One Water LA

LA Sanitation environment
CITY OF LOS ANGELES

LA DWP

City of Los Angeles — Founded 1781

ONE WATER LA 2040 PLAN

VOLUME 6

Climate Risk Assessment for Wastewater and Stormwater Infrastructure

FINAL DRAFT | APRIL 2018

One Water LA

CITY OF LOS ANGELES

ONE WATER LA 2040PLAN

VOLUME 6

Climate Risk and Resilience Assessment for Wastewater and Stormwater Infrastructure

FINAL DRAFT • APRIL 2018

This document is released for the purpose of information exchange review and planning only under the authority of
Sarah Deslauriers • April 30, 2018
State of California • PE License No. 82613

ch2m

IN COLLABORATION WITH:

carollo

READER GUIDE

SUMMARY OF ONE WATER LA

The One Water LA 2040 Plan (Plan) takes a holistic and collaborative approach to consider all of the City's water resources from surface water, groundwater, potable water, wastewater, recycled water, dry-weather runoff, and stormwater as "One Water." The Plan also identifies multi-departmental and multi-agency integration opportunities to manage water in a more efficient, cost effective, and sustainable manner. The Plan represents the City's continued and improved commitment to proactively manage all its water resources and implement innovative solutions, driven by the Sustainable City pLAn. The Plan will help guide strategic decisions for integrated water projects, programs, and policies within the City.

PLAN ORGANIZATION

The One Water LA 2040 Plan consists of the following ten volumes:

- VOLUME 1 - Summary Report
- VOLUME 2 - Wastewater Facilities Plan
- VOLUME 3 - Stormwater and Urban Runoff Facilities Plan
- VOLUME 4 - LA River Flow Study
- VOLUME 5 - Integration Opportunities Analysis Details
- VOLUME 6 - Climate Risk & Resilience Assessment for Wastewater and Stormwater Infrastructure
- VOLUME 7 - Implementation Strategy Supporting Documents
- VOLUME 8 - Technical Support Materials
- VOLUME 9 - Stakeholder Engagement Materials
- VOLUME 10 - Programmatic Environmental Impact Report

The information presented in this Volume (Volume 6) only includes the One Water LA Technical Memorandum 5.5 (TM 5.5.) that was prepared to document the climate risk and resilience assessment that was conducted for the City's wastewater and stormwater infrastructure. The purpose of this assessment is to summarize observed climate and trends, the most current climate science and projections and climate change assessments initiated in the region, and provide an assessment and recommendations for wastewater and stormwater infrastructure resilience through 2040.

In addition, information presented in this volume is summarized and referenced in:

- Chapter 7 and 8 of the Summary Report (Volume 1)
- Wastewater Facilities Plan (Volume 2)
- Stormwater and Urban Runoff Facilities Plan (Volume 3)

VOLUME 6 OVERVIEW & ORGANIZATION

An overview of information presented in this volume is provided in the table below.

Section No. and Name		Content Overview
ES	Executive Summary	Executive summary to the entire volume (TM 5.5) that focuses on key findings, conclusions, and recommendations/strategies.
1	Introduction	Provides an introduction to the Climate Risk and Resilience Assessment for Wastewater and Stormwater Infrastructure.
2	Summary of Historical and Potential Future Climate Conditions	Reviews and summarizes climate science, climate projections, and existing climate impact assessments (expanding on the summary of expected future conditions described in TM 2.2).
3	Climate Risk and Resilience Assessment and Recommendations	Identifies and evaluates adaptation options and strategies based on vulnerability assessments conducted for existing wastewater and stormwater infrastructure and systems.
4	Implementation Recommendations	Documents the climate change assessment implementation recommendations and provides material for use in the Los Angeles Sanitation's (LASAN) Climate Adaptation Plan.
Appendices		Provides supporting appendices (i.e., references, historical and potential future climate conditions, consequence categories and level descriptions, replace-in-kind and resilience improvement cost methodologies, facility risk assessment and adaptation summary sheets, and EPA Los Angeles Sanitation Climate Change Risk Assessment and Adaptation.

CITY OF LOS ANGELES

First Draft:	4/3/2017
Final Draft:	6/26/2017
Final:	8/14/2017
Lead Author:	Bill McMillin

TECHNICAL MEMORANDUM NO. 5.5
CLIMATE RISK AND RESILIENCE ASSESSMENT FOR WASTEWATER AND STORMWATER INFRASTRUCTURE

FINAL
August 2017

707 WILSHIRE BOULEVARD, SUITE 3920 • LOS ANGELES, CALIFORNIA 90017 • P. 213.489.1587 • F. 213.489.1500

CITY OF LOS ANGELES

TECHNICAL MEMORANDUM
NO. 5.5
CLIMATE RISK AND RESILIENCE ASSESSMENT
FOR WASTEWATER AND STORMWATER INFRASTRUCTURE

TABLE OF CONTENTS

Page No.

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviation	Description
°C	degrees Celsius
°F	degrees Fahrenheit
AAWRE	American Academy of Water Resources Engineers
ASCE	American Society of Civil Engineers
AWPF	Advanced Water Purification Facility
BFE	base flood elevation
BMPs	Best Management Practices
CAL FIRE	California Department of Forestry and Fire Protection
Cal OES	California Office of Emergency Services
CCTAG	Climate Change Technical Advisory Group
CDBG	Community Development Block Grant
CIP	Capital Improvement Plan
City	City of Los Angeles
CMOM	capacity management, operations, and maintenance
CoSMoS	Coastal Storms Modeling System
CREAT	Climate Resilience Evaluation and Awareness Tool
DCTWRP	Donald C. Tillman Water Reclamation Plant
DFE	design flood elevation
EPA	Environmental Protection Agency
EPP	Effluent Pumping Plant
FEMA	Federal Emergency Management Agency
FIRMs	flood insurance rate maps
FMA	Flood Mitigation Assistance
GCM	general circulation model
GI	green infrastructure
GIS	Geographic Information System
gpm	gallons per minute
HMA	Hazard Mitigation Assistance
HMGP	Hazard Mitigation Grant Program
HUD	Housing and Urban Development
HWRP	Hyperion Water Reclamation Plant
I/I	inflow and infiltration
IBC	International Building Code
IDF	intensity, duration, and frequency
IPCC	Intergovernmental Panel on Climate Change
IPS	intermediate pump station
IRP	Integrated Resources Plan
kW	kilowatt
LADWP	Los Angeles Department of Water and Power
LAGWRP	Los Angeles-Glendale Water Reclamation Plant

Abbreviation	Description
LASAN	Los Angeles Sanitation
LFD	low flow diversion
LFTF	low flow treatment facilities
LOCA	localized constructed analogs
MCC	motor control center
mgd	million gallons per day
N/A	not applicable
NFHL	National Flood Hazard Layer
NOAA	National Oceanic and Atmospheric Administration
NPCC	New York City Panel on Climate Change
NPDES	National Pollutant Discharge Elimination System
NYCDEP	New York City Department of Environmental Protection
O&M	operations and maintenance
PA	Public Assistance Grant Program
PDM	Pre-Disaster Mitigation
RAS	return activated sludge
RPA	Request for Public Assistance
SLR	sea level rise
SOP	Standard Operating Procedure
SW	stormwater
TDS	total dissolved solids
TIWRP	Terminal Island Water Reclamation Plant
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VAPP	Venice Auxiliary Pumping Plant
WARN	Water/Wastewater Agency Response Network
WW	wastewater

-This Page Left Blank Intentionally-

EXECUTIVE SUMMARY

ES.1 BACKGROUND

For the first time, the City of LA has taken an in-depth look and evaluation of the vulnerabilities associated with climate change and the impacts to stormwater and wastewater infrastructure. The evaluation of climate change impacts projected through 2040 consisted of:

- Performing climate risk assessments on stormwater and wastewater assets
- Developing adaptation strategies using EPA's Climate Resilience Evaluation & Awareness Tool (CREAT)
- Providing input on and recommendations for existing designs to integrate climate resiliency

The goal is to develop resilient water infrastructure in the face of a changing climate. To do this, the City's risk zones were identified based on their level of vulnerability and the projected climate threats each zone would face. It was recognized early on that recommendations for design and construction would be needed in order to ultimately have resilient water infrastructure. The focus for this particular study is on the City's stormwater and wastewater infrastructure, as comparable efforts have already been developed by Los Angeles Department of Water and Power (LADWP) on potable water infrastructure.

The key question to answer through this study is: How do future climate conditions impact the City's stormwater and wastewater assets through 2040?

The first step was to identify the baseline conditions for assessing threats and risks in the City of LA, which are:

- Temperature Increase
- High Winds
- Precipitation
- Sea Level Rise
- Earthquake
- Tsunami

The next step was to determine the related threats and risks, listed in Table ES.1.

Table ES.1 Characterization of Asset Threats and Risks
One Water LA 2040 Plan – TM 5.5

Threats To Assets	Risks To Assets
Power Outages During Peak Demand	Property/Structural/Equipment Damage
Severe Drought/Water Rationing	Loss of Power
More Frequent & Intense Wild Fires	Interrupted Service and Process Operations
Mudslides/Landslides	Emergency Fuel Depletion
Localized Flooding/Erosion	Inundation/Loss of Access
Coastal Flooding/High Tides/Storm Surges	Regulatory Non-Compliance
Prolonged Power Outage/Lack of Fuel	Loss of Revenue

Tasks completed by the Climate Resiliency team are summarized on Figure ES.1.

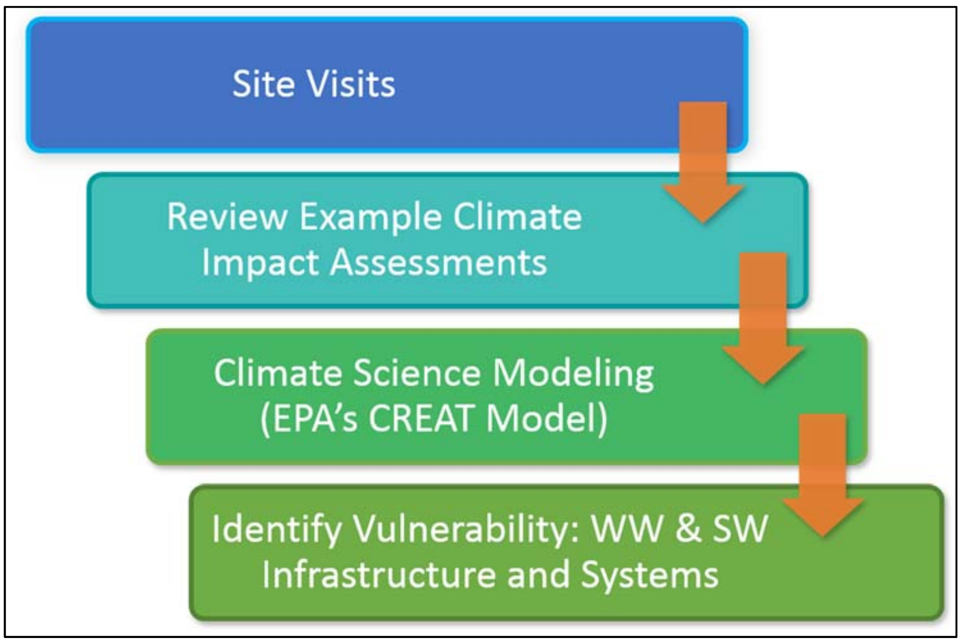


Figure ES.1 Summary of Climate Resiliency Steps Completed

Approximately 80 facilities were assessed:

- 4 water reclamation plants
- 43 wastewater pumping plants
- 11 stormwater pumping plants
- 20 low flow diversion (LFD) facilities
- 3 future facilities

Of the facilities assessed, 42 existing pumping plants were determined to have no or minimal hazards. The results are summarized in Technical Memorandum (TM) 5.5 in this Volume. Of the remaining assets that were identified to have hazards the specific hazards, as well as their risks and threats identified. Below are examples of a treatment plant and a pumping plant. Hazards that were identified for all treatment plant assets are as follows:

- 500-year Flood Zone (Elevation: 12.25 feet)
- Tsunami (Elevation: ~20 feet)
- Sea level rise of 0.5-1.5 meter based on Coastal Storms Modeling System (CoSMoS) (Elevation: 11.64 – 14.92 feet)

Based on the hazards identified there were damage threshold elevations:

- Door Elevation: 11.17 feet
- Generator Pad Elevation: 11.89 feet

These damage threshold elevations were used to determine if any of the treatment plants had assets that were at risk.

ES.1.1 Treatment Plant Example

Using the October 2016 U.S. Army Corps of Engineers (USACE) Hydraulics Report for updated Federal Emergency Management Agency (FEMA) flood insurance rate maps (FIRM)s, a new hydraulic modeling of 100- and 500-year Los Angeles River flooding was completed with the following results/issues identified at one of the City's treatment plants.

- There is a 1 percent and 0.2 percent annual chance exceedance.
- As-built representation of levees is sand box barriers on the levee at the Los Angeles Glendale plant.
- The barriers are not considered a permanent solution for increasing the conveyance capacity within the study reach and are not included in the analysis.

The hydraulic model developed for this study does not include the flood protection barriers as these were considered a temporary flood protection measure. An observation made related to flooding, included the water elevations during a 100- and 500-year storm event.

- The overbank flooding extends downstream to Los Feliz Boulevard with flow depths up to 15 feet. The impacted area includes residential houses, commercial buildings, Atwater Park, the Los Angeles Reclamation Plant, and Los Feliz Golf Course.
- LAG flood depths could range from 3 to 20 feet.
- The flow depths in this area are up to 20 feet, impacting commercial and residential areas, freeways, major roads, and public park areas.

Table ES.2 shows the recommended adaptation measures for the projected threats/risks that face all of the treatment plants in the City and a recommended adaptation measure.

Table ES.2 Adaptation Measures for Projected Threats/Risks One Water LA 2040 Plan – TM 5.5

Threats/Risks	Adaptation Measures
Flooding by storm surge and tsunami with sea level rise	Waterproof and protect from debris
Power loss	Permanent or temporary backup generators
Landslides with heavier rainfall	Slope stabilization
Street flooding worse with heavier rainfall/higher tides	More Best Management Practices (BMPs) for stormwater management w/ capture/reuse

ES.1.2 Pumping Plants Example

Based on the use and results of CREAT, Table ES.3 shows the number and type of pumping plant projects that are recommended to be added to the Capital Improvement Plan (CIP) for Los Angeles Sanitation (LASAN) based on their Hazard Priority ranking. The hazard priorities have associated time frames for short-term (5 years), medium-term (10 years) and long-term (25 years) project needs.

Table ES.3 Recommended Pumping Plant Projects by Hazard Priority One Water LA 2040 Plan – TM 5.5

Hazard Priority	Number of Pumping Plants
Short-Term (5 years)	11
100-year Flood Hazard	7 – Wastewater
Fire Hazard	1 – Stormwater
Landslide Hazard	3 – LFDs
Medium-Term (10 years)	2 Wastewater
100-year + SLR (0.5m)	
Long-Term (25 years)	20
100-year + SLR (1.5m)	17 – Wastewater
500-year Flood Hazard	2 – Stormwater
Tsunami	1 – LFDs

ES.2 RECOMMENDATIONS

Considering the practices being implemented in the State of New York, as well as specifically in New York City after Hurricane Sandy, and the impact of those practices on infrastructure, there are cost-effective recommendations that must be considered. These recommendations are broken into two components – management practices and design practices.

ES.2.1 Management Practices

Similar to New York's approach, it is recommended that a Committee be established, that includes academics, scientists, and design professionals that will periodically review, update, and specify projected ranges of threats to be considered in city-wide designs. Threats to consider include:

- Temperature
  - Seasonal ranges
  - Hot days (number)
  - Heat waves (duration and magnitude)
- Rainfall
  - Peak intensities
  - Annual rainfall
  - Drought
- Sea Level Rise
  - Hazard Area Delineations
  - FEMA Flood Hazard Zones
  - CA Tsunami Zones
  - CAL FIRE Fire Hazard Severity Zones
  - CA Landslide and Liquefaction Zones

ES.2.2 Design Practices

It is recommended that, as a function of the design review, the standard criteria for identifying projects in a CIP should be updated based on climate trends and changes that are immediate to the City. In addition, it is recommended that there should be a consistent approach and set of criteria used across engineering sectors via City-level planning and design policy. This includes both private and public projects and means that specifications, the Green and Brown books, and standard details and manuals for any and all projects that involve design should use these requirements, codes and design parameters.

It is also recommended that there is a periodic review of trends in ranges for the following parameters/threats that affect planning and design (similar to those under the Management Practices):

- Rainfall volumes and peak Intensities
- Number of hot days
- Tsunami and flood hazard zones with sea level rise
- Population
- Wildfire, landslides, liquefaction, etc.
- Drainage and roadway design
- Stormwater and sanitary sewer design
- Facilities design

The following is a list of steps and design criteria to consider for a project's planning and design specific to coastal flooding.

- Identify FEMA FIRM Flood Zones and Base Flood Elevations
- Apply ASCE 24-14 for freeboard
- Add sea level rise consideration based on 25-year lifecycle
- DFE = BFE + 2 feet freeboard + 1.64 feet SLR
- Other Specification Considerations:
  - Floodproofing: structure, I&C, MCC/VFD, power, etc.
  - Operating temperature ranges
  - Fireproofing
  - Site stability (landslide protection)
  - Site drainage

In addition, it is suggested that the flood hazard design be regularly updated. During this effort, it was recommended that the FEMA 100-year flood hazard zone and elevation, as well as the FEMA 500-year flood zone, be evaluated. It was noted that the areas that are flooded are only as good as the last time it was mapped, which was in 2008 for the City. Prior to that, the City last mapped the area in 1980 (28-year difference). Additionally, sea level rise will play a role in flood hazard design and it is important to document that what is a 100-year event now will likely be a 50- or 20-year event in the future.

Finally, it has been recommended that ASCE 24-14, Flood Resistant Design and Construction be required for all projects in the City of LA. Table 7-1 from ASCE 24-14 shows that the Flood Design Class 3 is the category in which most water projects reside. Class 3 is defined as follows: buildings and structures associated with power generating stations, water and sewage treatment plants, telecommunication facilities, and other utilities which, if their operations were interrupted by a flood, would cause significant disruption in day-to-day life or significant economic losses in a community. Based on this recommendation, the Department of Building and Safety could approve designs based on the type of service and function each project has based on the definition of ASCE 24-14. This ASCE report was last updated in 2016.

ES.3 IDENTIFYING PROJECTS ALREADY IN THE CIP

There are many projects that are already included in each City department's CIP. However, based on the findings of this effort, it is recognized that there may be opportunities to include climate resilient design and construction modifications now. As projects come up for funding and actual design and implementation, the following are recommended attributes to be reviewed:

- Service life exceeded
- Failures
- Changes in function (capacity, service area change)
- Add New Criteria for Climate Risk and Resilience
- Likelihood of failure based on hazards/risk
- Consequence of failure associated with those hazards/risks
- Cost
- Loss of Service for Public Health and Safety
- Environmental impacts

Recommendations from this Climate Risk and Resilience Assessment report should be implemented during design, during an emergency repair effort, and/or during a construction as soon as it is recognized a change is needed.

ES.4 CONCLUSION

The City has presented an innovative approach that is cost effective, protects the environment, and considers life safety in addressing the potential impacts of climate. The analysis is proactive and not reactive with recommendations that all City departments can utilize in some fashion for design and construction.

CLIMATE RISK AND RESILIENCE ASSESSMENT FOR WASTEWATER AND STORMWATER INFRASTRUCTURE

1.0 INTRODUCTION

1.1 One Water LA

The City of Los Angeles (City) recently embarked on the One Water LA 2040 Plan. This plan will provide a strategic vision and a collaborative approach for integrated water management. In 2006, the City completed and adopted its first integrated water resources plan (IRP). This plan was the start of a paradigm shift for the City and resulted in significant achievements. Since then, the water landscape in the City has changed with increased demands, new regulations, and threats of climate change.

In response to these changes and to help achieve water sustainability, the City initiated the One Water LA 2040 Plan. This plan builds upon the success of the Water IRP, which had a planning horizon to year 2020. The One Water LA 2040 Plan takes a holistic and collaborative approach, to consider all water resources from surface water, groundwater, potable water, wastewater, recycled water, dry-weather runoff, and stormwater as "One Water." The plan identifies multi-departmental and multi-agency integration opportunities to manage water in a more efficient, cost effective, and sustainable manner.

The One Water LA 2040 Plan represents the City's continued and improved commitment to proactively manage all its water resources and implement innovative solutions, driven by the Sustainable City pLAn. The Plan will guide the City with strategic decisions for water resource related projects, programs, and policies that will make Los Angeles a resilient and sustainable City.

1.2 Purpose of Task 5D

The purpose of Task 5D of the One Water LA project is to perform a climate change risk assessment for the City's wastewater and stormwater assets through 2040 and develop adaptation strategies to mitigate those risks. This includes:

- Reviewing and summarizing climate science, climate projections, and existing climate impact assessments (expanding on the summary of expected future conditions described in TM 2.2).
- Conducting vulnerability assessments for existing wastewater and stormwater infrastructure and systems.
- Identifying and evaluating adaptation options and strategies.

- Documenting the climate change assessment for the One Water LA 2040 Plan.
- Preparing material for use in the Los Angeles Sanitation's (LASAN) Climate Adaptation Plan.

1.3 Objective of TM No. 5.5

The objective of this TM is to summarize observed climate and trends, the most current climate science and projections and climate change assessments initiated in the region, and provide an assessment and recommendations for wastewater and stormwater infrastructure resilience through 2040.

2.0 SUMMARY OF HISTORICAL AND POTENTIAL FUTURE CLIMATE CONDITIONS

Projected changes in climate and hydrologic conditions have the potential to impact the City's wastewater and stormwater infrastructure and operations. Climate and hydrologic trends and threats have been identified via reviewing past and ongoing national, regional, and local studies and projects. The review was a literature search and compilation of case studies and federal, state, regional, and local efforts and documents. Appendix B provides a detailed description of historical and potential future climate conditions and summaries of previous and ongoing climate change assessments. Attachments 1 and 2 in Appendix B provide summaries of previous City of Los Angeles climate change vulnerability assessments and climate adaptation planning efforts, respectively. Current and potential climatic conditions that were used to perform risk assessments are summarized herein.

2.1 Historical Climate Conditions

The climate of southern California and Los Angeles has been noticeably changing in recent times. Temperatures have increased in the South Coast Region (Santa Barbara, Los Angeles, Orange County, and San Diego) by about 0.45 degrees Fahrenheit (°F) (0.25 degrees Celsius [°C]) in the past decade, while 2014, 2015 and 2016 were the three warmest calendar years on record since 1895. And while trends in precipitation are difficult to discern due to natural variability (the wettest year and the driest year on record since 1895 have both occurred since 1980), there has been a downward trend in annual precipitation since 1995 and below-average annual precipitation from 2011 to 2016.

Sea levels have steadily risen over the past century, although not at a consistent rate along the coastal Los Angeles region for a variety of factors. Relative sea levels rise and fall based on ocean and coastal conditions as affected by sea conditions, circulation patterns, land subsidence and uplift, seismic events, and other factors. Mean sea level at the Los Angeles and Santa Monica tide stations has increased by about 0.33 foot (0.10 meter) to 0.49 foot (0.15 meter) over the past century.

2.2 Potential Future Climate Conditions

Future changes to the global climate system are expected to cause changes in the Los Angeles hydroclimate over the next century. Average air temperature is projected to increase from 3.2°F (1.8°C) to 3.6°F (2.0°C) by 2050. By continuing existing emission patterns, average temperatures will raise outside of normal variability to create a new regional climate by the end of century. These changes will result in increasing the frequency of extremely hot days (greater than 95°F or 35°C) from 6 to 22 days by 2050.

While it is difficult to discern strong trends from the full range of climate projections, the median of the projections suggest no change in the future annual precipitation. Despite the relative uncertainty in annual precipitation changes, about two-thirds of the projections suggest increases in 3-day annual maximum precipitation by end of century. The median change in 3-day annual maximum precipitation for the Los Angeles Downtown area by end of century is projected to increase by about 10 percent. The wetter projections also suggest an increase in the daily extreme precipitation events such as the 100-year/24-hour storm that would occur approximately 1 percent of the time on an annual basis, and the 10-year/24-hour storm used for stormwater and sewer design. The 10-year/24-hour storm is projected to have a 17-percent increase in volume and a higher hourly peak intensity by the year 2050. The frequency and severity of droughts are expected to increase under future climate.

Mean sea level at Los Angeles, due to thermal expansion, ice melt, and local vertical land movement, is projected to increase by a range of 0.43 to 1.97 feet (0.13 to 0.6 meter) by 2050 and 1.44 to 5.45 feet (0.44 to 1.66 meter) by 2100 relative to 2000.

2.3 Current and Climate Change Conditions Applied to Risk Assessments

Historical, current, and potential climate-based threats and risks are described above and in detail in Appendix B. The future conditions of the potential climate-based threats affect particular risks such as flooding, erosion, landslides, wildfire, and power outages. This information was used as the basis to select baseline and projected climate threat conditions for risk assessments and resilience planning. Table 1 lists the baseline conditions for assessing current (baseline) threats/risks and the mid-century (year 2060) projected values for assessing future threats/risks with climate change. Temperature, the number of hot days, precipitation, and extreme storm events (100-year/24-hour storm) vary by location from coastal to inland areas of Los Angeles and are therefore location-based for baseline and projected future conditions. In addition to what is shown in the table for sea level rise (SLR), an overall SLR of 4.92 feet (1.5 meters) was also considered for year 2100 conditions.

Table 1 Climate Change Conditions Used in Risk Assessments and Resilience Planning One Water LA 2040 Plan – TM 5.5

Climate Variable	Baseline Condition	Projected Value for Mid-Century (Observed + Changes)
Annual Temperature	Location Based (~63°F)	+3°F to +4°F
Number of Hot Days (over 95°F)	6	22
Total Annual Precipitation	Location Based (14 to 18 inches/year)	-10.7% to +11.2%
100-Year/24-Hour Storm Event	Location Based (5 to 7 inches/24 hours)	+34.3%
Sea-Level Rise	0.06-0.09 inch/year	1.64 feet (0.5 meter)

3.0 CLIMATE RISK AND RESILIENCE ASSESSMENT AND RECOMMENDATIONS

Climate change is projected to impact the City's wastewater and stormwater systems in a variety of ways. The wastewater systems consist of sewer systems, sewage pumping facilities, wastewater treatment facilities and water reclamation facilities. The stormwater systems consist of collection systems, stormwater pumping plants, watershed protection, and Proposition O projects. Changes in temperature, precipitation, and sea levels will affect the physical plant and operational vulnerabilities of these facilities and operations.

A climate risk and resilience assessment was performed consisting of scenario development, screening analyses, site visits, risk analyses, and adaptation planning concurrent with ongoing meetings with LASAN staff. The assessments were performed for a total of 81 facilities including water reclamation plants, wastewater and stormwater pumping plants, low flow diversions (LFD), and facilities currently in design. Current and potential future climate conditions were considered to perform the assessments and develop recommendations. This section describes the assessment approach, existing resilience measures employed by the City, and the assessments of facilities with recommendations for improving resilience.

3.1 Climate Risk and Resilience Assessment Approach

Following a model developed by the U.S. Environmental Protection Agency (EPA), assessments were performed for several wastewater facilities in a successful pilot project from 2015 to 2016. The assessments were performed using EPA's CREAT (Climate Resilience Evaluation and Awareness Tool). The tool was also used to identify climate threats when evaluating several of the City's critical solid resources assets, alternative fuel delivery and distribution systems, and emergency debris management plan in 2015 and 2016. Based on the successful outcomes of these efforts, One Water LA decided to complete assessments of the remaining wastewater and stormwater facilities. The CREAT approach was used in the One Water LA 2040 Plan to assess all wastewater and stormwater pumping and treatment facilities. The following describes the CREAT approach, how current and potential future climate conditions were applied to identify threats, design conditions used to assess the associated risks, and the basis of costs used to develop the value of assets at risk and the costs to improve resilience where needed.

3.1.1 CREAT Assessment

CREAT enables a utility to assess and identify risks related to climate change impacts with the purpose of raising awareness and generating sets of adaptation options for further consideration. After selecting the analysis location, climate scenarios, threats and assets of concern, users assess their overall consequences from climate change-related threats, considering both existing resources and additional capabilities from implementing adaptation measures.

CREAT provides a consequence matrix with default economic data for four categories that capture the range of impacts a utility may experience from a particular climate change-related threat (Appendix C). These include:

- utility business impacts,
- utility equipment impacts,
- source and receiving water impacts, and
- environmental impacts.

CREAT users can also assess public health consequences from climate change impacts in either a qualitative or quantitative manner. Within each of these categories, users assess the impacts on a four-point scale from Low to Very High. CREAT calculates a monetized value of risk based on the user's selections, and calculates a reduction in that risk after implementing adaptation options. Users can evaluate the performance of potential adaptation measures to inform planning decisions based on risk reduction, cost, public health impacts, energy requirements, and socio-economic factors.

3.1.2 Climate Scenarios for Threat Identification

Risk assessments were performed for threats associated with two primary climate scenarios:

- current climate conditions
- future conditions considering potential climate change affects.

The current and future scenarios focused on climate hazards that exist now and may be affected by climate change. Current climate conditions were used to identify current climate hazard threats and associated risks to facilities as they are constructed and operate today. Anticipated future climate conditions were used to identify future climate hazard threats and associated risks to facilities for a mid-century time period consistent with the One Water LA 2040 time horizon (year 2040 to mid-century). Future hazards were also evaluated as threats to assets for future climate conditions to year 2100 for long-term Capital Improvement Plan (CIP) considerations. The climate hazard threats were assessed for:

- flooding (coastal storm, tsunami and drainage),
- landslides (mudslides),
- power loss, and
- wildfire.

Flooding threats to facilities were identified for inland and coastal flooding as well as tsunamis. The severity and spatial impact of inland flooding may be affected by increased extreme rainfall in the future. The severity and spatial impact of coastal storm flooding and tsunamis will increase with SLR. The Federal Emergency Management Agency (FEMA) 100- and 500-year flood hazard zones provided in current flood insurance rate maps (FIRMs) were used to define current flood hazard threats. A recent hydrologic/hydraulic analyses of the Los Angeles River by U.S. Army Corps of Engineers (USACE) was also used to define flood hazard zones where FEMA mapping was not complete (USACE, 2016). Tsunami flooding zones mapped by the State of California were used for assessing current tsunami threats.

Flood zones and depths calculated by the United States Geologic Survey (USGS) Coastal Storm Modeling System (CoSMoS) program were used for SLR considerations affecting FEMA flood hazard zones in coastal zones. SLR will likely result in larger tsunami zones and higher depths of submergence during a tsunami in those zones. Therefore higher depths were taken into consideration for threat and risk assessments of facilities currently in tsunami zones. Facilities currently located in close proximity to tsunami zones were also assessed for a possible future tsunami threat due to SLR.

Landslides and mudslides are affected by rainfall causing erosion and destabilizing slopes especially during El Niño years. Slopes may also be destabilized and fail due to seismic activity. Increased extreme rainfall conditions forecasted for the future may increase erosion and destabilize slopes further. The locations of facilities were compared to landslide zones mapped by the State of California to identify risks associated with this threat.

Wastewater and stormwater facility operations are dependent on power generation and distribution networks. Power supplies at facilities are vulnerable to operational failures, extreme storm events, and high demand periods that may cause brown-outs or black outs.

Critical facilities must have backup power when failures occur to assure continued service to the community to protect health and safety. Changes in temperatures, precipitation, and sea levels will increase the frequency and magnitude of power interruptions in the future. Backup power generation for wastewater and stormwater facilities was assessed uniformly for all facilities.

Wildfire threats were identified using wildfire zones mapped by the State of California and Los Angeles County.

Data source information for the threats is listed in Table 2.

Table 2 Data Source by Threat for Risk Assessment and Adaptation Planning One Water LA 2040 Plan – TM 5.5

Data	Source	Website
Precipitation	National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Precipitation Frequency Estimates	http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_gis.html
Flood	FEMA National Flood Hazard Layer	http://fema.maps.arcgis.com/apps/PublicGallery/index.html?appid=2faf36d4277a430fa84c34873599f5c1
Landslide	California Geological Survey	http://gmw.consrv.ca.gov/shmp/MapProcessor.asp?Action=SHMP&Location=All&Version=5&Browser=Netscape&Platform=Win
Liquefaction	California Geological Survey	http://gmw.consrv.ca.gov/shmp/MapProcessor.asp?Action=SHMP&Location=All&Version=5&Browser=Netscape&Platform=Win
Wildfire	Los Angeles County and California Department of Forestry and Fire Protection (CAL FIRE)	http://egis3.lacounty.gov/dataportal/2013/05/28/fire-hazard-severity-zones/ http://www.fire.ca.gov/fire_prevention/fhsz_maps_losangeles
Sea Level Rise	USGS CoSMoS	https://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/index.html
Tsunami	California Office of Emergency Services	http://egis3.lacounty.gov/dataportal/2015/12/30/tsunami-inundation-and-tsunami-inundation-lines/

Potential future climate conditions summarized in Section 2.0 and described in more detail in Appendix B were also considered. The following climate scenario condition details were used for the assessment of the City's facilities:

- **Number of Hot Days.** Hot days increase chances of losing power, having transmission problems and introducing health and safety concerns for staff. The total number of annual average days over a temperature threshold (95 degrees Fahrenheit), as well as the number of consecutive hot days was 6 days on average from 1981 to 2000. It is projected to increase over time and range from 6 days to 22 days per year by the 2060s. Therefore, all facilities were assessed for backup power generation capabilities in anticipation of more frequent power brown-outs or blackouts due to higher demands placed on power generation and distribution networks.

- **Flood.** More extreme precipitation events are expected to occur with climate change creating added flood risk. River flows, flood zones, and depths may increase in the future. SLR will likely increase the spatial extent and depths of coastal storm surges in the future (see below). FEMA provides FIRMs to identify flood potential. Maps are compiled into a Geographic Information System (GIS) format and presented in the National Flood Hazard Layer (NFHL). Both FIRM and NFHL data were used to determine the 100- and 500-year inundation zones and the base flood elevations (BFE) at each facility location to identify flood risks. Some FEMA FIRMs show the 500-year inundation zones but do not provide the associated elevation - FEMA suggests estimating the 500-year stillwater flood and wave crest elevations by multiplying the 100-year BFE 1.25 (FEMA, 2010).

  In October 2016 USACE released an updated floodplain analysis of the Los Angeles River from Barham Boulevard to First Street (USACE, 2016). This modeling shows new inundation areas and flooding depths above grade for 100- and 500-year river flooding conditions that are not represented in the existing FEMA FIRMs. The new flood modeling shows inundation of the Los Angeles-Glendale Water Reclamation Plant (LAGWRP), Los Angeles Zoo Pumping Plant, and Riverdale Pumping Plant No. 611.

- **Landslide, Liquefaction, and Wildfire.** Climate change is expected to bring more extreme variations in weather patterns. Models show more intense precipitation events as well as an increase in overall temperatures and number of hot days for Southern California. These extreme weather patterns can pose landslide, liquefaction, and wildfire risks to LASAN water reclamation facilities and pumping plants as well as the neighboring properties and access roads. Maps and data from the California Geological Survey Seismic Hazard Zonation Program were the primary source for identifying the local landslide and liquefaction risks to facilities. Maps and data from Los Angeles County and the California Department of Forestry and Fire Protection were used to identify wildfire risks for each facility. Characteristics of the surrounding area were also evaluated to determine the likelihood of these hazards. Liquefaction risks were only evaluated based on mudslide potential that would be increased by heavy rainfalls. Landslide and liquefaction risks caused by seismic events were not evaluated in this assessment.

