LOS CERRITOS WETLANDS
CONCEPTUAL
RESTORATION PLAN

HYDROLOGIC AND HYDRAULIC BASELINE REPORT

Prepared for:

Los Cerritos Wetlands Authority

100 North Old San Gabriel Canyon Road
Azusa, CA 91702

Prepared by:

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3780 Kilroy Airport Way, Suite 600
Long Beach, CA 90806

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M&N Job 7476

Executive Summary

The Los Cerritos Wetlands (LCW) complex affords the opportunity to restore some 500 acres of salt marsh, seasonal wetlands, and other freshwater wetlands. Historically, the complex covered approximately 2,400 acres and stretched approximately two miles inland. Today, only remnants of the historic wetlands occur in degraded patches. The LCW Conceptual Restoration Plan is to provide a roadmap for habitat enhancement and improved public access for approximately 200 acres of the LCW complex and potentially the entire 500 acres.

Restoration and enhancement of hydrologic conditions within the LCW is a priority for wetland restoration. The LCW already has many existing hydraulic connections which provide opportunities for tidal restoration. However, restoration of hydrologic functioning will be complicated by many factors including: channelization of the San Gabriel River (SGR), water intake from two nearby power plants and impacts on tidal circulation and entrainment of larval biota, thermal plumes in the SGR from power plant discharges, flood management concerns, and existing roads and infrastructure. Consideration of engineering and economic feasibility for various hydrologic regimes will be a major factor in identifying potential restoration alternatives.

A hydrodynamic model of the existing LCW complex has been developed and calibrated using measured field data as part of a previous project (Moffatt & Nichol 2007) and is applied to this project. This RMA finite element model represents the significant hydraulic features of the LCW complex, i.e. the SGR, Alamitos Bay, Marine Stadium, Colorado Lagoon, Los Cerritos Channel, Haynes Channel, Hellman Channel, the nearshore ocean, as well as other culvert connections to/from the existing LCW areas. It is capable of simulating tidal conditions, various power plant pump operating scenarios, storm events, and sea level rise (SLR).

The dominant existing circulation pattern is generally that water flows upstream (north) along both the Haynes and Los Cerritos Channels and then returns downstream to the ocean via the SGR as tides. However, this circulation pattern is expected to change upon the AES and Haynes Generating Stations implementation of Once-Through Cooling (OTC) Water technology. The Los Cerritos Wetlands Authority (LCWA) Phase 2 (Hellman) and LCWA Phase 1 properties receive muted tidal circulation via the Hellman Channel and Zedler Marsh culvert connections, respectively, to/ from the SGR. The other properties within the baseline 200-acre area receive only freshwater input from seasonal rains and runoff.

The model will be used to analyze the restoration alternatives as part of the future Task 12. Each alternative will be assessed for tidal range, tidal inundation frequency, flood levels, sea level rise, and potentially residence time.

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1.0 INTRODUCTION

The Los Cerritos Wetlands (LCW) complex affords the opportunity to restore some 500 acres of salt marsh, seasonal wetlands, and other freshwater wetlands. The general location of the Los Cerritos Wetlands is shown in Figure 1-1. Historically, the complex covered approximately 2,400 acres and stretched approximately two miles inland. Over the past century, the wetlands have been used for farming, oil production, landfills, burn dumps, and urban development. Today, only remnants of the historic wetlands occur in degraded patches. The LCW Conceptual Restoration Plan is to provide a roadmap for habitat enhancement and improved public access for approximately 200 acres of the LCW complex and potentially the entire 500 acres.

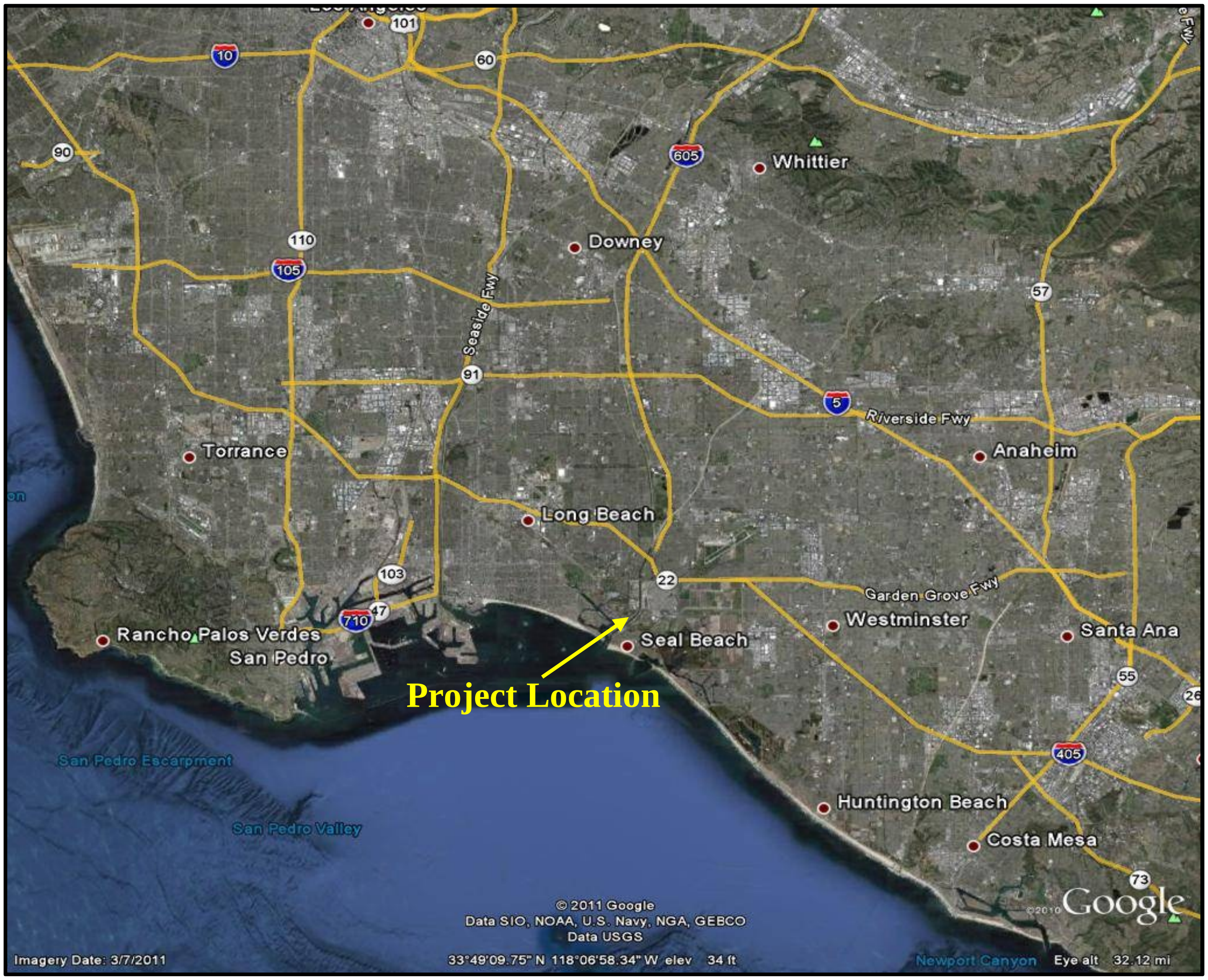

Figure 1-1. Vicinity Map
(Aerial Photograph Source: Google Earth)

The LCW complex adjoins the lower reach of the San Gabriel River (SGR) where, prior to channelization, the mouth of the river migrated back and forth across the coastal plain. Channelization of the SGR began in the 1930s and cut off tidal action to much of the wetland area. Other channels which service upstream power plants also bifurcate sections of the wetlands complex. Site maps are provided in Figure 1-2 and Figure 1-3, showing the land ownership for the areas within public ownership (approximately 200 acres) and for the total LCW complex (approximately 500 acres), respectively.

Figure 1-2. Map of LCW Areas of Public Ownership

Figure 1-3. Map of Entire LCW Complex

Restoration and enhancement of hydrologic conditions within the LCW is a priority for wetland restoration. The LCW already has many existing hydraulic connections, as shown in Figure 1-4, which provide opportunities for tidal restoration. However, restoration of hydrologic functioning will be complicated by many factors including: channelization of the SGR, water intake from two nearby power plants and impacts on tidal circulation and entrainment of larval biota, thermal plumes in the SGR from power plant discharges, flood management concerns, and existing roads and infrastructure. Consideration of engineering and economic feasibility for various hydrologic regimes will be a major factor in identifying potential restoration alternatives.

Figure 1-4. Existing Hydraulic Features of the LCW Complex
(Aerial Photograph Source: Google Earth)

A finite element RMA2 hydrodynamic numerical model simulating the LCW complex hydrodynamics was developed. As part of the future restoration alternatives task, the model will be run for various conditions: a) tidal hydrodynamics under the dry season; b) flood hydrodynamics under the 100-year storm event; and c) impacts of sea level rise (SLR).

A separate watershed impacts report summarizes the upstream watershed drainage areas and storm water sources for each of the LCW parcels. Potential impacts from pollutant sources were assessed based on available information including water quality monitoring data, land use information, prior pollutant source assessments, and planned water quality improvement efforts in each watershed.

2.0 SCOPE OF WORK

The scope of work for the overall study includes the following tasks:

Task 1 – Base data collection and topographic mapping;

Task 2 – Characterize biological resources and extent of special status species;

Task 3 – Characterize hydrologic and hydraulic conditions;

Task 4 – Characterize upstream activities impacting the wetland;

Task 5 – Conduct an initial environmental study to identify potential contaminant types and sources;

Task 6 – Evaluate options for sediment management or disposal;

Task 7 – Develop opportunities and constraints to habitat restoration;

Task 8 – Develop concepts for public access and interpretation;

Task 9 – Public involvement;

Task 10 – Develop process for meetings of the Steering and Technical Advisory Committees;

Task 11 – Refine project objectives;

Task 12 – Develop and evaluate restoration alternatives;

Task 13 – Develop consensus on alternatives;

Task 14 – Prepare conceptual restoration plan (final report);

Task 15 – Issues for next phase of restoration planning; and

Task 16 – Project management.

This report is the deliverable for Task 3 and is to characterize the hydrologic and hydraulic conditions of the existing system. Specifically, this report includes:

- Assessment of inputs and outputs from tides, storm runoff, dry season low flows, released/ treated water, and groundwater;
- Results of field sampling efforts:
- Characterization of hydraulic flow patterns into, out of, and within the wetlands;
- Identification of watershed improvement projects in the area adjacent to the LCW and analysis of the impacts of that infrastructure and the watershed to the wetlands;
- Development of a model to support the feasibility analysis and assess proposed project alternatives.

3.0 MODEL SELECTION AND DESCRIPTION

The technical background of the numerical modeling systems used in this study is summarized in this section.

The model selected for use in this study is RMA. This model can perform accurate hydrodynamic calculations for circulation conditions, determine tidal inundation frequency, and can provide estimates of water turn-over time, or residence time, within a system. Specific modeling of water quality for certain pollutants was not included in the scope, but some water quality modeling may be done at a later date if necessary.

RMA was identified to be appropriate for this work due to successful application of it for similar projects such as the Alamitos Bay Circulation Study, Colorado Lagoon Restoration Project, Bolsa Chica Wetlands Restoration, Huntington Beach Wetlands Restoration, and other projects. RMA is an integrated suite of models for quantifying hydrodynamics and water quality. It includes a user-friendly data illustration component to show model results in color animations. RMA is a federally-approved model developed by the U.S. Army Corps of Engineers (USACE) and used by other agencies for assessing hydrodynamic problems and solutions.

For previous projects, Moffatt & Nichol (M&N 2007) had already developed an RMA model for almost all of the LCW complex and its associated water bodies, e.g. SGR, Los Cerritos Channel, and Alamitos Bay / Marine Stadium / Colorado Lagoon, including effects of the adjacent power plants. The model for this LCW study will be expanded to also include the Hellman and Haynes Channels. A separate link-node model was previously developed for the Hellman Ranch property, including the Hellman Channel. No model previously existed for the Haynes Channel.

3.1 MODEL DESCRIPTION

RMA is part of the TABS2 collection of generalized computer and pre- and post-processor utility codes integrated into a numerical modeling system, used for studying two-dimensional (2-D) depth-averaged hydrodynamics, transport and sedimentation problems in rivers, reservoirs, bays, and estuaries. The TABS2 (McAnally and Thomas 1980) modeling system was developed by the USACE and consists of two-dimensional, vertically averaged finite element hydrodynamics (RMA2), pollutant transport/ water quality (RMA4) and sediment transport models (SED2D). The finite element method provides a means of obtaining an approximate solution to a system of governing equations by dividing the area of interest into smaller sub-areas called elements. Time-varying partial differential equations are transformed into finite element form and then solved in a global matrix system for the modeled area of interest. The solution is smooth across each element and continuous over the computational area. This modeling system is capable of simulating tidal wetting and drying of marsh and intertidal areas of the estuarine system.

A schematic representation of the TABS2 system is shown in Figure 3-1. TABS2 and its respective RMA models can be used either as a stand-alone solution technique or as a step in the hybrid modeling approach. For instance, RMA2 calculates water surface elevations and current patterns which are input to the pollutant transport (RMA4) and sediment transport (SED2D) models. Existing and proposed geometry can be analyzed to determine the impact of project designs on flow circulation, salinity, water quality and sedimentation in the estuary system. All models utilize the finite element method with Galerkin-weighted residuals.

