for each alternative. Alternative 1 was the least cost-effective from a cost-per-habitat-acre basis. Alternatives 2, 3, 4 and 4a had similar cost-per-acre values, considering the fidelity of the cost estimates.

Recommended next steps include:

- Continue meeting with resource agencies to further explore potential for compensatory mitigation funding;
- Identify other potential funding sources;
- Select an alternative and possibly refine the alternative based on funding source criteria, funding limitations, and public and agency inputs;
- Assess and implement additional CEQA requirements if necessary.

This Phase 2 study has resulted in four alternatives which significantly improve the conditions of Colorado Lagoon, of which three provide some restoration of the historic conditions in the area. All alternatives meet project objectives. Cost and funding sources would likely be the basis of the selection of the final alternative.

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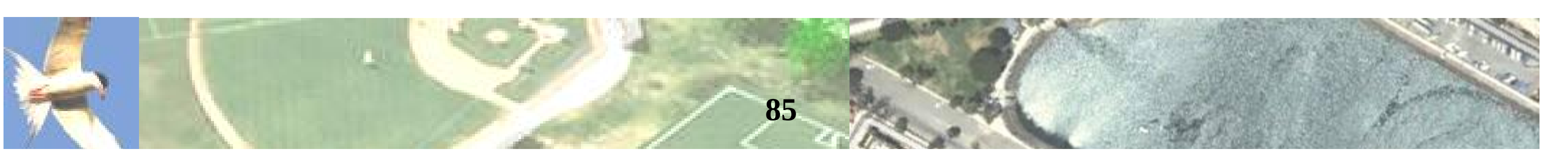
APPENDIX A
Conceptual Designs of Each Alternative

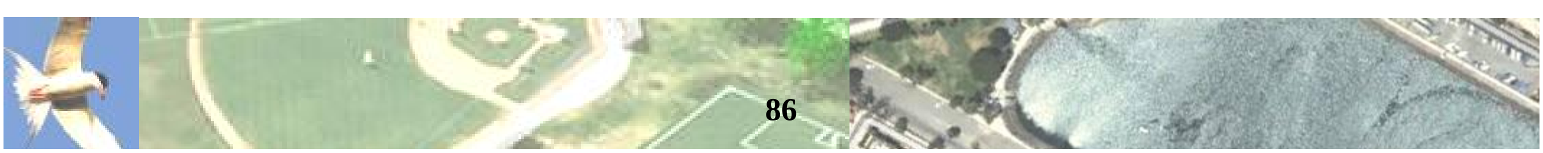
Plan Views
Bridge Details
Cross-Sections

APPENDIX B
Habitat Distributions of Each Alternative

Plan Views
Cross-Sections



APPENDIX C
Geomorphology Report



APPENDIX D
Hydrodynamics Report