- **Tsunami.** Submarine earthquakes and landslides can generate tsunamis posing inundation risks for coastal facilities. Tsunami risks are further amplified when combined with coastal storms and SLR. Although tsunami height predictions can vary greatly, a 20-foot wave height was assumed. California Geological Survey tsunami inundation maps were used to identify local tsunami zones for each facility. SLR will likely increase spatial extent of and depths of tsunamis in the future but no adjustments were made to the zones or depth assumption.

- **Sea Level Rise.** Global and regional sea level is expected to rise with climate change which exposes new hazards along the Los Angeles coastline. The USGS CoSMoS was used to identify inundation areas under different SLR scenarios. Phase I of CoSMoS 3.0 was completed in 2016 to calculate and map flood zones for the Southern California Coastline. To identify assets vulnerable to SLR, the 100-year coastal storm calculations with 1.64 feet (0.5 meter) and 4.92 feet (1.5 meters) of SLR were used to represent the mid-century and year 2100 projections, respectively, for coastal storm surge flood hazard zones and depths.

3.1.3 Likelihood of Occurrence in Threat Assessments

The specification of performance standards for infrastructure design is typically based on the recurrence interval of a condition for which a minimum level of service is required. For example, a design storm with a specific volume or peak intensity is used for drainage design to protect against the occurrence of the event at an acceptable and affordable interval and level of risk. The identification of acceptable and/or affordable is guided by federal, state, or local regulatory requirements, health and safety considerations, affordability, minimum insurance requirements, etc. The 100-year event is the basis for the National Flood Insurance Program administered by FEMA. However, the likelihood of occurrence of a 5-year rain event or a 100-year coastal storm surge event is often misinterpreted.

A 100-year event is an event that has a 1-percent annual exceedance probability, not an event that is expected to occur once every 100 years. For example, if it rains on 100 days of the year, then there is a high likelihood that at least one rain event will occur with the characteristics of a 100-year rain event; a 50-year event will likely occur twice in a given year. There is also a chance that such events could occur consecutively.

FEMA calculates 100- and 500-year flood hazard zones based on the characteristics of past occurrences, statistics and modeling. No considerations are reflected in FEMA maps for future conditions affected by SLR, short- or long-term changes in temperature and precipitation conditions, or other factors that may increase the spread of flood zones and the depths of flood waters. SLR will move coastal flood hazard zones farther inland and raise the flood elevations. Precipitation frequency estimates calculated by NOAA are based on past rainfall events and may not represent future conditions that may occur in the lifecycle of a stormwater pump station or a drainage channel that is being designed now. Increased rainfall intensities and volumes in local areas will increase stormwater water runoff flows and local stream flows and depths. Increased rainfall, changes in snow melt timing and other hydrological changes in upstream watersheds will affect the frequency and depths of local river flows. These changes translate into changes in the recurrence interval of the conditions that are currently used in planning and design. The current characteristics of a 100-year event may likely have the characteristics of a 50-year event in the future will translate to increased threats and risks to infrastructure.

3.1.4 Design Flood Elevation for Current and Future Conditions

The probability and consequences of damage and failures due to flooding were assessed by identifying flood zone elevations and comparing them to damage threshold elevations at the facilities. Design standards were then used to identify damage risks, resilience improvements and when they should be implemented for planning and design purposes.

Flood zone elevations were identified using FEMA FIRM flood hazard area elevations, estimated tsunami elevations and the CoSMoS elevations. Damage threshold elevations were identified by reviewing as-built design drawings and identifying the minimum elevation of a floodwater pathway into the facility that would damage assets. The pathways are hatches at grade, door thresholds, etc. Also taken into consideration is that some pumping plant electrical and mechanical assets are not isolated from the pump wet well and do not have influent gates that can be closed and isolate them from the collection system. Flood waters may flood out the pumping plant from within when influent sewers are inundated with hydraulic grade lines that exceed flood pathway elevations inside the pumping plant.

The City currently uses the FEMA 100-year (1 percent annual chance of occurrence) flood elevation as a basic design criteria for construction within a floodplain. This approach does not account for future flooding as a result of SLR and coastal storms. The American Society of Civil Engineers (ASCE) Standard 24-14 Flood Resistance Design and Construction (ASCE, 2015) provides minimum requirements for flood design criteria for new construction and improvements of existing structures. The facilities assessed in this exercise fall under the Flood Design Class 3 which includes buildings and structures associated with water and sewage.

The ASCE-recommended design flood elevation (DFE) in Standard 24-14 is calculated using the BFE plus a freeboard of 1 foot for inland areas or 2 feet for coastal areas. The BFE is the 100-year flood elevation as shown on a FEMA FIRM. The DFE was compared to threshold elevations at facilities for determining risks and needed improvements. Short-term risks were identified by comparing the threshold elevations to the BFE plus the relevant freeboard (inland vs. coastal) as the DFE. Medium-term risks used the BFE plus freeboard plus 1.64 feet (0.5 meter) of SLR for mid-century conditions. Long-term DFEs used either the 500-year (0.2 percent chance of annual occurrence) flood elevation plus freeboard, the BFE plus freeboard plus 4.92 feet (1.5 meters) of SLR, or a tsunami depth of 20 feet. DFEs can be summarized as follows:

- Short Term
  - 100-year Flood DFE = BFE + Freeboard
- Medium Term
  - 0.5 meter SLR DFE = BFE + Freeboard + 0.5 meter
- Long Term
  - 500-year Flood DFE = BFE*1.25 + Freeboard
  - 1.5 meter SLR DFE = BFE + Freeboard + 1.5 meters
  - Tsunami DFE = 20 foot estimated tsunami wave height

Assessments of risk and the recommended improvements for each facility based on these thresholds are described below.

3.1.5 Identification of Resilience Improvements

Potential resilience improvements were identified and evaluated to reduce the consequences from climate-based threats by applying a 4-step risk assessment process described in EPA's *Flood Resilience: A Basic Guide for Water and Wastewater Utilities* (*Flood Resilience Guide*, EPA 2014). Adaptive measures suggested in the *Flood Resilience Guide* for preventing intrusion of flood waters, protecting assets and operations and ensuring power reliability were screened and evaluated based on effectiveness, practicality, and cost.

The potential resilience improvements, their effectiveness, and costs were reviewed with LASAN staff during workshops to select recommended improvements. Final recommended improvements were then selected for each facility and are described below.

3.1.6 Basis of Replace-in-kind and Resilience Improvement Cost Estimates

Event-based threats were established for each facility for existing and future climate conditions described above. A risk analysis identified the assets at risk from flooding, debris strikes, landslides, power loss and surge, and the potential damage or destruction of specific assets. Anticipated replace-in-kind costs to clean and replace damaged or destroyed assets at facilities were then estimated assuming that all damaged assets would have to be replaced. The replace-in-kind cost estimates were not developed to entirely replace a facility. The facility assets evaluated for this climate risk and resilience assessment include electrical, mechanical, instrumentation, communication, ventilation, and power equipment at facilities. Replace-in-kind costs were then estimated as present value costs using One Water LA cost assumptions that are described in Appendix D.

The present value construction costs for resilience improvements at facilities were estimated based on cost estimates calculated for LASAN with EPA when CREAT assessments were performed for several wastewater facilities in 2015 to 2016. Those estimates were calculated for the Sunset Pumping Plant No. 632, Temescal Canyon Pumping Plant No. 634, and the Terminal Island Water Reclamation Plant (TIWRP).

The cost methodology for estimating replace-in-kind costs for damaged assets and for estimating resilience improvement costs is presented in Appendix D.

3.2 Existing and Recommended Operational Resilience Practices

There are a number of resilience practices that the City employs in its operations. These existing practices were considered in the risk assessments:

- Regularly monitor climate conditions and re-evaluate temperature, precipitation (intensity, duration, and frequency), hot days, extreme events, and other metrics to determine if design standards and weather-dependent operations require updating.
- Monitor updates to FEMA flood zones and elevations, tsunami zones and estimated wave heights, earthquake liquefaction zones, and other information resources maintained by state and federal agencies on a regular basis. Review and update relevant LA Sanitation planning materials accordingly.
- Train staff on how and when to shut down and start up power and gas supplies, electrical controls, operating systems and other equipment in system facilities prior to a flood to minimize damage (may need to be updated).
- Maintain a cache of spare parts to restart operations as soon as possible (may need to be updated annually).
- Regularly backup electronic and paper files outside the flood zone. Include all permits and compliance documentation, designs and as-built drawings, process diagrams, operations and maintenance (O&M) records, standard operating procedures, process and equipment manuals, material safety data sheets, asset management data, purchasing records, operations data, customer records and other critical information (may need to be updated).
- Maintain interconnections or other partnership opportunities such as Water/Wastewater Agency Response Network (WARN) to share resources with neighboring water utilities during emergencies (existing with City departments only).

- Fill backup generator fuel storage tanks in anticipation of heavy rains, extended heat waves or other forecasted climatic events.
- Perform energy audits of facilities to identify energy saving opportunities via operations and equipment modifications. Integrate reviews and recommendations of the audits (e.g., replace equipment with energy efficient models) into CIP development processes.

Additional operational resilience practices are recommended for implementation by the City in the short term as follows:

- Store on-site documents above flood elevations or in water-tight containers when storage is only available below flood elevations.
- Develop "start and connect" checklists specific to each piece of electrical equipment.
- Train staff on and plan for manual operation of facilities.
- Conduct half-day tabletop exercises and drills to exercise shut down procedures, providing backup power and refueling portable generators, restoring normal operations and performing post-event assessments after an event.
- Identify locations outside flood hazard zones where utility equipment (e.g., heavy equipment, vehicles, replacement parts, backup generators, pumps) can be stored safely, permanently or temporarily, to prevent damage from flood waters or debris.
- Develop alternative access plans in case normal access to buildings is blocked. Consult with other entities (e.g., Department of Transportation) to consider alternate road/transportation options (e.g., watercraft) during and immediately after an event.
- Purchase and have available portable equipment if permanent equipment becomes disabled.
- Check and confirm the capabilities and limitations of operating remotely in case a facility is inaccessible.
- Provide the local emergency management agency and power company with locations of facilities such that during an outage it will expedite electricity restoration.
- For electrical requirements, document the size and type of existing backup generators including voltage, phase configuration, horsepower/amperage, fuel, etc. in case generators are damaged and/or inoperable.
- Maintain a call list of multiple vendors that rent portable generators in an emergency, enter into an agreement with a particular vendor or joining a mutual aid network WARN that specifically shares portable backup generators.

- Establish an agreement with fuel vendors and provide estimates of fuel needs (e.g., volume and frequency) in the event of a power outage to assure adequate supply and delivery. Also, secure a list of alternative fuel suppliers. Maintain communication with City, County, State, and Federal emergency management agencies for priority in getting and transporting fuel supplies.
- Investigate purchasing fuel transport vehicles and train staff in delivering fuel to backup generators at facilities in an emergency.
- Maintain a call list of multiple vendors that can provide "pump around" services in an emergency or enter into an agreement with one or more for on-call emergency services.
- Regularly assess slope stability at facilities in landslide and liquefaction zones under threat from landslides or mudslides during heavy rains (i.e. El Niño periods) or seismic activity.
- Clear vegetation and debris away from facilities in wildfire zones in cooperation with firefighting, parks, and forestry agencies to reduce the threat and consequences of wildfires. Make sure to retain vegetation that is preventing erosion and/or replace such vegetation with drought-tolerant and/or fire-resistant vegetation.

3.3 Pumping Plant Assessments

The City owns and operates 77 wastewater and stormwater pumping plants, and LFD. Each of these facilities was screened and assessed for existing and potential future climate hazards and the associated risks. This section summarizes the current and/or future risks, damage replacement costs associated with the risks, resilience improvement recommendations, and costs. A more detailed summary of each facility is included in Appendix E.

3.3.1 Wastewater Pumping Plants

There are 43 wastewater pumping plants including 23 in the Hyperion Water Reclamation Plant (HWRP) collection system and 20 in the TIWRP collection system. The pumping plant capacities range from 20 gallons per minute (gpm) to 45,000 gpm. Table 3 lists the pumping plants by number, name, pumping capacity, and the risk assessment finding (none, minimal risk requiring no action, at risk requiring action).

Table 3 Wastewater Pumping Plants
One Water LA 2040 Plan – TM 5.5

Plant No.	Name	Capacity (gpm)	Risk Assessment Finding
601	Manchester	20,160	None
602	Union Pacific	4,600	None
604	Highbury	2,250	None
605	San Pasqual	30	None
606	Dacotah	10,000	None
608	Washington & Industrial	100	None
610	11th & Santa Fe	2,000	None
611	Riverdale	N/A[(1)]	At Risk
616	Cahuenga	1,600	None
624	Roscomare	500	At Risk
626	Riverdale	80	None
628	Corbin	400	At Risk
631	Hamden Place	110	None
632	Sunset	10,000	Minimal Risk
633	Chautauqua	300	Minimal Risk
634	Temescal	4,500	At Risk
638	Palisades	600	At Risk
639	North Pulga	3,000	At Risk
646	Venice Pumping Plant	45,000	At Risk
648	Thompson	700	At Risk
649	Jefferson	190	At Risk
654	Ballona Creek	18,000	None
659	Nors	20	None
666	Fries Ave.	7,400	At Risk
668	Henry Ford	6,800	At Risk
669	Harris Place	1,600	At Risk
671	Terminal Way	10,000	At Risk
672	Murdock & "I"	1,100	At Risk
674	190th & Vermont	2,800	None
675	P.C.H. & Figueroa	1,200	None
676	McFarland	8,000	At Risk

Table 3 Wastewater Pumping Plants
One Water LA 2040 Plan – TM 5.5

Plant No.	Name	Capacity (gpm)	Risk Assessment Finding
677	Hawaiian & "B"	5,800	At Risk
680	22nd & Signal	100	At Risk
681	Ports 'O' Call	300	At Risk
683	22nd Street	900	At Risk
684	Miner	500	At Risk
685	Signal	200	At Risk
686	Nissan Way	1,700	At Risk
687	North Neptune	880	At Risk
688	South Neptune	700	None
689	Seaside	1,000	At Risk
690	Anchorage	520	At Risk
691	San Pedro	18,000	At Risk

Note:
(1) No pump, bladder storage pumped out with tanker truck.
Abbreviation:
N/A = not applicable

The following is a summary of the risk assessment of 26 wastewater pump stations that were determined to have greater than minimal identified threats, the recommended resilience improvements, the estimated cleaning and replacement costs of damaged or destroyed assets at the facility should the identified risks occur, and the estimated capital costs of implementing the recommended resilience improvements.

Riverdale Pumping Plant No. 611 is at risk of inundation during the 100-year and 500-year flood events. The recommended resilience improvements are to waterproof instrumentation and controls. The estimated damage replacement cost of the facility is $21,060 (there are no pumps or controls; therefore, the assumed minimum replace-in-kind cost does not apply) and the estimated resilience improvements cost is $50,000. Considering the estimated resilience improvement cost exceeds the replace-in-kind cost, and that the station is actually a storage and pump-out station, no improvement is recommended at this time.

Roscomare Pumping Plant No. 624 is at risk of landslide and wildfire. The recommended resilience improvements are to increase the height of the existing retaining wall behind the facility and manage nearby vegetation to minimize fire risk. The estimated damage replacement costs of the facility is $1,000,000 and the estimated resilience improvements cost is $20,000.

Corbin Pumping Plant No. 628 is at risk for wildfire. The recommended resilience improvement is to manage the nearby vegetation to minimize fire risk. The estimated damage replacement cost of the facility is $1,000,000, and there is no capital cost for the recommended resilience improvements.

Temescal Pumping Plant No. 634 is at risk of landslide and wildfire. The recommended resilience improvements are to improve an existing wall at the facility to protect the facility from landslides and fire, and to manage the nearby vegetation. The estimated damage replacement costs of the facility is $3,159,000, and the estimated resilience improvements cost is $60,000.

Palisades Pumping Plant No. 638 is at risk for wildfire. The recommended resilience improvement is to manage the nearby vegetation to minimize fire risk. The estimated damage replacement cost of the facility is $1,000,000, and there is no capital cost for the recommended resilience improvements.

North Pulga Pumping Station No. 639 is at risk of landslide and wildfire. The recommended resilience improvements are to construct a wall around the facility to protect landslide and fire and to manage the nearby vegetation. The estimated damage replacement cost of the facility is $2,106,000, and the estimated resilience improvements cost is $60,000.

Venice Pumping Plant No. 646 is at risk of inundation during 500-year flood and tsunami events. The recommended resilience improvements are to waterproof the building, install watertight connections, and move the portable generator kept on site to higher ground. The estimated damage replacement cost of the facility is $31,590,000, and the estimated resilience improvements cost is $1,600,000.

Thompson Pumping Plant No. 648 is at risk of inundation during 500-year flood and tsunami events. The recommended resilience improvements are to waterproof the building, waterproof hatches, install watertight connections, and raise the portable generator to a higher elevation. The estimated damage replacement cost of the facility is $1,000,000, and the estimated resilience improvements cost is $480,000.

Jefferson Pumping Plant No. 649 is at risk of inundation during the 500-year flood event. The recommended resilience improvements are to waterproof instrumentation and controls. The estimated damage replacement cost of the facility is $1,000,000, and the estimated resilience improvements cost is $80,000.

Fries Pumping Plant No. 666 is at risk of inundation during a 100-year flood with 0.5 meter of SLR, a 500-year flood, and tsunami events. The recommended resilience improvements are to raise the generator pad, install watertight connections, waterproof the structure and interior instrumentation and controls to maintain its historical status, waterproof exterior hatches, and construct a flood wall with flood gates around the pump station building. The estimated damage replacement cost of the facility is $5,194,800, and the estimated resilience improvements cost is $1,110,000.

Henry Ford Pumping Plant No. 668 is at risk of inundation during the 100- and 500-year flood, a 100-year flood with 0.5 meter of SLR, and tsunami events. The recommended resilience improvements are to raise the generator pad and waterproof the building. The estimated damage replacement cost of the facility is $4,743,600, and the estimated resilience improvements cost is $230,000.

Harris Pumping Plant No. 669 is at risk of inundation during a tsunami event. The recommended resilience improvements are to raise the generator pad, waterproof the structure or interior instrumentation and controls to maintain its historical status, waterproof exterior hatches, and construct flood wall with gates around the pump station. The estimated damage replacement costs of the facility is $1,123,200, and the estimated resilience improvements cost is $810,000.

Terminal Way Pumping Plant No. 671 is at risk of inundation during the 500-year flood, a 100-year flood with 1.5 meters of SLR and tsunami events. The recommended resilience improvements are to raise the generator pad, install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, raise vents, waterproof building, and install bollards to protect above ground structures from tsunami wave debris. The estimated damage replacement cost of the facility is $7,020,000, and the estimated resilience improvements cost is $1,070,000.

Murdock & "I" Pumping Plant No. 672 is at risk of inundation during a 100-year flood with a 1.5 meters of SLR and tsunami events. The recommended resilience improvements are to raise the generator pad, install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, raise vents, waterproof building, and install bollards to protect above ground structures from tsunami wave debris. The estimated damage replacement cost of the facility is $1,000,000, and the estimated resilience improvements cost is $720,000.

McFarland Pumping Plant No. 676 is at risk of inundation during the 500-year flood, a 100-year flood with 1.5 meters of SLR, and tsunami events. The recommended resilience improvements are to raise the generator pad, install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, raise vents, waterproof building, and install bollards to protect above ground structures from tsunami wave debris. The estimated damage replacement cost of the facility is $5,616,000, and the estimated resilience improvements cost is $1,020,000.

Hawaiian & "B" Pumping Plant No. 677 is at risk of inundation during the 500-year flood, a 100-year flood with 1.5 meters of SLR, and tsunami events. The recommended resilience improvements are to raise the generator pad, install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, raise vents, waterproof control room with submarine doors, and install bollards to protect above ground structures from tsunami wave debris. The estimated damage replacement cost of the facility is $4,071,600, and the estimated resilience improvements cost is $870,000.

22nd & Signal Pumping Plant No. 680 is at risk of inundation during the 500-year flood, a 100-year flood with 1.5 meters of SLR, and tsunami events. The facility was rehabilitated in 1997-1998 with a cost of $566,000. The recommended resilience improvements are to install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, raise vents, and seal holes in exterior walls of the structure. The estimated damage replacement cost of the facility is $1,000,000, and the estimated resilience improvements cost is $126,000.

Ports O' Call Pumping Plant No. 681 is at risk of inundation during the 500-year, a 100-year flood with 1.5 meters of SLR, and tsunami events. The recommended resilience improvements are to install watertight connections, protect motor control centers, waterproof instrumentation and controls, and install bollards around the facility to protect from tsunami wave debris. The estimated damage replacement cost of the facility is $1,000,000, and the estimated resilience improvements cost is $340,000.

22nd Street Pumping Plant No. 683 is at risk of being inundated during a tsunami event. The recommended resilience improvements are to install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, raise vents, waterproof control room, and install bollards around the facility to protect from tsunami wave debris. The estimated damage replacement cost of the facility is $1,000,000, and the estimated resilience improvements cost is $500,000.

Miner Pumping Plant No. 684 is at risk of being inundated during a tsunami event. The recommended resilience improvements are to install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, raise vents, waterproof control room, and install bollards around the facility to protect from tsunami wave debris. The estimated damage replacement cost of the facility is $1,000,000, and the estimated resilience improvements cost is $500,000.

Signal Pumping Plant No. 685 is at risk of inundation during the 500-year, a 100-year flood with 1.5 meters of SLR, and tsunami events. The recommended resilience improvements are to install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, raise vents, waterproof control room, and install bollards around the facility to protect from tsunami wave debris. The estimated damage replacement cost of the facility is $1,000,000, and the estimated resilience improvements cost is $480,000.

Nissan Way Pumping Plant No. 686 is at risk of inundation during the 500-year, a 100-year flood with 1.5 meters of SLR, and tsunami events. The facility was replaced in 1997-1998 with a cost of $419,000. The recommended resilience improvements are to install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, raise vents, and install bollards around the facility to protect from tsunami wave debris. The estimated damage replacement cost of the facility is $1,193,000, and the estimated resilience improvements cost is $490,000.

North Neptune Pumping Plant No. 687 is at risk of inundation during the 500-year, a 100-year flood with 1.5 meters of SLR, and tsunami events. The recommended resilience improvements are to install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, and install bollards to protect from tsunami wave debris. The estimated damage replacement cost of the facility is $1,000,000, and the estimated resilience improvements cost is $400,000

Seaside Pumping Plant No. 689 is at risk of being inundated during a tsunami event. The recommended resilience improvements are to install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, raise vents, waterproof control room with submarine doors, and install bollards to protect above-ground structures from tsunami wave debris. The estimated damage replacement cost of the facility is $1,000,000, and the estimated resilience improvements cost is $600,000.

Anchorage Pumping Plant No. 690 is at risk of inundation during the 500-year, a 100-year flood with 1.5 meters of SLR, and tsunami events. The recommended resilience improvements are to install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatch, raise vent, and install bollards to protect from tsunami wave debris. The estimated damage replacement cost of the facility is $1,000,000, and the estimated resilience improvements cost is $300,000.

San Pedro Pumping Plant No. 691 is at risk of being inundated during a tsunami event. The recommended resilience improvements are to install watertight connections, protect motor control centers, waterproof instrumentation and controls and hatches, raise vents, waterproof control room, raise generator pad, and install bollards around the facility to protect from tsunami wave debris. The estimated damage replacement cost of the facility is $12,636,000, and the estimated resilience improvements cost is $1,080,000.

3.3.2 Stormwater Pumping Plants

The City owns and operates 11 stormwater pumping plants to reduce flooding and convey flows to local surface waters. The pumping plant capacities range from 100 gpm to 45,000 gpm. Table 4 lists the pumping plant numbers, names, pumping capacities, and the risk assessment finding (none, minimal risk requiring no action, at risk requiring action).

Table 4 Stormwater Pumping Plants
One Water LA 2040 Plan – TM 5.5

Plant No.	Name	Capacity (gpm)	Risk Assessment Finding
535	Lopez Canyon	30	Minimal Risk
609	4th & Figueroa	100	None
617	Lankershim	1,300	None
619	Sherman Way	12,000	None
620	Woodman	2,000	None
621	Van Nuys	13,400	None
622	Sepulveda	15,500	None
647	Kinney Circle	45,000	At Risk
678	Eubank & "Q"	1,400	Minimal Risk
692	Southerland	33,000	At Risk
693	Robidoux	500	None

The following is a summary of the risk assessment of the two stormwater pumping plants with identified threats, the recommended resilience improvements, the estimated cleaning and replacement costs of damaged or destroyed assets at the facility should the identified risks occur, and the estimated capital cost of implementing the recommended resilience improvements.

Kinney Circle Pumping Plant No. 647 is at risk of inundation during 500-year flood and tsunami events. LASAN is planning an upgrade of the facility and developed a preliminary estimate of construction costs in 2015. The preliminary opinion of cost for the upgrades including the replacement of non-submersible pumps, heating and ventilation, electrical, instrumentation and controls is approximately $5,500,000. This estimate includes $750,000 in structural upgrades that would not be damaged during a flooding event and the addition of a new portable generator for $1,000,000 (Tetra Tech, 2015). Therefore, the estimated damage replacement cost of the facility is $3,750,000. The recommended resilience improvements are to waterproof instrumentation and controls and hatches, raise vents, install watertight connections, and protect motor control centers for an estimated cost of $610,000, in addition to the estimated upgrade cost. Planned drainage improvements should be checked for capacity with additional precipitation intensity projected with climate change. The facility's stormwater outfall to Santa Monica Bay, which is owned and serviced by Los Angeles County, is frequently inundated with sand that reduces its discharge capacity. SLR will likely increase sand intrusion, which will require more frequent monitoring and cleaning by Los Angeles County in the future.

Southerland Pumping Plant No. 692 is at risk of inundation during the 500-year, a 100-year flood with 1.5 meters of SLR, and tsunami events. The recommended resilience improvements are to install watertight connections, protect motor control centers, waterproof instrumentation and controls, replace existing pumps with submersible pumps, install bollards to protect from tsunami wave debris, and move portable generator to high ground. The estimated damage replacement cost of the facility is $23,166,000, and the estimated resilience improvements cost is $1,860,000.

3.3.3 Low Flow Diversions

In order to enhance the water quality of the City's watersheds, mitigate pollutants found in stormwater, and meet Clean Water Act requirements of affected surface waters such as Santa Monica Bay, the City operates and maintains 20 LFD facilities that divert low, dry-weather runoff drainages to the sanitary sewer system, or treats it onsite for local reuse applications. Kinney Circle Pumping Plant No. 647 is a 45,000 gpm stormwater pumping plant with a 500 gpm LFD - the assessment for that facility is given above with the stormwater pumping plants. The City-owned LFD facilities are shown in Table 5 with their pumping plant numbers, names, pumping capacities, and the risk assessment finding (none, minimal risk requiring no action, at risk requiring action).

Table 5 City-Owned Low Flow Diversions
One Water LA 2040 Plan – TM 5.5

Plant No.	LFD Name	Pumping Capacity (gpm)	Risk Assessment Finding
614	Tuxford (LFD)	180	At Risk
615	Sun Valley Park	80	None
647	Kinney Circle (LFD)	500	At Risk
701	South LA Wetlands	6,700	Minimal Risk
703	Echo Park	450	Minimal Risk
705	Garvanza	190	None
710	8th/Enterprise	700	None
711	Downtown	Conveyed by Gravity	None
730	Palisades Park	1,480	Minimal Risk
732	Marquez Canyon	300	Minimal Risk
733	Santa Monica (New)	10,000	At Risk
734	Temescal	3,500	At Risk
735	Santa Monica Canyon	3,500	None
736	Temescal Canyon	3,500	Minimal Risk
739	Bay Club Drive	340	Minimal Risk
740	Westside Park	60	At Risk
741	Mar Vista	4,800	None
742	Penmar	2,700	None
747	Thornton	1,500	Minimal Risk
748	Westminster Dog Park	Conveyed by Gravity	Minimal Risk
750	Imperial Hwy	644	None
ZOO	LA Zoo	12,000	At Risk

The following is a summary of the risk assessment of five LFDs with identified threats, the recommended improvements to improve resilience, the estimated cleaning and replacement costs of damaged or destroyed assets at the facility should the identified risks occur, and the estimated capital costs of implementing the recommended resilience improvements.

Tuxford Pumping Plant No. 614 is at risk of inundation during the 100-year flood event. The recommended resilience improvements are to waterproof instrumentation and controls and hatches. The estimated damage replacement cost of the facility is $650,000, and the estimated resilience improvements cost is $90,000.

Santa Monica Pumping Plant No. 733 is at risk of inundation during the 500-year flood, a 100-year flood with 1.5 meters of SLR, and tsunami events. The recommended resilience improvements are to waterproof instrumentation and controls and hatches. The estimated damage replacement cost of the facility is $1,300,000, and the estimated resilience improvements cost is $140,000.

Temescal Pumping Plant No. 734 is at risk of landslide and wildfire. The recommended resilience improvements are to improve the wall around the facility to protect it from landslides and fire and to manage the nearby vegetation. The estimated damage replacement cost of the facility is $650,000, and the estimated resilience improvements cost is $60,000.

Westside Park Pumping Plant No. 740 is at risk of inundation from the 100- and 500-year flood events. The recommended resilience improvements are to waterproof instrumentation and controls and hatches. The estimated damage replacement cost of the facility is $650,000, and the estimated resilience improvements cost is $90,000.

Los Angeles Zoo Pumping Plant is at risk of inundation from the 100- and 500-year flood events. The recommended resilience improvements are to waterproof existing wall and install flood gates at both entrances, install influent and effluent gates to prevent flooding from within, waterproof control room, and raise its diesel fuel tank. The estimated damage replacement cost of the facility is $8,424,000, and the estimated resilience improvements cost is $960,000.

3.3.4 Existing Facilities with Minimal Hazards

A total of 42 existing facilities (18 wastewater pumping plants, 9 stormwater pumping plants, and 15 LFDs) were determined to have no or minimal hazards. Facilities with no hazards were identified as such because they are not located in any of the hazard zones currently and in the future. A list with more detailed descriptions of facilities with minimal risks is provided in Appendix E.

3.3.5 Future Facilities

Three facilities currently under design were also assessed including the Venice Auxiliary Pumping Plant (VAPP) and two low flow treatment facilities (LFTF) as shown in Table 6.

Table 6 Facilities in Design
One Water LA 2040 Plan – TM 5.5

CIP No.	LFD Name	Pumping Capacity (gpm)
C922	Venice Auxiliary	60,417$^{(1)}$
J598	Ballona Creek LFTF-1	15,972 diverted; 4,167 treated
J925	Sepulveda Channel LFTF-2	903

Note:
(1) Combined capacity of VAPP and Venice Pumping Plant No. 646

The following is a summary of the risk assessment of the three facilities with identified threats and recommended resilience improvements, if needed.

Venice Auxiliary Pumping Plant is a proposed wastewater pumping plant to complement the existing Venice Pumping Plant No. 646 with an estimated construction cost of $17,029,000. The new facility will be located across Hurricane Street from the existing pumping plant. Similar to the existing facility, the new facility is at risk of inundation during the 500-year flood and is in a tsunami zone. The facilities are located between two 100-year flood hazard zones: in the Marina Del Rey harbor with a flood elevation of 9 feet (NAVD88) and ocean-side with a flood elevation of 15 feet (NAVD88). The new facility design was assessed for the conservative 100-year flood elevation of 15 feet. New pumps outside of the new electrical building and below grade will be submersible. Equipment on the first level of the electrical building including variable frequency drives, switchgear, programmable logic controls, and a backup generator for the controls will be at risk to damage by flooding. Electrical transformers feeding the facility at ground level outside of the electrical building will be damaged. Backup power for the new pumps will be supplied by generators at the existing facility and they are also at risk of flooding (separate recommendations are given in Section 3.3.1 for protecting backup power at the existing facility). Operations will be relocated from the existing facility to the second floor of the new facility, which will be above the flood elevation. Recommendations were made to the Bureau of Engineering for consideration in the design to waterproof the first level of the electrical building.

Ballona Creek LFTF-1 is a proposed LFTF that will divert 29 million gallons per day (mgd) (15,972 gpm) of dry weather flow, of which 6 mgd (4,167 gpm) will be treated and discharged in Ballona Creek with the remaining flows discharged into the sewer. Although the facility is adjacent to a waterway, it is not at risk of flooding or inundation.

Sepulveda Channel LFTF-2 is a proposed LFTF that will divert 1.4 mgd (903 gpm) of dry weather flow to be treated onsite and discharged into Sepulveda Channel. Although the facility is adjacent to a waterway, it is not at risk of flooding or inundation.

The three facilities are not at risk of damages due to liquefaction, landslides, and wildfire, as they are evaluated in this assessment.

3.4 Water Reclamation Plant Assessments

The City owns and operates four major water reclamation facilities: HWRP in Playa del Rey, the Donald C. Tillman Water Reclamation Plant (DCTWRP) in the Sepulveda Basin, LAGWRP across the freeway from Griffith Park, and TIWRP in the vicinity of the Los Angeles Harbor. Each of these facilities was screened and assessed for existing and potential future climate hazards and the associated risks. This section summarizes the current and/or future risks, damage replacement costs associated with the risks, resilience improvement recommendations, and costs.

3.4.1 HWRP

The HWRP is located along the Pacific coast and adjacent to several flood hazard zones. Climate change conditions of increasing temperatures, SLR, and changes in rainfall may affect power supply, coastal flooding, tsunami and landslide hazards, as well as treatment processes. Increased temperatures and extreme events may cause more frequent power interruptions at the HWRP. Increased rainfall during extreme events may increase the risk of landslides or mudslides on the eastern slope of the facility. SLR may increase the impacts of coastal storm surges and tsunamis on the coastal zone and Vista del Mar roadway that is protecting the facility from flooding. SLR may also affect the impacts on tsunami wave action on the facility's outfalls. Assessments were performed on the flooding, power failure and erosion risks with climate change considerations to identify resilience improvements that address these risks.

Flood Hazard Assessment

The HWRP is not currently in but is adjacent to Pacific Ocean flood hazard zones. The FEMA BFE for the 100-year flood is 13 feet to 15 feet NAVD88 at the HWRP – two adjacent zones meet at the location of the HWRP. The 500-year BFE is not calculated by FEMA but is estimated to be 16.25 to 18.75 feet NAVD88. The HWRP is also adjacent to but not in a tsunami zone that may have wave heights of 20 feet. Vista Del Mar, the coastal road between the HWRP and the Pacific Ocean, is at elevations ranging from 39 feet to 47 feet NAVD88. This elevation provides protection against these current coastal flooding hazards. Estimated SLR of 1.5 to 5.0 feet will likely not raise the BFEs or potential tsunami waves above the elevation of Vista Del Mar. Erosion of the beach and roadway may ensue with SLR and reduced beach sand replenishment (Grifman et al, 2013), and if future coastal storms increase in frequency and intensity. Vista Del Mar is in an earthquake liquefaction zone that may not have the structural integrity to withstand a concurrent tsunami during or following a seismic event. Further study of its integrity is recommended in cooperation with Los Angeles County.