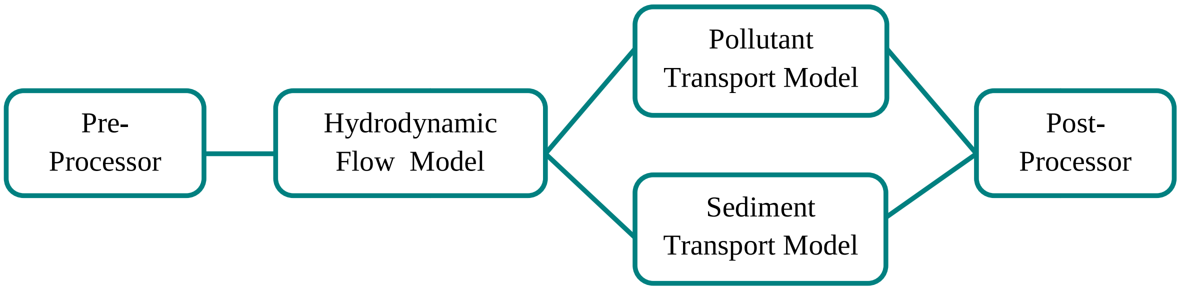

Figure 3-1. TABS2 Schematic

The RMA Model Series is a set of one-, two-, and three-dimensional models of hydrodynamics, sediment transport, and water quality. The suite of models has been extensively used in river, estuary, wetlands, and coastal applications. The RMA model can be applied effectively in this case since it models hydrodynamics using a finite element grid, suitable for irregular topography/ bathymetry and shorelines of wetlands, and it averages conditions throughout the water column representative of the unstratified (well-mixed) conditions of shallow tidal wetlands. Another advantage of the RMA model series is that water quality and sediment transport can also be readily modeled at a later date using hydrodynamic results and relevant input data.

Two-dimensional models, such as RMA2, consider the lateral circulation in large water-bodies such as coastal waters. The flow characteristics are assumed to be uniform throughout the water column at each computational point such that stratification is not described. In areas where vertical mixing is great or vertical gradients are not significant due to mixing, 2-D models are adequate to describe coastal hydrodynamics, sedimentation, and contaminant transport. The advantages of 2-D models versus three-dimensional (3-D) models are the time savings in model run-times and less input data requirements, as 3-D boundary data are rarely available.

This modeling system is capable of simulating tidal wetting and drying of marsh and intertidal areas of the estuarine system. Sources and sinks will be included to simulate storm water inflows to the LCW hydraulic system. Smaller contributors such as storm drains can also be added to the model to simulate all flow conditions. The model is also capable of considering wind-induced shear stress, and to model some tidal control structures such as gates, weirs, and culverts.

The RMA2 hydrodynamic model simulates 2-D flow in rivers and estuaries by solving the depth-averaged Navier Stokes equations for flow velocity and water depth. The equations account for friction losses, eddy viscosity, Coriolis forces and surface wind stresses. The general governing equations are:

Continuity equation:

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0$$

Conservation of momentum equations:

$$h\frac{\partial u}{\partial t} + uh\frac{\partial u}{\partial x} + vh\frac{\partial u}{\partial y} + gh\frac{\partial a}{\partial x} + gh\frac{\partial h}{\partial x} - h\frac{e_{xx}}{r}\frac{\partial^2 u}{\partial x^2} - h\frac{e_{xy}}{r}\frac{\partial^2 u}{\partial y^2} + S_{f_x} + t_x = 0$$

$$h\frac{\partial v}{\partial t} + uh\frac{\partial v}{\partial x} + vh\frac{\partial v}{\partial y} + gh\frac{\partial a}{\partial y} + gh\frac{\partial h}{\partial y} - h\frac{e_{yx}}{r}\frac{\partial^2 v}{\partial x^2} - h\frac{e_{yy}}{r}\frac{\partial^2 v}{\partial y^2} + S_{f_y} + t_y = 0$$

where:

u,v = x and y velocity components

t = time

h = water depth

a = bottom elevation

g = gravity

Sf_x = bottom friction loss term in x-direction

Sf_y = bottom friction loss term in y-direction

t_x = wind and Coriolis stresses in x-direction

t_y = wind and Coriolis stresses in y-direction

e_{xx} = normal eddy viscosity in the x-direction on x-axis plane

e_{xy} = tangential eddy viscosity in the x-direction on y-axis plane

e_{yx} = tangential eddy viscosity in the y-direction on x-axis plane

e_{yy} = normal eddy viscosity in the y-direction on y-axis plane

3.2 RESIDENCE TIME ANALYSIS

While the primary analyses for the LCW restoration alternatives evaluations are tidal range, inundation frequency, and flood levels, an additional consideration is residence time. Residence time (i.e., average time a particle resides in a hydraulic system) provides a useful measure of the rate at which water in the hydraulic system is renewed and thus provides a measure of water quality. Constituent concentrations in a water body reflect a balance between the rate of constituent supply and the rate of constituent removal by tidal flushing.

Consider the reduction of a tracer concentration in a tidal embayment due to flushing after being released (Fischer et al. 1979), in which C_0 is initial concentration, K is a reduction coefficient and C(t) is the concentration at time t.

$$C(t) = C_0 e^{-Kt}$$

The residence time of the tracer in the embayment is determined from:

$$T_r = \frac{\int_0^\infty t\, C(t)\, dt}{\int_0^\infty C(t)\, dt} = \frac{1}{K}.$$

Since the concentration at t = Tr is:

$$C(T_r) = C_0 e^{-1} = \frac{C_0}{e}$$

T_r can be calculated from a regression analysis of the tracer concentration time series computed by the numerical model RMA4.

Based on the above methodology, the general procedure of computing the residence times for different parts of a tidal embayment is as follows:

- Assign an initial tracer concentration of one over the entire embayment (entire bay for this study) and a value of zero at the open water boundaries to simulate an instantaneous release of a contaminant in an embayment;
- Run the numerical model RMA4 for an adequate number of tidal cycles until substantial reductions of tracer concentrations have occurred due to tidal flushing at the locations of interest;
- Analyze the computed concentration results by regression analysis to obtain the tracer reduction distributions at the locations of interest; and
- Find the residence times for the locations of interest from the distribution curves.

4.0 MODEL SETUP

Setup of the hydraulic model for the existing LCW area included determination of the model area, mesh selection, bathymetry, culverts geometry, and boundary conditions.

4.1 MODEL AREA

Figure 4-1 shows the finite element model area, not including the Haynes Cooling Channel and Hellman Channel. The model mesh covers a relatively large area. It includes the entire Alamitos Bay, Marine Stadium, Colorado Lagoon, several miles along the SGR and Los Cerritos Channel, and the nearshore ocean.

The ocean boundary (at an average contour elevation of -50 feet relative to the NGVD29 vertical datum) is approximately two miles from the shoreline. The side boundaries are approximately one and half miles northwest and southeast from the project site. Designating the open model boundaries far from the area of interest is required to minimize boundary effects.

4.2 MODEL MESH

The RMA2 model requires the hydraulic system to be represented by a network of nodal points defined by coordinates in the horizontal plane and water depth, and elements created by connecting these adjacent points to form areas. Nodes can be connected to form 1- and 2-dimensional elements, having from two to four nodes. The resulting nodal/ element network is commonly called a finite element mesh and provides a computerized representation of the basin geometry and bathymetry. The results discussed herein correspond to 2-D analyses with the exception of the culverts leading to the Colorado Lagoon which is represented by one-dimensional (1-D) elements.

The two most important aspects to consider when designing a finite element mesh are: (1) determining the level of detail necessary to adequately represent the area of interest, and (2) determining the extent or coverage of the mesh. The model described in this section is numerically robust and capable of simulating tidal elevations, flows, and constituent transport with reasonable resolution. Accordingly, the bathymetric features of the basin generally dictate the level of detail appropriate for the mesh.

Figure 4-1. Finite Element Model
(Aerial Photograph Source: Google Earth)

There are several factors used to decide the areal extent of a mesh. First, it is desirable to extend mesh open boundaries to areas which are sufficiently distant from the proposed areas of change so as to be unaffected by that change. Additionally, mesh boundaries must be located along sections where conditions can reasonably be measured and described to the model. Finally, mesh boundaries can be extended to an area where conditions have been previously measured to eliminate the need to interpolate conditions from other locations.

The LCW model mesh (shown in Figure 4-1) includes an area of open ocean sufficiently large enough to eliminate potential model boundary effects, and covers the tidally-influenced portions of the Los Cerritos Channel and the SGR. The entire modeling area, approximately 7.3 square miles, is currently represented as a finite element mesh consisting of about 2,500 elements and

7,800 nodes. The model grid does not include the Haynes Channel or Hellman Channel. Those features may be analyzed using separate numerical models due to their complicated geometry, as the Haynes Channel crosses underneath the SGR, and Hellman Channel is very small-scale and connected to the SGR with a culvert.

4.3 BATHYMETRY AND CULVERTS

The Alamitos Bay and ocean bathymetry are based on data obtained from the National Oceanic and Atmospheric Administration (NOAA) chart 18749. The bathymetry of Colorado Lagoon and a portion of the Marine Stadium near the culvert connecting the Colorado Lagoon are based on a February 2004 survey by the Los Angeles County Department of Public Works (LACDPW).

The dimensions of the SGR and Los Cerritos Channel are based on aerial photography provided by the City of Long Beach, and the bathymetry was based on depth readings conducted with a fathometer along the centerline of the channel and River during the Alamitos Bay Circulation Study. The design cross-section of the SGR is shown in Figure 4-2.

The Haynes Channel model is based on design drawings from the Los Angeles Department of Water and Power (LADWP). Haynes cooling intake water is drawn from Alamitos Bay via an inverted siphon (seven 96" diameter underground culverts) beneath the SGR and the flows are then conveyed to the Haynes power plant to the north via an open concrete channel. The Haynes intake locations are shown in Figure 4-3 and the details of the channel and intake geometry are shown in Figure 4-4 and Figure 4-5. The Haynes power plant discharges the water into the SGR.

The model of the culvert section of the Hellman Channel is based on information from a M&N (1996) Hellman Ranch restoration study. The Hellman Channel transitions from an open earthen channel to an underground 48" diameter culvert just to the east of the Haynes Channel. The culvert bends around the south end of the Haynes Channel and into the SGR. The plan view and profile of the culvert section is shown in Figure 4-6 and Figure 4-7, respectively.

Design drawings of the culvert connecting Marine Stadium and the Colorado Lagoon were provided by the City of Long Beach. The flow through the culvert is simulated as a rating curve in the RMA2 model. The rating curve was adjusted during the model calibration performed as part of the Colorado Lagoon Restoration Feasibility Study in 2004 (M&N 2004).

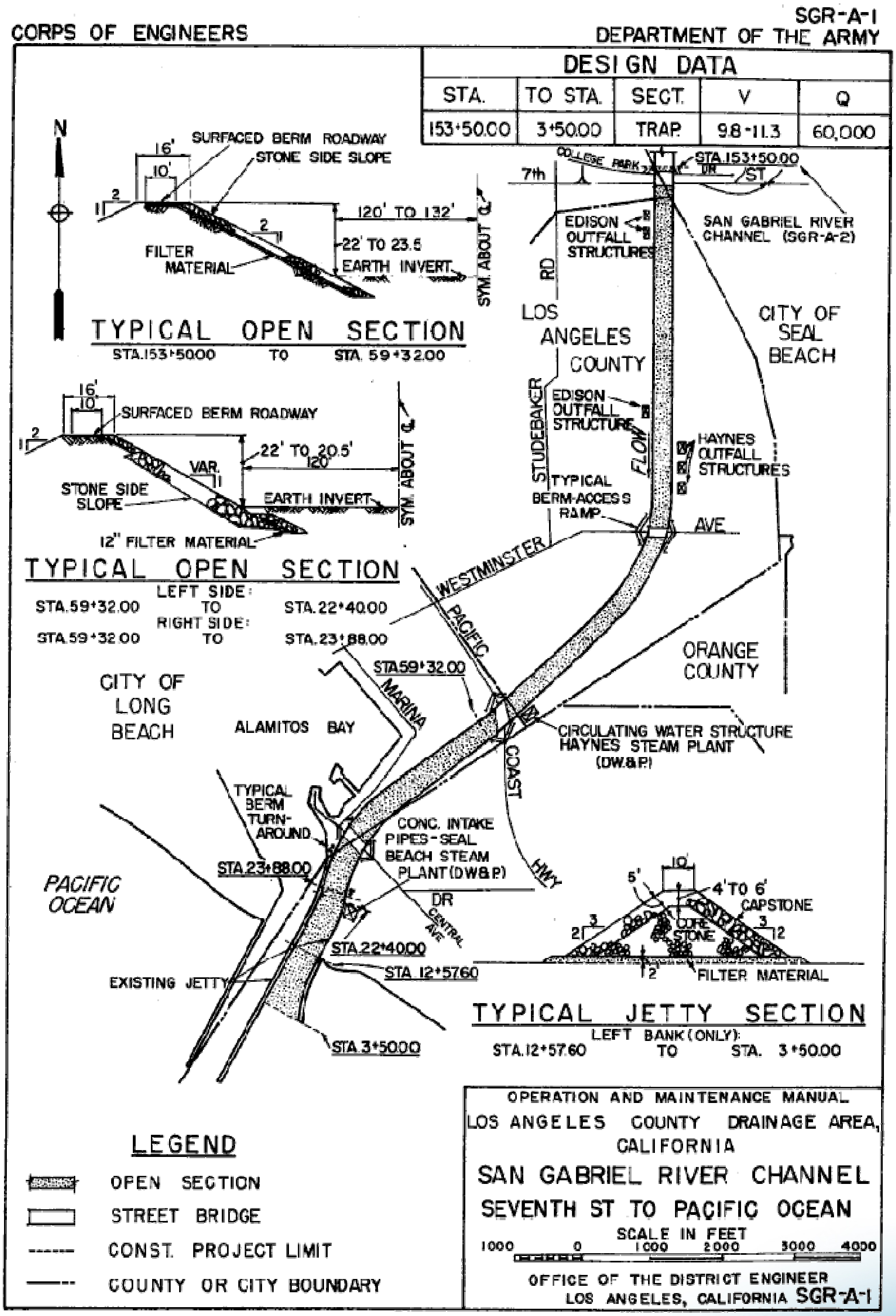

Figure 4-2. Lower San Gabriel River Design
(L.A. County 2011)

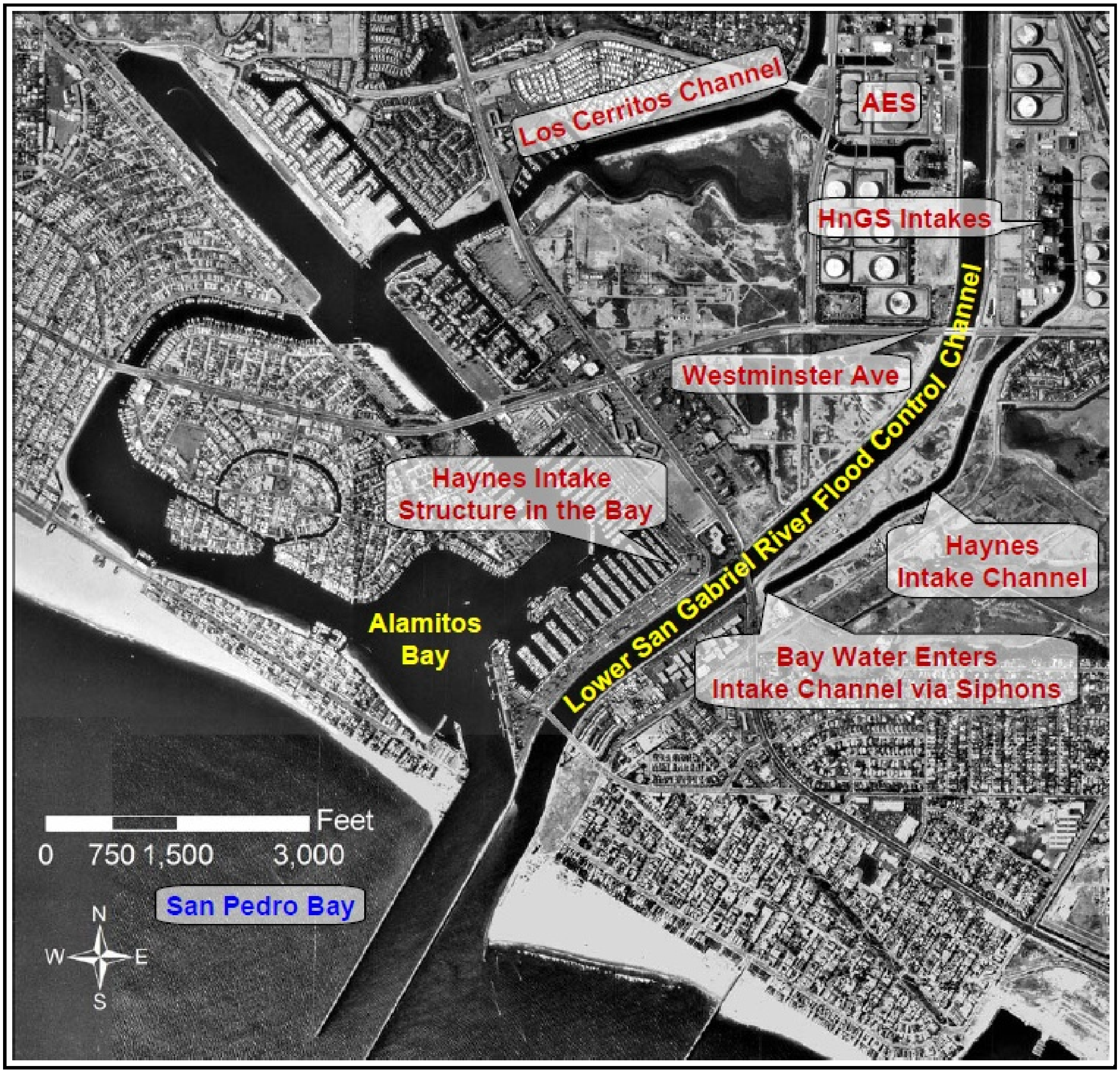

Figure 4-3. Haynes Channel Intake Locations
(Flow Sciences 2009)

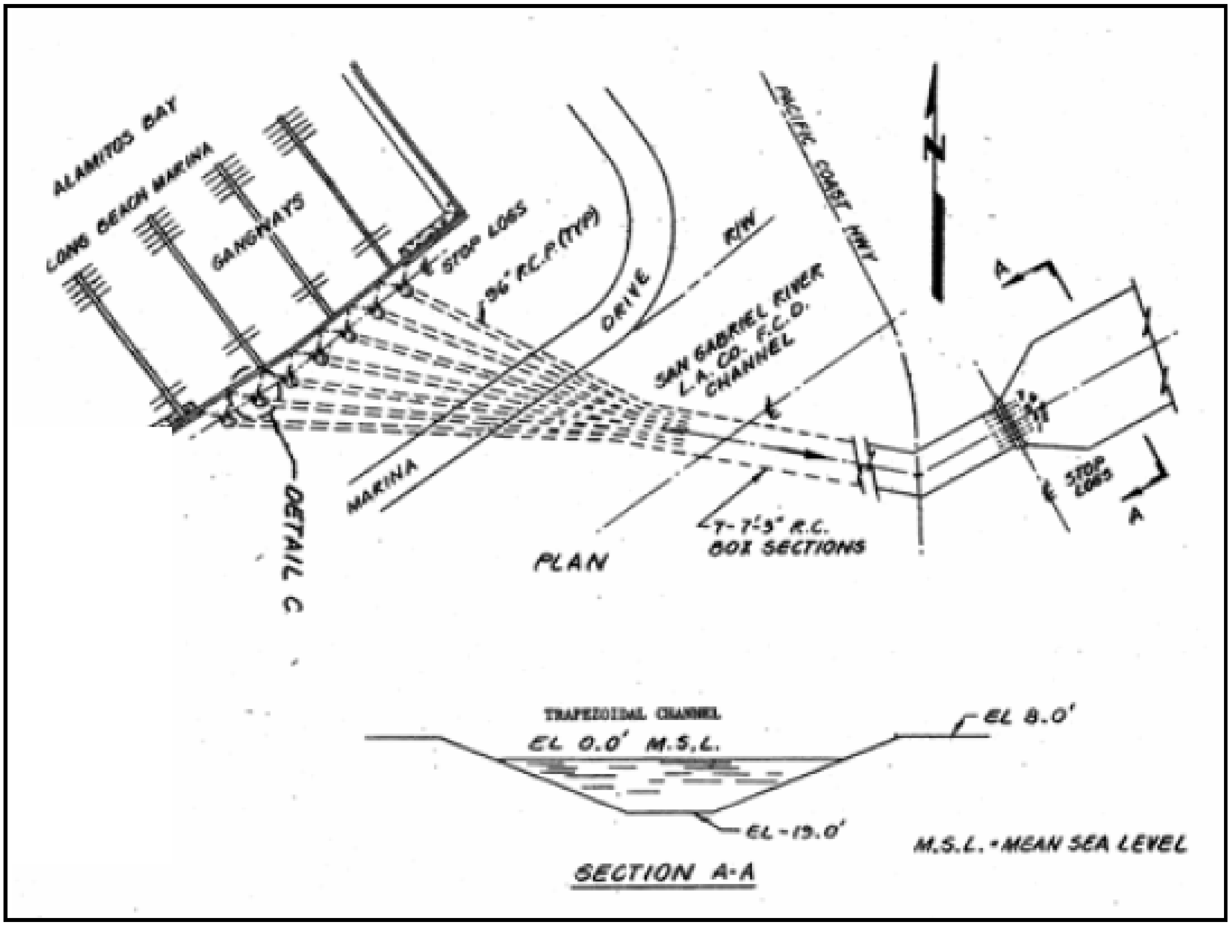

Figure 4-4. Haynes Intake from Alamitos Bay to Haynes Open Channel – Plan View and Channel Cross Section
(LADWP from Flow Sciences 2009)

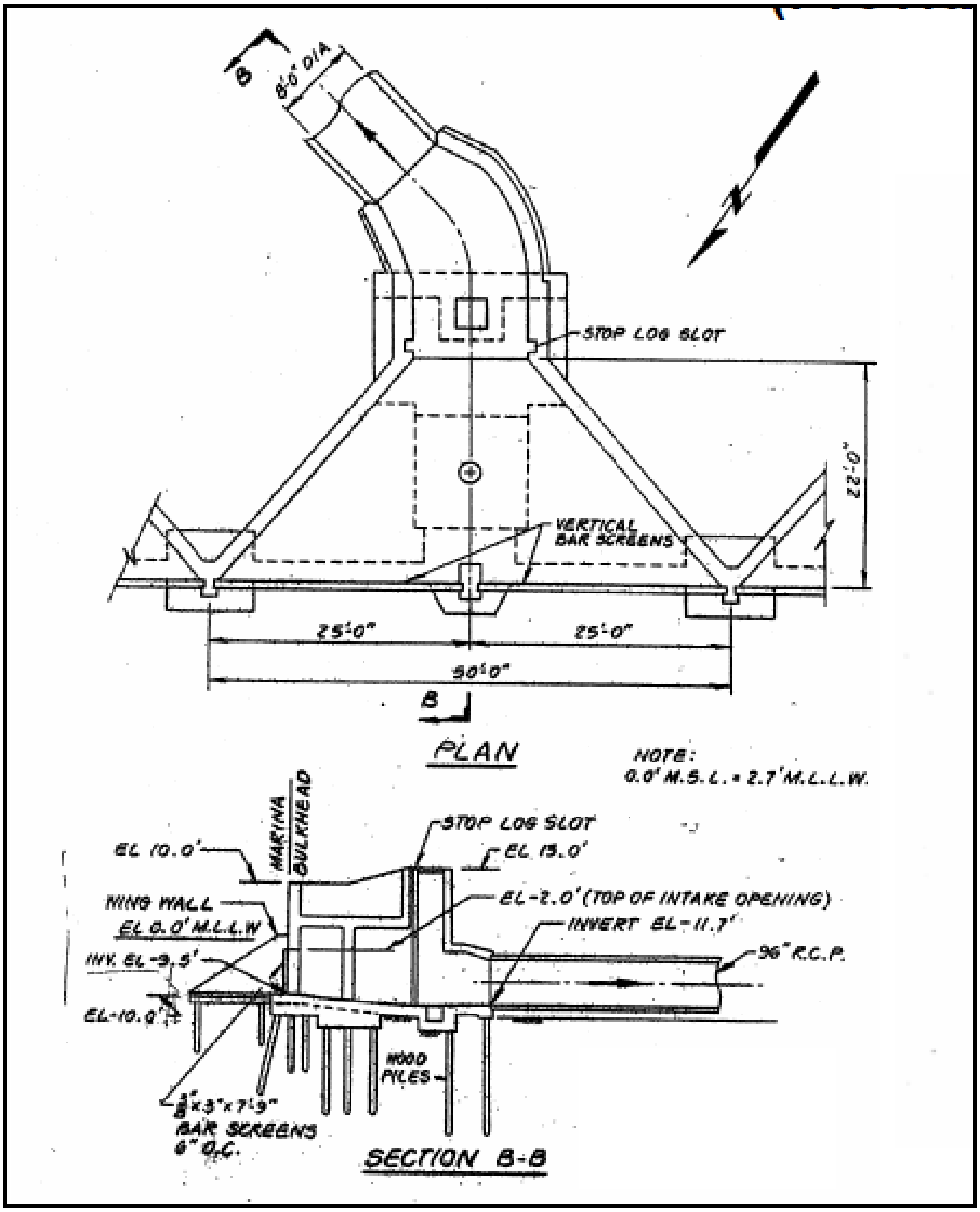

Figure 4-5. Detail of Haynes Intake at Alamitos Bay – Plan View and Intake Cross Section
(LADWP from Flow Sciences 2009)