The overall total replacement value of the HWRP has been estimated to be $3 Billion (Grifman et al, 2013). Impacts to individual pieces of equipment would cost significantly less than the loss of the entire facility for a given catastrophic event. Grade elevations at the facility are approximately 30 feet or higher compared to sea levels and therefore above-grade assets are not likely at risk to flooding due to coastal storms and tsunamis now and with SLR should a breach of Vista del Mar occur. However, the HWRP is served by subgrade galleries that house pumps, power feeds, controls, etc. Access to the galleries is raised above grade to prevent stormwater from entering. Sump pumps in the galleries pump out groundwater seepage via the stormwater system to the 1-mile ocean outfall but are not designed for a gallery flooding event. Should a flooding event occur, the galleries may be flooded and significant damage would be sustained by the facility that would cause a process shutdown and necessitate significant repairs costing millions of dollars.

Effluent pumping assures discharge during higher tidal and coastal storm conditions. This will likely require more power usage in the future at higher sea levels and during more frequent coastal storms. The 1- and 5-mile ocean outfalls may also be susceptible to worse hydraulic forces in the future during a coastal storm or tsunami with SLR and should be investigated further.

Backup Power Generation Assessment

Power is supplied to the HWRP via two independent power feeds. One feed is from the Scattergood Generating Station operated by Los Angeles Department of Water and Power (LADWP) on the south side of the HWRP. An emergency generator and fuel source is available to only power four of the pumps at the intermediate pump station (IPS) in case of a power outage. Individual uninterruptible power supplies are distributed throughout the facility for instrumentation and controls. Full operations could not be sustained should a power failure occur. Project development is underway with LADWP to provide full backup power to the facility to eliminate this risk.

Erosion and Landslide/Mudslide Assessment

The high eastern slope at the HWRP is a landslide hazard zone that may erode during extreme wet weather or seismic events. An existing retaining wall along the foot of slope protects most assets during a landslide event. There is approximately 1,100 feet without wall and some assets may be damaged and facility roadways may be blocked should a slide occur. A damage cost due to a landslide could total $5,000,000.

Enhancing slope stabilization methods and lengthening existing retaining walls along the foot of the eastern slope are recommended to stabilize slopes and protect assets during a landslide event in the short term with an estimated construction cost of $600,000.

Saltwater Intrusion Assessment

Saltwater intrusion of influent flows at the HWRP is a growing concern with rising influent total dissolved solids (TDS) concentrations that may worsen with SLR and could impact future effluent reuse; it should be monitored and evaluated for the cost-effectiveness of future source reduction efforts vs. enhanced treatment.

Findings and Recommended Resilience Improvements

The overall current and future climate hazards risk assessment for the HWRP is low.

Capital and non-capital facility planning recommendations for the HWRP for climate change considerations are as follows:

- Enhance slope stabilization and lengthen existing retaining wall approximately 1,100 feet to complete wall along eastern edge of facility - $600,000 conceptual construction cost.
- Perform a structural analysis of Vista Del Mar with Los Angeles County to determine structural stability of roadway during future flood and seismic/tsunami conditions.
- Evaluate tsunami impacts to HWRP hydraulics including tsunami magnitude needed to damage outfalls or hydraulically block effluent discharge.
- Monitor influent TDS and consider performing a cost benefit analysis of lining pipes versus treatment to mitigate higher influent TDS concentrations for reuse purposes.

3.4.2 DCTWRP

The DCTWRP is located in the Sepulveda Flood Control Basin administered by USACE. Climate change conditions of increasing temperatures and changes in rainfall may affect power supply and flooding hazards, causing more frequent power interruptions at the DCTWRP. Assessments were performed to understand the flooding and power failure risks associated with climate change considerations to identify resilience improvements that address these risks.

Flood Hazard Assessment

The DCTWRP is located in the Sepulveda Flood Control Basin administered by the USACE. The facility is between Haskell Canyon Creek to the east, Woodley Creek to the west and the Los Angeles River to the south that each contains a 100-year flood within their banks according to the FEMA FIRMs. The DCTWRP is currently in a mapped flood zone but outside a 500-year flood hazard zone with no calculated BFE on the FEMA FIRMs. Earthen berms on the south and east sides, and a floodwall on the west side protect the facility from flooding for a 100-year flooding event with a BFE of 712.0 feet NGVD29 (714.6 feet NAVD88) plus freeboard. The 200- and 500-year flood elevations calculated by the USACE are 713.5 feet NGVD29 (716.1 feet NAVD88) and 714.6 feet NGVD29 (717.2 feet NAVD88), respectively.

The USACE informed LASAN in 2014 that it requires the flood protection be raised to a Standard Project Flood elevation of 713.5 feet NGVD29 (716.1 feet NAVD88) plus 2.7 feet of freeboard. The DFE would be 716.2 feet NGVD29 (718.8 feet NAVD88). Raising protective berms and improving structures and gates to this DFE will be required for an estimated construction cost of $4,500,000. The implementation of the improvements is a short-term priority as per the USACE agreements.

LASAN estimated in December 2015 that the cost of flooding the DCTWRP is $52,345,275. This estimate is for value of the equipment generally below elevation 716.72 feet NGVD29 (719.32 feet NAVD88), which is the elevation of the primary settling tank walls (Arcadis, 2016).

Changing rainfalls may increase the frequency and severity of high river flows and flooding in the Sepulveda Flood Control Basin. The improvements required by the USACE will protect the DCTWRP for a current 200-year flood protection level plus freeboard. The additional 2.7 feet of freeboard, a DFE of 716.2 feet NGVD29 (718.8 feet NAVD88), protects the DCTWRP for the current 500-year event with 1.6 feet of freeboard. This 1.6 feet of freeboard provides extra protection for the facility should climate change increase extreme rainfalls and river flows in the future. No additional flood protection improvements for climate change considerations are warranted at this time.

Backup Power Generation Assessment

Power is supplied to the DCTWRP via two power feeds. Backup power is provided only for the headworks with 12 hours of onsite fuel. Full operations are not possible should a power failure occur. Individual uninterruptible power supplies are distributed throughout the facility for instrumentation and controls. In case of an emergency, the DCTWRP can bypass to the HWRP. Process recovery for full secondary treatment however would take approximately two weeks or longer if all processes were shut down and biomass is lost.

CIP #6145, Backup Power, will provide emergency backup power for the critical load so DCTWRP will not violate its National Pollutant Discharge Elimination System (NPDES) permit in case the existing power feeders are lost. This ongoing project will also remove the existing emergency backup generator and underground tank. Backup generators are scheduled to be installed as a medium priority in the next 10 years for a cost of $7,712,900.

Findings and Recommended Resilience Improvements

The overall current and future climate hazards risk assessment for the DCTWRP is low with implementation of the flood protection and power improvements that are already planned as follows:

- Add backup power generation for the critical load - $7,712,900
- Raise protective berms and add structures and gates - $4,500,000

No additional capital or non-capital resilience improvements are recommended for the DCTWRP for climate change considerations.

3.4.3 LAGWRP

LAGWRP is located along the Los Angeles River in a flood hazard zone. Climate change conditions of increasing temperatures and changes in rainfall may affect power supply and flooding hazards. This may change the recurrence interval, extent, and impact of flooding events. For instance, river flows and associated flood hazards for the 100-year event (1 percent chance of annual occurrence) may have the characteristics of the 500-year event (0.2 percent chance of annual occurrence) in the future. Increased temperatures and extreme events may cause more frequent power interruptions at the LAGWRP. Assessments were performed on the flooding and power failure risks with climate change considerations to identify future projects that address these risks.

Flood Hazard Assessment

An engineered riverbank along the Los Angeles River protects the LAGWRP from high river stages. The LAGWRP is currently in a flood zone but outside a 500-year flood hazard zone with no calculated BFE. The outfall to the Los Angeles River through the engineered riverbank does not have gates to prevent backflow from the river into the outfall at elevated river stages. The dechlorination effluent weir is at a high elevation such that processes are protected from backflow from the Los Angeles River. However, there is an open grate on the outfall between dechlorination and the engineered riverbank such that the river will flood the facility at river stages higher than the grate elevation but lower than the top of the riverbank. Installing gates on the outfall with an estimated construction cost of $400,000 will prevent river backflow from flooding the LAGWRP in this scenario.

A recent floodplain analysis by the USACE shows the facility will be flooded during 100- and 500-year flood events by the Los Angeles River (USACE, 2016). Calculated inundation pathways are overland along the north side of the LAGWRP and over the levee along the west side of the LAGWRP. Four-foot high temporary barriers were positioned by the USACE along the levee in December 2015, but they are not intended as permanent protection and would not protect the facility during 100- and 500-year events. Entrances to below-grade pipe galleries, pump rooms, and control rooms are protected by submarine doors. However, the USACE calculations are for 3 to 5 feet of water above grade in the facility for the 100-year event and 5 to 10 feet of water above grade for the 500-year event. These depths may be higher in the future with climate change affecting future rainfalls and river flooding conditions. Should a flooding event occur, it would likely damage all structures and processes with damage costs to the facility on the order of $75,000,000.

Subgrade structures may be protected by the existing submarine doors. However, the existing administration building, motor control centers (MCC) and pumps, instrumentation and controls and other electrical and mechanical systems above grade are vulnerable to being damaged by flooding. Elevating and/or waterproofing individual assets or constructing a flood barrier system around the LAGWRP would be required to protect the facility from Los Angeles River flooding. Constructing floodwalls with flood-proof gates and other structural enhancements integrated with the existing engineered riverbank to protect the entire facility would be required for a likely construction cost of $10,000,000.

Backup Power Generation Assessment

Power is supplied to the LAGWRP via two power feeds. A backup generator powers the influent pumping plant and one aeration blower only. Individual uninterruptible power supplies are distributed throughout the facility for instrumentation and controls. Full operations are not possible should a power failure occur. In case of an emergency, the LAGWRP can bypass to the HWRP. Biomass can be maintained with one blower for the aeration system in operation at low level but not for an extended period. Process recovery for full secondary treatment, however, would take approximately two weeks or longer if all processes were shut down and biomass is lost.

To power the LAGWRP for full operations, additional backup power generation would be required for the administration building, existing primary clarifiers, aeration tanks, final clarifiers, return activated sludge (RAS) pumps, filter pumps, tertiary filters, chlorination and dechlorination systems, and reclaimed water delivery systems. The likely construction cost of adding backup power for these systems would be $4,000,000. This estimated conceptual-level cost is based on the $7,712,900 cost for adding backup power generation to the DCTWRP for powering the minimal critical load to meet NPDES requirements, and scaling it down considering the smaller size of LAGWRP (20 mgd) compared to DCTWRP (80 mgd) and existing partial backup power generation at LAGWRP.

Findings and Recommended Resilience Improvements

The overall current and future climate hazards risk assessment for the LAGWRP is very high due to the flood hazard and backup power deficiency.

Capital and non-capital facility planning recommendations for the LAGWRP for climate change considerations are as follows:

- Add backup power generation for entire facility - $4,000,000 construction cost.
- Install backflow prevention gates on outfall to Los Angeles River - $400,000 construction cost.
- Construct floodwalls with flood-proof gates and other structural enhancements - $10,000,000 construction cost.
- Evaluate condition of existing submarine doors and include maintenance and regular exercise of doors in the facilities Standard Operating Procedure (SOP).

3.4.4 TIWRP

The TIWRP is surrounded by flood hazard zones and is in a tsunami zone. Climate change conditions of increasing temperatures and SLR may affect power supply, coastal flooding, and tsunami hazards. Increased temperatures and extreme events may cause more frequent power interruptions at the TIWRP. Assessments were performed on the flooding and power failure risks with climate change considerations to identify resilience improvements that address these risks.

Flood Hazard Assessment

The TIWRP is currently in a flood zone, but outside a 500-year flood hazard zone with no calculated BFE. The 100-year BFE in harbor waters at the TIWRP is 9 feet NAVD88. The average ground elevation on the TIWRP property is 10 feet NAVD88, just above the BFE for the 100-year flood. A BFE for the 500-year flood is not provided on FEMA FIRMS. However, the 500-year BFE may be estimated as 11.25 feet NAVD88, which is higher than the TIWRP ground elevation. The TIWRP is in a tsunami zone that may have wave heights of 20 feet. SLR of 1.5 to 5.0 feet will raise the 100-year BFE to flood the facility in the medium to long term.

Below-grade pipe galleries, pump rooms, and control rooms are unprotected for flooding during an inundation event. Entrances to the galleries are typically at curb level to prevent stormwater ponding from entering stairways but there are no submarine or other watertight doors on the entrances or vent grates. The facility experienced a flooding incident in January 2017 in which a spill occurred (an estimated 1,000 gallons breached a sand bagged area and sewage mixed with storm runoff flowed onto Terminal Way). Two below-grade galleries were flooded and equipment was damaged (pump motors, actuators, and communication cabinets). The damage would have been lessened if critical equipment vulnerable to water damage were not located below-grade in galleries.

Administration buildings, MCCs and pumps, instrumentation and controls and other electrical and mechanical systems above grade throughout the facility are vulnerable to being damaged by flooding. A cost analysis was performed during the 2015-2016 EPA CREAT (Appendix F) exercise to determine the anticipated replacement costs if TIWRP is inundated by a coastal flooding event. Systems critical to the operation of the facility will likely be damaged or destroyed by the flood waters and debris. An American Academy of Water Resources Engineers (AAWRE) Class 5 cost estimate was performed to identify the value of work to repair or replace the following electrical, instrumentation, control, and mechanical assets that would likely be affected by flood waters:

- Headworks building and lift station - $11,000,000
- MCCs throughout the facility - $15,800,000
- Advanced Water Purification Facility (AWPF) - $15,000,000
- Effluent pumping plant including standby generators - $11,000,000
- Aeration system replacement (i.e., blower facility) - $12,800,000 (construction cost prepared by LASAN staff)

The combined replace-in-kind cost estimate for the headworks building and lift station, MCCs throughout the facility, AWPF and the effluent pumping plant is $65,600,000. This estimated cost does not represent the likely full value of replace-in-kind costs for the existing facility, which would likely exceed $100,000,000. In addition, the TIWRP AWPF expansion is valued at over $50,000,000, which will also be at risk in a flooding event. A likely damage cost for the entire facility could exceed $150,000,000.

Elevating and/or waterproofing individual assets that are vulnerable to water damage would provide protection from coastal storm flooding, tsunamis, and/or internal flooding events such as the event that occurred in January 2017. Constructing a flood barrier system around the TIWRP would be required to protect the entire facility from coastal storm and tsunami flooding, but would not protect individual assets from internal flooding events. Constructing floodwalls using the existing perimeter walls as a base, adding flood-proof gates, and other structural enhancements to protect the entire facility would be required as a medium term priority for a likely construction cost of $10,000,000.

Backup Power Generation Assessment

An electrical substation is located at the TIWRP and is fed with two separate feed lines with switchgear that facilitates a power feed from one line at a time. There are two large diesel backup generators for the facility, one located at the Effluent Pumping Plant (EPP), and a stand-alone generator designed for filter operations only. The EPP generators have a 1,500 kilowatt (kW) capacity with a 23-hour run time before needing refueling of its 9,800-gallon tank. The Filter Area generators have a 500 kW capacity with a 25-hour run time before needing refueling of its 400 gallon tank. These generators do not power the entire facility, but do power the following processes and mechanical equipment: In-plant Lift Station Pump, Bar Screen, Grit Collector, Aeration Tank Blower, Return Activated Sludge Pump, EPP Pump, Filter Influent Pump, 2# Filter Influent Pump, Filter Backwash Air Blower and Pump, and Compressor. Individual uninterruptible power supplies are distributed throughout the facility for instrumentation and controls.

Backup generators are included in the Phase II of the AWPF (BOE CIP #5244, LASAN CIP #1583) but only to power the AWPF at an estimated cost of $10,000,000. Additional backup power generators will be needed for the entire facility in the case of a power failure at a likely cost of $4,000,000. This estimated conceptual-level cost is based on the $7,712,900 cost for adding backup power generation to the DCTWRP for powering the minimal critical load to meet NPDES requirements, and scaling it down considering the smaller size of TIWRP (30 mgd) compared to DCTWRP (80 mgd) and existing partial backup power generation at TIWRP.

Findings and Recommended Resilience Improvements

The overall current and future climate hazards risk assessment for the TIWRP is high due to the flood hazard and backup power deficiency.

Capital facility planning recommendations with conceptual construction costs for the TIWRP for climate change considerations are as follows:

- Add backup power generation to power the entire facility - $4,000,000
- Construct flood walls and add structures and gates - $3,730,000

4.0 IMPLEMENTATION RECOMMENDATIONS

Facility improvement prioritization is based on the hazard conditions at each location. After selecting asset locations, climate scenarios, threats, and assets of concern, LA Sanitation and CH2M assessed the risks and consequences of climate-related threats considering existing resources and projects previously planned. Resilience improvement recommendations described in Section 1.0 were prioritized for short-, medium-, or long-term implementation depending on the level and timing of risks as shown in Table 7. The schedule time periods listed in Table 7 are assumed to include the initiation of facility planning activities that would move to design and construction.

Table 7 Climate Change Risk Analysis Prioritization One Water LA 2040 Plan – TM 5.5

Priority	Schedule	Criteria
Short term	1 to 5 years	100-year flood, or fire hazard, or landslide zone
Medium term	5 to 10 years	100-year flood zone with 0.5 meter of sea level rise
Long term	10 to 25 years	500-year flood zone, or 100-year flood zone with 1.5 meters of sea level rise, or current tsunami zone

The operational resilience practices described in Section 3.2 are recommended to be implemented in the short term. The following describes the prioritization and scheduling of pumping plant, LFD, and water reclamation plant recommendations.

4.1 Pumping Plants and LFD Improvements Prioritization

Table 8 lists the wastewater and stormwater pumping plants and LFDs at risk to current or future threats, type of pumping plant, their prioritization for short-, medium-, or long-term improvements, the estimated damage replacement costs, and the estimated resilience improvement capital costs. Table 8 is sorted by priority according to the criteria shown in Table 7.

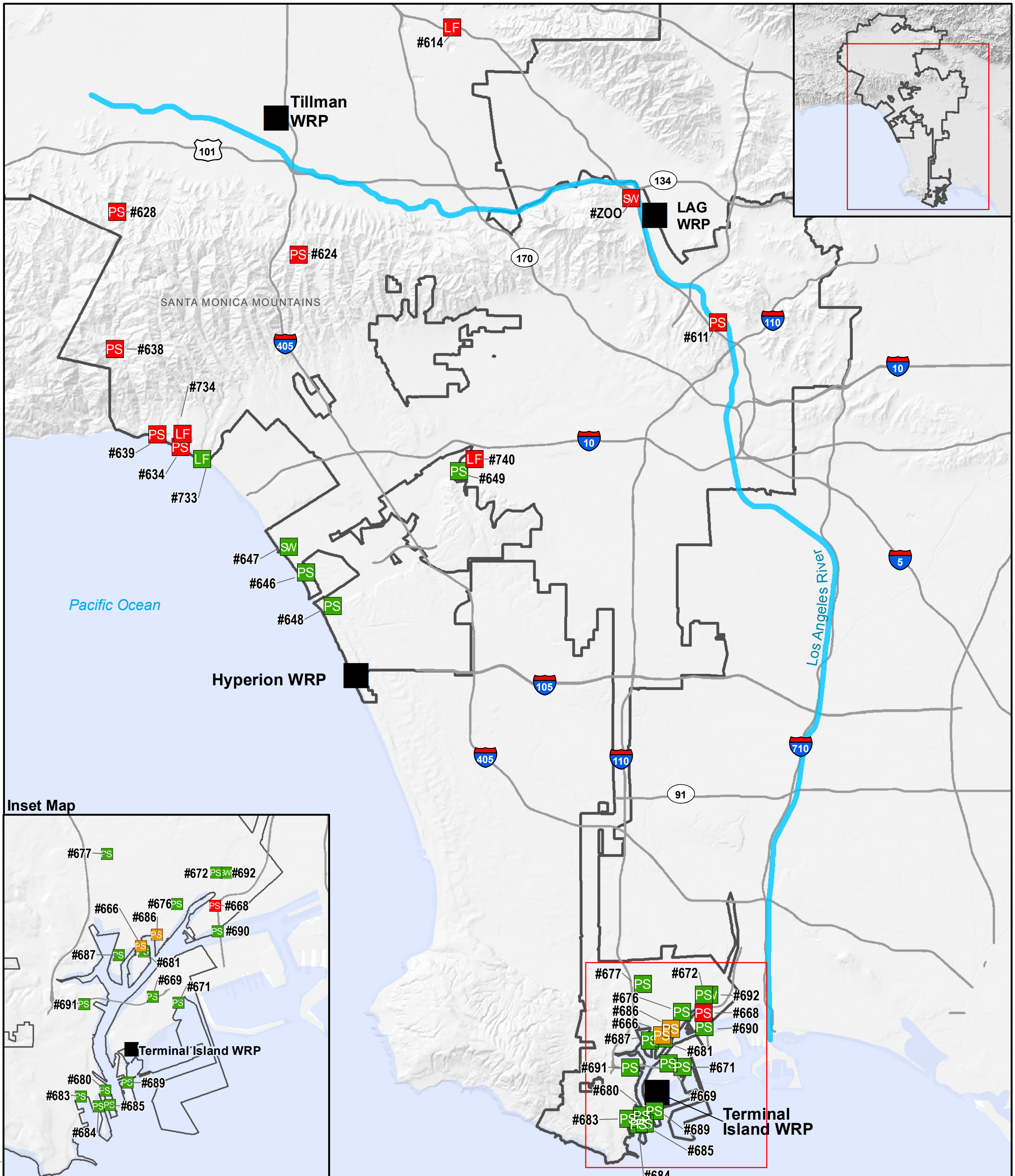
Estimated resilience improvement capital costs total $1,620,000 for short-term, $1,600,000 for medium-term, and $13,586,000 for long-term implementation, in current dollars. The estimated resilience improvement cost for wastewater pumping plants is $12,966,000, for stormwater pumping plants is $1,860,000, for LFDs is $380,000, and $1,570,000 for LFD/stormwater facilities (647 Kinney Circle and LA Zoo). The overall estimated resilience improvement cost for pumping plants and LFDs is $16,806,000.

Figure 1 shows the locations of the water reclamation plants and at-risk wastewater, stormwater pumping plants and LFDs.

Table 8 Pumping Plants Identified for Climate Hazard Improvements One Water LA 2040 Plan – TM 5.5

Plant No.	Name	Type	Priority	Estimated Damage Replacement Cost	Resilience Improvement Capital Cost
611	Riverdale	WW	Short Term	$21,600	$50,000
614	Tuxford (LFD)	LFD	Short Term	$650,000	$90,000
624	Roscomare	WW	Short Term	$1,000,000	$20,000
628	Corbin	WW	Short Term	$1,000,000	$0
634	Temescal	WW	Short Term	$3,159,000	$60,000
638	Palisades	WW	Short Term	$1,000,000	$0
639	North Pulga	WW	Short Term	$2,106,000	$60,000
668	Henry Ford	WW	Short Term	$4,743,600	$230,000
734	Temescal	LFD	Short Term	$650,000	$60,000
740	Westside Park	LFD	Short Term	$650,000	$90,000
ZOO	LA Zoo	LFD/SW	Short Term	$8,424,000	$960,000
666	Fries Ave	WW	Medium Term	$5,194,800	$1,110,000
686	Nissan Way	WW	Medium Term	$1,193,000	$490,000
687	North Neptune	WW	Long Term	$1,000,000	$400,000
646	Venice Pumping Plant	WW	Long Term	$31,590,000	$1,600,000
647	Kinney Circle	SW/LFD	Long Term	$3,750,000	$610,000
648	Thompson	WW	Long Term	$1,000,000	$480,000
649	Jefferson	WW	Long Term	$1,000,000	$80,000
669	Harris Place	WW	Long Term	$1,123,200	$810,000
671	Terminal Way	WW	Long Term	$7,020,000	$1,070,000
672	Murdock & I	WW	Long Term	$1,000,000	$720,000
676	Mcfarland	WW	Long Term	$5,616,000	$1,020,000
677	Hawaiian & "B"	WW	Long Term	$4,071,600	$870,000
680	22nd & Signal	WW	Long Term	$1,000,000	$126,000
681	Ports 'O' Call	WW	Long Term	$1,000,000	$340,000
683	22nd Street	WW	Long Term	$1,000,000	$500,000
684	Miner	WW	Long Term	$1,000,000	$500,000
685	Signal	WW	Long Term	$1,000,000	$480,000
689	Seaside	WW	Long Term	$1,000,000	$600,000
690	Anchorage	WW	Long Term	$1,000,000	$300,000
691	San Pedro	WW	Long Term	$12,636,000	$1,080,000
692	Southerland	SW	Long Term	$23,166,000	$1,860,000
733	Santa Monica	LFD	Long Term	$1,300,000	$140,000
			Total Cost	**$131,064,800**	**$16,806,000**

Abbreviations:
LFD = low flow diversion; SW = stormwater; WW = wastewater



Legend

Existing Water Reclamation Plant (WRP)

City of Los Angeles

Resilence Work Priority by Plant

Low Flow Diversion Plant
- LF Long Term Priority
- LF Short Term Priority

Stormwater Pumping Plant
- SW Long Term Priority
- SW Short Term Priority

Wastewater Pumping Plant
- PS Long Term Priority
- PS Medium Term Priority
- PS Short Term Priority

N

0 1 2 Miles

Hillshade Source: CalAtlas
http://www.atlas.ca.gov

Figure 1 - Wastewater and Stormwater Pumping Plants and Low Flow Diversions with Current and/or Future Climate Hazard Risks
One Water LA 2040 Plan
TM 5.5 - Climate Risk and Resilience Assessment for Infrastructure

carollo

One Water LA

4.2 Water Reclamation Plant Improvements Prioritization

The overall climate-hazard risk assessment and recommendations for the four water reclamation plants were described in Section 1.0. Some of the recommendations are for capital improvements and operational changes that could be implemented following the prioritization schedule shown in Table 7. While other recommendations are for investigative or other activities that would be implemented prior to facility planning. Operational recommendations may be implemented immediately. The following are recommendations on the implementation of those recommendations for each of the water reclamation plants, prioritized based on the individual threat/risk pairs and associated timing.

HWRP has an overall current and future climate hazards risk assessment of low. The ongoing project to provide full backup power to the facility is recommended to continue in the short term. Given the recent extreme rainfalls experienced in the Los Angeles area in 2017 and potential worsening future El Niño conditions, enhancing slope stabilization and lengthening the existing retaining wall along the eastern edge of facility is recommended in the short term for the estimated $600,000 conceptual construction cost. Monitoring influent TDS and performing a cost benefit analysis of lining pipes versus treatment to mitigate higher influent TDS concentrations for reuse purposes is also recommended for the short term in order to plan ahead for future sewer improvement of WRP process improvements. Evaluating tsunami impacts to HWRP hydraulics and performing a structural analysis of Vista Del Mar with Los Angeles County are recommended for medium-term implementation.

DCTWRP has an overall current and future climate hazards risk assessment of low with the immediate implementation of the flood protection and power improvements that are already planned as follows. Adding backup power generation and raising the protective berms for a combined estimated cost of $12,212,900 is recommended to be prioritized and implemented in the short term.

LAGWRP has an overall current and future climate hazards risk assessment of very high due to the Los Angeles River flood hazard and backup power deficiency. Therefore, all resilience improvements are recommended to be implemented in the short term. The condition of the existing submarine doors should be evaluated and new operation and maintenance procedures should be implemented immediately to protect the galleries from flooding. Project planning and design for improving flood protection for a combined estimated capital cost of $10,400,000 for raising the flood protection elevation and adding backflow prevention gates on the outfall is recommended to be implemented in the short term. Adding backup power generation for entire facility for $4,000,000 in estimated construction cost is also recommended for the short term.

TIWRP has an overall current and future climate hazards risk assessment of high due to the flood hazard and backup power deficiency. The TIWRP is not in a current flood hazard zone but SLR may put it in the flood hazard zone by mid-century. The TIWRP is in a tsunami zone. Therefore, the flood protection improvement recommendation of constructing flood walls is recommended for medium-term prioritization ($10,000,000 estimated construction cost) following the prioritization schedule in Table 7. However, a January 2017 spill event at the TIWRP resulted in the flooding of two below-grade galleries and damaging assets. Therefore, relocating and/or waterproofing equipment in below-grade galleries is recommended for any TIWRP improvement project in the short-term. Backup power generation should be added for the entire facility in the short term for an estimated construction cost of $4,000,000.

In summary, short term recommended resilience improvements for the water reclamation plants total $31,212,900 in estimated construction costs. The medium-term estimated construction cost in today's dollars is $10,000,000. There are no long-term resilience recommendations for water reclamation plants.

4.3 Cost Benefit Analysis

This assessment identified a number of climate-related threats with associated risks to the City's wastewater and stormwater infrastructure that may be worsened with climate change in the future. All 4 of the City's water reclamation plants and 11 pumping plants and LFDs have current risks to flooding, power failures, and other climate-based threats that should be addressed in the short term. An additional 22 pumping plants will likely have a future climate-related risks due to climate change.

The estimated replacement costs for risks for all pumping stations and LFDs, combined, for one event is $131,064,800 in today's dollars (Table 8). The combined replacement costs for assets at all four water reclamation plants subject to the identified risks would likely exceed $300,000,000 in today's dollars for one event. These costs may be incurred more than once should repeated extreme events occur in the future, which is projected to occur with climate change. The total replacement and resilience improvement costs are summarized in Table 9.

Table 9 Estimated Replacement Costs and Resilience Improvement Costs One Water LA 2040 Plan – TM 5.5

Assets	Estimated Replacement Costs	Estimated Resilience Improvement Costs
Water Reclamation Plants	$300,000,000	$41,212,900
Wastewater Pumping Plants	$92,474,800	$12,996,000
Stormwater Pumping Plants	$23,166,000	$1,860,000
Low Flow Diversions	$3,250,000	$380,000
Low Flow Diversion/Stormwater	$12,174,000	$1,570,000
Total Estimates	**$431,064,800**	**$58,018,900**

The recommended resilience improvements, totaling $58,018,900 in today's dollars, in combination with the recommended operational improvements, protect the City's assets and potential single-event losses of $431,064,800, and enables rapid recovery of full service to the community following an extreme event. This also reduces the risks of sewer backups into homes and the likelihood of the release of untreated sewage into the environment.

4.4 Recommendations for Future Designs and Operations

Drainage, conveyance, process and facility engineering, planning, and design are performed for infrastructure with life cycles of various durations. Sewers, structures, treatment facilities and other types of hard infrastructure are built with life cycles of 50 years or longer. Mechanical systems are often designed for life cycles of 25 years. The uncertainty of climate change requires risk-based planning and design for construction of new infrastructure or replacements that may last through the next 25 or 50 years and possibly through the year 2100. Therefore, design, operations and maintenance recommendations for the City's wastewater and stormwater systems are presented for mid-century and through the year 2100 that can be applied based on the service life (life cycle) of improved and new infrastructure.

4.4.1 Facility and Structure Design Standards

The City is recommended to consider integrating the following resilience strategies into design processes for new and, improvements made to existing pumping plants, LFDs, stormwater treatment facilities and water reclamation plants.

Flood Protection

Flood hazard reduction measures should be uniformly applied to designs in or nearby flood hazard zones and tsunami zones following all applicable building codes with additional considerations for changing conditions due to climate change. FEMA recommends that essential facilities be elevated or protected to the higher of: the code-mandated elevation, the community-mandated elevation, or the 500-year flood elevation (FEMA, 2013a). Because of the inherent difficulties in predicting the exact elevation of flood waters due to variables such as weather, new land developments, blockages in the floodway, and other potential factors, a freeboard elevation should be taken into consideration for flood protection on top of the flood zone elevations. Freeboard is defined by FEMA as an additional amount of height above the BFE used as a factor of safety (e.g., 2 feet above the base flood) in determining the level at which a building's lowest floor must be elevated or flood-proofed to be in accordance with state or community floodplain management regulations (FEMA, 2013b). Hazard Mitigation Assistance and other Federal or State grants for elevating or reconstructing buildings often require projects to use BFEs or other freeboard requirements. The BFE is the elevation of flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year – the 100-year storm.

Revisions made to the California Building Code in 2016 became effective on January 1, 2017. The 2016 California Building Code is based on the 2015 International Building Code (IBC). The IBC requires buildings to be designed and constructed in accordance with ASCE 24. ASCE 24-14 requires between 0 and 2 feet of freeboard above a BFE (BFE + freeboard) or using a DFE, whichever is higher. The determination of the freeboard depends on the flood hazard zone, the importance of the building and how it may be categorized using an ASCE classification system (ASCE, 2014). Flood Design Class 2 buildings and structures "pose a moderate risk to the public or moderate disruption to the community should they be damaged or fail due to flooding," which could be applied to stormwater pump stations, LFDs and stormwater treatment facilities. Class 3 includes "buildings and structures associated with power generating stations, water and sewage treatment plants, telecommunication facilities, and other utilities which, if their operations were interrupted by a flood, would cause significant disruption in day-to-day life or significant economic losses in a community." Class 4 includes buildings or structures that store or use hazardous fuels and hazardous chemicals. Water reclamation plants may be classified as per ASCE 24-14 as a Class 3 but more conservatively as a Class 4 building or structure.

The ASCE-recommended DFE in Standard 24-14 is calculated using the BFE plus a freeboard of 1 foot for inland areas or 2 feet for coastal zones for Class 3 buildings and structures. The DFE is the BFE plus a freeboard of 2 feet for inland and coastal zones or the 500-foot flood elevation, whichever is higher, for Class 4 buildings and structures.

Designs for facilities and operations with lifecycles extending through mid-century or the year 2100 should apply the FEMA and ASCE 24-14 requirements with an additional consideration for climate change. These considerations should include larger flood zones and higher flood elevations for inland waterways due to more intense precipitation in the future. Coastal design flood elevations should consider SLR. Facility designs in or adjacent to coastal flood hazard zones through mid-century should add 1.64 feet (0.5 meter) of SLR to the DFE. Long-term designs should add 4.92 feet (1.5 meters) of SLR to the DFE. These recommendations can be summarized as follows for lifecycles through mid-century and through year 2100:

- Mid-century: DFE = BFE + Freeboard + 1.64 feet (0.5 meter)
- Year 2100: DFE = BFE + Freeboard + 4.92 feet (1.5 meters)

The DFE should be applied to all structural, mechanical, electrical, and other components of facility designs for locating or relocating buildings and structures themselves or individual assets of a facility. The BFE should be first verified with the latest FEMA FIRMs and other flood management resources such as that provided by the USACE. The SLR component should be updated regularly by checking trends reported by NOAA and future projections by the IPCC, National Climate Assessment, and regional efforts.

Submersible pumps are typically specified in any situation where a pump room may be flooded by either inundation during an event or by a failure of piping within the confined space of a facility where no drainage is possible. Electrical cabinets, motor control centers, variable frequency drives, instrumentation and controls, uninterruptable power sources, electrical supply, switch gear, backup power generation, on-site document storage, other water-sensitive equipment, and air vents should be located above the DFE. If not possible, then redundant floodproofing should be applied to exteriors and interiors of structures depending on their criticality.

Fire and Landslide Protection

Pumping plants and other facilities are located in wildfire, landslide, and liquefaction zones. As the threat from fire increases in the future with higher temperatures and droughts, more proactive fire protection and prevention measures added to the design of facilities and the grounds around them will reduce that risk. Landslide potential will also increase with more extreme rainfalls (i.e. El Niño periods) alone and even more so in liquefaction zones and fire burn areas. Facility planning and design should first check the location of the facility against wildfire, landslide, and liquefaction zones to identify the risks and apply relative building codes.