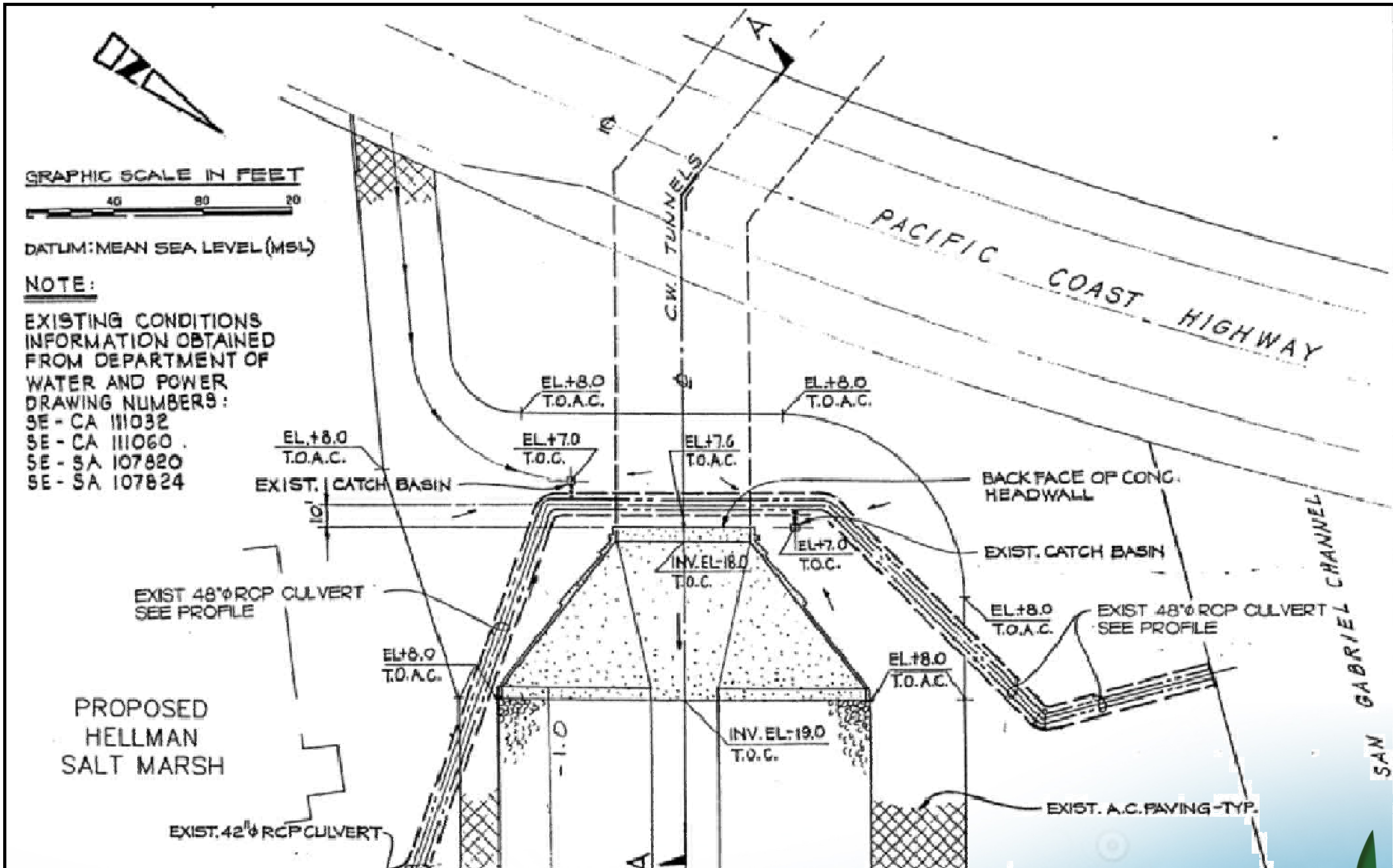

Figure 4-6. Plan View of Hellman Channel in the Vicinity of the Haynes Channel and San Gabriel River
(M&N 1996)

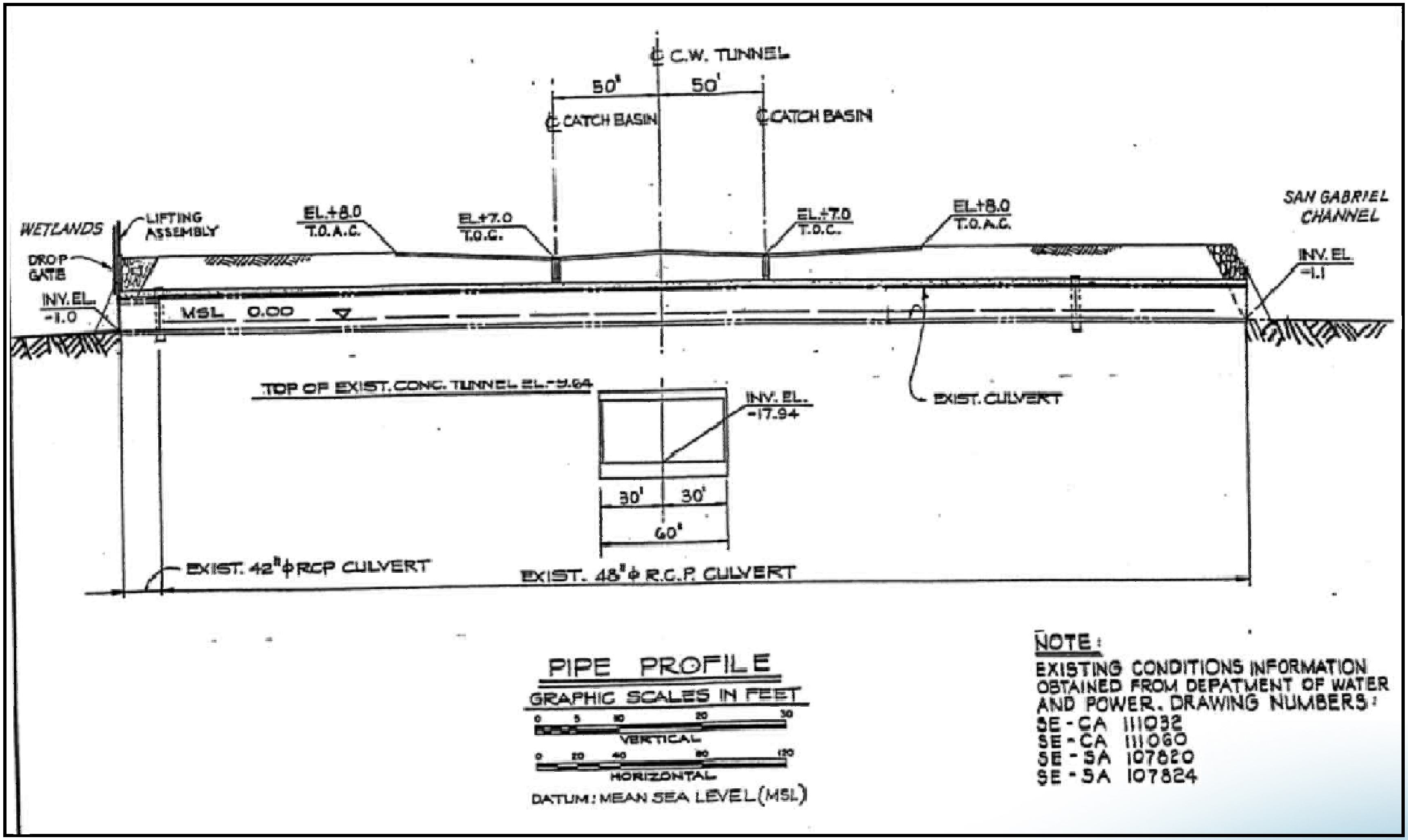

Figure 4-7. Profile of Culvert Section of Hellman Channel Above the Haynes Channel ("Tunnel")
(M&N 1996)

4.4 BOUNDARY CONDITIONS

The boundary conditions are the inputs and outputs to the LCW system model. These include the tides, power plant pumping (intake and discharged/ released water), and storm event runoff. Dry season runoff is negligible in comparison to tidal and storm inputs to the wetlands and is thus not included in this modeling study. Groundwater within the LCW complex is high, has been found to be saline and is strongly influenced by tidal movement (AECOM 2011), however it is not a relevant factor for hydraulic modeling of restoration alternatives. Groundwater will be an important factor for wetlands function and developing construction cost estimates.

4.4.1 Tides

There are no official tide stations within the LCW area or Alamitos Bay. As such, the nearest tide station administered by the National Oceanic and Atmospheric Administration (NOAA) at Los Angeles Outer Harbor was assumed to represent the ocean boundary tidal condition as shown in Table 4-1. The diurnal tide range is approximately 5.49 feet from Mean Lower Low Water (MLLW) to Mean Higher High Water (MHHW) and Mean Sea Level (MSL) is at +2.82 feet relative to MLLW.

Table 4-1. Recorded Water Levels at Los Angeles Outer Harbor
(1983-2001 Tidal Epoch) (NOAA 2004)

Description	Elevation (feet, MLLW)	Elevation (feet, NGVD29)
Extreme High Water (1/27/83)	+7.82	+5.18
Mean Higher High Water (MHHW)	+5.49	+2.85
Mean High Water (MHW)	+4.75	+2.11
Mean Tidal Level (MTL)	+2.85	0.21
Mean Sea Level (MSL)	+2.82	0.18
National Geodetic Vertical Datum 1929 (NGVD29)	+2.64	0.00
Mean Low Water (MLW)	+0.94	-1.70
Mean Lower Low Water (MLLW)	0.00	-2.64
Extreme Low Water (12/17/33)	-2.73	-5.37

Water level measurement data provide astronomical tides and other components including barometric pressure tide, wind setup, seiche, and the El Nino Southern Oscillation. Tidal variations can be resolved into a number of sinusoidal components having discrete periods. The longest significant periods, called tidal epochs, are approximately 19 years. In addition, seasonal variations in MSL can reach amplitudes of 0.5 feet in some areas, such as LAOH. Superimposed on this cycle is a 4.4-year variation in the MSL datum elevation that may increase the amplitude by as much as 0.25 feet in San Pedro Bay. Water level measurement data are typically analyzed over a tidal epoch to account for these variations and obtain statistical water level information (e.g., MLLW and MHHW).

A further discussion of the detailed input data tides are described in the calibration section of this report.

4.4.2 Sea Level Rise

The restoration alternatives must also consider relative SLR, which is the local rate of SLR relative to the land. SLR primarily affects two aspects of this study: 1) the potential for flooding and 2) the rising tide's impact on wetland habitat. The former will be addressed as part of the hydrodynamic analyses. The latter will be addressed as part of other future tasks.

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. The global average rate of SLR 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 4-8 (M&N 2010) 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 SLR). These authors generally have not provided numerical tables giving the projected SLR at intermediate dates; the curves on this chart have been developed by M&N by fitting to the published values (either tabulated or read from charts). As can be seen in this graph, the values specified by the California State Coastal Conservancy (2009) – 16 inches (40 cm) by 2050 and 55 inches (140 cm) by 2100 – represent an upper limit on the SLR anticipated absent any catastrophic changes (such as dramatic losses to the ice sheets).

It is assumed that the vertical land movements in the LCW complex are 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 SLR projections.

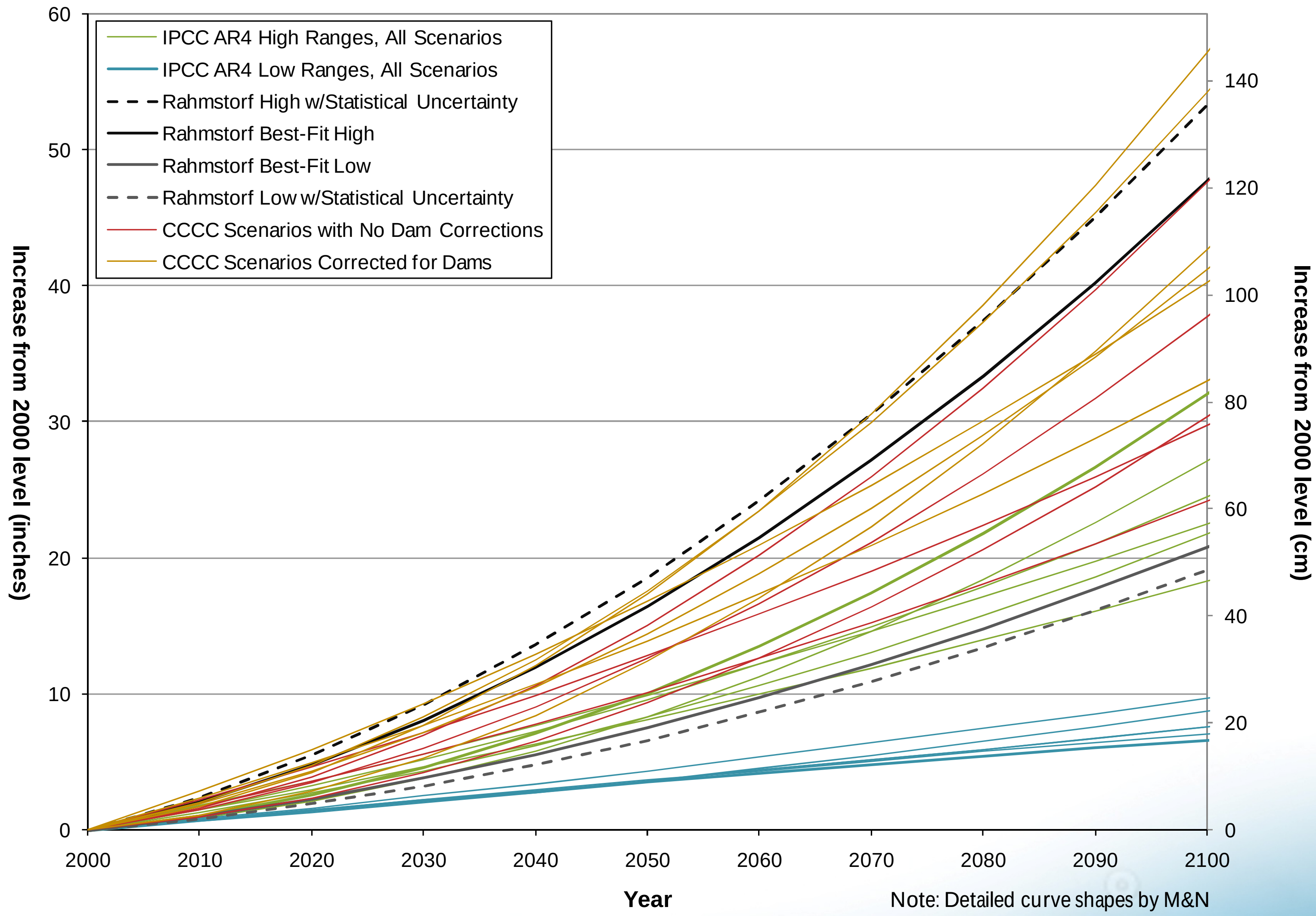

Figure 4-8. Range of Projected Increases in Sea Level Rise: California Coast Generally
(M&N 2010)

Three plausible scenarios can be identified for future SLR (through 2100). The values given below take into account the small amount of assumed localized uplift.