Designs in wildfire zones should include fire protection for assets themselves and clearing vegetation and debris away from facilities in wildfire zones in cooperation with firefighting, parks, and forestry agencies to reduce the threat and consequences of wildfires. Slope stability at facilities in landslide and liquefaction zones should be verified and proactive design of erosion control and soil stabilization at facilities will reduce the risk of mudslide and other impacts associated with increased average rainfall and intense rain events. Landscaping designs should include new vegetation that is preventing erosion and/or replace existing vegetation with drought-tolerant and/or fire-resistant vegetation.

Power Supply and Backup Power Generation

All four water reclamation plants have two power feeds for electrical supply to provide redundancy in emergency conditions. However, power failures may still occur across multiple power grids and regions that will cause failures and backup power generation is needed to maintain operations and prevent environmental impacts. Pumping plants, LFDs and stormwater treatment systems typically have a single power feed. Permanent onsite or temporary portable backup power generation exists at these facilities across the City and instrumentation and controls are typically supplied with uninterruptable power sources for limited times. Power supply failures may increase in frequency and duration with increasing flooding risks and hotter days stressing power grids. Reliance on backup power will likely increase in the future.

Facility designs should include an initial energy audit to identify power requirements and energy saving opportunities via operations and equipment modifications and specification. Designs should use energy efficiency considerations to lower power requirements and in the case of a failure, extend the runtimes of permanent and/or portable backup power supplies with limited fuel reserves. The planning decision of designing for onsite permanent vs. temporary portable generators should still be made based on criticality of the facility, space, safety and other considerations presently taken. Where backup power is provided by portable generators, designs should feature "quick connect" capability (waterproof cabinets and connections in flood hazard zones), and the designated location of the portable generator.

4.4.2 <u>Drainage, Sewer and Outfall Design Standards</u>

The City uses a design storm for sewer and drainage designs. Design storms are typically identified via data analysis of historical rainfall records without consideration of future conditions. Changes in rainfall patterns and extreme events may result in future conditions overwhelming infrastructure based on outdated design conditions. The application of an appropriate design condition has implications on the City's overall operations including, but not limited to, capacity management, operations, and maintenance (CMOM), MS4 permit compliance and floodplain management. The following describes recommendations for drainage, sewer, and outfall designs.

Rainfall Monitoring and Data Analysis

Rainfalls are monitored and data is collected by various agencies, organizations, and institutions in the Los Angeles region. The City should periodically recalculate probability curves for design storm statistics (intensity/duration/frequency and volume/duration/frequency) and annual statistics (volumes, frequency, extreme events). The frequency of recalculation should be a minimum of every five years and then evaluated to determine if design storm criteria such as the 10-year/24-hour design storm applied in drainage and conveyance planning and design projects should be revised.

Sewer and Storm Drain Systems

The City uses a back-loaded storm with a 10-year recurrence interval for a 24-hour duration (10-year/24-hour) as a design storm for sewer and storm system drainage, conveyance and facility designs based on an intensity-duration-frequency (IDF) curve. The development of this storm can be found in the Advanced Planning Report, Vol. 3, TM No. 6B, dated January 1990. System responses to increased rainfall due to climate change may be realized in not only higher flows, hydraulic elevations, and surcharging but also in more infiltration and inflow (I/I).

About two-thirds of climate projections suggest increases in 3-day and daily annual maximum precipitation by end of century. The median change in 3-day annual maximum precipitation for the Los Angeles Downtown area by end of century is projected to increase by about 10 percent. The wetter projections also suggest an increase in the daily extreme precipitation events such as the 100-year/24-hour storm that would occur approximately

1 percent of the time on an annual basis, and the 10-year/24-hour storm used for stormwater and sewer design.

A modified 10-year/24-hour design storm based on climate change projections through the year 2050 is described in Appendix B. The 10-year/24-hour storm is projected to have a 17 percent increase in volume and a higher hourly peak intensity. The cumulative rainfall produced in a twenty-four period is about 4.44 inches for the current design storm and 5.21 inches for the modified design storm. The modified design storm has a peak intensity of 1.34 inches compared to the peak intensity of 1.14 inches for the current storm.

Designs of drainage, conveyance, and treatment systems with life cycles through the year 2050 and beyond should be evaluated by applying the modified design storm as a safety factor. The design storm is recommended for engineering, planning and design purposes for drainage, sewers and facilities. Existing infrastructure was most likely designed in the past to different design criteria. The utmost care and best engineering practices must therefore be applied in the use of larger design storms. Drainage and conveyance calculations using a larger storm would most likely result in determining that larger capacity conveyance would be required. However, resizing existing infrastructure during replacement projects using the new design storm must involve downstream calculations to assure that any additional flow allowed into and conveyed by drainage, sewers and storm drain systems have sufficient downstream conveyance capacity so as not to cause additional surcharge in downstream infrastructure.

Drainage or source controls designed to delay or prevent stormwater from entering storm sewer systems or infiltrating sanitary sewers may be used in the future to mitigate the forecasted increases in event rainfall volumes and peak intensities. Best management practices (BMPs), green infrastructure (GI), and other source controls can temporarily retain or infiltrate runoff which will reduce peak flows being conveyed by storm drain systems.

Storm Drain Outfalls

There are many public and private outfalls throughout the City discharging from storm drain systems. When submerged, drainage is impeded and back-flooding may occur into storm water systems, onto streets and properties. Tide gates, flap valves and other backflow prevention systems prevent this from occurring. SLR in coastal areas and higher river flows due increased extreme rainfalls in the future may submerge these outfalls. Many outfalls without tide gates may back-flood the City via the storm sewer system during storm surges that will increase in frequency and magnitude with future higher high tides due to SLR. Larger floodplains and higher river elevations in response to worse extreme rainfalls may also similarly back-flood drainage systems. The DFE calculations described above should be used as a guide for determining which storm drain outfalls should be controlled with tide gates, flap valves or other inflow devices for the life cycles of the outfalls.

Tide Gate Designs

SLR will increase the amount of time that the City's tide control structures and outfalls will be under water in corrosive saline environments. The design specification of materials used for tide gates and outfalls should be periodically evaluated in the future to assure resilient designs and reliable operations.

4.4.3 Centralized Climate Trend Analyses, Projections and Recommendations

Planning, design and construction of wastewater and stormwater systems and facilities rely on design criteria and forecasts of the conditions they are intended to serve. Many of the criteria and considerations are used by many City agencies across infrastructure systems and public services. Individual agencies may apply design criteria based on their own interpretation of climate trend analyses and projections of future conditions or rely on others. This may result in inconsistent designs across the City's infrastructure. Centralized evaluations and forecasts of future conditions may better serve the City's purposes and provide for consistent long-term resilient and sustainable designs and services.

The City of New York released its "PlaNYC" in 2007 to manage growth with aging infrastructure and address the effects of climate change (City of New York, 2007). Initially, the Mayor's Office of Long-Term Planning and Sustainability coordinated with all other City agencies to develop, implement, and track the progress of PlaNYC and other issues of infrastructure and the environment that cut across multiple City departments. New York City currently has a Mayor's Office of Recovery and Resiliency to oversee the City's multilayered OneNYC climate resiliency program. New York City also first convened its New York City Panel on Climate Change (NPCC) in August 2008, which advises the Mayor and the New York City Climate Change Adaptation Task Force on issues related to climate change and adaptation as it relates to infrastructure. In September 2012, the City passed Local Law 42 that established the New York City Panel on Climate Change as an ongoing body. The NPCC is required to meet at least twice a year to review recent scientific data on climate change and its potential impacts, make recommendations for projections for future conditions within one year of the publication of Intergovernmental Panel on Climate Change (IPCC) Assessment Reports, or at least every three years, and advise the Mayor's Office on communications strategies related to climate science. The NPCC recommends specific global climate model or general circulation model (GCM) scenarios for changes in precipitation and SLR to be used citywide.

4.5 Federal and State Funding Mechanisms

Some resilience improvement projects may be eligible for federal or state funding. For example, facilities that are in current flood hazard zones (especially those on the short term list) may be eligible for funding assistance through FEMA. Several federal and state funding mechanisms that may potentially be available as alternative funding sources for resilience improvement projects are described below.

4.5.1 FEMA via California Office of Emergency Services

The California Office of Emergency Services (Cal OES) administers FEMA grant fund programs that receive funding on an annual basis. Cal OES will review and screen grant applications and prioritizes them for FEMA review and approval; where the state acts as the applicant. Projects must comply with Federal environmental laws and regulations, be cost-effective, technically feasible, and meet any additional program criteria. The total cost to implement approved mitigation activities is funded by a combination of federal and non-federal sources. FEMA Hazard Mitigation Assistance (HMA) includes three key programs:

- **Hazard Mitigation Grant Program (HMGP)** provides grants to state and local governments to implement long-term hazard mitigation measures after a major disaster declaration. California is eligible to receive HMGP funds up to 20 percent of the costs of recovery resulting from a major disaster. The program's cost sharing requirements are 75/25.

- **Pre-Disaster Mitigation (PDM) Grant Program** provides funds to local governments and state agencies on an annual basis for hazard mitigation planning and implementing mitigation projects prior to a disaster. The program's cost sharing requirements are 75/25.

- **Flood Mitigation Assistance (FMA) Program** provides grants to assist states and communities in implementing measures to reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insurable under the National Flood Insurance Program. The program's cost sharing requirements are 75/25 for insured properties and planning grants and up to 100/0 for severe repetitive loss property with a repetitive loss strategy.

Table 10 provides a comparison between the programs of activities eligible for funding. To apply for grant funding the City must contact Cal OES to confirm eligibility and obtain filing forms.

Table 10 FEMA Hazard Mitigation Assistance Eligible Activities
One Water LA 2040 Plan – TM 5.5

Eligible Activity	HMGP	PDM	FMA
Mitigation Projects	X	X	X
Property Acquisition and Structure Demolition	X	X	X
Property Acquisition and Structure Relocation	X	X	X
Structure Elevation	X	X	X
Mitigation Reconstruction	X	X	X
Dry Floodproofing of Historic Residential Structures	X	X	X
Dry Floodproofing of Non-Residential Structures	X	X	X
Generators	X	X	
Localized Flood Risk Reduction Projects	X	X	X
Non-Localized Flood Risk Reduction Projects	X	X	
Structural Retrofitting of Existing Buildings	X	X	X
Non-Structural Retrofitting of Existing Buildings and Facilities	X	X	X
Safe Room Construction	X	X	
Wind Retrofit for One- and Two-Family Residences	X	X	
Infrastructure Retrofit	X	X	X
Soil Stabilization	X	X	X
Wildfire Mitigation	X	X	
Post-Disaster Code Enforcement	X		
Advance Assistance	X		
5 Percent Initiative Projects(1)	X		
Miscellaneous/Other(2)	X	X	X
Hazard Mitigation Planning	X	X	X
Planning-Related Activities	X		
Technical Assistance			X
Management Costs	X	X	X

Source http://www.caloes.ca.gov/HazardMitigationSite/Documents/FEMA_HMA_tri_2015_508%20(2).pdf

Notes:

(1) FEMA allows increasing the 5% Initiative amount up to 10% for a Presidential major disaster declaration under HMGP. The additional 5% Initiative funding can be used for activities that promote disaster resistant codes for all hazards. As a condition of the award, either a disaster-resistant building code must be adopted or an improved Building Code Effectiveness Grading Schedule is required.

(2) Miscellaneous/Other indicates that any proposed action will be evaluated on its own merit against program requirements. Eligible projects will be approved provided funding is available.

If a facility has been damaged during a presidentially declared disaster, funding may be available through FEMA's Public Assistance (PA) Grant Program. Federal disaster grant assistance may be awarded for debris removal and the repair, replacement, or restoration of disaster damaged publically owned facilities. This program also provides assistance for protection against subsequent disasters. After the disaster is declared, applicants must submit to the State a Request for Public Assistance (RPA). FEMA Fire Management Assistance Grant Program is also awarded in this way.

The first step is to contact Cal OES to determine if the City's infrastructure is a part of the PDM for California. If so, the PDM was likely approved during the last FEMA review and the California HMP Director is likely the point of contact to administer the filing of forms etc. If not, the City will need to purse a PDM as an addendum to the correct state PDM for future grant monies. There are FEMA grants to assist with this process as well.

For a FEMA grant, the City must identify past disasters that were declared in Los Angeles County. If so, a RPA would likely have been filed by the City administration during those disasters. If no RPA was filed, the City is likely not eligible for these funds.

4.5.2 United States Department of Housing and Urban Development

The United States Department of Housing and Urban Development (HUD) administers the Community Development Block Grant (CDBG) Disaster Recovery Program to provide flexible grants to help cities, counties, and States recover from presidentially declared disasters. Funds for recovery efforts can include housing, economic development, infrastructure and prevention of further damage to affected areas. The City can file independently of the state.

4.5.3 NOAA

NOAA is currently requesting applicants for special projects and programs associated with their strategic plan and mission goals. One of NOAA's long term mission goals is climate adaptation and mitigation. Eligible applicants include institutions of higher education, nonprofits, commercial organizations, international or foreign organizations or governments, individuals, state, local and Indian Tribal governments. Funding has not yet been allocated and cost sharing is not required unless it is determined that a project can only be funded under an authority that requires matching/cost sharing funds. Applications must be submitted to Grants.gov by September 30, 2017. The City can follow independently of the state.

4.5.4 Additional Resources

Grand funding is available through several different sources and additional funding opportunities occur during declared disasters. Funding opportunities are continuously posted to Grants.gov. The following departments may also provide assistance with long-term hazard mitigation planning or funding:

- Department of Energy
- Department of Commence
- Department of Agricultural
- Department of Defense
- Department of Interior
- Department of Health and Human Services, Centers for Disease Control
- Office of Public Health Preparedness and Reponses

-This Page Left Blank Intentionally-

APPENDIX A – REFERENCES

American Society of Civil Engineers (ASCE), 2014. *Flood Resistant Design and Construction.* ASCE/SEI 24-14. 2014.

Barnard, P. L., van Ormondt, M., Erikson, L.H., Eshleman, J., Hapke, C., Ruggiero, P., Adams, P. N., and Foxgrover, A. C. 2014. Development of the Coastal Storm Modeling System (CoSMoS) for predicting the impact of storms on high-energy, active-margin coasts. Natural Hazards, 31 p., doi:10.1007/s11069-014-1236-y

Berg, N., Hall, A., Sun, F., Capps, S., Walton, D., Langenbrunner, B., and Neelin, D. 2015. Twenty-First-Century Precipitation Changes over the Los Angeles Region. *Journal of Climate*, 28.

Borrero, Jose C., Mark R. Legg, and Costas E. Synolakis, 2004. Tsunami Sources in the Southern California Bight. Geophysical Research Letters, Vol. 31, L13211. Doi:10.1029/2004GL020078, 2004.

Brekke et al. 2013. Downscaled CMIP3 and CMIP5 Climate Projections Release of Downscaled CMIP5 Climate Projections, Comparison with Preceding Information, and Summary of User Needs

Bureau of Reclamation (Reclamation). 2013. Downscaled CMIP3 and CMIP5 Climate Projections. Release of Downscaled CMIP5 Climate Projections, Comparison with Preceding Information, and Summary of User Needs.

BWSC. 2015. Wastewater and Storm Drainage System Facilities Plan. Prepared by CH2M for the Boston Water and Sewerage Commission, Boston, MA. June, 1015.

California Department of Water Resources Climate Change Technical Advisory Group (CCTAG). 2015. Perspectives and guidance for climate change analysis. California Department of Water Resources Technical Information Record. p. 142.

Cayan, D.R., M. Tyree, M. Dettinger, H. Hidalgo, T. Das, E.P. Maurer, P. Bromirski, N. Graham, and R. Flick. 2009. Climate Change Scenarios and Sea Level Rise Estimates for the California 2008 Climate Change Scenarios Assessment.

City and County of San Francisco. 2016. The Sea Level Rise Action Plan. Prepared by AECOM, CH2M and Risk Management Solutions for San Francisco Planning and San Francisco Public Works. March, 2016.

CH2M. 2012. Technical Memorandum No. 1, Analysis of Projected Changes in Precipitation IDF Values Based on Climate Change Projections. Prepared by CH2M for the City of Los Angeles Bureau of Sanitation. May 15, 2012.

FEMA. 2010. *Technical Fact Sheet No. 1.6, Designing for Flood Levels Above the BFE, Home Builder's Guide To Coastal Construction*. December 2010.

FEMA. 2013a. *Designing for Flood Levels above the BFE after Hurricane Sandy, Hurricane Sandy Recovery Advisory*. FEMA, Federal Insurance and Mitigation Administration, Risk Reduction Division, Building Science Branch. Washington, DC. April.

FEMA. 2013b. *Flood Insurance Manual*. FEMA, Federal Insurance and Mitigation Administration. Washington, DC. October.

Garfin, G., G. Franco, H. Blanco, A. Comrie, P. Gonzalez, T. Piechota, R. Smyth, and R. Waskom, 2014: Ch. 20: Southwest. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 462-486. doi:10.7930/J08G8HMN.

Grifman, P. M., J. F. Hart, J. Ladwig, A. G. Newton Mann, M. Schulhof. 2013. Sea Level Rise Vulnerability Study for the City of Los Angeles. USCSG-TR-05-2013.

Hall, Alex. 2013. Fact Sheet on Climate Change in the Los Angeles Region: Temperature Results. UCLA Dept. of Atmospheric and Oceanic Sciences. December 2013

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, eds. Cambridge, United Kingdom and New York, New York: Cambridge University Press. p. 996.

IPCC. 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley, eds. Cambridge, United Kingdom and New York, New York: Cambridge University Press. p. 1535.

Jin, Y., Goulden, M. L., Faivre, N., Veraverbeke, S., Sun, F., Hall, A., and Randerson, J. T. 2015. Identification of two distinct fire regimes in Southern California: Implications for economic impact and future change. Environmental Research Letters, 10(9).

Lee, H.J., W.R. Normark, M.A. Fisher, H.G. Greene, B.D. Edwards, J. Locat, 2004. Timing and Extent of Submarine Landslides in Southern California. *Proceedings of the Annual Offshore Technology Conference 3*. January 2004.

Lee, H.J., H.G. Greene, B.D. Edwards, M.A. Fisher, and W.R. Normark, 2009. Submarine Landslides of the Southern California Borderland. *Geological Society of America Special Papers*, Vol. 454, pp 251-269. 2009.

Ligtvoet W et al. 2015. Adaptation to climate change in the Netherlands – Studying related risks and opportunities. The Hague: PBL Netherlands Environmental Assessment Agency.

Locat, J., H.J. Lee, P. Locat and J. Imran, 2004.Numerical analysis of the mobility of the Palos Verdes debris avalanche, California, and its implication for the generation of tsunamis. *Marine Geology*, Vol. 203, pp 269-280. January 2004.

Maurer, E.P. 2007. Uncertainty in hydrologic impacts of climate change in the Sierra Nevada, California under two emissions scenarios. Climatic Change, Vol. 82, No. 3-4, 309-325, DOI: 10.1007/s10584-006-9180-9.

Moffatt & Nichol, 2007. Tsunami Hazard Assessment for the Ports of Long Beach and Los Angeles, Final Report. April, 2007.

National Oceanic and Atmospheric Administration. 2016. Sea Level Trends. Available online at http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml. Accessed April 15, 2016.

National Academy of Sciences. 2006. Surface Temperature Reconstructions for the Last 2,000 Years. National Academies Press.

NYC Department of Environmental Protection (NYCDEP). 2013. NYC Wastewater Resiliency Plan Climate Risk Assessment and Adaptation Study

PBL. 2013. The Effects of Climate Change in the Netherlands: 2012. PBL Netherlands Environmental Assessment Agency. http://www.pbl.nl/en/publications/the-effects-of-climate-change-in-the-netherlands-2012/

Pierce, David W., Daniel R. Cayan, and Bridget L. Thrasher. 2014. "Statistical Downscaling Using Localized Constructed Analogs (LOCA)." J. Hydrometeor. 15, 2558–2585.

Raff, D. A., T. Pruitt, and L.D. Brekke. 2009. "A framework for assessing flood frequency based on climate projection information, Hydrol." Earth Syst. Sci. 13, 2119-2136.

Rupp DE, JT Abatzoglou, KC Hegewisch, and PW Mote. 2013. "Evaluation of CMIP5 20th century climate simulations for the Pacific Northwest USA." *Journal of Geophysical Research: Atmospheres*. 118(19):10,884-10,906.

Sun, F., Hall, A., Schwartz, M., Walson, D., and Berg, N. 2016. Twenty-First-Century Snowfall and Snowpack Changes over the Southern California Mountains. *Journal of Climate*, 29.

Sun, F., Walton, D. B., and Hall, A. 2015. A Hybrid Dynamical–Statistical Downscaling Technique. Part II: End-of-Century Warming Projections Predict a New Climate State in the Los Angeles Region. *Journal of Climate*, 28(12).

Taylor, Karl E., Ronald J. Stouffer, and Gerald A. Meehl. 2012. An Overview of CMIP5 and the Experiment Design. Bull. Amer. Meteor. Soc. 93, 485–498.

U.S. Army Corps of Engineers (USACE), 2016. *Floodplain Analysis, Los Angeles River: Barham Boulevard to First Street, Flood Plain Management Services Special Study, Los Angeles, California*. U.S. Army Corps of Engineers, Los Angeles District, Engineering Division, Hydrology and Hydraulics Branch, Los Angeles, CA. October 2016.

U.S. Geological Survey (USGS), 2015. Climate Change impacts to the Southern California Coast. Presented at AdaptLA climate change workshop in Los Angeles, CA, October 2, 2015. Available at: http://walrus.wr.usgs.gov/coastal_processes/cosmos/Barnard_CoSMoSOverview_AdaptLA_Oct2015.pdf

Villaraigosa, A. R. 2008. Securing L.A.'s water supply. City of Los Angeles Department of Water and Power Rep., 32 pp. [Available online at http://www.greencitiescalifornia.org/assets/water/LA_Emergency-Water-Conservation-Plan_Water-Supply-Report-2008.pdf.]

Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, S. Doney, R. Feely, P. Hennon, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville, 2014: Ch. 2: *Our Changing Climate. Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 19-67. doi:10.7930/J0KW5CXT.

-This Page Left Blank Intentionally-

APPENDIX B – HISTORICAL AND POTENTIAL FUTURE CLIMATE CONDITIONS

B.1 INTRODUCTION

A growing body of evidence indicates that Earth's atmosphere is warming. Observed changes in oceans, snow and ice cover, and ecosystems are consistent with this warming trend (NAS 2006; IPCC 2007, 2013). The temperature of Earth's atmosphere is directly related to the concentration of atmospheric greenhouse gases (GHG). Growing scientific consensus suggests that climate change will occur as the result of increased concentrations of GHG and related temperature increases (IPCC 2007, 2013).

Climate is the average weather a region experiences over time, not individual seasonal or annual anomalies. Generally, climate is measured over 30-year periods, during which statistically significant trends may be observed for changes in key climate parameters such as precipitation, temperature, wind speeds, and sea level rise (SLR). In other words, a single flood or extreme weather event is not evidence of a changing climate; however, changes in temperature or precipitation over many years may indicate climate change.

Future climate change projections are made primarily on the basis of coupled atmosphere-ocean general circulation model (GCM) simulations under a range of future emission scenarios. While the GCMs have improved significantly in recent years, the models continue to have substantial uncertainty, especially for regional conditions. Because of the coarse-scale of GCMs, it is necessary to "downscale" model results (translate changes simulated at the coarse grid scale to changes at a regional or watershed scale) to the local region. Whether through dynamic or statistical methods, downscaling adds another source of uncertainty to projections. In addition, the range of projections, especially beyond 2030, is governed by the assumed future global emissions.

The science and predictive tools related to global climate studies are rapidly evolving. While general consensus exists regarding the observed global warming trend, considerable uncertainty remains regarding regional projections of future precipitation. This section includes a review and summary of the most recent climate science, climate projections, and existing climate impact assessments for the City's assets or services.

B.1.1 Observed Climate and Trends

While climate change is often considered a phenomenon that will occur in the future, the climate of southern California and Los Angeles has already experienced changes in recent times. This section provides a brief overview of the main observed changes in regional climate for temperature, precipitation, and sea levels.

B.1.1.1 Observed Temperature

Annual water year[1] mean temperature departure for the California south coast region (Santa Barbara, Los Angeles, Orange County, and San Diego) from 1895 to September 2016 are shown on Figure B.1. This shows the variability of temperature from year to year compared to the mean temperature recorded from 1949 to 2005, which was 61.4 degrees Fahrenheit (°F) (16.3 degrees Celsius [°C]). A significant increase in temperature is apparent beginning about 1977. Although periods of cooling have occurred historically, most important is the warming trend that has occurred since the late 1970s. This warming trend also has been observed in North American and global trends. Observed climate and hydrologic records indicate that more substantial warming has occurred since the 1970s and that this observation is likely a response to the increases in GHG emissions during this time. The average annual temperature in the Los Angeles area from 1981 to 2010 was 63°F (17.2°C). Temperatures have increased by about 0.45°F (0.25°C) in the past decade, while 2014, 2015, and 2016 represent the three warmest years since 1895. The average temperature from October 2015 to September 2016 in the south coast region was 64°F (17.8°C), the fourth warmest since 1895.

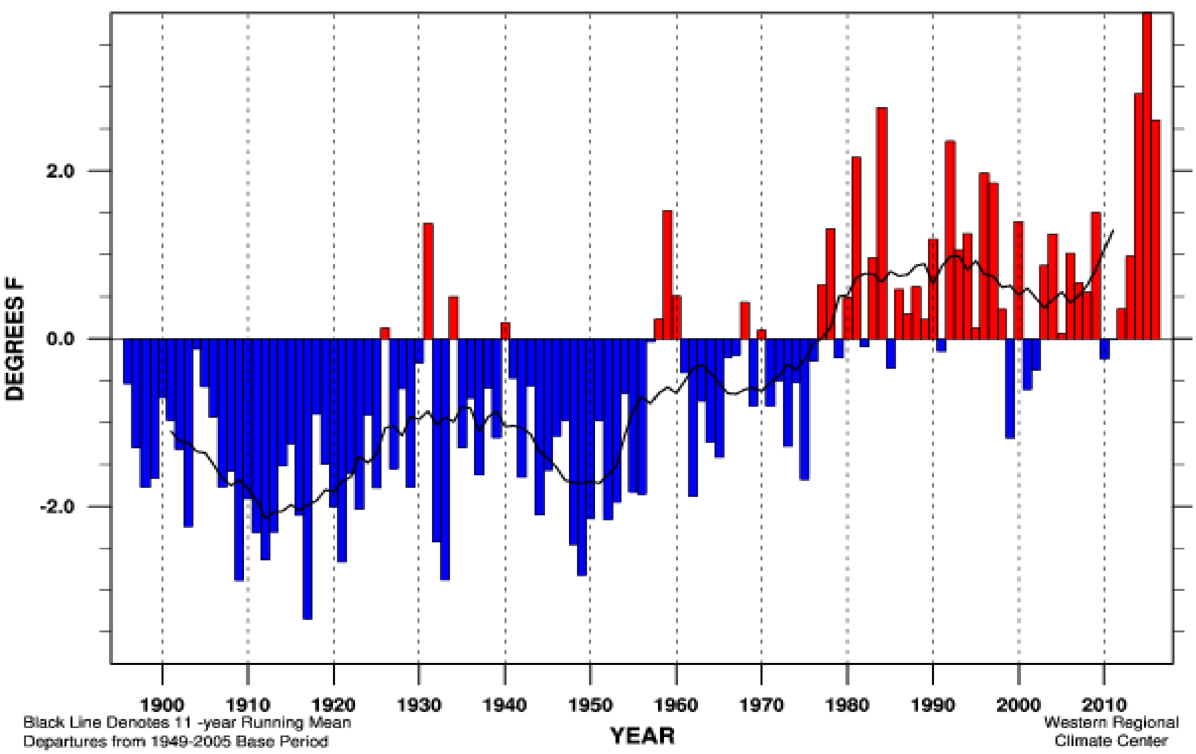


Figure B.1 California South Coast Region Mean Temperature Departure (Oct-Sep)
Notes: 1896-2016 Bars: mean water year temperature; solid line: 11-year running mean. Source: Western Regional Climate Center, 2016.

[1] A water year is defined as the 12-month period October 1, for any given year through September 30, of the following year. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. The year ending September 30, 1999 is called the "1999" water year.

Daily average and extreme temperatures vary across the Los Angeles area. Hot days increase chances of losing power, having transmission problems and introducing health and safety concerns for staff. The measured number of days with maximum temperatures greater than or equal to 95°F for three different climate stations in the Los Angeles area from 2011 to 2015 are summarized in Table B.1. The summary shows how inland areas such as Woodland Hills have many more hot days than coastal areas and hence power demands for air conditioning may vary significantly across the region affecting the availability of power.

Table B.1 Annual Number of Hot Days from 2011 to 2015 in the Los Angeles Region
One Water LA 2040 Plan – TM 5.5

Climate Station	Number of Days (daily maximum > 95°F or 35°C)				
	2011	2012	2013	2014	2015
Long Beach(1)	1	5	0	12	9
Pierce College in Woodland Hills(1)	48	80	65	69	75
Santa Monica(2)	0	2	4	2	3

Notes:
(1) Data from the Pierce College Weather Station: http://piercecollegeweather.com/data/monthly-historical-data/
(2) Data from the University of California Agricultural and Natural Resources Department: http://www.ipm.ucdavis.edu/WEATHER/index.html

B.1.1.2 Observed Precipitation

The water year annual mean precipitation for the California south coast region from 1895 to September 2016 is shown on Figure B.2. This shows the variability of annual precipitation from year to year compared to the mean precipitation recorded from 1949 to 2005, which was 17.38 inches (44.1 centimeters [cm]). Annual precipitation shows substantial variability and periods of dry and wet spells. Most notable in the precipitation record is the lack of a significant long term annual trend, yet the annual variability appears to be increasing. More years with larger than long-term annual precipitation seem to appear in the most recent 30-year record. The wettest year on record and the driest year on record have both occurred since 1980. The total precipitation from October 2015 to September 2016 in the south coast region was 8.75 inches (22.2 cm), the ninth lowest since 1895. Historical data show 14 to 18 inches (35.6 cm to 45.7 cm) of annual precipitation in the Los Angeles area from 1981 to 2010, but total annual precipitation in Los Angeles has been about 6.8 inches for the past few years. The local rainy season is typically October 15 to April 15. Very heavy rainfalls also occur during El Niño events and coastal storms. The most-recent, Third National Climate Assessment indicates a 5 percent increase in very heavy precipitation events (the heaviest 1 percent) for the Southwest for the period 1958-2011 (Walsh et al 2014).

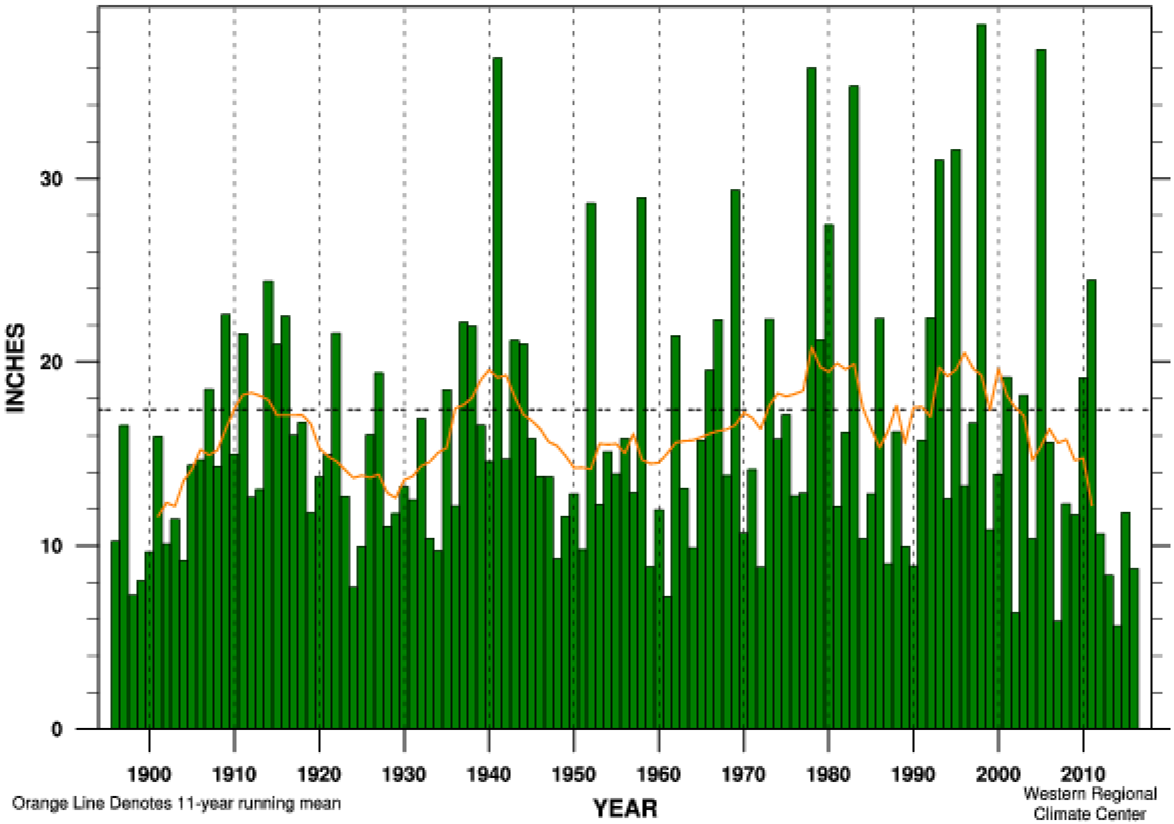


Figure B.2 California South Coast Region Annual Precipitation (Oct-Sep)
Notes: 1896-2016 Bars: annual water year recorded precipitation; solid line: 11-year running mean. Source: Western Regional Climate Center, 2016.

B.1.1.3 Observed Sea Level

Global and regional sea levels have been increasing over the past century and are expected to continue to increase throughout this century. Historical global sea-level rise is estimated as 0.08 inch/year (in/yr) (2 millimeters per year [mm/yr]) over the past century. Regional and local weather, ocean circulation patterns, vertical land movement, and seismic events influence local SLR. Over the past several decades (since the 1930s), sea level measured at tide gauges along the California coast has risen at a rate of about 6.69 inches to 7.87 inches (17 cm to 20 cm) per century, nearly the same as global SLR (Cayan et al 2009). The differences are caused by local circulation and land motion components. There is considerable variability amongst tide gauges along the Pacific Coast, primarily reflecting local differences in vertical movement of the land and length of gauge record.

Locally, there are three National Oceanic and Atmospheric Administration (NOAA) gauges measuring tide levels at and nearby Los Angeles since the 1930s. Figure B.3 shows the mean sea level trend for the NOAA tide gauge in the Port of Los Angeles at the south end of Signal Street (Berth 60). This is the Los Angeles, California gauge (NOAA Tide Gauge No. 9410660). The mean sea level trend is 0.04 in/yr (0.95 mm/yr) with a 95 percent confidence interval of +/- 0.01 in/yr (+/- 0.24 mm/yr) based on monthly mean sea level data from 1923 to 2015 which is equivalent to a change of 3.74 inches (9.5 cm) in 100 years. At the Santa Monica tide gauge (Figure B.4) the mean sea level trend is 0.06 in/yr (1.52 mm/yr) with a 95 percent confidence interval of +/- 0.01 in/yr (+/- 0.35 mm/yr) based on monthly mean sea level data from 1933 to 2015 which is equivalent to a change of 6.0 inches (15.24 cm) in 100 years. This station is at the seaward end of the Santa Monica Pier.

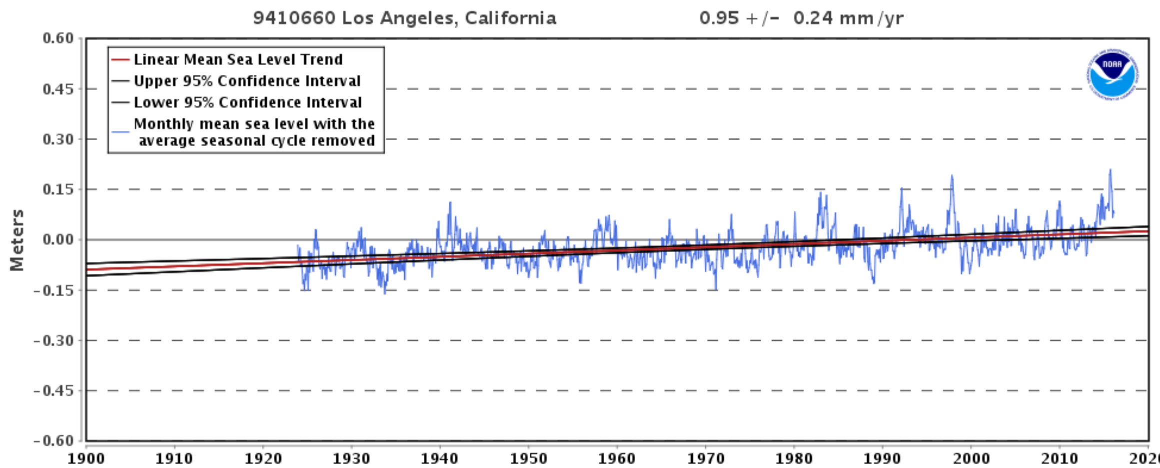


Figure B.3 Monthly Mean Sea Level and Trend at Los Angeles, California Tide Gauge (NOAA Gauge No. 9410660, April 15, 2016)

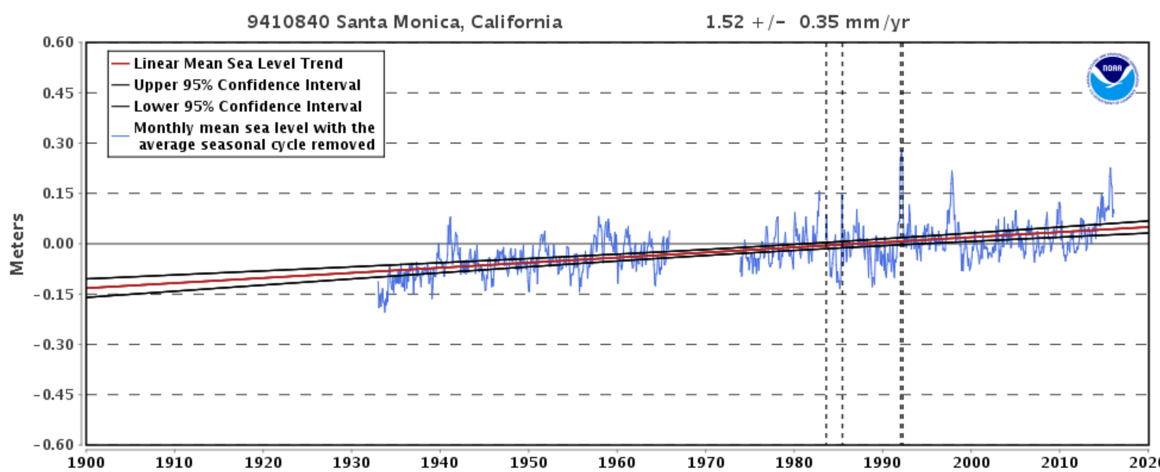


Figure B.4 Monthly Mean Sea Level and Trend at Santa Monica, California Tide Gauge (NOAA Gauge No. 9410840, April 15, 2016)

At the Newport Beach tide gauge on the Orange County Harbor District Office pier south of Los Angeles, the mean sea level trend is 2.22 mm/yr with a 95 percent confidence interval of +/- 0.09 in/yr (+/- 1.04 mm/yr) based on monthly mean sea level data from 1955 to 1993 which is equivalent to a change of 8.76 inches (22.25 cm) in 100 years (Figure B.5). It should be noted that the period of record for the Newport Beach tide gauge is much shorter than the other gauges displayed in Figure B.3 and Figure B.4. It is difficult to examine trend statistics for the Newport Beach tide gauge given such a short period.

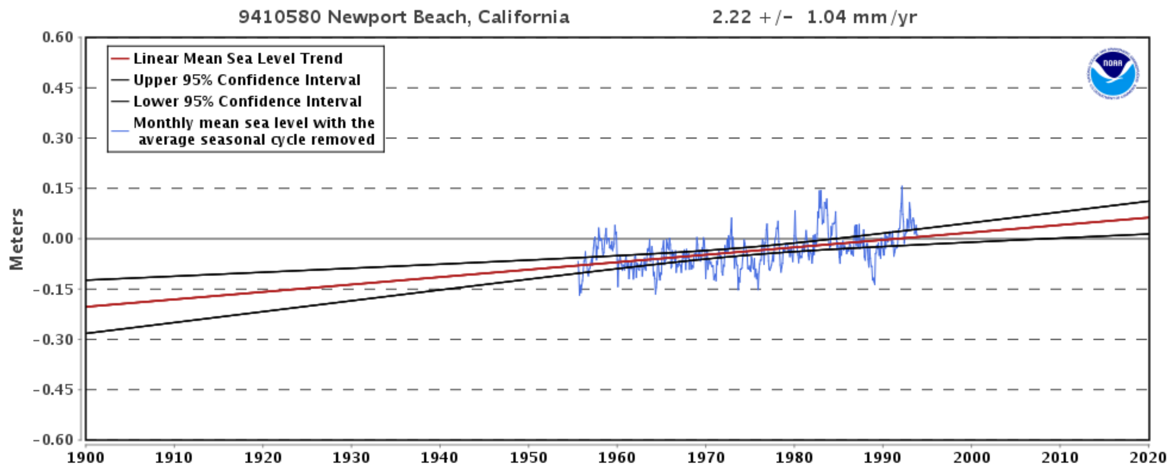


Figure B.5 Monthly Mean Sea Level and Trend at Newport Beach, California Tide Gauge (NOAA Gauge No. 9410580, April 15, 2016)

B.1.2 Climate Change Scenario Development

In 2000, the Intergovernmental Panel on Climate Change (IPCC) published the Special Report on Emission Scenarios (SRES) on GHG emissions scenarios that described a family of six emission scenarios to condition GCMs (IPCC, 2000). The emissions scenarios are defined by alternative future development pathways, covering a wide range of demographic, economic, and technological driving forces and resulting GHG emissions. The B1 scenario results in the lowest GHG emissions and the A2 scenario results in the highest emissions by 2100 of those considered in the SRES report. Subsequent to the 2000 SRES report, the SRES modeling teams ran additional simulations with GHG emissions stabilized at different levels ("post-SRES" scenarios). The Coupled Model Intercomparison Project Phase 3 (CMIP3) climate model simulations under SRES emission scenarios was the basis for the IPCC Fourth Assessment Report (AR4) released in 2007 (IPCC 2007).

The Coupled Model Intercomparison Project Phase 5 (CMIP5) climate model simulations were used in the most recently released IPCC Fifth Assessment Report (AR5) (IPCC 2013). The climate models in the CMIP5 (Taylor et al., 2012; Karl et al., 2012; Rupp et al., 2013; CA DWR 2015) were driven using a set of newly developed emission scenarios (called Representative Concentration Pathways, or RCPs) to reflect possible trajectories of greenhouse gas emissions over the course of the century. There are four scenario pathways (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) used in the CMIP5 (van Vuuren et al., 2011). Each RCP defines a specific emissions trajectory and subsequent radiative forcing (a radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system).

The RCPs differ from the scenarios used in the IPCC 2007 report (IPCC 2007) which were developed based on a range of possible future greenhouse gas emissions using assumptions of fossil fuel use, regional political and social conditions, technologies, population, and governance decisions. Both the current RCPs and the older emission scenarios, labeled as SRES are shown in Figure B.6.

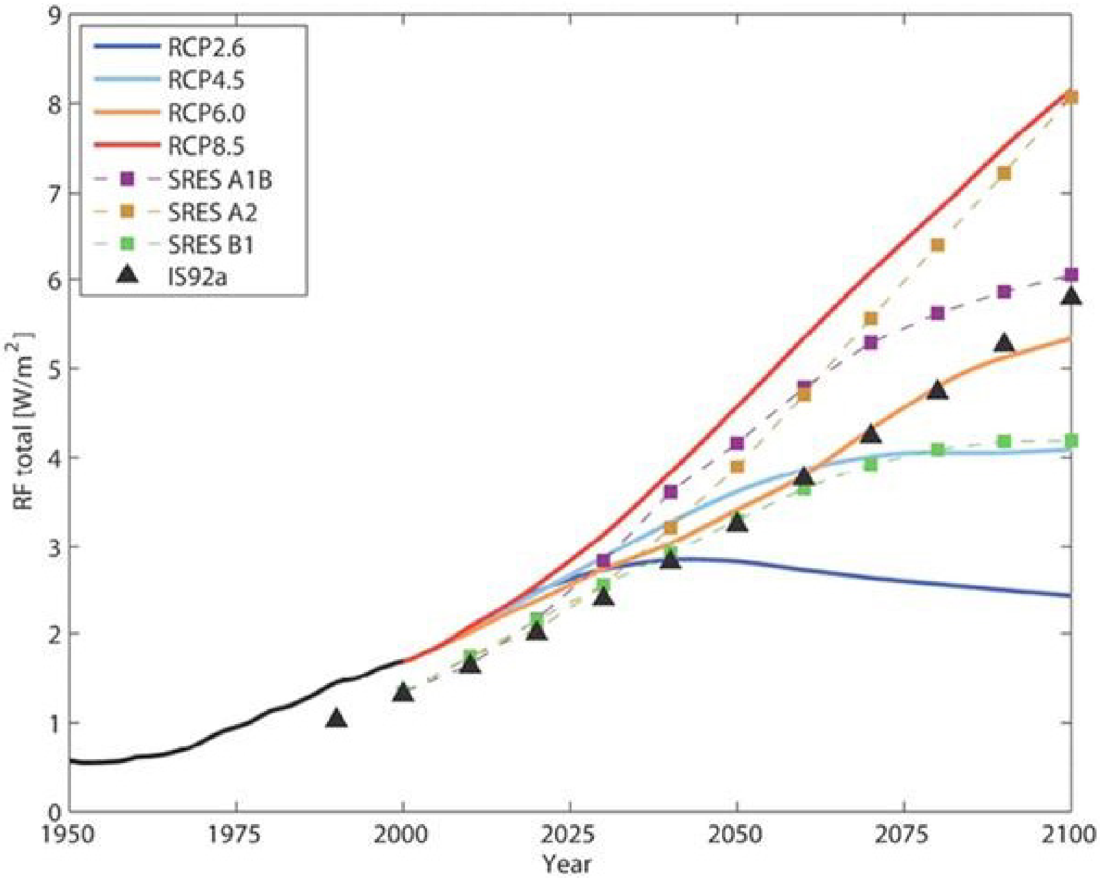


Figure B.6 Comparisons of Total Radiative Forcing from Previous IPCC Assessments (SAR IS92a, TAR/AR4 SRES A1B, A2 and B1) with RCP Scenarios (IPCC, 2013)

This section describes how the global GCM calculations are downscaled to regional and local levels and translated into potential temperature, precipitation, and sea level conditions in the future. These conditions include increasing variability in rainfall and drought, surface warming, extremely hot days and stronger winds that affect particular risks such as flooding, erosion, landslides, wildfire, and power outages.

B.1.2.1 Global and Regional Climate Change Projections

Climate change assessments rely upon existing global projections of future climate changes and regional downscaled results. Given the high degree of uncertainty that any single model will accurately project future climatic conditions, the assessment presented in this report incorporates the results of multiple climate model simulations from CMIP3 and CMIP5 obtained from an existing publicly available database (http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html; Maurer et al. 2007; Reclamation 2013). The results represent a range of potential future climate conditions resulting from climate change.

The CMIP3 database includes the results of 16 GCMs simulating the three emissions scenarios (SRES A2, SRES A1B, and SRES B1) to provide a range of specific climatological factors, principally temperature and precipitation, during the period 1950 to 2099. The CMIP5 database includes the results of 36 GCMs simulating the three emissions scenarios (RCP8.5, RCP6.0, and RCP4.5) to provide a range of specific climatological factors, principally temperature and precipitation, during the period 1950 to 2099. Many of the GCMs were simulated multiple times for the same emission scenario because of differences in starting climate system state (initial oceanic and atmospheric conditions). Research (Pierce et al., 2009; Gleckler et al., 2008) has shown the importance of incorporating multiple climate projections (even when derived from the same GCM) and the superiority of the multi-model ensemble for a wide array of climate metrics. The subsequent results presented on future climate (primarily temperature and precipitation), and indirectly streamflow, rely on the data generated by these GCMs. The CMIP3 and CMIP5 multi-model data set is one of the most comprehensive downscaled climate model datasets available for the United States. The GCM projections that are used in this data set are consistent with those applied in the latest IPCC AR5 report (IPCC 2013).

Due to the coarseness of the GCM grids and associated biases in their calculations to available historical data within large grids, the GCM calculations have been transformed into a local scale (approximately 12 kilometers or 7.5 miles) through a process called bias correction and spatial downscaling (BCSD) (Maurer et al. 2007; Reclamation 2013).

Climate model simulations exhibit continued warming, globally and regionally over California (Cayan et al., 2009; Reclamation 2016). Figure B.7 shows the median annual mean temperature and precipitation changes for California and Nevada derived from the full ensemble of climate projections. The current suite of GCMs, when simulated under potential, future GHG emission pathways and current atmospheric GHGs, exhibit warming both globally and regionally over California. The median, or "central tendency" scenario indicates substantial warming by end of mid-century. The Third National Climate Assessment reported that warming in the southwest is projected to increase more rapidly in inland areas than coastal areas, reflecting a continued ocean cooling influence. Regional annual average temperatures are projected to rise by 2.5°F to 5.5°F (1.4°C to 3.1°C) by 2041-2070 and by 5.5°F to 9.5°F (3.1°C to 5.3°C) by 2070 to 2099 with continued growth in global emissions (A2 emissions scenario), with the greatest increases in the summer and fall (Garfin et al. 2014). If global emissions are substantially reduced (as in the B1 emissions scenario), projected temperature increases are 2.5°F to 4.5°F (1.4°C to 2.5°C) by 2041-2070, and 3.5°F to 5.5°F (1.9°C to 3.1°C) by 2070-2099. Summertime heat waves are projected to become longer and hotter as will the number of very hot days.

Statewide trends in annual precipitation are not as apparent as those for temperature. Future projections for Southern California are for drier conditions. The north-south transition of precipitation change may be attributable to a more northerly push of storm tracks caused in part by increased sea level pressure blocking systems under future climate conditions (Cayan et al. 2009).

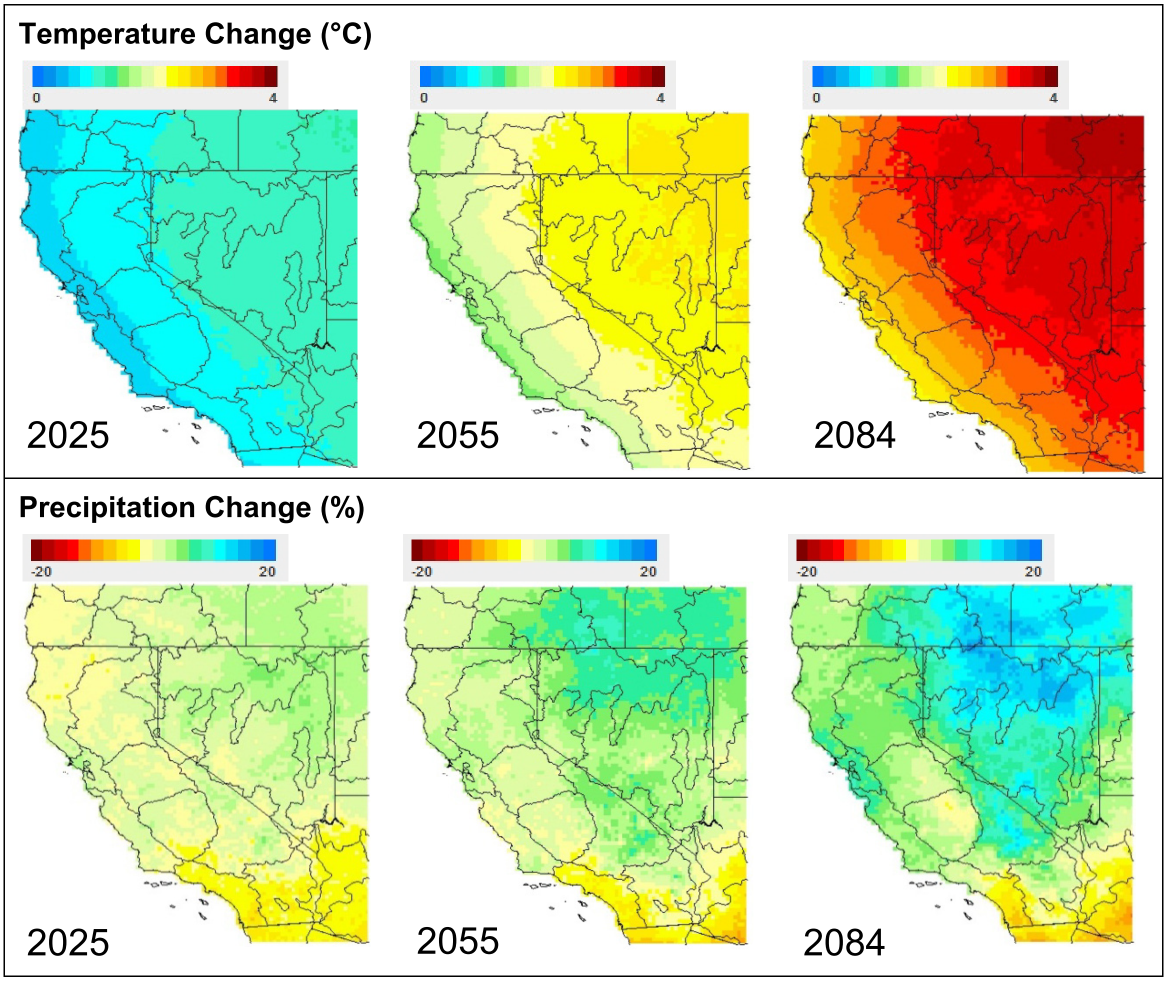


Figure B.7 Projected Changes in Mean Annual Temperature and Precipitation for 2011-2040 (2025), 2041-2070 (2055) and 2070-2099 (2084)

Note: Figures show change as compared to the 1981-2010 model simulated period. Top panel shows °C. Bottom panel shows percent change.

As cited in Section B.1.1.3, sea levels along the California coast have risen at the same rate as global sea levels in general, excluding local circulation and land motion components. Global sea level rise calculations with GCMs are likely to underestimate future sea level rise although "semi-empirical" methods have been developed to project future rates of sea level rise based on a simple statistical relationship between past rates of globally averaged temperature change and sea level rise. Sea level rise from the year 2000 may range from about 2 feet to more than 6 feet by 2100, depending on emissions scenario (Wilson et al). Figure B.8, taken from the Third National Climate Assessment, shows estimated, observed, and possible future global sea level rise from 1800 to 2100, relative to the year 2000.

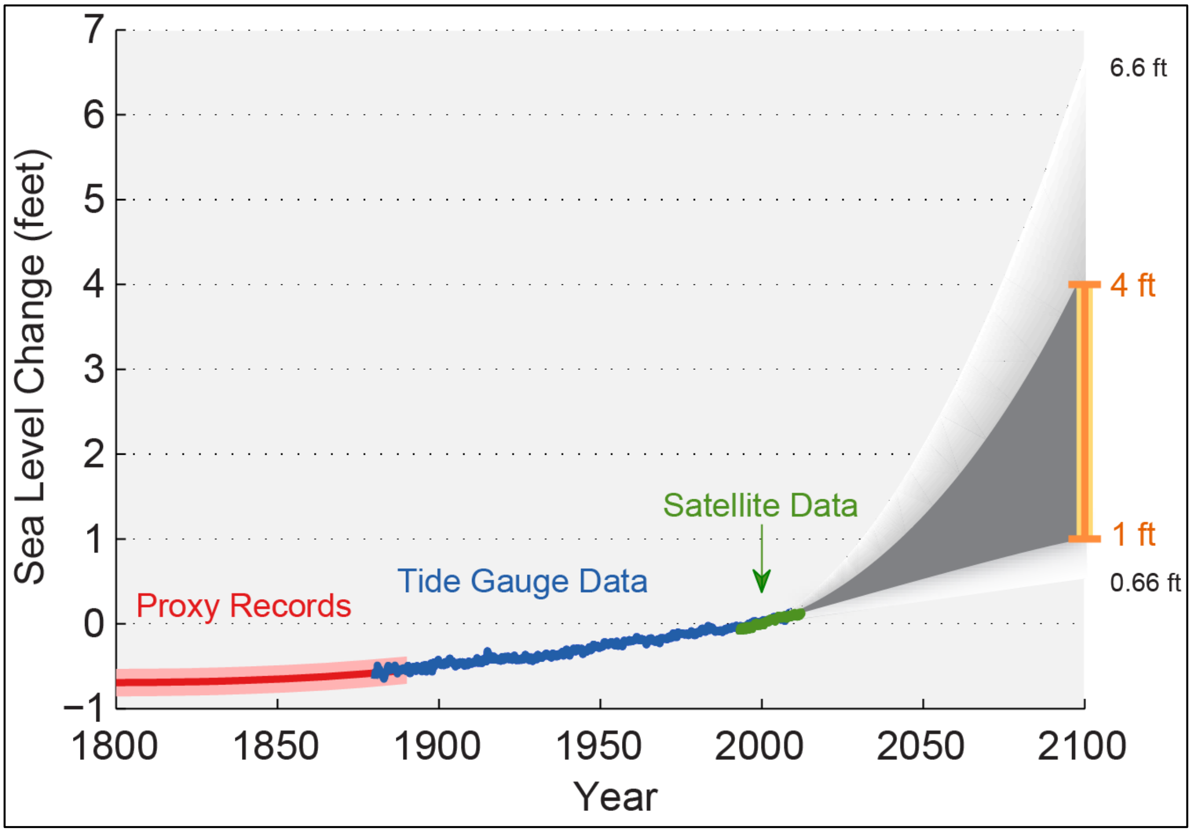


Figure B.8 Past and Projected Changes in Global Sea Level
Source: Wilson et al 2014.

B.1.2.2 Projected Changes in Temperature

Under all available future climate scenarios, air temperatures are projected to increase in California. All projections are consistent in the direction of the temperature change (increase), but vary in terms of climate sensitivity (magnitude) (Brekke et al. 2013). The median of the available climate model projections suggests annual warming of up to 3.2°F to 3.6°F (1.8°C to 2.0°C) by mid-century and up to 4.5°F to 5.4°F (2.5°C to 3.0°C) increase by end-of-century for the Los Angeles Downtown area (Figure B.9).

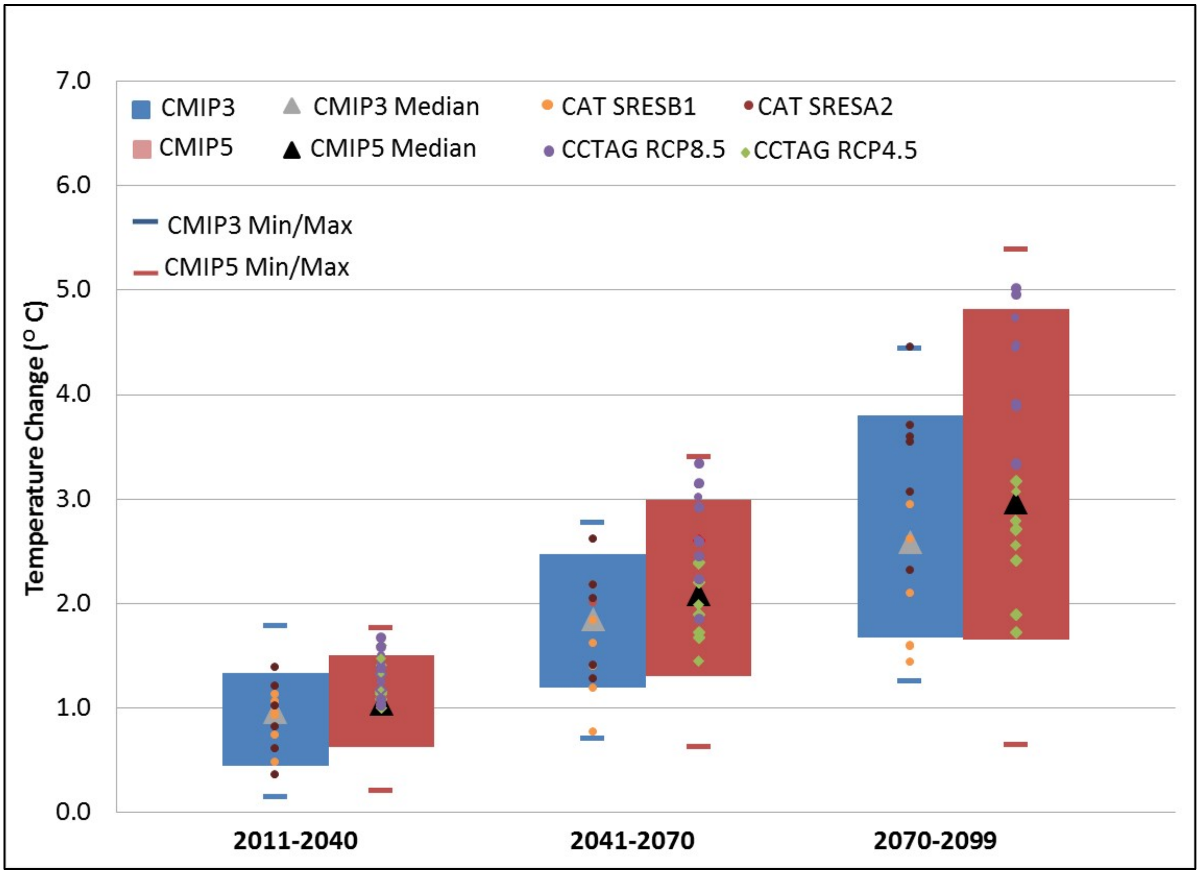


Figure B.9 Projected Changes in Mean Annual Temperature for Los Angeles Downtown based on CMIP3 and CMIP5 Projections

Note: The projected changes for CMIP3 and CMIP5 are computed using more than 100 and 200 downscaled climate model projections used in the IPCC's AR4 and AR5, respectively. CMIP3 and CMIP5 climate model projections have been bias-corrected and spatially downscaled (Maurer et al. 2007; Brekke et al. 2013). Bars represent the range between the 10th and 90th percentiles.

By continuing existing emission patterns, average temperatures will raise outside of normal variability to create a new regional climate by the end of century, causing higher frequency of extremely hot days (greater than 95°F or 35°C). Consequently, the number of days where the minimum temperature will drop below freezing will decrease by more than half. By mid-century, the projected changes over the region have an ensemble mean of 4.1°F (2.3°C) (Figure B.10), with a 95 percent confidence interval ranging from 1.8°F to 6.5°F (1.0°C to 3.6°C) (Sun et al., 2015). Inland and high elevation areas are expected to warm more than coastal areas year round, and by as much as 60 percent in the summer months. Under the higher emission scenarios, except for the highest elevations and a narrow swath very near the coast, locations will likely experience 60 to 90 additional extremely hot days per year, effectively adding a new season of extreme heat.

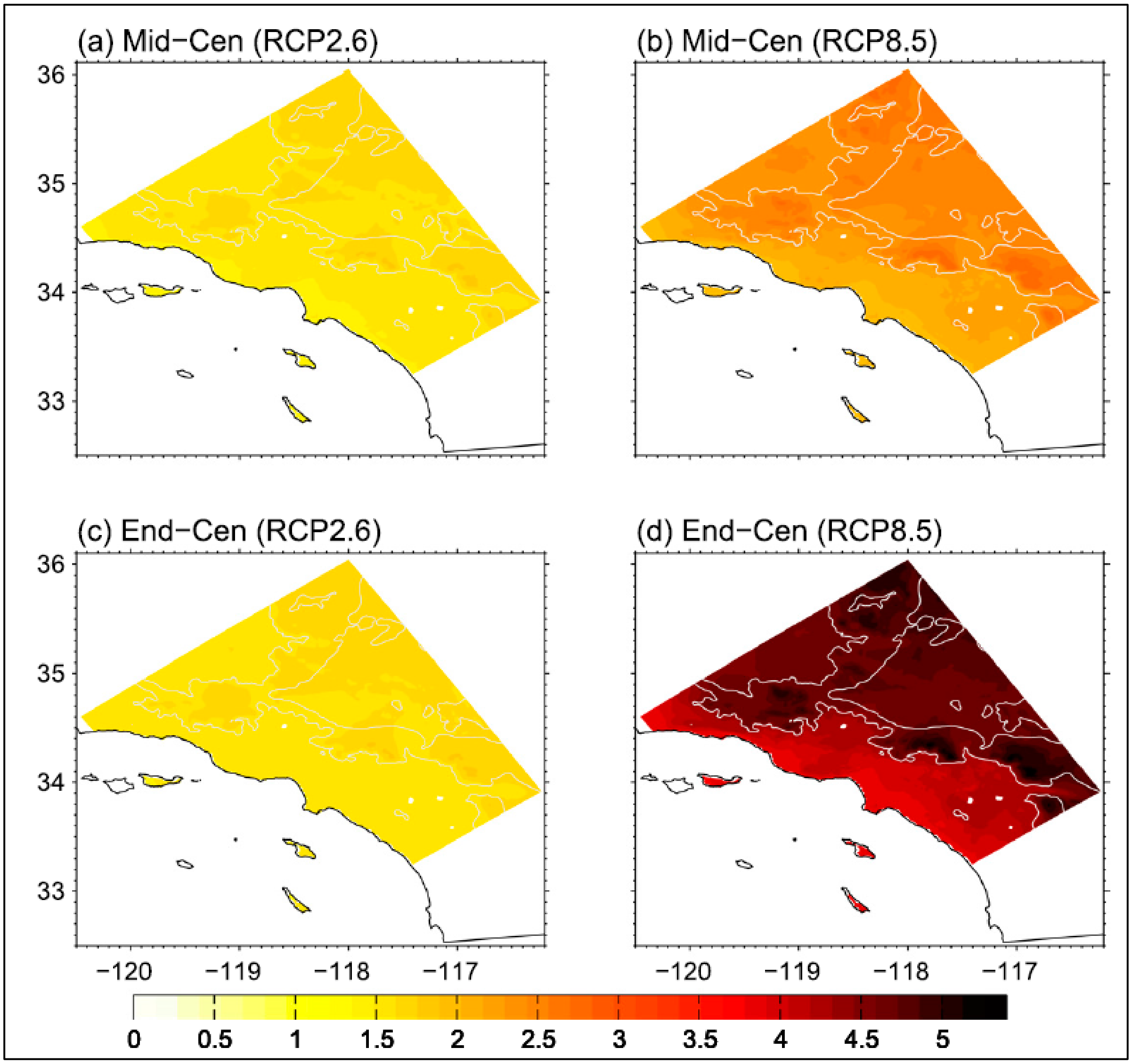


Figure B.10 Ensemble Mean of Downscaled Annual-Mean Surface Warming (°C) for (a) Mid-Century (2041–2060) under RCP2.6, (b) Mid-Century under RCP8.5, (c) End of Century (2081–2100) under RCP2.6, and (d) End of Century under RCP8.5

Note: White contours are plotted at 1000-m elevation (Sun et al., 2015)

Under the reduced emissions scenario, the model predicted a less pronounced shift in temperature. Temperature increase will still be substantial but remains within the baseline variability.

Extremely hot days will increase significantly across the region, but to a greater extent in the interior compared with coastal areas (Table B.2). The values in Table B.2 are the result of a detailed regional assessment conducted by Alex Hall's research group at the University of California, Los Angeles.

Table B.2 Average Number of Extremely Hot Days (daily maximum > 35°C or 95°F) Per Year for Selected Sites in the Los Angeles Region
One Water LA 2040 Plan – TM 5.5

	Baseline	RCP2.6 Midcentury	RCP8.5 Midcentury	RCP2.6 End of Century	RCP8.5 End of Century
Bakersfield	111	127	134	127	154
Long Beach	4	11	16	11	37
Los Angeles	6	16	22	15	54
Mojave Desert	90	110	120	109	141
Palm Springs	135	149	158	149	179
Palmdale	36	59	71	58	104
Riverside	58	86	98	86	128
San Gabriel Valley	32	62	74	61	117
San Gabriel Mountain	0	0	1	0	8
Santa Monica	0	1	1	1	3

Note:
(1) Results are shown for the baseline, midcentury, and end-of-century projections for both RCP8.5 and RCP2.6 emission scenarios. (Sun et al., 2015)

Similarly, there will be a reduced number of days where minimum temperatures drop below freezing (Sun et al., 2015). The end of century predictions showed an 80 percent similarity to the baseline conditions. Comparisons of both models conclude that reducing emissions does not halt climate change but is necessary to prevent a dramatic shift in climate by the end of century. In each scenario and time period, the coastal areas warm less than inland areas, with the mountain peaks warming the most.

B.1.2.3 Projected Changes in Precipitation

While it is difficult to discern strong trends from the full range of climate projections, the median of the projections suggest little to no change in the future annual precipitation for the Los Angeles region as a whole. The median of the future climate projections included in CMIP3 ensemble suggest a decrease by about 4.5 percent in annual precipitation by mid-century for Los Angeles downtown area, however use of CMIP5 ensemble data (Brekke et al., 2013) suggests almost zero change in future annual precipitation; specifically the median projection suggests an increase in the annual precipitation by about 1.0 percent by mid-century and about 2 percent by end of century for Los Angeles downtown area (Figure B.11).