- Low rate of increase: SLR continues at the average of low SLR 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.
- Likely high rate of increase: 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.
- Highest rate of increase: 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 4-2 gives intermediate values for the three scenarios, together with the final (100-year, to 2100) projection. SLR is given relative to the year 2000.

Table 4-2. Recommended Sea Level Rise Scenarios

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 SLR in a 50-year time frame.

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 MHHW is rising more rapidly than the mean sea level. 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 SLR. Consequently, it does not seem necessary to account for the increase in tidal range in most planning activities.

For the flood hydrodynamic analysis, the ramification of SLR is that the base flood elevation is increased by the SLR amount for the design life being considered.

4.4.3 Storm Events

For the flood hydrodynamics analysis, a 100-year storm event will be modeled in conjunction with an extreme high tide series. The input 100-year storm event hydrograph for the SGR reach in the vicinity of the LCW (downstream of Coyote Creek) is shown in Figure 4-9. The extreme tide series is a vertical adjustment of the existing tide conditions to match the FEMA base flood elevation in the lower reach of the SGR. Another extreme tidal series will be developed to also take into account future potential SLR.

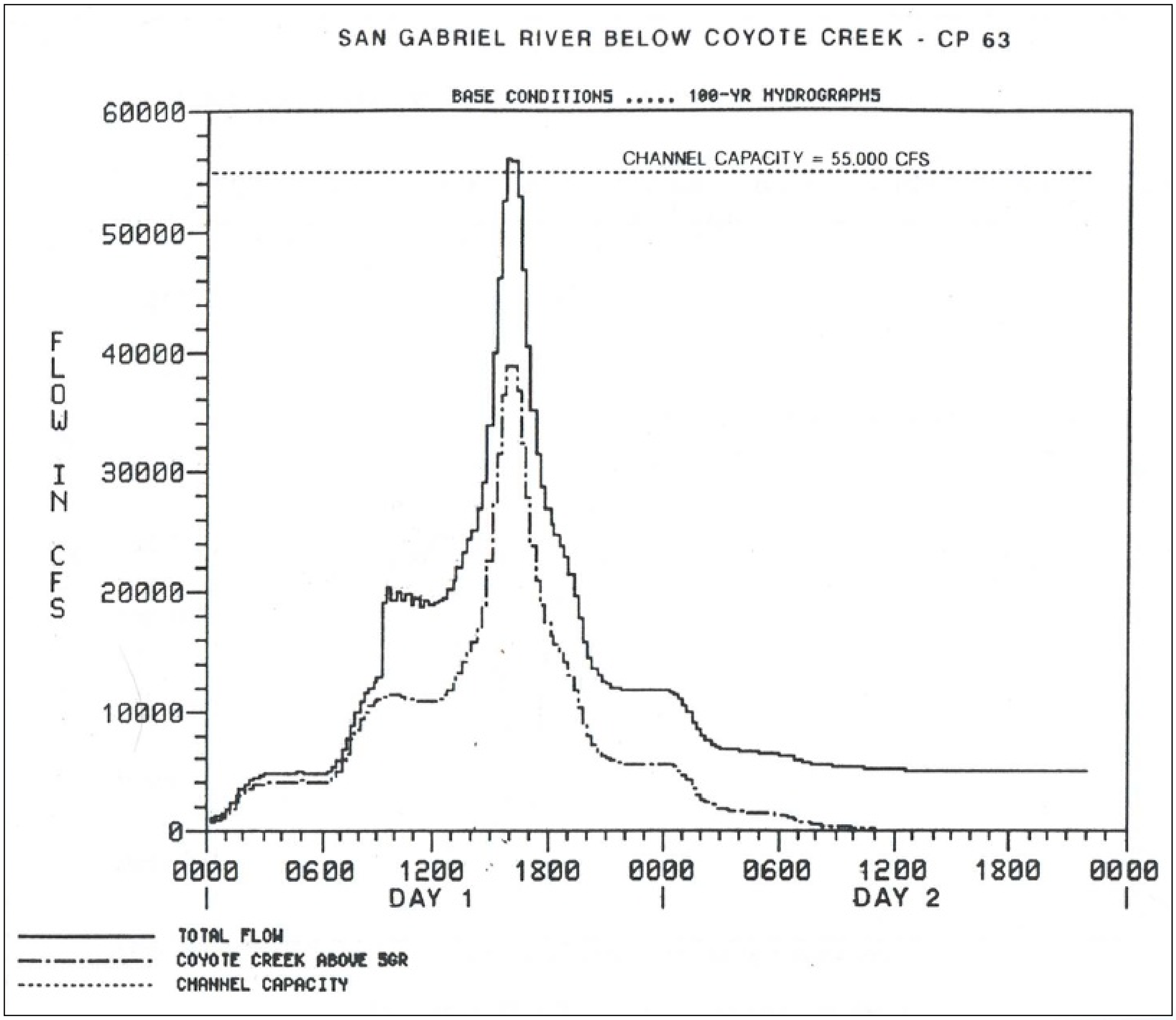

Figure 4-9. Lower San Gabriel River 100-Year Storm Event Hydrograph
(USACE 1991)

4.4.4 Power Plants

Two power plants, namely the AES power plant and Haynes power plant intake cooling water from the Alamitos Bay complex and discharge it into the SGR. The Haynes plant is operated and owned by the LADWP. The AES plant is owned and operated by a private company. The AES power plant intakes cooling water directly from the Los Cerritos Channel and the Haynes plant intakes water from the Haynes Channel. Both plants discharge the heated water back into the SGR. The power plant intakes are modeled as sinks and the power plant discharges are modeled as sources.

The pumping flow rates in 2006 were provided by both AES and Haynes power plants and are shown in Figure 4-10. The pumping rate of the Haynes plant is relatively stable varying from approximately 600 to 1,500 cfs over the year while that of the AES plant varied more from zero to approximately 2,000 cfs over the year. Two scenarios of high and low pumping were identified for modeling to assess the Alamitos Bay circulation patterns and are shown in Figure 4-11.

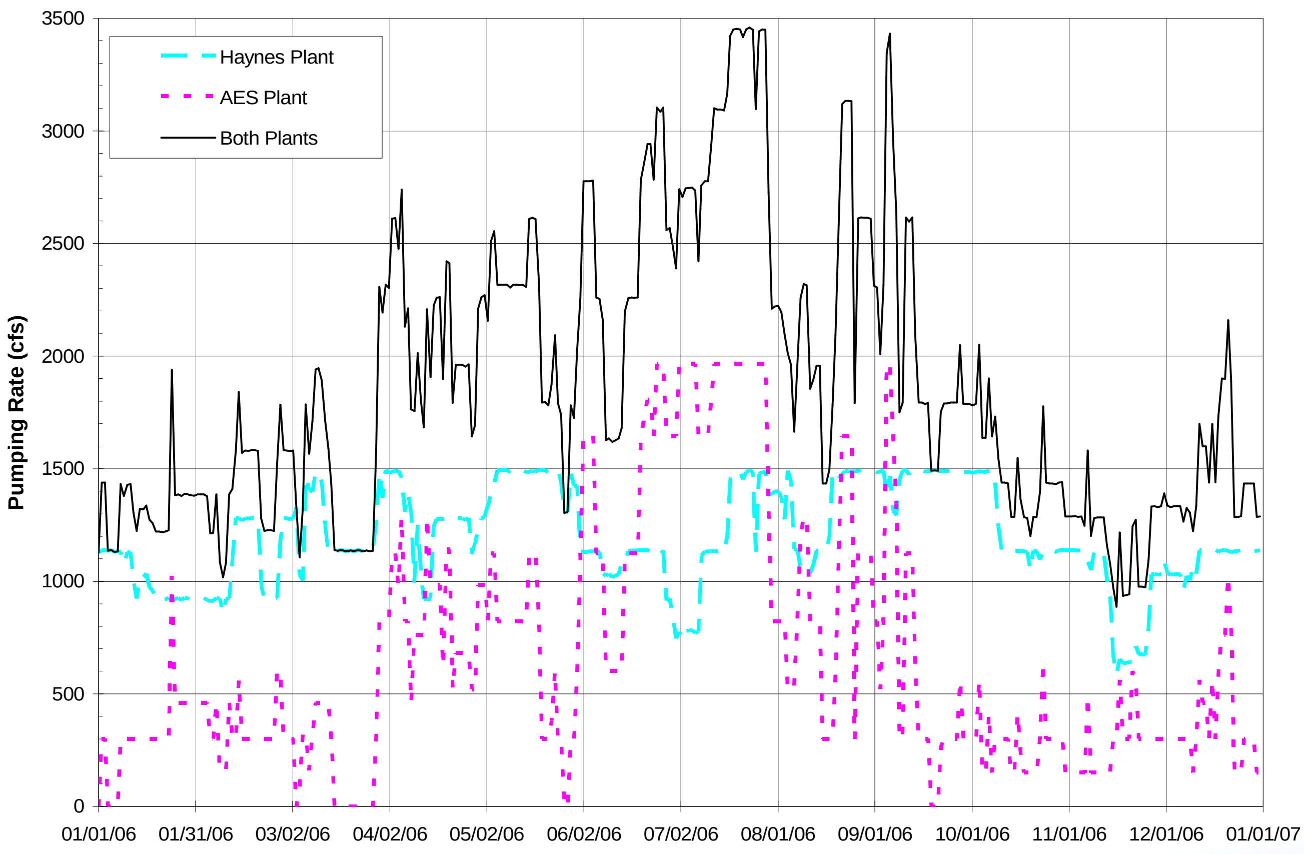

Figure 4-10. 2006 Pumping Rates of the Two Power Plants
(M&N 2007)

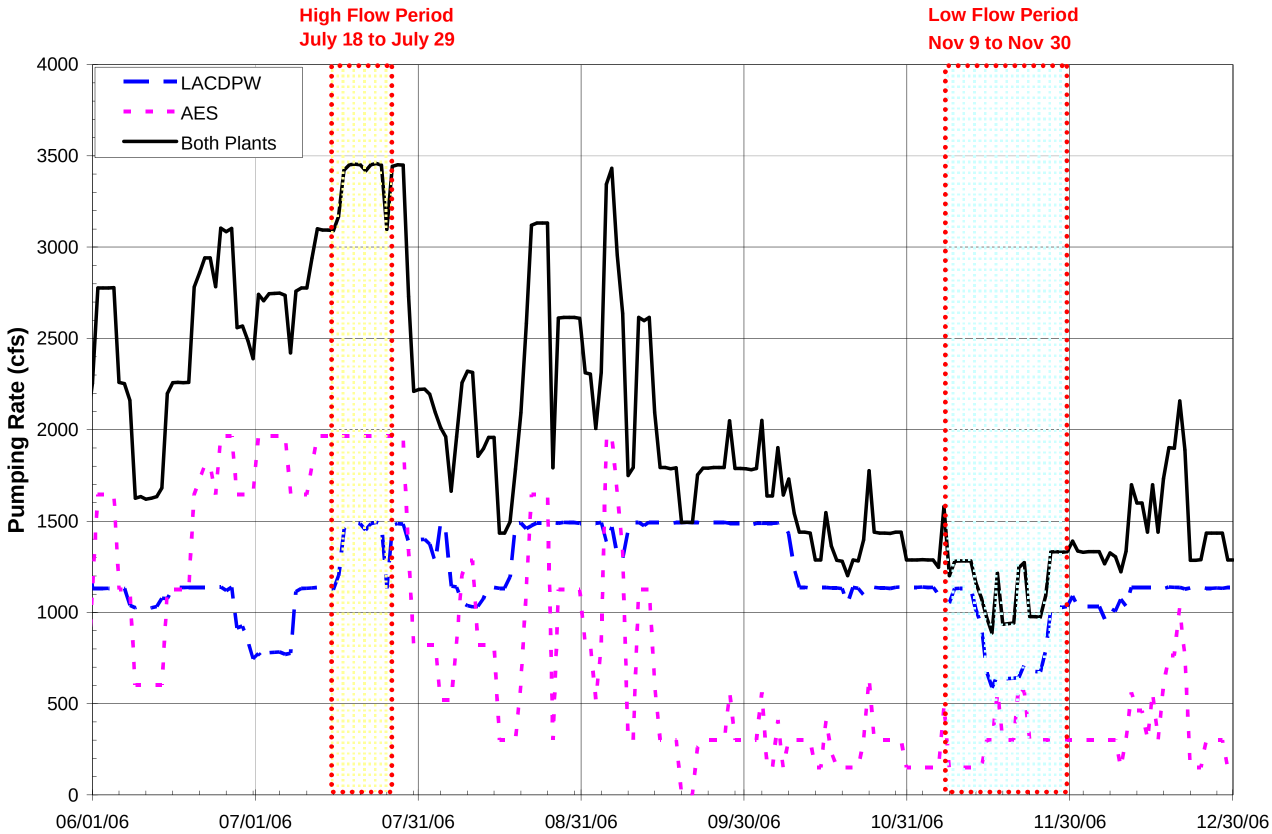

Figure 4-11. High and Low Pumping Rate Periods
(M&N 2007)

4.5 ONGOING AND FUTURE WATERSHED IMPROVEMENTS PROJECTS

The watersheds associated with each of the LCW parcels are described in detail in the separate Task 4 deliverable report. That report summarizes current watershed conditions as well as future watershed improvements and primarily focuses on the water quality implications of the watershed activities for the LCW restoration. These ongoing and future watershed projects could also potentially change the hydraulic conditions within the LCW. These projects include:

- AES Alamitos Generating Station changes to comply with the State-mandated Once-Through Cooling (OTC) Water Policy;
- Haynes Generating Station changes to comply with the State-mandated OTC Water Policy.