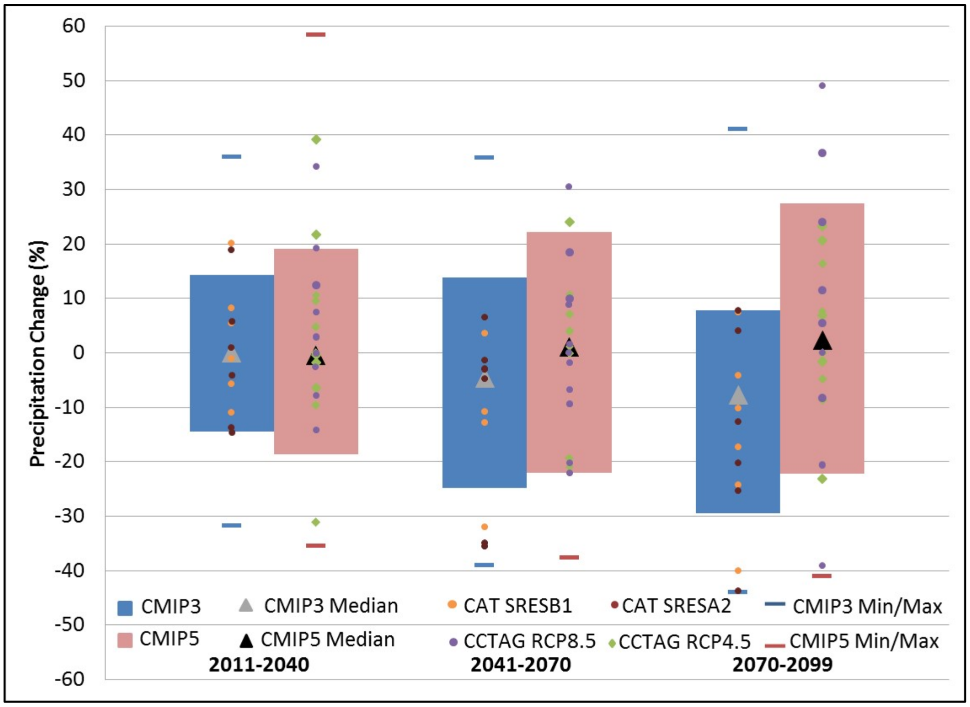


Figure B.11 Projected Changes in Mean Annual Precipitation for Los Angeles Downtown based on CMIP3 and CMIP5 Projections

Note: The projected changes for CMIP3 and CMIP5 are computed using more than 100 and 200 downscaled climate model projections used in the IPCC's AR4 and AR5, respectively. CMIP3 and CMIP5 climate model projections have been bias-corrected and spatially downscaled (Maurer et al. 2007; Brekke et al. 2013). Bars represent the range between the 10th and 90th percentiles.

A recent study by Berg et al. (2015) found that the ensemble-mean change for both mid-twentieth-century and end-of-century periods is essentially zero. However, the GCM-calculated annual precipitation projections for the Los Angeles area from CMIP5, RCP8.5, which is a higher trajectory for projected greenhouse gas concentrations, range from -5.5 percent to +5.7 percent by 2035 and -10.7 to +11.2 percent by 2060.

Predicting changes to precipitation in the Los Angeles region is challenging using the coarse resolution of a GCM simulation which cannot adequately represent diverse patterns of rainfall over the area. In this study, dynamical and statistical downscaling were used to address this limitation. A hybrid dynamical-statistical approach was used to project mid- and end-of-twenty-first-century December–February (DJF) precipitation changes at a high resolution over the greater Los Angeles region under the RCP8.5 representative concentration pathways from the CMIP5 (Berg et al. 2015). The authors indicated the near-zero ensemble-mean change reflects off-setting tendencies of moistening and drying in the GCMs, and either positive or negative changes are likely to occur in the future. While downscaled CMIP5 models disagreed on both the sign and magnitude of future precipitation changes over Los Angeles (Berg et al. 2015), the spread of possible changes is modest compared to current levels of variability.

Precipitation in most of California, including Los Angeles, is dominated by extreme variability, both seasonally, annually, and over decadal time scales. Projections of future precipitation are much more uncertain than those for temperature. In general, projections of future climate over the United States suggest that the recent trend towards increased heavy precipitation events (5 percent in the Southwest) will continue. This is projected to occur even in regions where total precipitation is projected to decrease, such as the Southwest (Walsh et al 2014). The GCM-calculated extreme event (100-year/24-hour storm) precipitation projections for the five wettest projections in the Los Angeles area from CMIP5, RCP8.5, are an increase of 15.6 percent by 2035 and 30.43 percent for the year 2060. The not-as-stormy projections are a 5.0 percent increase by 2035 and 9.6 percent increase by 2060.

Despite the relative uncertainty in annual precipitation changes, about two-thirds of the projections suggest increases in 3-day annual maximum precipitation by end of century (Figure B.12), which is commonly the driving variable for flooding especially during coastal storm and El Niño events. The median change in 3-day annual maximum precipitation for the Los Angeles downtown area by end of century is projected to increase by about 10 percent.

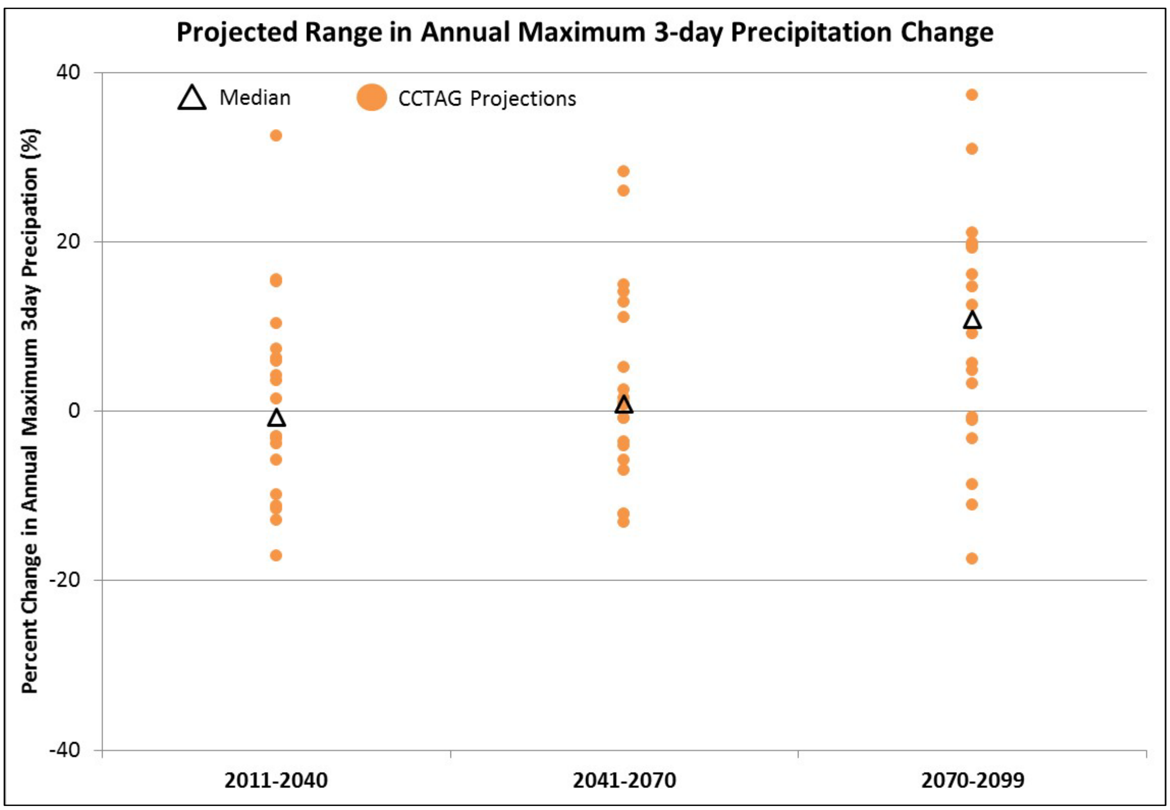


Figure B.12 3-Day Annual Maximum Precipitation Projections for the Los Angeles Downtown Area

Note: The projected changes were computed based on 20 downscaled climate projections using localized constructed analogs (LOCA) daily statistical downscaling method. These twenty climate projections were downscaled using a statistical downscaling method called localized constructed analogs (LOCA) at 1/16th degree (~6 km) (~3.75 miles) spatial resolution by Scripps Institution of Oceanography (Pierce et al., 2014). This new technique for statistically downscaling climate model simulations of daily temperature and precipitation has been developed by researchers at the Scripps Institution of Oceanography (Pierce et al., 2014). This spatial downscaling method includes a bias-correction process based on frequency-dependent correction of the coarse resolution global climate model daily temperature and precipitation fields prior to the spatial downscaling (Pierce et al., 2015). A key feature of the bias correction is that it preserves the original global climate model-predicted change in temperature and precipitation, unlike other commonly used bias correction methods, such as quantile mapping, that alter the original model-predicted change in unexpected ways. These climate projections are from 10 GCMs and two RCPs (RCP8.5 and RCP4.5) selected by DWR CCTAG for California climate and water assessments. Changes are computed with respect to 1981-2010 model simulated period. GCMs Selected by CCTAG: ACCESS-1.0, CCSM4, CESM1-BGC, CMCC-CMS, CNRM-CM5, CanESM2, GFDL-CM3, HadGEM2-CC, HadGEM2-ES, MIROC5.

Figure B.13 shows the projected changes in 3-day annual maximum precipitation with various return periods. Three-day annual maximum precipitation with 100-years return period is projected to increase by about 12 percent by early-century (2011-2040) and by about 28 percent by mid-century (2041-2070) relative to historical period (Figure B.13).

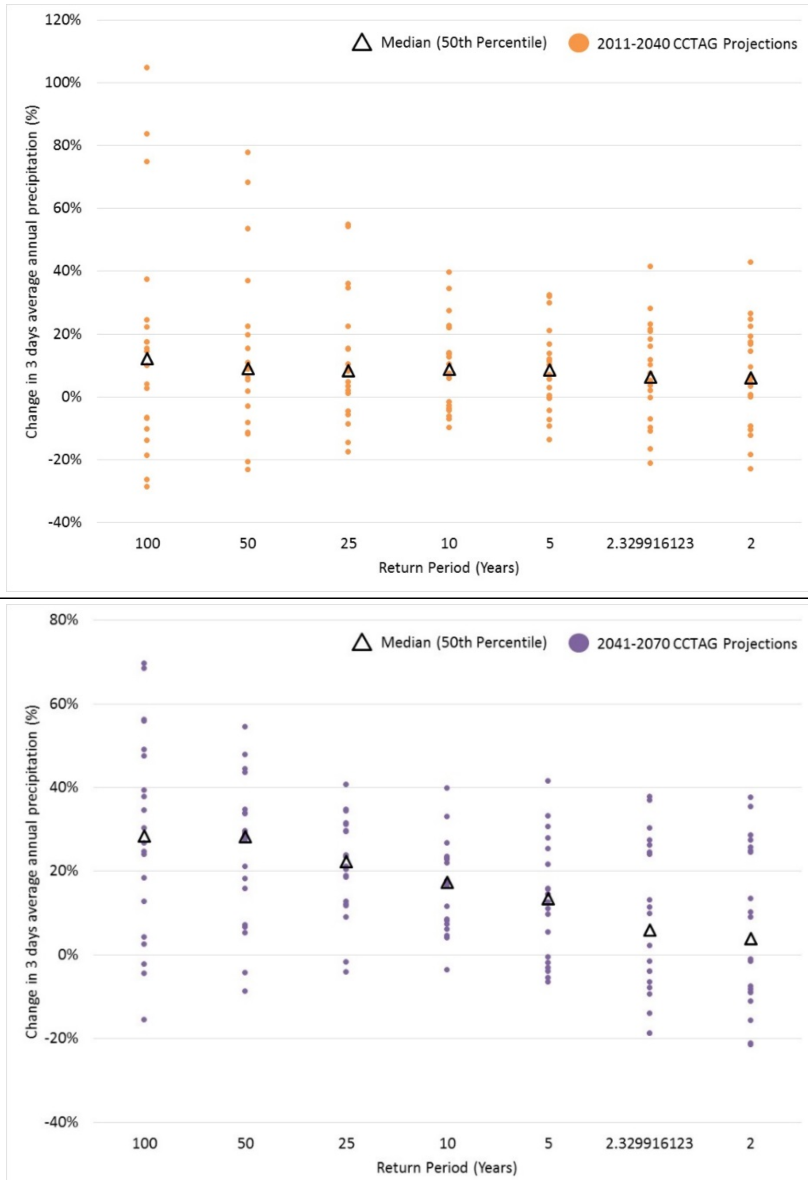


Figure B.13 Projected Changes in 3-day Annual Maximum Precipitation Projections for Different Return Periods for the Los Angeles Downtown Area

Note: The projected changes were computed based on 20 downscaled climate projections using localized constructed analogs (LOCA) daily statistical downscaling method. These twenty climate projections were downscaled using a statistical downscaling method called localized constructed analogs (LOCA) at 1/16th degree (~6 km) (~3.75 miles) spatial resolution by Scripps Institution of Oceanography (Pierce et al., 2014). This new technique for statistically downscaling climate model simulations of daily temperature and precipitation has been developed by researchers at the Scripps Institution of Oceanography (Pierce et al., 2014). This spatial downscaling method includes a bias-correction process based on frequency-dependent correction of the coarse resolution global climate model daily temperature and precipitation fields prior to the spatial downscaling (Pierce et al., 2015). A key feature of the bias correction is that it preserves the original global climate model-predicted change in temperature and precipitation, unlike other commonly used bias correction methods, such as quantile mapping, that alter the original model-predicted change in unexpected ways. These climate projections are from 10 GCMs and two RCPs (RCP8.5 and RCP4.5) selected by DWR CCTAG for California climate and water assessments. Changes are computed with respect to 1981-2010 model simulated period. GCMs Selected by CCTAG: ACCESS-1.0, CCSM4, CESM1-BGC, CMCC-CMS, CNRM-CM5, CanESM2, GFDL-CM3, HadGEM2-CC, HadGEM2-ES, MIROC5.

Droughts are projected to extend longer in duration and be more severe in the future, largely caused by above average temperatures and changes in precipitation timing and quantity. Droughts are often characterized by prolonged periods of below average precipitation and above average temperatures, resulting in prolonged periods of water deficits. Future changes in climate, even with average increases in precipitation, can result in increases in drought severity or frequency. Definitions of drought vary and are most often expressed in terms of the condition for which water systems are most sensitive. The inter-annual variability of climate and hydrology in Southern California produces frequent periods when the mean climate and flow during that period is below the long-term mean. These occurrences are referred to as periods of precipitation and streamflow deficit or deficits for the purpose of this report.

Figure B.14 presents the duration and severity of deficits in the observed precipitation record (black lines) and projected precipitation projections (other lines) for the Los Angeles downtown area. Each line depicts the amount of "deficit" (annual precipitation below long-term mean annual precipitation) and "duration" (number of years in which continuous deficit occurs) for the period of 1922 to 2015. Prolonged droughts such as the in the late 1940s-50s, early 1990s, and current period are shown as heavy black lines. Twenty future climate projections are shown in comparison to the observed droughts. Several projections suggest that future droughts could extend as long as 10 years (compared to 7 years in the historical record), and result in total deficits that are nearly double that in the historical record.

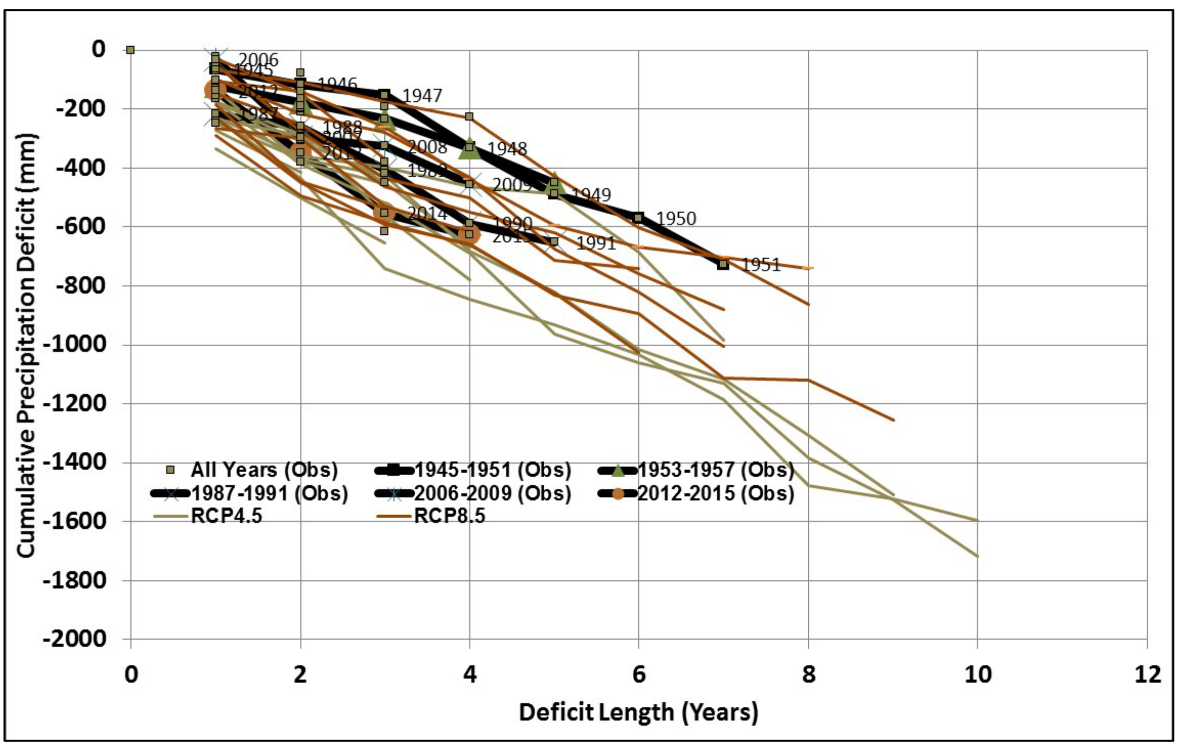


Figure B.14 Cumulative Precipitation Deficits in Observed Precipitation and Projected Precipitation for the Los Angeles Downtown Area

Note: Deficit defined as 1-year mean below long-term mean.

B.1.2.4 Projected Tsunami Risk

Estimates of potential landslide-induced tsunamis in Southern California and specifically the Port of Los Angeles (POLA) and the Port of Long Beach (POLB) were generated by numerical modeling efforts conducted by Moffatt & Nichol (2007). The Moffatt & Nichol study focused on predicting maximum water levels in the POLA and POLB for a range of tsunami events including those generated by significant distant earthquakes, earthquakes along local strike-slip faults, and local submarine landslides along the Southern California Continental Borderland (SCCB). This analysis also provided estimated recurrence intervals for such events. The Moffatt & Nichol study was supported by work from Dr. Jose Borrero and Dr. Costas Synolakis from USC, who have published numerous papers and articles on tsunami events and risks in Southern California. Results from the Moffatt & Nichol study are used to estimate comparable conditions from local landslide-induced tsunamis on the Santa Monica Bay area, and specifically adjacent to the Hyperion Treatment Plant.

The Moffatt & Nichol study reviewed water level gauge records corresponding to historic tsunami events including the 1960 Chilean earthquake/tsunami (magnitude 9.5) and the 1964 Alaskan earthquake/tsunami (magnitude 9.2). These earthquakes were along mega-thrust faults along oceanic subduction zones where tectonic plates converge; locations long known to have the potential to generate destructive tsunamis because of the nature of the ground fault movement. Maximum local increases in water levels at Long Beach reached 4.6 to 5.5 feet above still water level during the 1960 Chilean tsunami; these are the largest tsunami waves on record at the POLB in the historic record dating back to 1922. The southern California coastline is more susceptible to tsunami waves from events in Alaska and Chile than in the Far East, owing to the orientation of the shoreline and the offshore bathymetry, including the Channel Islands chain. Work performed at San Onofre yielded similar conclusions on the relative importance of tsunami origin.

A significant landslide scar and debris field is clearly visibly in bathymetric surveys along the Palos Verdes Slope in Southern California between Los Angeles and Long Beach. This scar, also termed the Palos Verdes Debris Field, has been estimated by carbon dating of sediments to have occurred 7,500 years ago. Volume estimates for the slide range from 0.3 to 0.8 cubic kilometer. There is no evidence that the slide produced a tsunami, but any nearshore evidence would not be readily observable since sea levels have risen significantly in the past 7,500 years. This landslide provides evidence for the potential of large local tsunami events generated from submarine landslides.

Moffatt & Nichol used the MIKE21 Boussinesq Wave Model to propagate tsunami waves into POLB/POLA Harbor for two local submarine landslides, one at the historic Palos Verdes Debris Field and a second slide with an origin closer to the POLB/POLA in order to represent a more severe event. Results indicate that the slight shift in origin yielded large differences in predicted wave heights in the harbor. For the slide at the historic debris field site, incident waves outside the harbor reached one meter and peak water levels inside the harbor (allowing for reflection, shoaling, and constructive interference) approached three meters. For the second local landslide scenario, incident waves outside the harbor reached five meters and peak water levels inside the harbor exceeded seven meters. Predicted wave periods for these locally sourced tsunamis were generally ten minutes or less.

Estimating recurrence intervals for events that have not occurred in the historic record is difficult. Moffatt & Nichol first reviewed historic earthquake and tsunami records and determined that only approximately 10 percent of significant earthquakes along faults in the world's oceans generated tsunamis. Historic records catalogue 15 local earthquake events along the SCCB with magnitudes greater than 5.0 since 1877, the largest being magnitude 6.4. There are significantly more and larger events on local land-based faults. The Moffatt & Nichol study states: "Historical seismicity in the SCCB is relatively sparse and widely spread compared to the onshore area and most of the larger events in the offshore are strike-slip earthquakes. The lack of large earthquakes within the SCCB in itself indicates a lower level of seismicity." No specific-slip rate or recurrence data on specific faults in the area are available. Earth Mechanics conducted a seismic hazards evaluation for POLB/POLA and found earthquakes controlling seismic design at the ports are likely to have recurrence intervals from about a thousand to a couple thousand years. Offshore events would be expected to have even longer recurrence intervals. A recurrence interval of about 10,000 years is a reasonable assumption for earthquakes of sufficient magnitude (~7 to 7.5) to yield tsunami-generating landslides in Southern California. Lee et al. (2004) provide an identical estimate.

Borrero et al. (2004) also report on a numerical modeling investigation into earthquake fault and landslide-generated tsunamis along the Southern California coastline. In their model application, predicted local run-up heights ranged from 0.5 to 6 meters along the coast depending on the type, size, and location of the earthquake or landslide source. Landslide tsunamis produced extreme run-up peaks with a narrow alongshore distribution, while tectonic sources produced broader, more regional effects. Local bathymetry of the San Pedro Shelf was found to focus and amplify tsunami wave height. Borrero et al. also reference studies by Bohannon and Gardner (2004) and Locat et al. (2004) which state that the Palos Verdes Shelf was capable of generating a substantial tsunami with initial waves from 8 to 50 meters. These waves would disperse radially so that wave height at the shore would be significantly smaller; however, the Locat et al. study did not propagate the initial tsunami waves to shore, so nearshore wave height estimates are not available.

Low resolution maps of peak water level increases along the shoreline in Santa Monica Bay are provided in the Borrero et al (2004) paper. However, these modeled events were more likely to have larger impacts east of Palos Verdes peninsula than west. It is possible that alternate source locations along the Palos Verdes Escarpment further to the west could produce larger waves in Santa Monica Bay than those presented in the paper, which peaked at approximately one meter. It is expected that the nearshore bathymetry in Santa Monica Bay will amplify incident wave heights in a fashion similar to that noted for San Pedro Bay in the Moffatt & Nichol and Borrero et al. studies.

B.1.2.5 Projected Sea Level Rise

A National Research Council (NRC) study suggests a future increase in sea level in the range of 0.43 to 1.97 feet (0.13 to 0.6 meter) by 2050 and 1.44 to 5.45 feet (0.44 to 1.66 meters) by 2100 relative to 2000 at Los Angeles, California (NRC 2012) (Figure B.15). The NRC study on West Coast sea level rise relies on estimates of the individual components that contribute to sea level rise and then sums those to produce the future mean sea level projections. These components include thermal expansion; wind-driven differences in ocean heights; gravitational and deformational effects (sea level fingerprints) of melting of ice from Alaska, Greenland, and Antarctica; and vertical land motions along the coast. These projections have been adopted by the Coastal and Ocean Working Group of the California Climate Action Team (CAT) as guidance for incorporating sea level rise projections into planning and decision making for projects in California. In addition to increases in mean sea level, there is a high likelihood of increases in storm surge and greater coastal inundation associated with tidal energy.

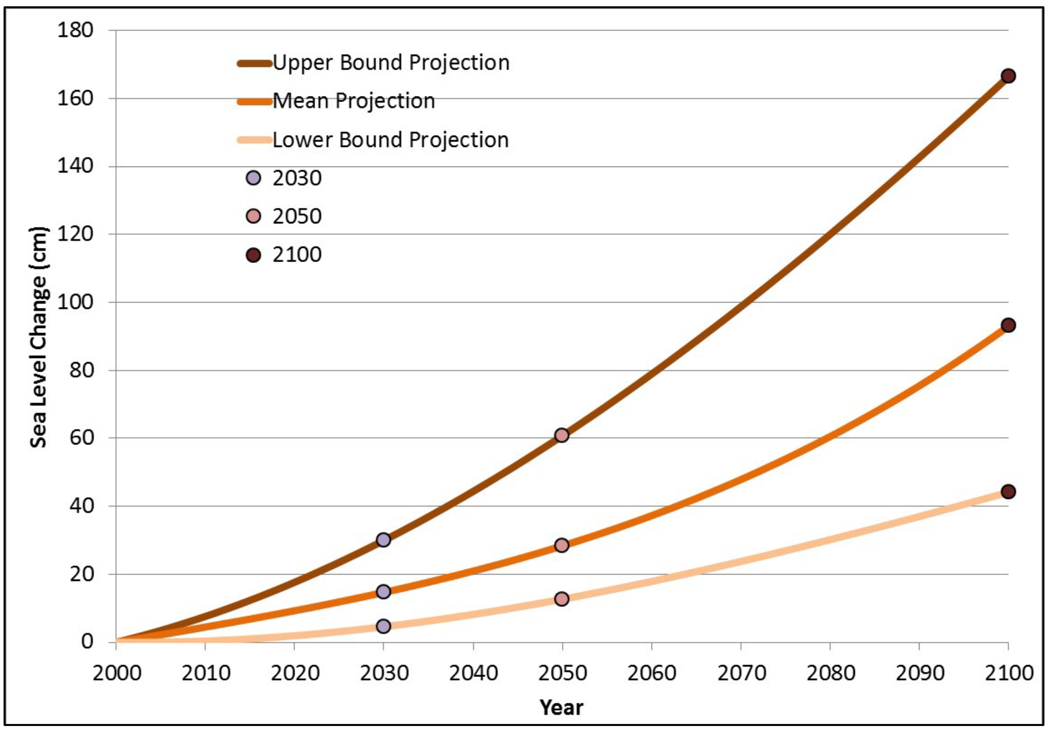


Figure B.15 Projections of Future Change in Mean Sea Level for Los Angeles (NRC 2012)

Note: The NRC study on west coast sea level rise relies on estimates of the individual components that contribute to sea level rise and then sums those to produce the projections The report suggested sea level rise projections at three future times relative to 2000 (2030, 2050, and 2100), along with upper- and lower-bound projections for Los Angeles. These projections were fit to polynomial equations to obtain transient annual sea level rise projections over the period 2000 through 2100. The NRC sea level rise projections for California have wider ranges, but the upper limits are not as high as those from Vermeer and Rahmstorf's (2009) global projections. The National Academy of Sciences' reported projections have been adopted by the Coastal and Ocean Working Group of the CAT as guidance for incorporating sea level rise projections into planning and decision making for projects in California.

B.1.2.6 Climate Change Threats (Flooding, Power Outages, Wildfire, etc.)

For watersheds with little or no snow accumulation, changes in the 3-day, one hundred year flood volumes are expected to increase from 10 percent to 20 percent. Recent work performed by CH2M for the California Department of Water Resources (DWR) evaluated flood risks for all major watersheds in the Central Valley associated with projected changes in extreme precipitation and warming (DWR 2016). Hydrologic modeling simulated changes in flood volumes associated with projected changes in extreme precipitation and temperature. Changes were substantially larger for high elevation watersheds with significant historical snow accumulations.

Wildfires are a common occurrence in many parts of California and Los Angeles County, and have grown increasingly more destructive in recent years. Meteorology is an important contributing factor to the spread and control of wildfires. Fires in Southern California typically happen during either during the Santa Ana winds in October through April or during the dry, hot months of June through September. Climate change is generally expected to increase the wildfire risk in the Los Angeles region through increased incidence of dry conditions (drought) and higher temperatures over a longer and longer fire season. However, significant other factors that contribute to wildfire risk include urban development and vegetation structure and abundance. As shown in Figure B.16, the projections suggest a substantial increase in the probability of wildfires in the region.

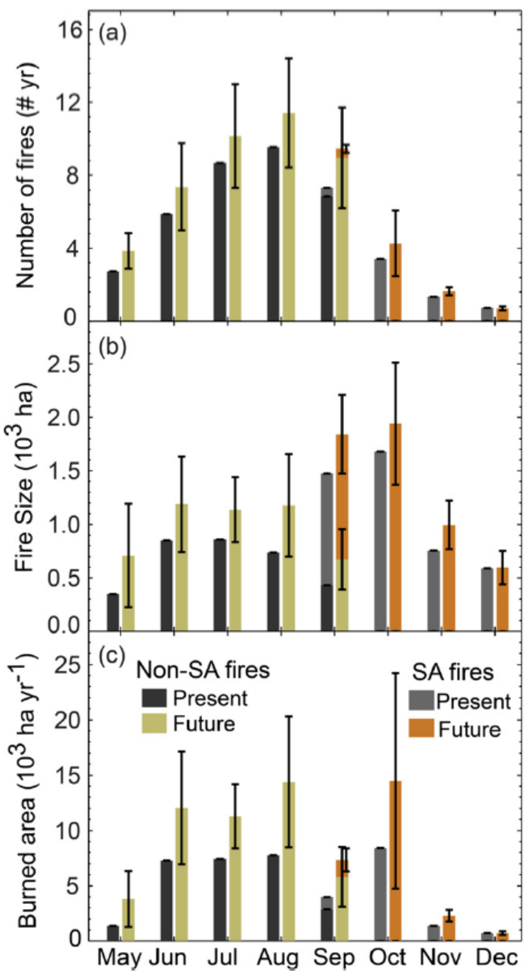


Figure B.16 The Response of Santa Ana (SA) and Non-SA Fires to Climate Change during the Middle Part of the 21st Century for the RCP8.5 Scenario

Climate change projections suggest stronger winds which will result in higher intensity Santa Ana fires. It was projected that the burn area of the Santa Ana fires will increase by 64 percent by 2041 to 2060 as compared to the baseline years of 1981 to 2000. However, the estimated burn area from non-Santa Ana fires is predicted to increase by 77 percent as a result of a warmer, drier climate (Jin et al. 2015). The projected number of structures burned is projected to increase by 20 percent for Santa Ana fires and increase by 74 percent for non-Santa Ana fires. Jin et al (2015) found that meteorology was the greatest factor in Santa Ana fires whereas non-Santa Ana fires are heavily dependent on fuel availability.

B.1.3 Previous and Ongoing Climate Change Assessments

Various studies examining the City's vulnerability to climate change impacts are summarized below. Sea level rise and the changes in precipitation were common themes, and the threat of these effects on City infrastructure was examined. Full descriptions of these studies can be found in Attachment 1.

B.1.3.1 Previous City of LA Climate Change Vulnerability Assessments

Sea Level Rise Vulnerability Study for the City of Los Angeles

The 2013 report *Sea Level Rise Vulnerability Study for the City of Los Angeles,* prepared by the University of Southern California Sea Grant Program (Grifman et al, 2013), evaluated the physical, social, and economic vulnerability of four key locations in Los Angeles. Physical vulnerabilities were found in wastewater, stormwater, potable water, and roadway infrastructure. Social vulnerabilities were found in low lying communities with poor adaptability such as San Pedro, Wilmington, and Venice. Economic vulnerabilities included building losses ranging from $242.7 million for a 10-year flood event (without sea level rise) up to $1,441.3 million for a 100-year flood combined with higher sea levels. The report recommended an iterative "Adaptive Adaptation Planning Approach" for sea level rise planning dependent on continuous adaptation to new science, reassessment of vulnerabilities, as well as stakeholder involvement.

Southern California Coastal Impacts Project

The region-specific model used in the *Sea Level Rise Vulnerability Study for the City of Los Angeles* is the Coastal Storms Modeling System (CoSMoS). The model was developed by Dr. Patrick Barnard and Dr. Li Erickson of the United States Geological Survey and is used to project flooding and erosion as a result of climate change induced sea level rise and storms (Barnard et al., 2014). CoSMoS 3.0 provides daily, annual, 20-year, and 100-year coastal storm calculations at sea-level rise of 0 to 6.6 feet (0 to 2 meters) in 0.8 foot (0.25 meter) increments, plus a 16.4 feet (5 meter) scenario.

Regional AdaptLA: Coastal Impacts Planning in the Los Angeles Region

The *Regional AdaptLA: Coastal Impacts Planning in the Los Angeles Region* is an ongoing project to provide a link between scientific tools and local governments for regional planning (Regional AdaptLA, 2016). The Ocean Protection Council has provided funding to develop a shoreline change and erosion model for Los Angeles. The model has been integrated with the United States Geological Survey's CoSMoS. The project has been done in collaboration with a number of stakeholders including 11 jurisdictions and the University of Southern California Sea Grant Program.

The University of California Sea Grant Program held a workshop in Los Angeles on November 13, 2014 to provide an overview and training of the model. The Regional AdaptLA Webinar Series was launched on January 12, 2015 to provide information on tide and storm impacts in Southern California. The second webinar was held on March 17, 2015 which focused on beach dynamics and ecology of the region.

Analysis of Projected Changes in Precipitation IDF Values Based on Climate Change Projections

In 2012, CH2M conducted a study for the City of Los Angeles Bureau of Sanitation to evaluate projected changes in precipitation, duration, and frequency for the year 2090 using 12 IPCC GCMs under two emissions scenarios (B1 and A1FI) (CH2M 2012). Projected intensity, duration, and frequency (IDF) curves were developed for 2025, 2050, 2090 for a range of durations from 5 minutes to 24 hours, and for return frequencies from 2 to 100 years, at three national weather station (NWS) locations. Projected precipitation amounts were also compared to those historical values derived by the SimCLIM modeling tool, NOAA Atlas 14 amounts, results derived from a three station L-Moments analysis, and results provided by the City of Los Angeles. Median annual precipitation from the GCMs shows a slight decrease by end of century; by 2090 the median precipitation declines by 3 percent for the low emission scenario and 6 percent for high emission scenario.

Sea Level Rise Potential for City of Los Angeles, CA

Results from 13 IPCC GCMs under the two emissions scenarios (B1 and A1FI) were used by CH2M in 2012 to generate projected changes in mean sea level (MSL) and mean higher high water (MHHW) for the NOAA Los Angeles and Santa Monica tide gauges in the Los Angeles basin area through the year 2090 using the SimCLIM application. Studies comparing sea level rise rates with IPCC projections are detailed, and the effect of excluding increased meltwater contributions from Greenland and Antarctica is examined. Select recommendations of the Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT) from their Sea level Rise Interim Guidance Document are also presented. Projected median rise in mean sea level for the year 2100 at the Los Angeles tide gauge ranges from 0.9 foot to 1.2 feet without ice sheet flow, and 1.3 feet to 2.3 feet including ice sheet flow. For the Santa Monica tide gauge, median rise in mean sea level for the year 2100 ranges from 1.2 feet to 1.9 feet without ice sheet flow, and 1.5 feet to 2.5 feet including ice sheet flow.