As described in the watershed report, the Federal Clean Water Act (CWA) Section 316(b) requires cooling water intake structures to use the best technology available to protect aquatic life. The California State Water Resource Control Board has adopted the OTC Water Policy on the use of coastal and estuarine waters for power plant cooling. The Alamitos and Haynes

Generating Stations are required to comply with the OTC Policy and reduce the intake of seawater. The significant reduction or elimination of the seawater intake from these generating stations will drastically reduce the associated discharges to the SGR and change the circulation pattern of the Alamitos Bay complex.

The AES Alamitos Generating Station has a compliance date of December 31, 2020. AES Alamitos plans to follow Track 1 of the OTC Policy by replacing the six existing units with either simple-cycle or combined-cycle gas turbine generating facilities. The type of cooling system has not been determined yet, but three alternatives are being considered – air-cooled condensers, confidential cooling technology, and closed-cycle mechanical draft cooling tower using reclaimed/ recycled water (AES 2011).

The Haynes Generating Station has a compliance date of December 31, 2013 for Units 5 and 6 and a compliance date of December 31, 2029 for Units 1, 2, and 8. LADWP plans to follow Track 1 and replace the OTC units to dry- or wet-closed cycle cooling, thus eliminating seawater intake. Units 5 and 6 for the Haynes Generating Station will be replaced with six, 100-MW simple cycle gas turbines with dry cooling for inter-stage cooling. Repowering of Units 5 and 6 began in April 2011 with completion anticipated by June 1, 2013. Replacement of Units 1, 2, and 8 will be either a dry- or wet-closed cycle cooling system (LADWP 2011).

5.0 RMA2 MODEL CALIBRATION

RMA2 model calibration involves matching model predictions with measured data by selecting appropriate input parameter values to model [e.g., Manning's roughness coefficient (n) and turbulence exchange coefficients (eddy viscosity)].

The RMA2 User's Manual recommends ranges of values for Manning's roughness coefficient (n) and eddy viscosity to be used in the model (USACE WES, 1996). The value of Manning's roughness coefficient (n) is a function of the characteristics of the hydraulic system and represents the roughness of the channel bed. As discussed in Chaudhry (1993), values can range from 0.011 to 0.075 or higher for natural rivers and estuaries. Relatively high values (0.04 to 0.05) are specified for rough surfaces, such as channels with cobbles or large boulders. Mid-range values (0.03) represent clean and straight natural streams. Low values (0.013 to 0.02) are specified for smooth surfaces, such as concrete, cement, wood, or gunite. Values of Manning's roughness coefficient (n) used for this analysis are in the middle range of the recommended values.

Eddy viscosity represents the degree of turbulence in the flow. In this application, the values range from 50 to 300 lb-sec/ ft^2. The modeling grid size depends on and is limited by the Peclet number and eddy viscosity. The Peclet number is defined as $\frac{r V \Delta X}{E_{ij}}$, in which r, V, DX, and E_{ij} are the water density, velocity, grid size, and eddy viscosity, respectively. In order for the solution to be stable, the Peclet number has to be less than 50. The Peclet number can be reduced by increasing the mesh density or by increasing the eddy viscosity. However, it is unrealistic and time-consuming to perform the modeling with a very fine grid. Therefore, a relatively high value of eddy viscosity is used in order to preserve numerical stability and to streamline the modeling efforts.

5.1 FIELD DATA COLLECTION FOR MODEL CALIBRATION

For previous studies, three tide gauges and two current meters were deployed in January 2007, although one of the current meters malfunctioned. As part of this LCW study, a tide gauge was deployed in the Hellman Channel in July-August 2011. Pending approval by the LADWP, a tide gauge will also be deployed in the Haynes Channel. The descriptions of the gauge types and locations are listed in Table 5-1 and shown in **Figure 5-1**.

Table 5-1. Gauge System and Locations

Data Type	Gauge Location
Currents	Mother's Beach (malfunctioned)
	2nd Street Bridge @ Bayshore
Water Levels (Tides)	Alamitos Bay Entrance
	Los Cerritos Channel @ 7th Street
	San Gabriel River @ 2nd Street
	Hellman Channel

The tide gauges are small cylindrical pressure transducers manufactured by Richard Branckar Research that record water levels. The two current meters are spherically-shaped and self-contained InterOcean S-4DW current measuring sensors. The S-4DW is designed to measure the magnitude and direction of horizontal currents in any water environment. The recorded water levels and current velocities are used to calibrate the model.

Figure 5-1. Gauge Locations
(Aerial Photograph Source: Google Earth)

As seen in Figure 5-2, the tide gauge placed in Hellman Channel indicates the Hellman Channel low water levels are significantly muted in comparison to the open ocean tides.

Tide gauges and current meters were also previously deployed in the Los Cerritos Channel near the AES power plant intake location (M&N 1999) to assess whether the ocean migration of juvenile fish would be hampered by AES pumping operations. The results showed a dominant flood tide condition (water draw into the AES station to the north) and that ebb currents (water flow to the south) are rare. No tidal muting, relative to ocean tides, was observed.

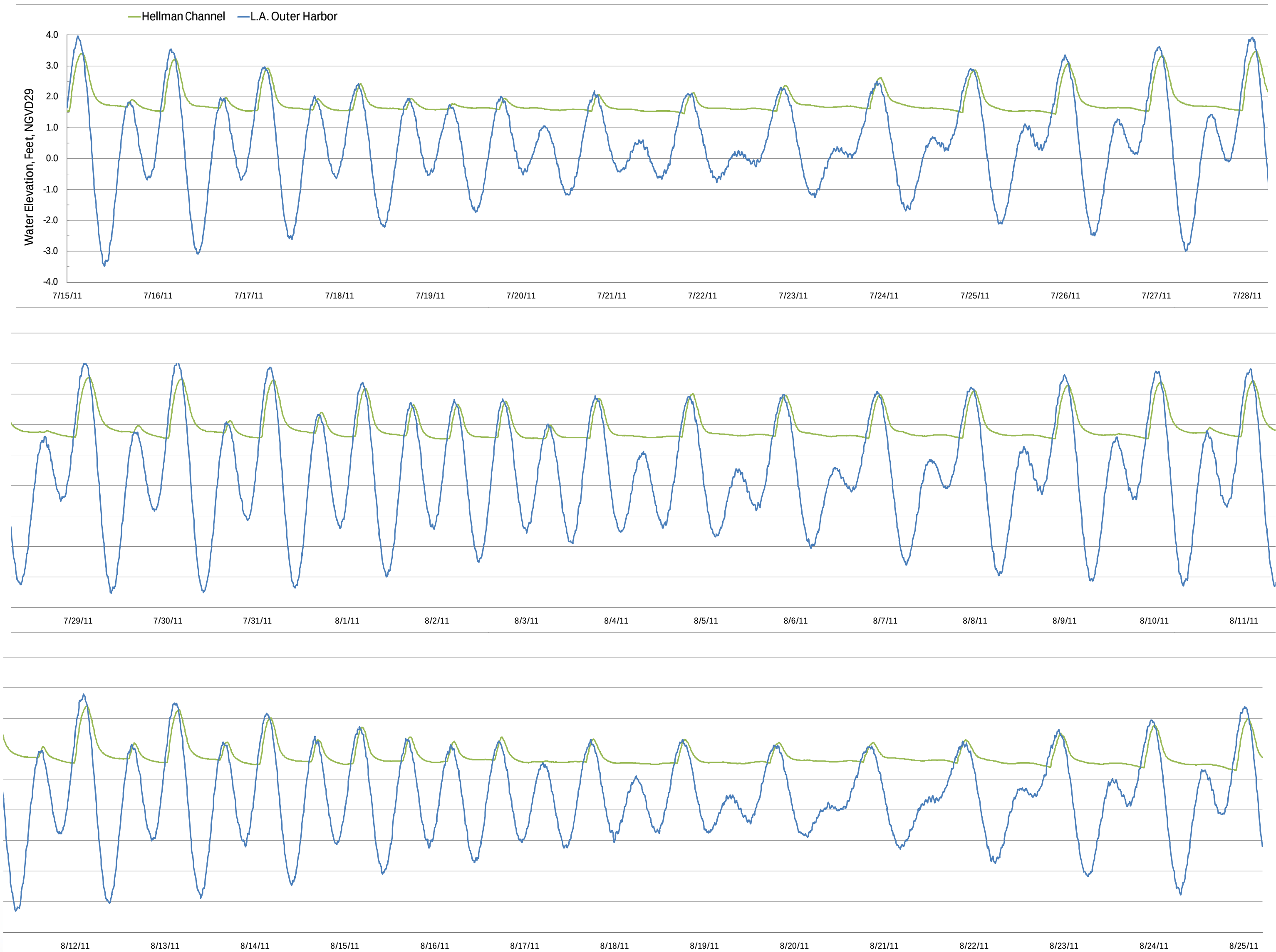

Figure 5-2. Hellman Channel Tide Gauge Data

(Hellman Channel in Green, Ocean Tides in Blue)

5.2 BOUNDARY CONDITIONS FOR MODEL CALIBRATION

Boundary inputs for the RMA2 hydrodynamic model include the ocean tides and intake pumping flow rates of the two power plants. Tides measured at the L.A. Outer Harbor tide station (NOAA 2004) during the Alamitos Bay study field work period, between January 10 and 31, 2007, were applied in the RMA2 model boundary. The water level time series is shown in Figure 5-3 as a solid black line. The two magenta lines in Figure 5-3 show the intake pumping flow rates by the two power plants. The values of flow rate are shown in the right hand y-axis of the plot. During this field work period, the Haynes plant was pumping approximately 1,150 cubic feet per second (cfs) and the AES was pumping between 150 and 300 cfs.

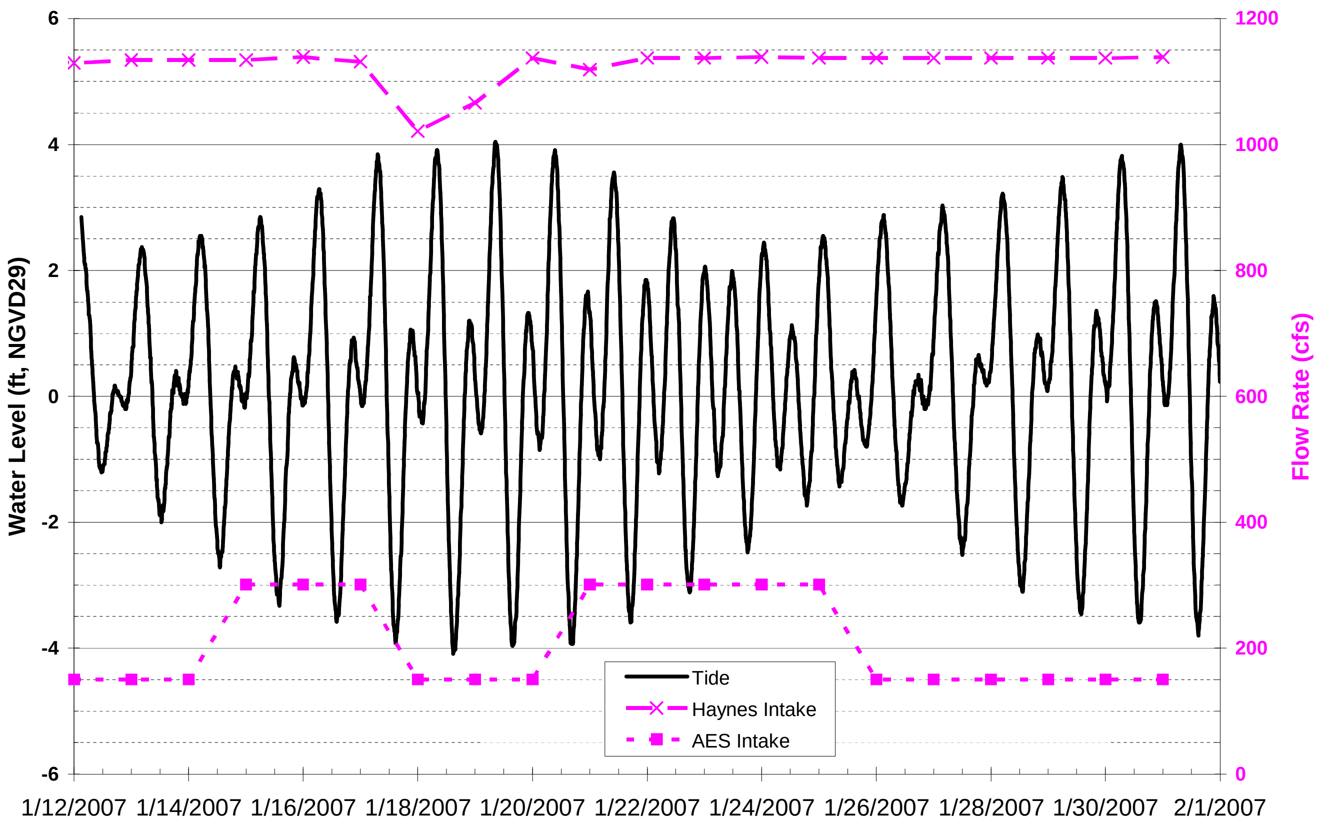

Figure 5-3. Boundary Input Data for Model Calibration
(M&N 2007)

5.3 MODEL CALIBRATION RESULTS

The measured tidal elevations were compared with the model-predicted tidal elevations. Figure 5-4 through Figure 5-6 show the water level comparisons at Alamitos Bay entrance, Los Cerritos Channel under the 7th Street Bridge, and the SGR under the Westminster Street Bridge, respectively. The measured water levels and their phases matched very well with the model-simulated tides, except for an anomaly in the SGR gauge, in which the recorded water level shifted upward after 10-days of the record due to gauge malfunction. However, the first 10-days of the record were sufficient for calibrating the model at the SGR location.

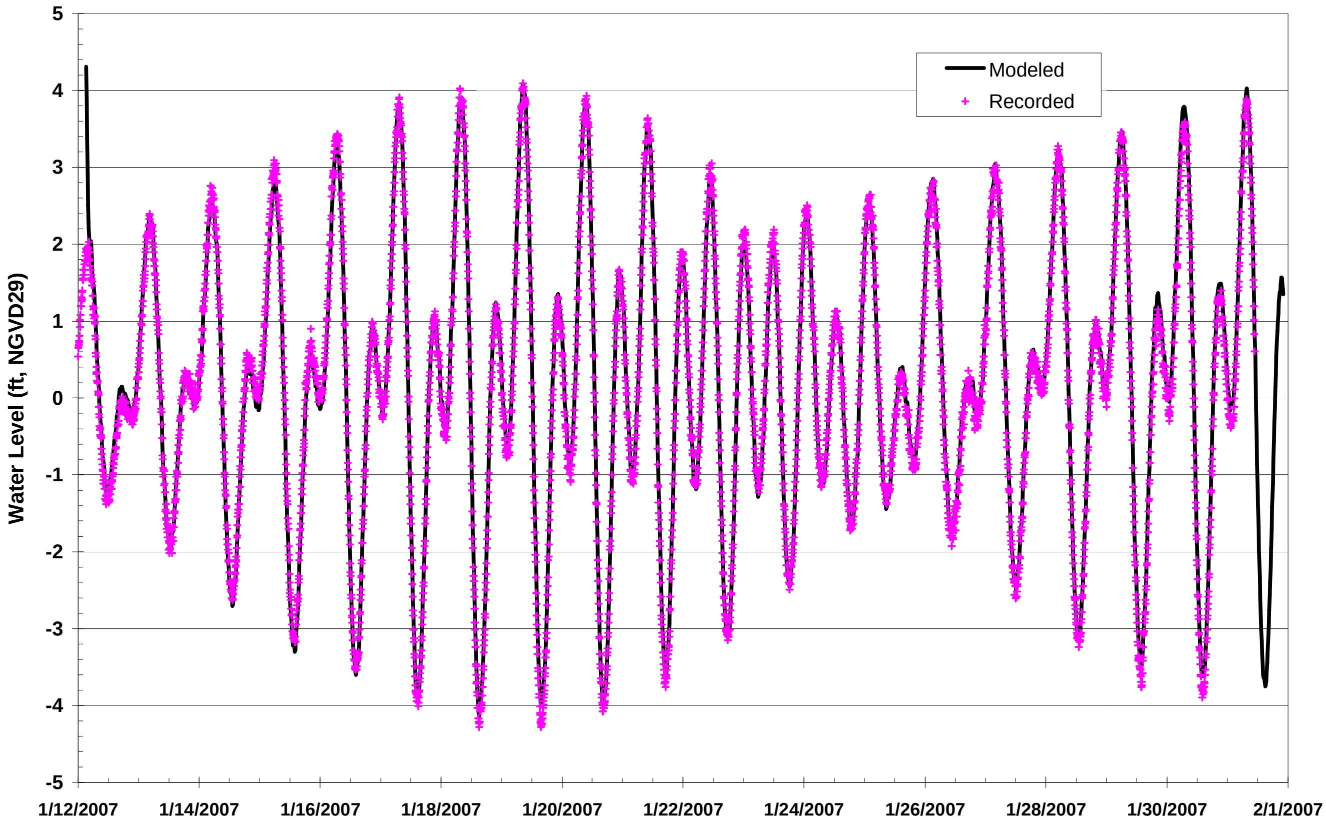

Figure 5-4. Water Level Comparison at Alamitos Bay Entrance
(M&N 2007)

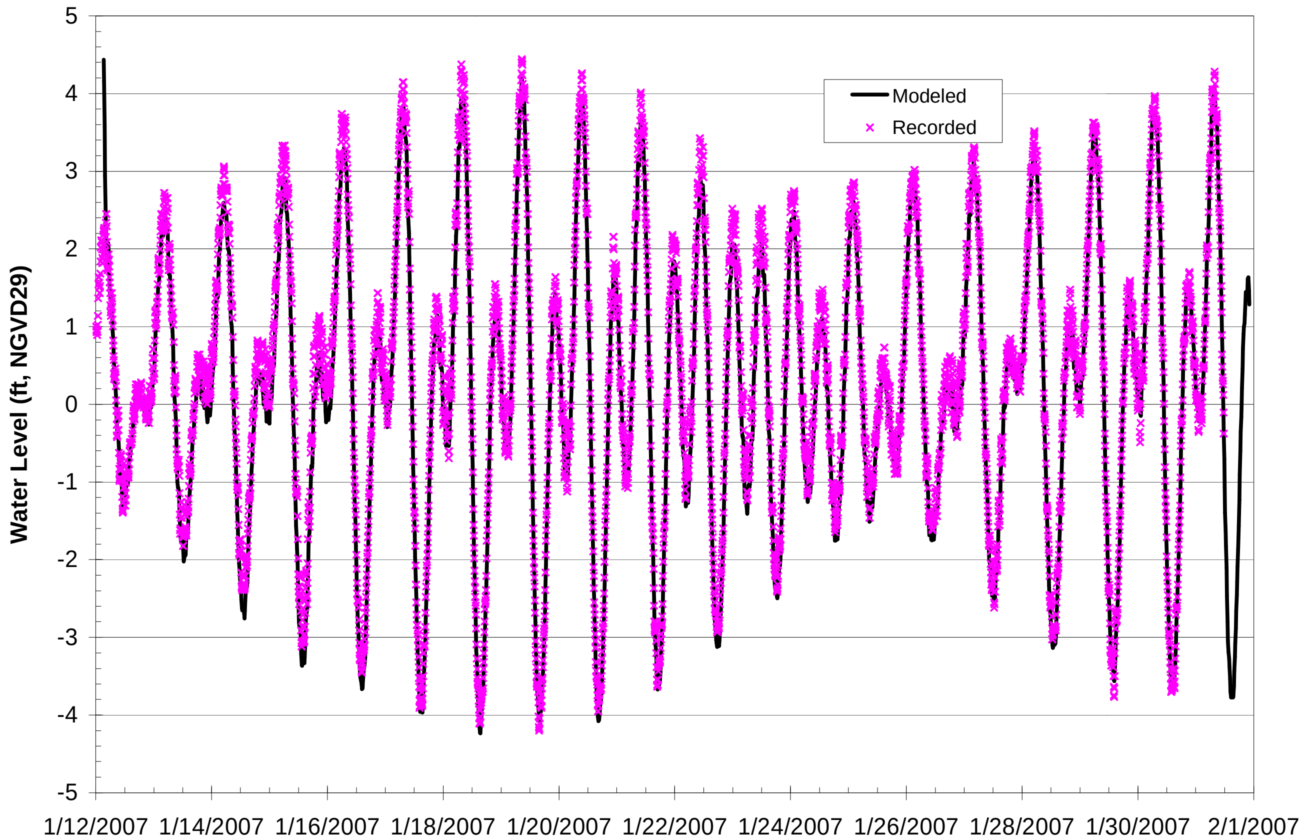

Figure 5-5. Water Level Comparison at Los Cerritos Channel at the 7th Street Bridge
(M&N 2007)

As can be seen in Figure 5-6, and as observed by M&N (1996), the water levels in the SGR closely match ocean tides during dry-weather conditions. It is also worth noting though that data collected by the U.S. Geologic Survey (USGS 2007) show that in the warm, dry summer season, the flow/ velocity/ salinity/ temperature in the SGR estuary is dominated by the cooling water discharges from the natural-gas power generating station.

Literature (e.g. M&N 1996 and Flow Sciences 2009) suggests that the water levels in the Haynes Cooling Channel also closely match ocean tides as the intake structure from Alamitos Bay is large enough so as to not restrict tidal flows. This will be confirmed via the future deployment of a tide gauge in the Haynes Channel, upon approval of LADWP.

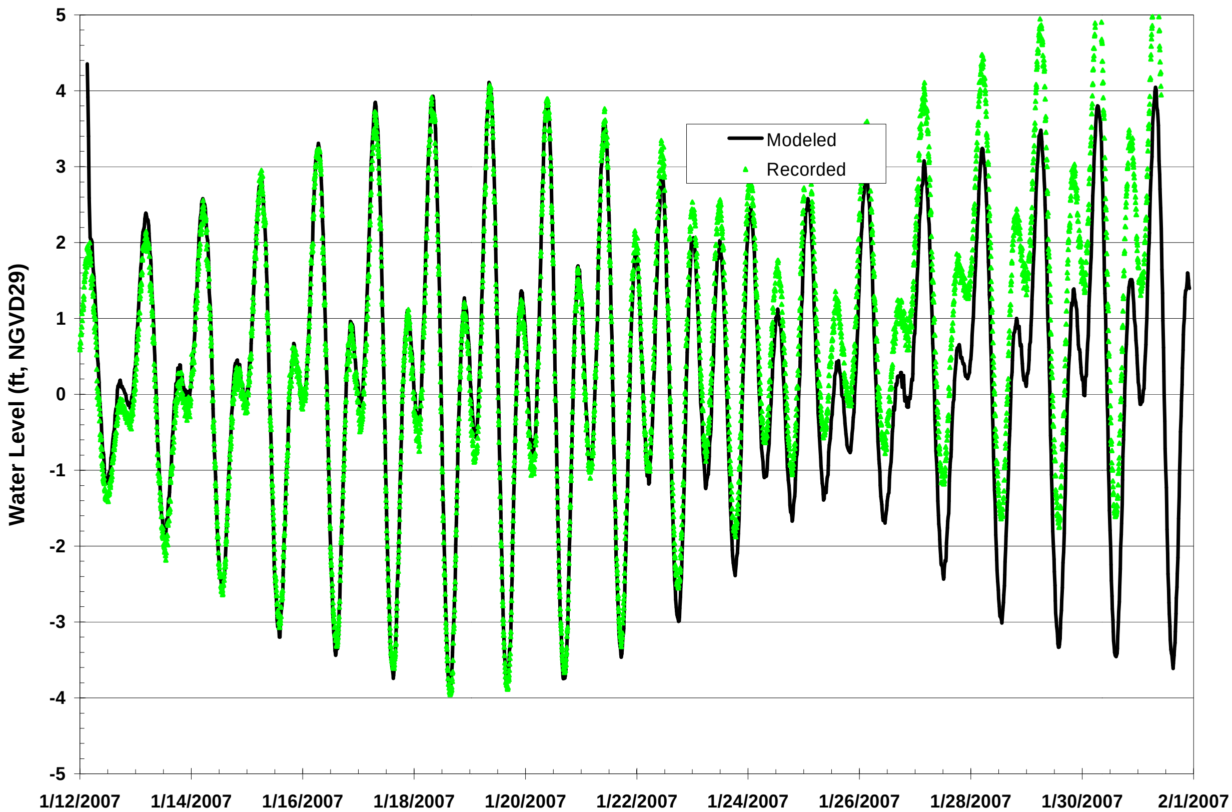

Figure 5-6. Water Level Comparison at San Gabriel River at Westminster Street Bridge
(M&N 2007)

Two S-4ADW current meters were deployed at Mother's Beach and 2nd Street @ Bayshore as shown in Figure 5-1. The meter at Mother's Beach malfunctioned. The measured currents at 2nd Street-Bayshore were compared with the model-simulated currents and are illustrated in Figure 5-7. The current meter recorded currents in the channel about one foot above the channel bed. The model-simulated currents are vertically averaged velocities in the middle of the channel. Current ranges and phases generally matched well. As the measured and predicted tidal conditions and current conditions matched well, it was concluded that the data missing from Mother's Beach were not critical to the study and analyses could be done using model-predicted data.

The modeling parameters, including roughness coefficients and turbulence eddy viscosities, used in the model calibration are shown in Table 5-2. The turbulence eddy viscosity varies with the flow situations. Under a higher power plant pumping condition, the turbulence is stronger than that under a low power plant pumping scenario. These changes were reflected in the scenario model simulations.

The time step is a very important parameter in the modeling. Sensitivity tests were conducted and results showed that the RMA2 model becomes unstable with an increasing time step if the wetting and drying processes are considered. A time step of 0.1 hour was used in order for the solution to be stable and to reflect the dynamic tidal fluctuations.