City of Los Angeles Wastewater Collection and Storm Drain System's Climate Change Vulnerability Assessment

In this report, CH2M (2012) investigated potential climate change impacts to the Venice Pumping Plant No. 646 and the San Pedro storm drain network using the City's current design storm and the modified storm generated from three local rainfall stations. The SimCLIM model was also used to conduct a sea-level rise analysis for a period from 1990 to 2100. Hydraulic models for each network were used to simulate the modified storms and wet weather flows for the target years 2010, 2025, 2050, and 2090. The 10-year design storm and 10-year modified storms were evaluated at both study sites for the year 2090. While a slight increase in depth over diameter and wet-weather wastewater flows were observed upstream of the network including the Venice Pumping Plant, a significant increase in spilling at the Santa Monica area was projected. A 1.9 percent increase in peak discharge flow from the system was also projected. For the San Pedro drain network, the model predicts an 11.7 percent increase in peak outfall discharge due to climate change and the incorporation of a 1-foot sea level rise by 2090 also introduces backwater at the outfall.

B.1.3.2 Current City of Los Angeles Climate Adaptation Planning Efforts

Current efforts of the City of Los Angeles to adapt to climate change are detailed below. Many studies recommended collaboration between governmental agencies, integration of climate change into all aspects of City planning, and individual-scale adaptation plans for critical assets. Full descriptions of these efforts can be found in Attachment 2.

Climate Change & Hazard Mitigation: Local Plans and Resources

The USC Sea Grant Program is engaging in an ongoing coordination with the Los Angeles City Emergency Management Department and other local agencies across the Los Angeles region to integrate climate change into hazard assessments, mitigation priorities, and stakeholder engagement.

Rising to the Challenge: Results of the 2011 California Coastal Adaptation Needs Assessment

The report *Rising to the Challenge: Results of the 2011 California Coastal Adaptation Needs Assessment* presents a summary survey responses on coastal management challenges, climate change adaptation, and resource and support needs within California. This report surveyed up to 600 professionals in local, state, and federal agencies as well as private and nongovernmental organizations to assess coastal management challenges and knowledge. Qualitative responses about coastal managers' preparedness in meeting climate change were gathered and overall narratives of California's coastal professional needs are communicated.

Los Angeles Sanitation – Wastewater Assets Report

A risk assessment of seven priority assets was conducted by the City of Los Angeles' Bureau of Sanitation using the U.S. Environmental Protection Agency (EPA) Climate Resilience Evaluation and Awareness Tool (CREAT) 3.0 to examine climate change effects under current flooding and wet weather conditions and considering increases in temperature, hot days, storm intensity and sea level rise projected for the year 2060. Five wastewater pumping plants, a stormwater pumping plant, and the Terminal Island Water Reclamation Plant (TIWRP) were evaluated. Temperature and precipitation scenarios representing a warm and wet with stormy climate was selected for risk assessments of future changes. CREAT and previous projections estimate a 3°F to 4°F (0.6°C to 2.2°C) increase in average annual temperature. The annual number of hot days over 95°F (35°C) is also expected to increase from 6 to 22, which poses a risk to power loss and transmission problems potentially affecting Los Angeles Sanitation. A sea level rise of 1.64 feet (0.5 meter) was selected to evaluate coastal flooding for a 100-year storm and tsunamis. Mitigation measures from EPA's Flood Resilience Guide were selected and evaluated for effectiveness. Replacement and mitigation costs were developed via detailed cost estimating. Recommendations were made based on practicality and cost for short- and long-term implementation.

Los Angeles Sanitation Solid Resources Climate Change Resiliency Assessment and Recommendations Summary

A two-day assessment of eight Los Angeles Sanitation solid resources facilities by the department and CH2M was an integral part of climate change risk assessments conducted for these facilities. CREAT and other information was used to determine climate-related areas of concern for Los Angeles Sanitation, including: sea-level rise and extreme rainfall affecting flooding; temperature increases causing blackouts due to increased energy demand; more frequent/intense/longer droughts and high winds affecting wildfires; and, all of these factors exacerbating the impacts of earthquakes (with subsequent landslides and liquefaction or flooding from tsunamis). Short and long-term adaptation measures were suggested and costs were quantified for each adaptation measure.

Los Angeles Aqueduct System Climate Change Study, Los Angeles Department of Water and Power

TetraTech (2010) helped prepare a report for the Los Angeles Department of Water and Power (LADWP) examining climate change effects on hydrologic patterns in the Eastern Sierra Watershed. The report focused on reviewing climate projections relevant to the Eastern Sierra, identifying the likely hydrologic changes from these projections including runoff and flow to the City, performing a hydraulic analysis of the Los Angeles Aqueduct (LAA) system in light of these changes, and identifying adaptation options to prepare for climate scenarios. The results of this analysis reflected a hydrologic cycle that is expected to become more variable over the 21st century. Extremes in runoff were of particular concern to LADWP as upper extremes may exceed the capacity of the LAA and lower extremes may cause inadequate flow to the City (FTC). 10 percent of the years simulated through 2099 are projected to have runoff below the historical minimum (216,159 acre-feet per year [AFY]) and 7 percent of the years are projected to have higher runoff than the historical maximum (885,812 AFY). Adaptation options proposed in this report included operational changes such as changing reservoir targets, modification of existing structures such as increasing the volume of existing reservoirs, and the addition of new infrastructure such as constructing diversions for imported water.

B.1.3.3 Regional Climate Change Assessments and Adaptation Efforts

Climate change assessments performed by regional and national entities that include relevant information to Los Angeles are included below. These studies include assessments related to the City's water or stormwater systems, or provide a larger framework in which Los Angeles can consider its own climate change assessment. Full descriptions of these studies can be found in Attachment 3.

Los Angeles Basin Stormwater Conservation Study

The Bureau of Reclamation's Los Angeles Basin Stormwater Conservation Study used the Los Angeles County Flood Control District's Watershed Management Modeling System adjusted for climate change to study the flood control and water conservation impacts resulting from changes in climate and population. Historic hydrologic modeling was done for a period of 1987 through 2000 and projections were done for a future period of 2012 through 2095. The study analyzed operation of current infrastructure including 18 dams, 26 major spreading ground facilities, and 5 major channel outlets under the current and future climate.

Projections of this report specific to Los Angeles include an increase of average temperature by 2 to 5°F, 2 to 5 percent less precipitation, and less frequent but more intense storms. Projections of stormwater flows through 2099 showed an overall average increase of 4 percent to 37 percent under different climate scenarios. Recommendations were developed for structural and non-structural concepts to manage stormwater and aid in climate resiliency. Twelve project groups of recommendations were developed and evaluated based on stormwater capture potential and quantifiable and non-quantifiable costs and benefits. Under high projections for climate change, the greatest stormwater capture potential was recognized in Los Angeles County Flood Control District (LACFCD) dams, stormwater policies, green infrastructure programs, and regional impact programs.

Los Angeles Region Framework for Climate Change Adaptation and Mitigation

The Los Angeles Region Framework for Climate Change Adaptation and Mitigation connected climate change, water resources, and water quality in order to address potential impacts through the Los Angeles Regional Water Quality Control Board. Los Angeles impacts that will need to be addressed include: 4-5°F temperature increase and two to six times more "extreme heat days" by 2050, no mean precipitation change but increased likelihood of extreme precipitation events, sea level rise of 5 to 24 inches by 2050, a reduction in groundwater and available imported water supplies and water quality drop due to decreased stream flows and increased water temperatures. The framework in this report provides the foundation to facilitate future discussions on climate change adaptation and mitigation incorporation into the various Regional Water Board programs. The next steps identified included stakeholder involvement to identify and prioritize projects, research, monitoring, and other contract needs.

California Climate Change Assessments

Four climate change assessments have been conducted for the State of California. The first report (2006) evaluated climate change impacts on key state resources. The second report (2009) provided initial estimates of economic impacts resulting from climate change. The third report (2012) evaluated the state's vulnerability and adaptation options. The fourth report is currently in progress and aims to articulate near-term climate change research needs to ensure that the state stays on track to meet its climate goals for 2020, 2030, and beyond.

California Coastal Commission Sea Level Rise Policy Guidance

The Sea Level Rise Policy Guidance adopted in 2015 by the California Coastal Commission laid out a framework to address sea level rise planning and regulatory action. The report recommended the best available data for coastal planners to use, and detailed sources of uncertainty to be used in scenario-based planning. Addressing sea level rise in Local Coastal Programs and Coastal Development Permits was recommended.

Safeguarding California

The Natural Resources Agency released two reports under the Safeguarding California banner: a 2014 report that serves as a policy guide for California to incorporate climate change risks into relevant aspect of government activities, and a 2016 report that developed plans and strategies for 10 sectors of the California economy. Plans and strategies were developed for the 10 sectors including agricultural, biodiversity and habitat, emergency management, energy, forestry, land use and community development, oceans and coastal resources, public health, transportation, and water. Collaboration across sectors to address climate change and resource optimization was stressed.

B.1.3.4 National and International Case Studies

Other assessments done outside of Southern California, on both an individual City and national level, are gathered and summarized here as case studies. Many of these cities face similar challenges to Los Angeles, such as wastewater facility vulnerability, risks to water conveyance systems, and the possibility sea level rise flooding. Cities around the world are dealing with similar challenges in the face of climate change, and lessons can be learned from similar adaptation efforts.

New York City Wastewater Resiliency Plan

The damage caused by Hurricane Sandy in October 2012, including damage to wastewater facilities that spilled millions of gallons of untreated wastewater into the harbor, reinforced the need for the City of New York City to ensure the highest levels of protection from future storms. The New York City Department of Environmental Protection (NYCDEP) is committed to ensuring the continued performance and reliability of one of the largest wastewater collection and treatment systems in the world that serves more than eight million New Yorkers through 14 wastewater treatment plants and 96 pumping stations. CH2M led an existing project team, which was already evaluating climate change impacts on wastewater systems for the NYCDEP, prepare the New York City Wastewater Resiliency Plan to assess facilities at-risk from future storms, quantify potential costs, and suggest measures to protect critical equipment and reduce the risk of damage and loss of services (NYCDEP, 2013).

Climate analysis in this study focused on establishing future storm surge conditions and extreme precipitation (Table B.3). The report established a critical flood elevation, which was chosen to be the 100-year floodplain with 30 inches of sea level rise. This flood elevation was obtained for each wastewater facility location from online Federal Emergency Management Agency (FEMA) ABFE maps which provide flood levels accounting for specific local conditions, such as topography. Precipitation changes due to climate change are also anticipated to impact New York's sewer and storm drainage system.

Table B.3 Precipitation Values for Selecting Historical Years Representing Baseline and Future Scenarios One Water LA 2040 Plan – TM 5.5

	Baseline		Future Central		Future Precautionary	
Parameter	**Aggregate Statistic (1969-2010)**	**Best Fit Annual Time Series JFK 2008**	**Target Value (Change Factor)**	**Best Fit Annual Time Series JFK 2005**	**Target Value (Change Factor)**	**Best Fit Annual Time Series LGA 2006**
Annual Depth (in)	45.5	46.3	47.8 (+5%)	48.5	50.1 (+10%)	54
July Depth (in)	4.3	3.3	4.5 (+4.5%)	5.2	4.9 (+14%)	6
November Depth (in)	3.7	3.3	3.8 (+3.5%)	4	4.3 (+17%)	5.8
Number of Days >2 in	2.4	3	2.8 (+17%)	3	3.2 (+33%)	4
Average Intensity (in/hr)	0.15	0.15	0.18 (+18%)	0.16	0.2 (+32%)	0.2

<u>Abbreviations</u>:
in = inch/inches; in/hr = inch/inches per hour

Combined sewer overflow (CSO) discharges and local flooding are likely to increase under future climate conditions in response to potential increases in precipitation volume and intensity. Overall annual rainfall volume was found to be the most important driver of increased CSO volume and potential effects on water quality. To evaluate future conditions and impacts in the study, the year 2050 was chosen in order to be consistent with NYCDEP capital planning programs. Relevant variables from climate projections used in analysis of impacts included change in average temperature, change in precipitation, and sea level rise.

Vulnerability assessment in this report was done at a higher resolution than typically seen in climate studies. Potential risks at each facility were identified through site visits, analysis of facility blueprints, and interviews with facility personnel. Information about conditions during Hurricane Sandy also helped pinpoint specific risks and operational challenges. The elevations of flood pathways and infrastructure were then compared to the flood elevation defined in the Climate Analysis to determine which infrastructure is potentially at risk (Figure B.17). Cost estimates for the replacement of at-risk equipment under emergency conditions, cleaning of facilities, and temporary power and pumping were developed, and then used as a metric to inform the prioritization of risks.

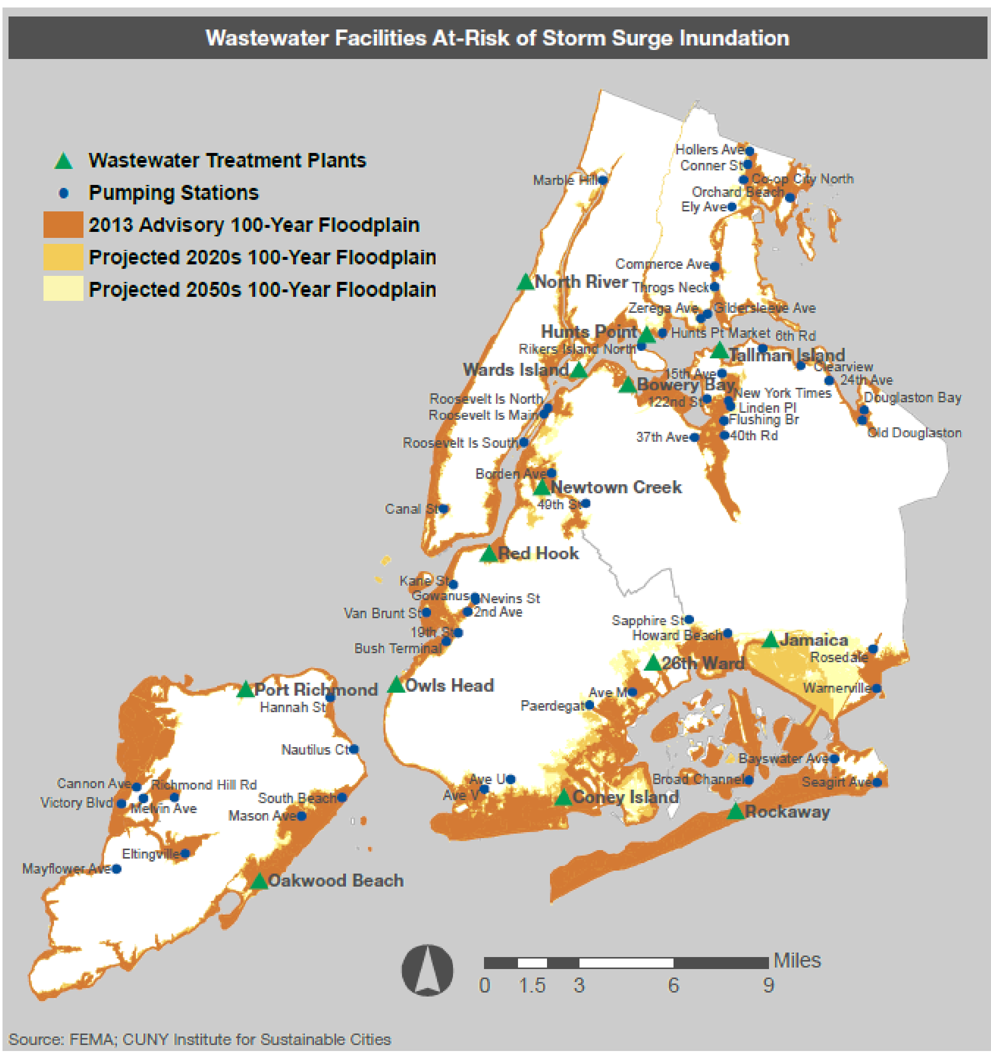


Figure B.17 Wastewater Facilities At-Risk of Storm Surge Inundation (NYCDEP, 2013)

The plan included an adaptation analysis section that selected adaptation strategies through a broad literature review of efforts around the world. The strategies that were determined to be most applicable to New York City wastewater facilities included sealing buildings with watertight windows and doors, elevating equipment, making pumps submersible, encasing electrical equipment in watertight casings, constructing static barriers across doors and other access ways, temporary sandbagging, and providing backup power generation to pumping stations where feasible. Every strategy was judged based on its failure potential, or the probability that the strategy will fail during a flood event as estimated form manufacturer details, site observations, and engineering judgment. The plan recommended $315 Million in mitigation measures to protect the potential loss of $1.1 Billion in assets in a single event at present value and $2.5 Billion over the next 50 years should events happen repeatedly. The NYCDEP has implemented the recommendations by modifying designs and re-prioritizing its capital improvement plan with consideration of climate change risks and vulnerabilities.

Boston Wastewater and Storm Drainage System Facilities Plan

Since its inception in 1977, the Boston Water and Sewer Commission (BWSC) has continually sought to improve the sewer and storm drainage systems in order to increase the system capacity for the conveyance of wastewater flows to the Massachusetts Water Resources Authority (MWRA) treatment facilities, reduce the occurrence and volume of CSOs and sanitary sewer overflows (SSOs), and comply with regulatory requirements. In August 2011, the BWSC engaged CH2M to perform an updated comprehensive evaluation of the sewer and storm drainage systems and to develop an updated Wastewater Facilities Plan identifying and prioritizing recommended maintenance and capital improvements of the sewer and storm drainage systems over the next 25 years (BWSC, 2015). A significant driver of evolution in Boston's sewer and storm drainage system is expected to be climate change, and the BWSC has incorporated climate change effects in their updated Wastewater Facilities Plan.

The climate change evaluation focused on four climate change issues that will potentially have the most impact on the BWSC's wastewater and stormwater drainage systems: increased precipitation, river flooding, sea level rise, and storm surge. The evaluation was conducted using emission scenarios and GCM projections available from the IPCC's AR4. A risk framework was developed to consider one medium scenario (B2) and one consistently high scenario (A1FI), termed "precautionary," to bound risk associated with climate change. The medium scenario anticipates modestly-rising emissions through the year 2100, at which point it is about the middle of range of GHG scenarios. The precautionary scenario represents a conservative forecast in the upper end of the range of climate projections although not the highest projected emission scenario at all times in the future.

Annual rainfall is forecasted to increase by 4 to 7 inches from 1990 to 2100 with climate change. The 10-year, 24-hour design storm is forecasted to increase to as much as 6.65 inches with a peak hourly intensity of 2.11 inches per hour by the year 2100 with climate change. Sea level rise is also happening at an increased rate, with levels forecasted to rise by 4 to 7 feet by the 2100 with climate change (BWSC, 2015). Higher collection system flows, more system flooding, and tidal inflow could potentially occur throughout the BWSC's service area in the future.

A variety of aspects of the City of Boston's sewer and drainage systems were identified to be at risk due to climate change. Minor shoreline and street flooding is calculated by FEMA to occur in its 100-year coastal storm. Should a 100-year storm surge of 5.12 feet strike Boston at MHHW as Hurricane Sandy did to New York City in 2012, much more street flooding will occur when shorelines are overtopped. This street flooding will then cause inflows into the BWSC's stormwater, sanitary and combined sewer systems. Street flooding due to SLR alone is forecasted to become a monthly event along shorelines and in parts of the City as early as the year 2060 and eventually by the year 2100. Figure B.18 illustrates a view of calculated flooded areas for the Precautionary, year 2035 scenario with storm surge. BWSC and MWRA pump stations are shown on the map as well. All CSO outfalls and many public and private storm drain outfalls will be entirely submerged in the future such that they will require tide gates in order to prevent inflow of the systems and flooding by the year 2100.

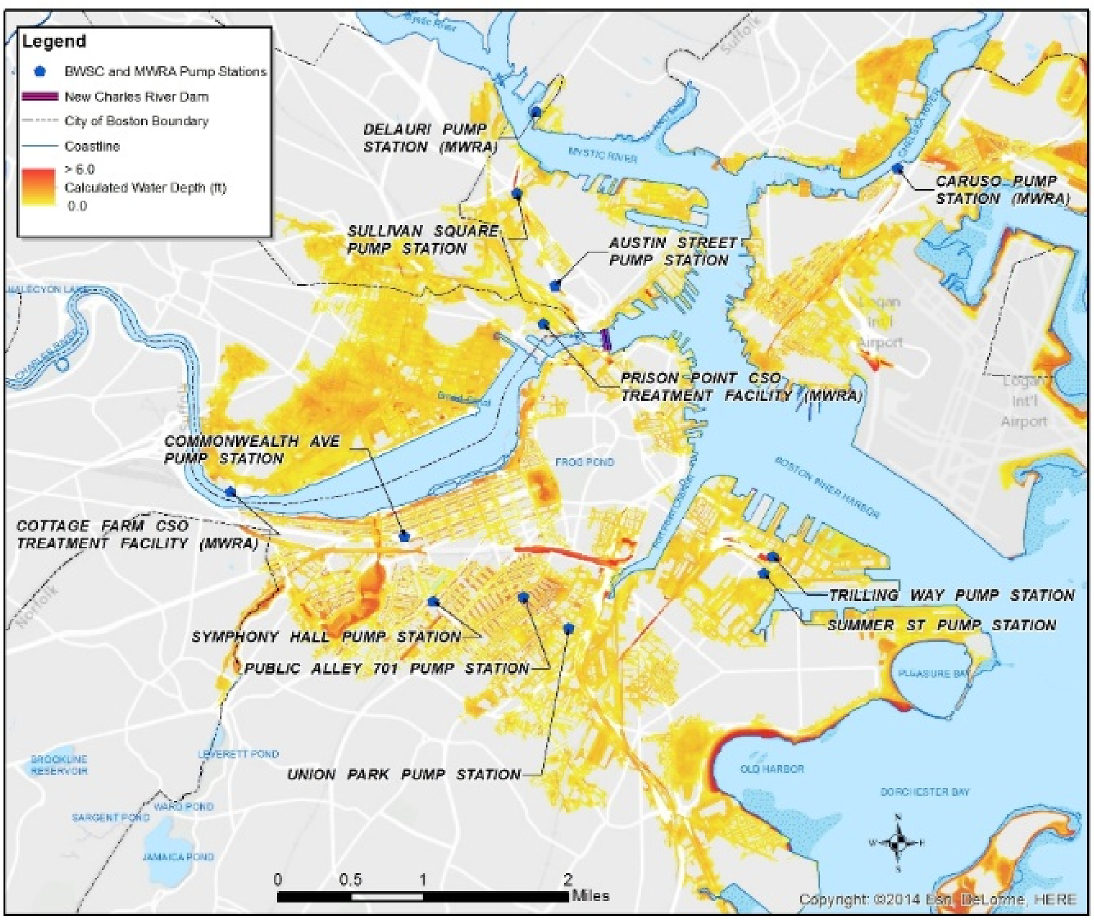


Figure B.18 Example of Calculated Inundation Depths for a Precautionary 2035 Climate Change Scenario with Storm Surge (BWSC, 2015)

The risks of inundating more of the BWSC's pump stations and those operated by MWRA increase with climate change such that by the year 2100, more than half of the pump stations will be at a high risk. Figure B.19 shows the results of a storm surge risk assessment for pump stations, ranked by scored risks that were used for prioritizing recommendations.

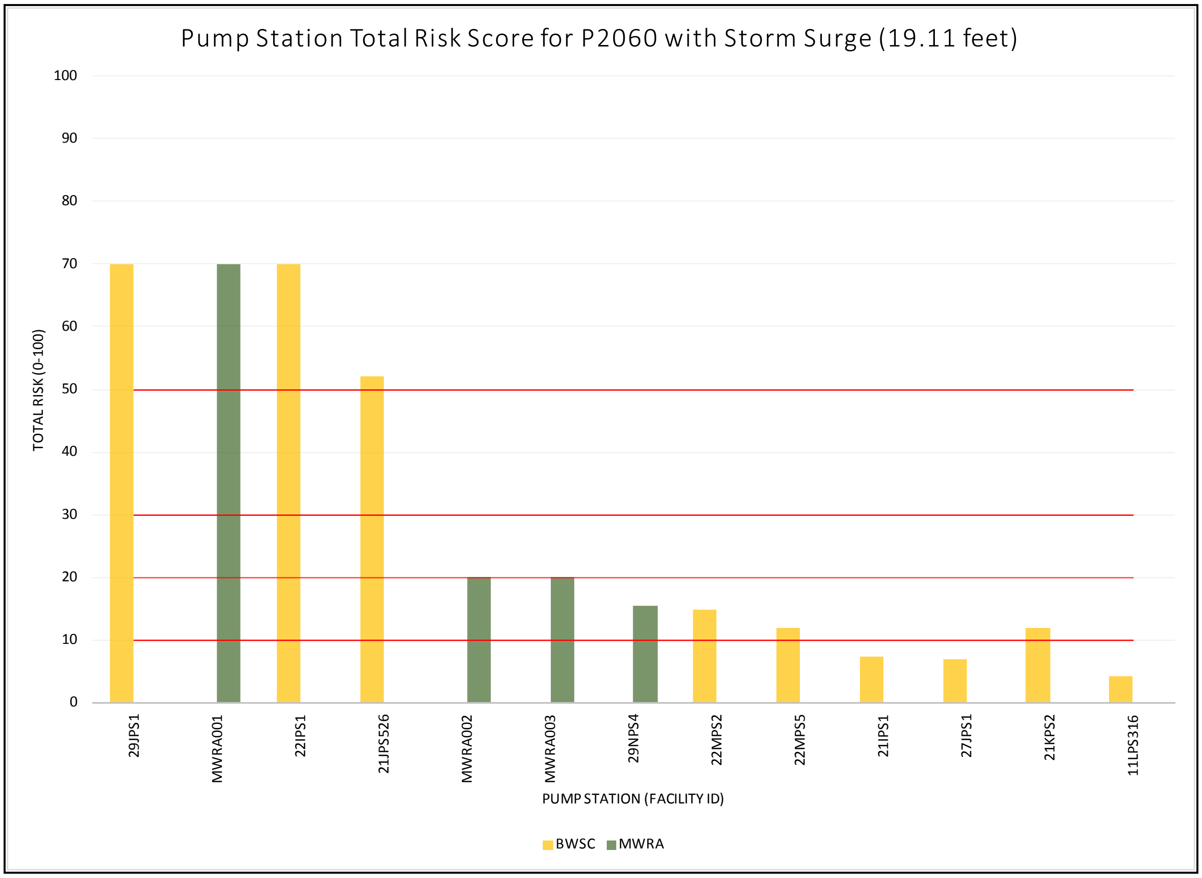


Figure B.19 Example of Pump Station Risk Scoring for Precautionary 2060 Scenario with Storm Surge (BWSC, 2015)

Design storm and typical-year hydraulic modeling of sanitary, combined and stormwater collection systems were performed for current precipitation conditions and for climate change scenarios. Hydraulic performance was evaluated to identify potential surcharging conditions that would cause SSOs and impact street drainage. Combined sewer overflow performance was also calculated for future conditions. Recommendations were then made for future planning for capacity enhancements to mitigate surcharging and flooding.

The updated Wastewater Facilities Plan recommended actions on a local and regional scale to help the City of Boston adapt to the effects of climate change. The Boston Redevelopment Authority surveyed the preparedness of all buildings and assets likely to face climate change-related vulnerabilities. The Boston Conservation Commission drafted a Wetlands Ordinance that incorporated best practices for protection against sea-level rise and storm surge and developed new floodplain maps that incorporated projected changes in sea level and storm intensity and frequency. Inspectional Services Department and Boston Public Health Commission developed guidelines and prioritization for better enforcement of flood proofing standards for buildings in currently designated flood hazard. Future control projects have also been identified or are being planned by the BWSC to address conveyance capacity issues, eliminate surcharges, and reduce CSOs. CH2M developed a conceptual flood protection wall project similar to a 1988 proposed harbor barrier plan known as the Boston Safety Belt that never came to fruition. This series of flood walls would be located to block major flood pathways and prevent inundation from the harbor.

San Francisco Sea Level Rise Action Plan

With the shoreline of the San Francisco Bay consisting of approximately one-third of California's coastline, climate change will impact San Francisco largely through SLR. The City has recognized the threat that SLR poses to the City and county, and the mayor's office appointed a Sea Level Rise Technical Committee in 2013 to begin to address SLR vulnerability with a focus on City-owned assets. The first task of the committee was to develop the Sea Francisco Sea Level Rise Action Plan (SLRAP), published in 2016 (City and County of San Francisco, 2016), to communicate the latest climate science and set an agenda for further analysis, adaptation planning, and implementation.

The effects of an 8 inch rise in sea level over the last century can already be seen in the San Francisco Bay, with periodic coastal flooding of low-lying shorelines, increased shoreline erosion, and salt water impacts to San Francisco's wastewater treatment systems. The rate of SLR is expected to increase, with increases of 6 inches to 12 inches by 2030, 11 inches to 24 inches by 2050, and 36 inches to 66 inches by 2100 (City and County of San Francisco, 2016). San Francisco is expected to face a variety of coastal hazards due to SLR, including temporary coastal flooding from extreme tides, urban flooding, shoreline erosion, and daily tidal inundation.

San Francisco has done extensive work to identify areas and systems that are particularly vulnerable to SLR. The City has identified geographic spaces that fall within a "SLR Vulnerability Zone" (Figure B.20), an area along San Francisco's shoreline that would be exposed to upper range, end-of-century SLR coastal flood hazards (66 inches) coupled with a 100-year (1 percent annual chance) extreme tide or storm (City and County of San Francisco, 2016). SFO Airport was identified as especially vulnerable to flooding from extreme storm events in light of the potential economic losses to the region due to interrupted air operations.

Adaptation response by the City to SLR involves a combination of three options: accommodate, protect, and retreat. Accommodate actions facilitate current assets temporarily remaining in areas at risk for flooding by raising or waterproofing individual assets. Protect actions involve temporary or permanent flood barriers (natural or engineered solutions) to keep an asset in place. These barrier techniques may include individual building-scale flood barriers, restoring a wetland around a neighborhood shoreline, or regional-scale levees. Retreat actions relocate sensitive assets from at-risk areas. In San Francisco, this response is expected to be used along less developed shorelines or when other options have been exhausted.

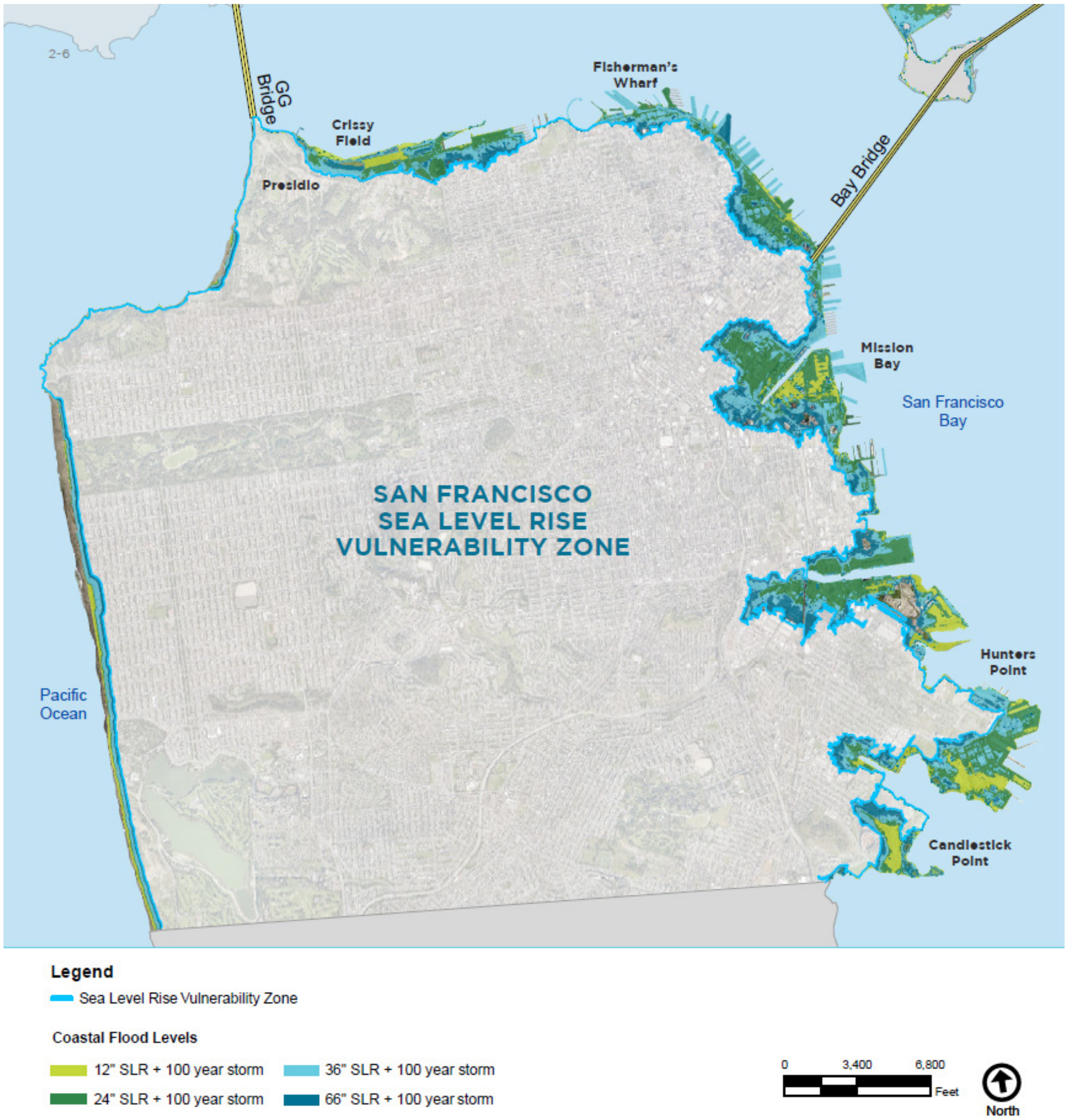


Figure B.20 San Francisco Sea Level Rise Vulnerability Zone Map (City and County of San Francisco, 2016)

Miami-Dade County Water and Sewer Department's Ocean Outfall Legislation Program

Sitting at an average of six feet above sea level and in the path of powerful hurricanes, Miami is a city whose infrastructure is threatened by the effects of climate change. Miami has historically grappled with coastal water issues as a low-lying city, but the combination of sea level rise and increased frequency of extreme precipitation is expected to exacerbate existing challenges.

Flooding impacts are expected to worsen as the climate changes. Rainfall of the 2-year 24-hour storm is expected to increase from 4.5 inches (current levels) to 4.8 - 6.05 inches (2040 to 2075 under two RCPs), putting Miami-Dade County's wastewater system at risk. The 100-year storm is projected to increase from 14.5 inches to 17.4 - 20 inches by 2075. Figure B.21 illustrates the modelled extent of flooding from a combination of the 100-year storm and 4 feet of sea level rise.