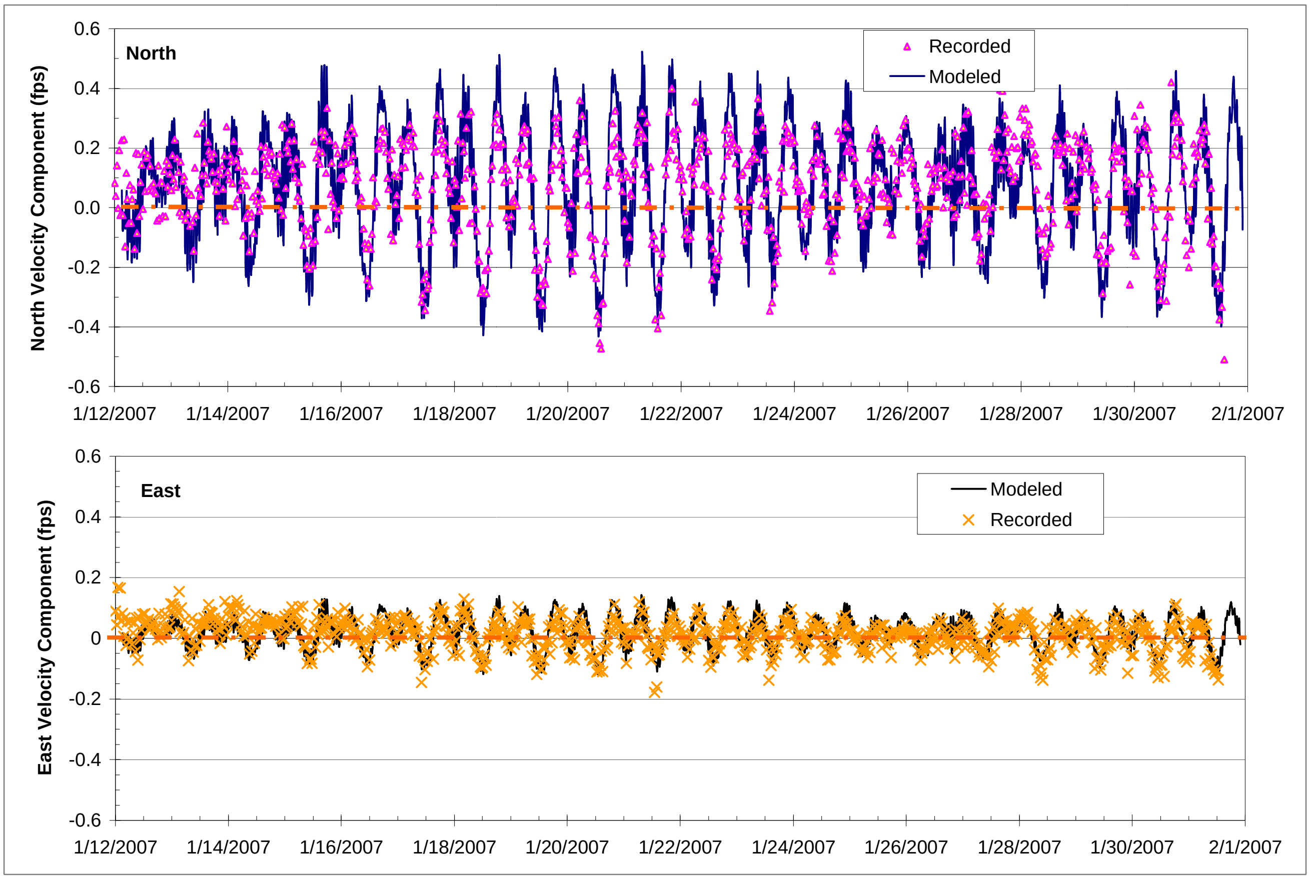

Figure 5-7. Currents Comparison at 2nd Street @ Bayshore
(M&N 2007)

Table 5-2. Setup Values for Model Calibration
(M&N 2007)

Modeling Area	Manning's Roughness Coefficient (n)	Eddy Viscosity Coefficient (lb-sec/ ft2)
Lagoon Intertidal Areas	0.037	100
Lagoon Subtidal Areas	0.03	50
Marine Stadium Intertidal Areas	0.035	100
Narrow Channels and Marinas	0.025	75
Marine Stadium Subtidal & Alamitos Bay Areas	0.025	300
Nearshore Surf Zone	0.030	60
Offshore of the Surf Zone	0.02	80

6.0 INITIAL MODELING RESULTS

The calibrated model will be used to assess the hydraulic conditions of each LCW restoration alternative as part of the future Task 12. This section discusses the modeling results from the previous Alamitos Bay Circulation Study (M&N 2007) which may be relevant to this LCW study.

In the Alamitos Bay Circulation Study, the calibrated RMA2 numerical model, together with the RMA4 water quality model, were applied to evaluate the hydrodynamic circulation conditions under five scenarios. These scenarios were:

1. High power plan pumping rates, intended to determine the best hydraulic circulation condition in Alamitos Bay in 2006.
2. Relatively poorer hydraulic circulation condition within Alamitos Bay in late summer of 2006.
3. Potentially worst-case circulation condition in the future if the AES plant were no longer pumping water from Alamitos Bay and the Haynes plant were pumping at its minimum typical pumping rate. The lowest pumping rate for 2006 of 600 cfs at the Haynes plant was assumed for this scenario.
4. Reasonable minimum AES pumping rate that the plant would have to maintain to induce a net water movement from Mother’s Beach to upstream areas. For the Haynes plant, the lowest pumping rate of 600 cfs in 2006 is applied for this model simulation.
5. New tidal inlet connecting the ocean to Alamitos Bay at the north side of Treasure Island near 54th street.

The first two scenarios are the highest and lowest power plant pumping rate conditions for 2006, assumed to represent the pattern of annual high and low pumping rates, respectively. Scenario 3 most closely replicates the likely future condition wherein the AES and Haynes power plants no longer intake cooling water in compliance with the State-mandated OTC Water Policy.

For each scenario, residence time was calculated at various nodes within the model (example shown in Figure 6-1). Table 6-1 summarizes the water residence times under the five different modeling scenarios.

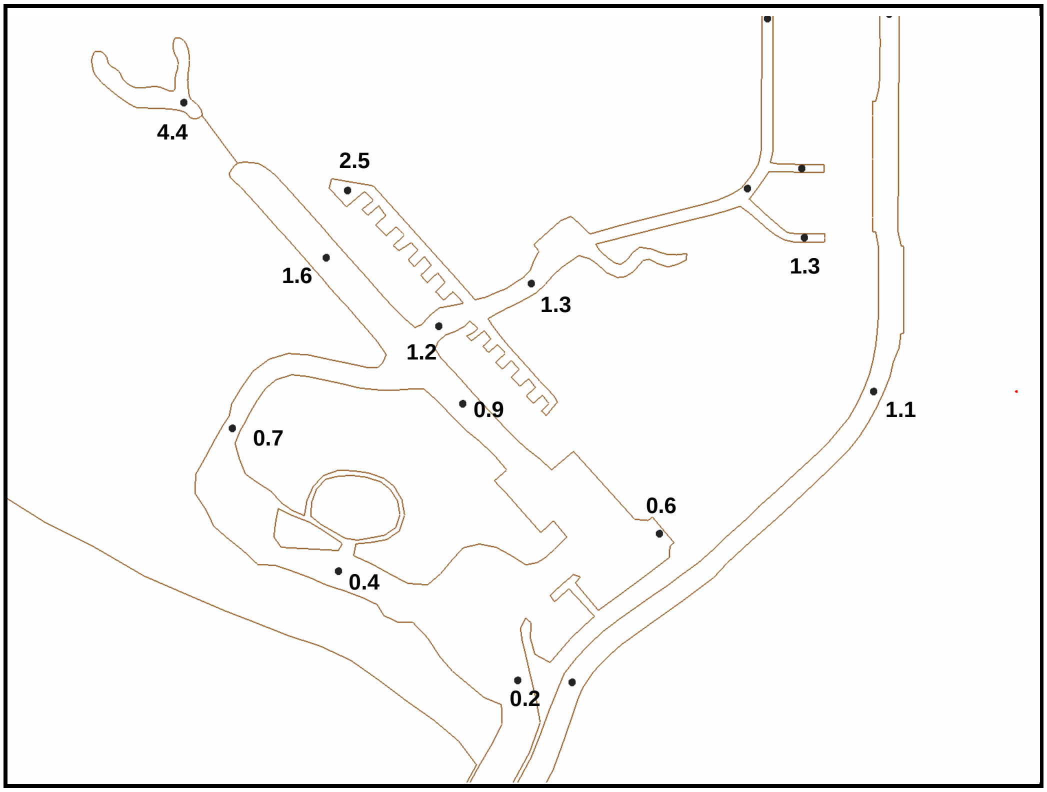

Figure 6-1. Example Result - Alamitos Bay Circulation Study – Residence Time (Days)

Table 6-1. Residence Time Summary

Scenarios	Description	Residence Time (Days)		
		San Gabriel River	Mother's Beach	2nd St.-Bayshore
Scenario 1	High Flow Pumping Period in 2006	1.1	0.9	0.7
Scenario 2	Low Flow Pumping Period in 2006	3.8	4.8	2.8
Scenario 3	No Pumping at AES and 600 cfs Pumping at Haynes	4.1	9.5	5.4
Scenario 4	600 cfs Pumping @ both AES and Haynes	2.8	2.8	2.2
	600 cfs Pumping @ AES and 1,500 cfs @ Haynes	1.8	1.9	1.4
Scenario 5	A New Inlet, No Pumping at AES and 600 cfs Pumping at Haynes	4.1	6.5	2.9

The results of the Alamitos Bay Circulation Study (M&N 2007) led to the following findings:

- The dominant existing circulation pattern is generally that water flows up (north) along both the Haynes and Los Cerritos Channels and then down to the ocean via the SGR.
- The water residence times are shortest and the circulation is the most efficient under Scenario 1 while both power plants are pumping at their maximum capacities.
- The water residence times are longest under the low or no pump scenarios at the AES power plant, and while the Haynes Plant is pumping at its annual low capacity of 600 cfs. The modeling indicates that aging water from upper Alamitos Bay (Colorado Lagoon and Spinnaker Bay) would frequently move downstream past Mother's Beach toward the Haynes intake and the ocean during ebbing tides.
- The pumping rate at the AES power plant has the most significant impact on circulation in Alamitos Bay since it removes some of the aging and poor quality water from upstream areas of the Bay and discharges it into the SGR. Otherwise, the poor-quality water would all circulate downstream past Mother's Beach toward the Haynes intake and the ocean during ebbing tides.
- A minimum pumping rate of 600 cfs at the AES plant is required to create a net upstream flow direction at Mother's Beach toward the Los Cerritos Channel.
- Constructing a second inlet into Alamitos Bay near 54th Street slightly reduces residence times, but is only marginally better than Scenario 3 (no pumping at the AES plant), and is therefore is a limited enhancement to circulation within the Bay.
- Scenarios 1 (maximum pumping) and 4 (maintain pumping of 600 cfs) are the optimum scenarios evaluated in this study for improving circulation at Alamitos Bay and water quality at Mother's Beach.

7.0 SUMMARY

Hydraulic and hydrologic conditions of the LCW area are known and documented in this report. These conditions vary tremendously over the site because the hydraulic system is complex. It varies from fully tidal systems to muted tidal systems and non-tidal systems.

The main components of the hydraulic system are waterbodies on or adjacent to the LCW complex and connections from waterbodies to the site. Adjacent waterbodies include Alamitos Bay, the SGR, and the Haynes and Los Cerritos Channels, all connected to the nearshore ocean, while on-site waters include the Hellman Channel, Zedler Marsh, and runoff and perched groundwater on-site in other areas.

Conditions are complicated by effects of the San Gabriel River on water levels from flood routing, and from effects of pumping associated with power plants. Pumping by upstream power plants affects flow directions and dictates that some channels (Los Cerritos and Haynes Channels) flow only upstream, while constant effluent released to the SGR causes it to flow constantly downstream. Also, certain connections (Haynes Channel and Alamitos Retarding Station outlets) are siphons under existing channels that further complicates the flow pattern.

To represent this complexity, a hydrodynamic finite element model of the existing system has been developed and calibrated for a previous project (M&N 2007) using measured field data and applied to this project. This model represents the significant hydraulic features of the LCW complex, i.e. the SGR, Alamitos Bay, Marine Stadium, Colorado Lagoon, Los Cerritos Channel, Haynes Channel, Hellman Channel, the nearshore ocean, as well as other culvert connections to/from the existing LCW areas. It is capable of simulating tidal conditions, various power plant pump operating scenarios, storm events, and SLR. It is a powerful tool capable of fully representing future conditions for analyses of restoration alternatives, which will be done as part of the future Task 12. Each alternative will be assessed for tidal range, tidal inundation frequency, circulation patterns, flood levels, SLR, and potentially residence time.

General hydrology conditions are characterized as full tidal areas, muted tidal areas, and non-tidal areas. Full tide ranges exist in Alamitos Bay, SGR, and Haynes Channel. These waterbodies would likely be water sources for this restoration project and therefore full tidal restoration of certain areas may be possible. The LCWA Phase 2 and Phase 1 properties receive muted tidal circulation via the Hellman Channel and Zedler Marsh culvert connections, respectively, to/from the SGR. Restoration may be constrained if existing culverts are used for tidal connections. No tidal action occurs at the Marketplace Marsh and northern portion of the LCWA Phase 1 properties. These sites are typified by high ground water and impounded surface runoff or rainwater.

The dominant existing circulation pattern is generally that water flows upstream (north) along both the Haynes and Los Cerritos Channels and then downstream to the ocean via the SGR as tides. However, this circulation pattern is expected to change upon the AES and Haynes Generating Stations implementation of OTC Water technology.

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