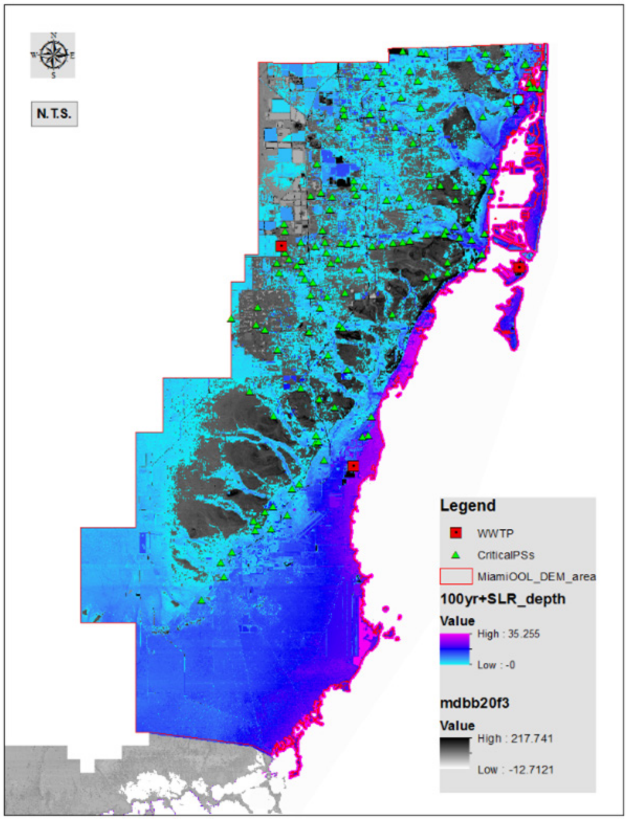


Figure B.21 Miami Coastal Flooding Impacts of 2075 Sea Level Rise (4 feet) and Extreme Rainfall

CH2M assisted Miami-Dade county evaluate risk to wastewater facilities from different climate change scenarios, as well as the associated costs of protecting facilities. Factors used in this vulnerability assessment included the planning horizon for different types of infrastructure and a valuation of the criticality of each component of the system. Climate change impacts to facilities were assessed on an individual basis for facility-specific hardening recommendations.

Like most cities who are preparing for climate change, Miami-Dade County is updating its' design criteria for peak sewer flows based on future precipitation projections. CH2M facilitated a series of workshops with WASD staff and design consultants to select design criteria that specified flood control elevations and facility hardening options, which were documented in the document "Design Guide for Hardening Wastewater Facilities against Flooding from Surge, Sea Level Rise, and Extreme Rainfall." These measures are now currently used and updated as lessons are learned from each design effort.

Adaptation to Climate Change in the Netherlands

The Netherlands is a low-lying country that anticipates unique water-related impacts of climate change, as two thirds of its area is vulnerable to flooding. The country has been actively engaging with flooding issues since the 13th century, when the first large-scale dike-building effort started. Currently, the country has a complex and interconnected flood protection system to minimize flood occurrence. Natural sand dunes and constructed dikes, dams, and floodgates aim to prevent water encroachment from the sea. River dikes prevent river overflow from both the Rhine and Meuse rivers and a complicated system of drainage ditches, canals, and pumping stations keep low-lying areas dry for habitation and agriculture.

Figure B.22 describes climate change effects in the Netherlands in the next 100 years, both beneficial and harmful. Temperatures will continue to rise by an expected 1.8 to 5.1°C by 2100 (Planbureau voor de Leefomgeving [PBL], 2013), and mild winters and hot summers will occur more often. Extreme precipitation in both the summer and winter will increase in intensity, with the possibility of drier summers. The associated increased river discharges, combined with an expected sea level rise of 35 to 85 cm (PBL, 2013), are anticipated to increase the frequency and severity of flooding.

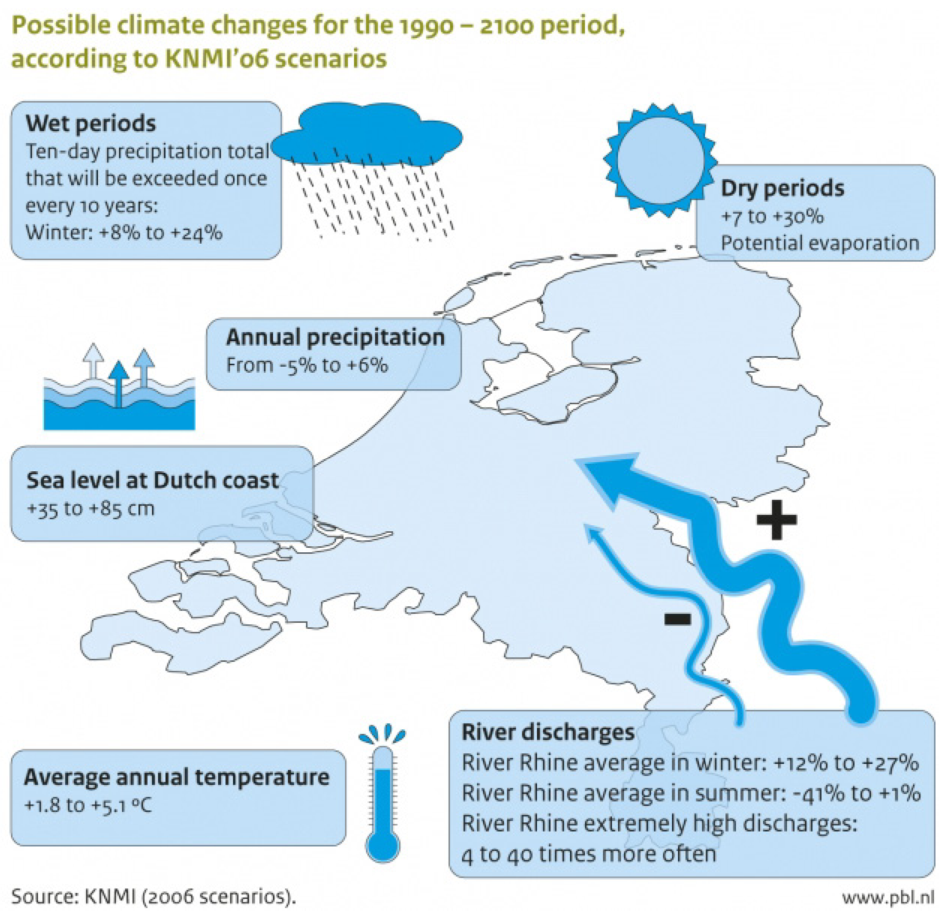


Figure B.22 Possible Climate Changes for the 1990-2100 Period in the Netherlands (PBL, 2013)

The Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving or PBL) has been instrumental in identifying risks of climate change. A PBL report in 2012 detailed the potential impacts of climate change in the Netherlands, identifying risks to the economy, people, and to the environment. Impacts in each category were grouped by severity into small, medium, and large impacts (Ligtvoet et al., 2015). Risks identified in this decade include local water drainage flooding due to extreme rainfall and damage to water pipes caused by the pull of tree roots during wind gusts. In the next century, risks identified included failure in crucial parts of the power grid due to prolonged heat/drought or no wind and limited shipping due to extremely high or low water levels. Additionally, new risk assessments of the dyke system reveal a need for dyke reinforcements in the face of uncertain flood probability.

The Netherlands is one of the most active countries in the world preparing for SLR. The Dutch government formulated an action plan called the Delta Programme that included steps to cope with 1.1-meter sea level rise, prescribing actions such as the reinforcement of dikes and dunes with 1.3 meters of additional flood protection. Another effort, The Room for the River project, is a government design plan to address flood protection and the improvement of environmental conditions surrounding the country's rivers. The plan grants more flow space to rivers to protect major populated areas and allows for periodic flooding of indefensible lands whose residents have been relocated to higher ground. The Netherlands has not developed a National Adaptation Strategy (NAS), but current thinking is aimed at ensuring that climate adaptation becomes a structural element in the public's thinking and actions. The Dutch government has already recognized its role as integral in the process of facilitating cooperation between companies, citizens, non-government organizations (NGOs), and government authorities, and further action aims to establish a consistent vision for how the Netherlands will adapt to the impacts of climate change.

B.1.4 Potential Climate Change Threats and Risks

Projected changes in climate and hydrologic conditions discussed in the previous section have the potential to impact the City's wastewater, stormwater, and water supply infrastructure and operations. The subsequent climate vulnerability assessment and resilience strategy development will explore the threat of these changes to specific City wastewater and stormwater infrastructure and operations with consistent climate scenarios and timeframes. The climate and hydrologic threats are described in the following sections followed by the specific climatic conditions that will be evaluated in risk assessments and resilience planning.

B.1.4.1 Climate Change Threat Summary

The climate of southern California and Los Angeles has already been changing in recent times. Temperatures have increased by about 0.45°F (0.25°C) in the past decade, while 2014 and 2015 represent the two warmest years in the over 100 year record. Similarly, sea levels have steadily risen over the past century. Mean sea level at the Los Angeles and Santa Monica tide stations has increased by about 0.33 foot (0.10 meter) to 0.49 foot (0.15 meter) over the past century. And while trends in precipitation are difficult to discern due to the extreme natural variability, the wettest year on record and the driest year on record have both occurred since 1980.

Future changes to the global climate system are expected to cause changes in the Los Angeles hydroclimate over the next century. Average air temperature is projected to increase from 3.2°F (1.8°C) to 3.6°F (2.0°C) by 2050. By continuing existing emission patterns, average temperatures will raise outside of normal variability to create a new regional climate by the end of century. These changes will result in increasing the frequency of extremely hot days (greater than 95°F or 35°C) from 6 to 22 days, and, consequently, the number of days where the minimum temperature will drop below freezing will decrease by more than half.

While it is difficult to discern strong trends from the full range of climate projections, the median of the projections suggest no change in the future annual precipitation. Despite the relative uncertainty in annual precipitation changes, about two-thirds of the projections suggest increases in 3-day annual maximum precipitation by end of century. The median change in 3-day annual maximum precipitation for the Los Angeles Downtown area by end of century is projected to increase by about 10 percent. The wetter projections also suggest an increase in the daily extreme precipitation events such as the 100-year/24-hour storm that would occur approximately 1 percent of the time on an annual basis. The frequency and severity of droughts are expected to increase under future climate.

Mean sea level at Los Angeles, due to thermal expansion, ice melt, and local vertical land movement, is projected to increase by range of 0.43 to 1.97 feet (0.13 to 0.6 meter) by 2050 and 1.44 to 5.45 feet (0.44 to 1.66 meter) by 2100 relative to 2000.

A summary of the projected climate and hydrologic changes for the Los Angeles region from regional and local assessments prepared by State of California, guidance from the U.S. Army Corps of Engineers (USACE), Scripps Institution of Oceanography (SIO), University of California Los Angeles (UCLA), and University of Southern California (USC) and others are summarized in Table B.4.

Table B.4 Potential Climate and Hydrologic Changes in the Los Angeles Region One Water LA 2040 Plan – TM 5.5

Climate Variables	Projected Changes and Range	Likelihood	References
Temperature			
Annual Mean Temperature	+3.2°F (2.2 to 4.5°F) [+1.8°C (1.2 to 2.5°C)] by mid-century from CMIP3 models +3.6°F (2.3 to 5.4°F) [+2.0°C (1.3 to 3.0°C)] by mid-century from CMIP5 models The projected changes over the region have an ensemble mean of 4.1°F (2.3°C), with a 95% confidence interval ranging from 1.8°F to 6.5°F (1.0° to 3.6°C) based on the UCLA Study on Temperature Change. Higher warming anticipated for inland valleys and mountain ridges.	High degree of confidence in future warming; magnitude is uncertain within reported range	Maurer et al (2007); Brekke et al (2013); Hall (2014); Sun et al (2015)
Extreme High Temperature	Higher frequency of extremely hot days (greater than 95°F or 35°C). Extremely hot days is projected to increase significantly across the region, but to a greater extent in the interior compared with coastal areas. Downtown Los Angeles is projected to experience 10 to 16 additional extremely hot days per year as compared to baseline period by mid-century. The number of days where the minimum temperature will drop below freezing will decrease by more than half.	High degree of confidence in future extreme warming	Hall (2013); Sun et al (2015)
Precipitation			
Annual Mean Precipitation	-4.5% (-29 to 14%) by mid-century from CMIP3 models +1% (-22 to 22%) by mid-century from CMIP5 models	Magnitude and direction of future precipitation are uncertain; although the median of the projections suggest almost no change in the future annual precipitation.	Maurer et al (2007); Brekke et al (2013); Berg et al (2015)
Annual 3-day Extreme Precipitation	Maximum 3-day accumulations are expected to increase. 3-day annual maximum precipitation with 100-year return period is projected to increase by about 28% (-2% to 57%) relative to historical period by mid-century (2041-2070).	Medium degree of confidence in increase of future extreme precipitation, magnitude is uncertain	Computed based on downscaled climate projections from Pierce et al (2014).

Table B.4 Potential Climate and Hydrologic Changes in the Los Angeles Region One Water LA 2040 Plan – TM 5.5

Climate Variables	Projected Changes and Range	Likelihood	References
Hydrologic, Watershed Conditions Variables			
Drought	Increased variability in water supply due to greater variability in precipitation, combined with warming. Future precipitation projections suggest longer duration precipitation deficits over the mid-century.	Medium confidence in greater drought severity and frequency	Computed based on downscaled climate projections from Pierce et al (2014).
River Flooding	Potential to increase in future floods. For watersheds with little or no snow accumulation, changes in the 3-day, 100-year flood volumes are expected to increase from 10% to 20%.	Medium degree of confidence in increase of future extreme precipitation which drive flooding risk	DWR (2016)
Wildfire	Wildfire risk is projected to increase due to warmer temperatures associated with drier conditions. Climate change forecasting predicts stronger winds which will result in higher intensity Santa Ana fires. It was predicted that the burn area of the Santa Ana fires will increase by 64% by 2041 to 2060 as compared to the baseline years of 1981 to 2000. However, the estimated burn area from non-Santa Ana fires is predicted to increase by 77% as a result of a warmer, drier climate.	High degree of confidence due to warming and extended dry season length variability	Jin et al (2015)
Sea Level Changes			
Mean sea level	+0.92 feet (0.39 to 1.97 feet) [+0.28 m (0.12 to 0.60 m)] by 2050 relative to the level in 2000. Probability of increases in future storm surges and high waves on the coast.	High degree of confidence of future sea level rise; magnitude is uncertain within reported range	National Research Council (2012); USGS (2015); Barnard et al (2014)

Based on the climate science review summarized in Table B.4 and climate change scenarios in the CREAT database, the current and future climate conditions listed in Table B.5 have been applied for assessing vulnerability due to climate change using the CREAT tool. The vulnerability assessment using the CREAT tool is presented in separate technical memorandum. Within CREAT, specific climate parameters are utilized for different areas of the Los Angeles region depending on the location of the major asset. The climate assessment for OWLA includes an assessment of the vulnerability of various assets to the potential effects of climate change through 2060.

Table B.5 Potential Climate Impacts to the City's Wastewater System One Water LA 2040 Plan – TM 5.5

Wastewater System Component	Potential Climate Impacts
Wastewater Treatment: Aeration, clarifiers, filtration, disinfection, solids handling, equalization	Increased summer temperatures may impact biological and chemical process (positively and negatively), altering the operations of treatment plants. Increased extreme precipitation may translate into increased flood risk to coastal wastewater infrastructure and increased peak flows and infiltration entering wastewater treatment plants during storm events. Sea level rise and coastal flooding may impact physical infrastructure (e.g. inundation) or operation (e.g. power).
Water Reclamation: Water reclamation facilities	Similar to those for wastewater treatment. Likely increase in demand for reuse of reclaimed water during spring and summer.
Pumping Facilities: Pumping plants	During increased precipitation events, infiltration of stormwater may exceed plant capacity. Facilities in coastal areas and floodplains may lose critical components during extreme sea levels (coastal storm surge, tsunami) and/or extreme precipitation. Increased potential regulatory compliance impacts.
Sewer Systems: Sewer systems	During increased precipitation events, sewers may have infiltration of stormwater that exceeds the capacity of the sanitary sewer systems. Increased potential for regulatory compliance impacts. Pump systems may be undersized.
Discharge/Disposal: Stream discharge or reuse delivery systems	Increased warming may reduce assimilative capacity for stream discharge during warm, low flow periods. During increased flood periods, hydraulic limitations may exist that reduce the ability to discharge without pumping, or require additional duration of pumping.
Operations and Maintenance	Reduced access to certain facilities due to increased flooding. Increased number of days where worker safety precautions will need to be managed due to extreme heat. Power outage risks for facilities with no backup.

The CREAT assessment uses current climate data and projections of future climate conditions to identify those threats and how they may change over time. CREAT defines a scenario as projected changes in climate with respect to historical conditions (temperature and precipitation), extreme events (intense precipitation and extreme heat), and sea level rise. The climate data sources and scenarios utilized in the One Water Los Angeles (OWLA) assessment are the same as those used in previous Los Angeles Sanitation assessments for wastewater and solid resources. The City of Los Angeles has overseen a number of previous studies related to climate change. These reports examined climate change vulnerabilities and adaptation measures involving the City of Los Angeles.

Anticipated impacts to the City's wastewater, stormwater, and water supply, based on a review of these prior evaluations, are summarized below:

- Warmer temperatures and the frequency of hot days will result in more demands on the power grid and may lead to more frequent power interruptions at stormwater and wastewater facilities that will require more distributed backup generation at all facilities.
- Increases in extreme precipitation will increase erosion and cause slopes to become more unstable threatening facilities during landslides caused by rainfall or seismic events while stormwater and wastewater flows during wet events will likely increase and may exacerbate problematic portions of these systems.
- Drought, more hot days, and wildfires combine to increase the vulnerability of some City facilities to fire risk.
- Sea level rise is likely to increase infrastructural and operational vulnerabilities for coastal wastewater and stormwater facilities during coastal storm and tsunami events.

The City has already begun exploring a range of adaptation measures to become more resilient in the face of a changing climate. Initial efforts by the City to improve the resiliency of the wastewater, stormwater, and water supply systems have identified a range of potential resilience strategies:

- Asset protection measures such as waterproofing, perimeter floodwalls, backup power supply, slope stabilization, and expanded stormwater best management practices
- Application of various green infrastructure programs, changes in stormwater management, and coordination flood control operations
- Changes to water supply operations, increasing storage and diversion capacity, and other water supply infrastructure to adapt to a more variable hydrologic regime

The work being conducted as part of this OWLA effort builds upon these previous efforts and seeks to offer a more comprehensive set of actions of strategies for improving the resiliency of the City's wastewater and stormwater systems.

B.1.4.2 Wastewater System Risks

Climate change is projected to impact the City's wastewater systems through changes in ambient temperatures for both wastewater treatment processes and discharge, changes in flows into the wastewater system, and through increased flooding risks to low-lying or insufficiently sized wastewater infrastructure. The wastewater systems consist of wastewater treatment facilities, water reclamation facilities, sewage pumping facilities, and sewer systems. Increases in the frequency and intensities of extreme rainfall may increase infiltration/inflow rates in sanitary systems. However, LA Sanitation is more concerned with drainage as opposed to the pumping and process capacity of plants. The system experiences a 2.2 peaking factor during storms; although the sewer system is completely separated, the first flush of stormwater is diverted to sanitary sewers at low flow diversions and is limited by their pumping capacities. Table B.5 provides a summary of the potential climate impacts to the main wastewater system components.

B.1.4.3 Stormwater System Risks

Climate change is projected to impact the City's stormwater systems through changes in extreme precipitation and flows into the stormwater system, through increased flooding risks to low-lying or insufficiently sized wastewater infrastructure, and potential increase in sediment/debris associate with extreme events. The stormwater systems consist of collection systems, stormwater pumping plants, watershed protection, and Proposition O projects. Table B.6 provides a summary of the potential climate impacts to the main stormwater system components.

Table B.6 Potential Climate Impacts to the City's Stormwater System
One Water LA 2040 Plan – TM 5.5

Stormwater System Component	Potential Climate Impacts
Collection Systems: Storm sewer systems	Many municipal storm sewers in the U.S. are designed based on older precipitation frequency analysis and recent updates have revealed insufficient storm sewer sizing for the stated return periods. Considerations of future climate changes further demonstrates insufficient system performance. Increased potential for sewer overflows, regulatory compliance, and risk of urban flooding.
Pumping Facilities: Pumping plants	During increased precipitation events, infiltration of stormwater may exceed plant capacity. Facilities in coastal areas and floodplains may lose critical components during extreme sea levels (coastal storm surge, tsunami) and/or extreme precipitation. Increased potential for spills and regulatory compliance impacts.
Watershed Protection: Watershed protection programs	Increased sediment loads associated with increased precipitation intensity and flashier flows (especially following wildfire) may require more frequent stream maintenance and sediment removal, or reduced flood conveyance. Warming may increase growth of riparian vegetation. Increases in extreme precipitation will likely challenge existing stormwater-storage-recharge efforts, but increases in more frequent events could increase the opportunity for groundwater recharge.
Operations and Maintenance	Reduced access to certain facilities due to increased flooding. Increased number of days where worker safety precautions will need to be managed due to extreme heat. Power outage risks for facilities with no backup.

B.1.4.4 Current and Climate Change Conditions Applied to Risk Assessments

Historical, current, and potential climate-based threats and risks are described above for temperature, precipitation, tsunami, and sea levels. This information was used as the basis to select baseline and projected climate threat conditions for risk assessments and resilience planning. The conditions are primarily taken from the Los Angeles Sanitation CREAT exercise for consistency – Los Angeles Sanitation used the Warm & Wet scenario with a stormy future (see Attachment 2.3). Table B.7 lists the baseline conditions for assessing current (baseline) threats/risks and the mid-century (year 2060) projected values for assessing future threats/risks with climate change. Temperature, the number of hot days, precipitation, and extreme storm events (100-year/24-hour storm) vary by location from coastal to inland areas of the City and are therefore location-based for baseline and projected future conditions. Sea level rise of 4.92 feet (1.5 meters) was also considered for year 2100 conditions. As discussed in Section B.1.2, the future conditions of the potential climate-based threats affect particular risks such as flooding, erosion, landslides, wildfire, and power outages.

Table B.7 Climate Change Conditions Used in Risk Assessment and Resilience Planning
One Water LA 2040 Plan – TM 5.5

Climate Variable	Baseline Condition	Projected Value for Mid-Century (Observed + Changes)
Annual Temperature	Location Based (~63°F)	+3°F to +4°F
Number of Hot Days (over 95°F)	6	22
Total Annual Precipitation	Location Based (14 to 18 in/yr)	-10.7% to +11.2%
100-Year/24-Hour Storm Event	Location Based (5 to 7 inches/24 hours)	+34.3%
Sea-Level Rise	0.06-0.09 in/yr	1.64 feet (0.5 meter)

The next section will describe how these conditions were used as threats to assess facility resilience risks for current and future conditions.

ATTACHMENT 1 – SUMMARY OF PREVIOUS CITY OF LOS ANGELES CLIMATE CHANGE VULNERABILITY ASSESSMENTS

Various studies examining LA's vulnerability to climate change impacts are summarized below. Sea level rise and the changes in precipitation were common themes, and the threat of these effects on City infrastructure was examined.

1.1 SEA LEVEL RISE VULNERABILITY STUDY FOR THE CITY OF LOS ANGELES

The 2013 report on *Sea Level Rise Vulnerability Study* for the City of Los Angeles prepared by the University of Southern California Sea Grant Program assesses the potential physical, social, and economic impacts of sea level rise for the coastal communities (Grifman et al., 2013). The study evaluates four key locations: Pacific Palisades, Venice/Marina Peninsula/Playa Del Rey/Los Angeles International Airport, San Pedro/Wilmington/Terminal Island/Los Angeles Harbor Exposed Coast, and Los Angeles Harbor. Although each community will require a unique adaptation to climate change, the report outlined several actions to help prepare for future sea level rise including storm, beach width, and cliff retreat monitoring, incorporation of existing historical beach and wave data into predictions, and agency coordination.

An "Adaptive Adaptation Approach" is recommended for sea level rise planning. Success of climate change planning is dependent on continuous adaptation to new science, reassessment of vulnerabilities, as well as stakeholder involvement. The iterative steps to this approach include identification of current observed vulnerabilities, sea level rise vulnerability assessments, identification of sea level rise adaptation measures, and development of sea level rise adaptation plan. To initiate the first step of this process, an observation of current vulnerabilities was done in 2012 by consulting with City of Los Angeles staff to identify major coastal assets and their associated vulnerabilities and replacement values.

The physical vulnerability assessment for the study was done by the International Council for Local Environmental Initiatives (ICLEI) – Local Governments for Sustainability, U.S.A. Sea level rise was simulated using the coastal impact model developed the United States Geological Survey and calibrated with data from the January 2010 Los Angeles storm representing a moderately severe 10-year event. Coastal storm scenarios, including tidal and wind affects, were incorporated into the model to assess impacts from waves and storm surging likely to happen with changing seas. Future sea levels were modeled to rise 1.6 feet (0.5 meter) by 2050 and 4.6 feet (1.4 meters) by 2100, based on the 2007 report

Recent Climate Observations Compared to Projections (Rahmstorf, 2007). However, as newer information becomes available, the model can be continuously adapted.

The ICLEI assessment found vulnerabilities in wastewater, stormwater, potable water, and roadway infrastructure. Flooding of low lying areas can result in wastewater leaching, damage and reduced access to underground infrastructure and utilities, and inundation to transportation facilities, posing a risk to public health and emergency services. Some coastal buildings are also at risk of flooding, especially in Venice. However, the ICLEI assessment found lower levels of vulnerability at the Port of Los Angeles and City of Los Angeles coastal energy facilities due to replacement schedules and system redundancies.

Some of Los Angeles' most critical coastal infrastructure is located at just 10 feet above mean sea level including two power plants, two wastewater treatment facilities, and the Port of Los Angeles. The port is the entryway to over 40 percent of the imports entering the United States contributing to over $260 billion in the national economy (Port of Los Angeles, 2012). Beach tourism is another important revenue stream contributing to $16.5 billion expenditures from over 41 million tourists as reported in 2012 (Los Angeles Division of Tourism, 2012).

An economic vulnerability assessment was conducted by Dr. Dan Wei and Dr. Sam Chatterjee to assess the economic losses due to sea level rise. The study focused on communities of Pacific Palisades, Venice/Playa Del Rey, and San Pedro/Wilmington in scenarios of temporary flooding from 10-year and 100-year storm events and sea level rise. Economic impact factors included property damages, direct and indirect business interruption, and impacts to infrastructure. Loss estimates were done using the HAZUS MH 2.1 model from the Federal Emergency Management Agency. The assessment concluded that a building losses can range from $242.7 million for a 10-year flood event (without sea level rise) up to $1,441.3 million for a 100-year flood combined with higher sea levels. An input-output model was used to quantify economic losses from business interruption and found that interruption losses range from $3.4 million for a 10-year flood to $21.9 million for a 100-year flood with sea level rise. However, there are only limited impacts to utilities during the simulated events.

Although most of Los Angeles' coastal zone is highly urbanized, the Ballona Wetlands is one of the largest coastal wetlands in Los Angeles County and serves an important ecological role. Climate change impacts to this wetland were evaluated by Loyola Marymount University and the Santa Monica Bay Restoration Foundation. (Bergquist et al. 2012) The study concluded that flooding could cause significant impacts to the wetlands resulting from changes in hydrology and tidal influence. The authors suggest protection of this key natural resource be considered in climate change planning.

1.2 SOUTHERN CALIFORNIA COASTAL IMPACTS PROJECT

The Coastal Storms Modeling System (CoSMoS), is a region-specific model to project flooding and erosion as a result of climate change induced sea level rise and storms. The model was developed by Dr. Patrick Barnard and Dr. Li Erickson of the United States Geological Survey. The first iteration of the model was developed for the Southern California region and utilized in the 2013 study *Sea Level Rise Vulnerability Study* for the City of Los Angeles (Grifman et al., 2013). The second iteration of the model was for San Francisco Bay. The third iteration was further developed for the Southern California region to account for shoreline changes as well as incorporating regional storm factors and a full spectrum of sea level rise scenarios.

The University of Southern California Sea Grant received funding to build the model's capacity in coastal communities by leading workshops with local organizations. The initial workshops were held in San Diego on October 30, 2014, Los Angeles on November 13, 2014, and in Orange County on February 23, 2015.

CoSMoS 3.0 provides daily, annual, 20-year, and 100-year coastal storm calculations at sea-level rise of 0 to 6.6 feet (0 to 2 meters) in 0.8 foot (0.25 meter) increments, plus a 16.4 feet (5 meter) scenario. CoSMos 3.0 Phase 1 has been completed. The model results for Phase 2 are expected to be available in summer 2016.

1.3 REGIONAL ADAPTLA: COASTAL IMPACTS PLANNING IN THE LOS ANGELES REGION

The Regional AdaptLA: Coastal Impacts Planning in the Los Angeles Region is an ongoing project to provide a link between scientific tools and local governments for regional planning (Regional AdaptLA, 2016). The Ocean Protection Council has provided funding to develop a shoreline change and erosion model for Los Angeles. The model has been integrated with the United States Geological Survey's Coastal Storms Modeling System (CoSMoS). The project has been done in collaboration with a number of stakeholders including 11 jurisdictions and the University of Southern California Sea Grant Program.

The University of California Sea Grant Program held a workshop in Los Angeles on November 13, 2014 to provide an overview and training of the model. The Regional AdaptLA Webinar Series was launched on January 12, 2015 to provide information on tide and storm impacts in Southern California. The second webinar was held on March 17, 2015 which focused on beach dynamics and ecology of the region.

1.4 ANALYSIS OF PROJECTED CHANGES IN PRECIPITATION IDF VALUES BASED ON CLIMATE CHANGE PROJECTIONS

In 2012 CH2M conducted a study for the City of Los Angeles Bureau of Sanitation to evaluate projected changes in precipitation, duration, and frequency (IDF) for the year 2090 using the IPCC general circulation models (GCMs). Infrastructure studied included the Venice Pumping Plant No. 646 and a portion of the San Pedro storm drain system.

Historical precipitation IDF values from three active National Weather Service climate stations in the City of Los Angeles (City) were analyzed using the SimCLIM generalized extreme value (GEV) statistical distribution. The historical analysis provided the baseline for determining projected changes in precipitation intensity, duration, and frequency derived from 12 daily general circulation models and the B1 (low) and A1FI (high) greenhouse gas emissions scenarios (IPCC, 2000) for the years 2025, 2050, and 2090.

Projected intensity, duration, and frequency curves were developed for 2025, 2050, 2090 for a range of durations from 5 minutes to 24 hours, and for return frequencies from 2 to 100 years, at three NWS station locations: Los Angeles International Airport (LAX), Los Angeles Downtown (LA Downtown), and Torrance Airport (Torrance AP). Projected precipitation amounts were also compared to those historical values derived by the SimCLIM modeling tool, NOAA Atlas 14 amounts, results derived from a three station L-Moments analysis, and results provided by the City of Los Angeles. The design storm hyetographs provided by the City are shown in Table 1.1.

To determine the projected trends in total annual precipitation for the Los Angeles project area, results from the three project climate stations were averaged from the median of 12 daily GCMs for each of the two emissions scenarios; B1 (low) and A1FI (high) starting in 1990 and ending in 2100, as shown in Figure 1.1. Little change in annual precipitation is shown by 2025; by 2050 the median precipitation amounts decline by 2 percent for the low emissions and 3 percent for the high emissions scenario; by 2090 the median precipitation declines by 3 percent for the low emissions and 6 percent for high emissions.

Although annual precipitation is projected to decline by the end of the century, climate change models are indicating an increase in daily precipitation intensities as the earth warms. As shown in Figure 1.2, the larger daily amounts may increase from between 25 percent from the B1 (low) and 45 percent for the A2 (high) by the end of the 21st century, for the United States as a whole.

Table 1.1 Hourly Distribution of 24-Hour Precipitation Amounts: Design Storm Hyetographs – 4th Quartile Distribution (Back Loaded) from 3-Station Average IDF Storms for Varying Recurrence Interval Rainfall Intensity (Inches/Hour) Provided by the City of Los Angeles												
	2-year		**5-year**		**10-year**		**25-year**		**50-year**		**100-year**	
Hour	**In/hr**	**Inc. %**	**In/hr**	**Inc. %**	**In/hr**	**Inc. %**	**In/hr**	**Inc. %**	**In/hr**	**Inc. %**	**In/hr**	**Inc. %**
1	0.03	1.23%	0.04	1.10%	0.05	1.13%	0.06	1.10%	0.07	1.14%	0.08	1.17%
2	0.03	1.23%	0.04	1.10%	0.05	1.13%	0.07	1.29%	0.07	1.14%	0.08	1.17%
3	0.03	1.23%	0.05	1.37%	0.05	1.13%	0.07	1.29%	0.08	1.31%	0.08	1.17%
4	0.03	1.23%	0.05	1.37%	0.06	1.35%	0.07	1.29%	0.08	1.31%	0.09	1.31%
5	0.03	1.23%	0.05	1.37%	0.06	1.35%	0.07	1.29%	0.08	1.31%	0.09	1.31%
6	0.03	1.23%	0.05	1.37%	0.06	1.35%	0.07	1.29%	0.08	1.31%	0.09	1.31%
7	0.03	1.23%	0.05	1.37%	0.06	1.35%	0.08	1.47%	0.09	1.47%	0.1	1.46%
8	0.04	1.65%	0.05	1.37%	0.07	1.58%	0.08	1.47%	0.09	1.47%	0.1	1.46%
9	0.04	1.65%	0.06	1.64%	0.07	1.58%	0.09	1.65%	0.1	1.63%	0.11	1.61%
10	0.04	1.65%	0.06	1.64%	0.07	1.58%	0.09	1.65%	0.1	1.63%	0.11	1.61%
11	0.04	1.65%	0.06	1.64%	0.08	1.80%	0.09	1.65%	0.11	1.79%	0.12	1.75%
12	0.04	1.65%	0.07	1.92%	0.08	1.80%	0.1	1.84%	0.11	1.79%	0.13	1.90%
13	0.07	2.88%	0.1	2.74%	0.12	2.70%	0.15	2.76%	0.17	2.77%	0.19	2.77%
14	0.07	2.88%	0.11	3.01%	0.13	2.93%	0.16	2.94%	0.18	2.94%	0.2	2.92%
15	0.08	3.29%	0.11	3.01%	0.14	3.15%	0.17	3.13%	0.19	3.10%	0.21	3.07%
16	0.08	3.29%	0.12	3.29%	0.15	3.38%	0.18	3.31%	0.2	3.26%	0.23	3.36%
17	0.09	3.70%	0.13	3.56%	0.16	3.60%	0.2	3.68%	0.22	3.59%	0.25	3.65%
18	0.1	4.12%	0.14	3.84%	0.17	3.83%	0.21	3.86%	0.24	3.92%	0.27	3.94%
19	0.14	5.76%	0.21	5.57%	0.25	5.63%	0.31	5.70%	0.35	5.71%	0.39	5.69%
20	0.15	6.17%	0.23	6.30%	0.28	6.31%	0.34	6.25%	0.38	6.20%	0.43	6.28%
21	**0.62**	**25.51%**	**0.94**	**25.75%**	**1.14**	**25.68%**	**1.4**	**25.74%**	**1.58**	**25.77%**	**1.76**	**25.69%**
22	0.26	10.70%	0.39	10.68%	0.48	10.81%	0.58	10.66%	0.66	10.77%	0.74	10.80%
23	0.19	7.82%	0.28	7.67%	0.34	7.66%	0.42	7.72%	0.47	7.67%	0.52	7.59%
24	0.17	7.00%	0.26	7.12%	0.32	7.21%	0.38	6.99%	0.43	7.01%	0.48	7.01%
24-hr Total	**2.43**		**3.65**		**4.44**		**5.44**		**6.13**		**6.85**	
1-hr Total	0.62	25.51%	0.94	25.75%	1.14	25.68%	1.4	25.74%	1.58	25.77%	1.76	25.69%
4-hr Total	1.24	51.03%	1.87	51.23%	2.28	51.35%	2.78	51.10%	3.14	51.22%	3.5	51.09%
8-hr Total	1.72	70.78%	2.58	70.68%	3.14	70.72%	3.84	70.59%	4.33	70.64%	4.84	70.66%
12-hr Total	2.02	83.13%	3.02	82.74%	3.68	82.88%	4.5	82.72%	5.07	82.71%	5.67	82.77%

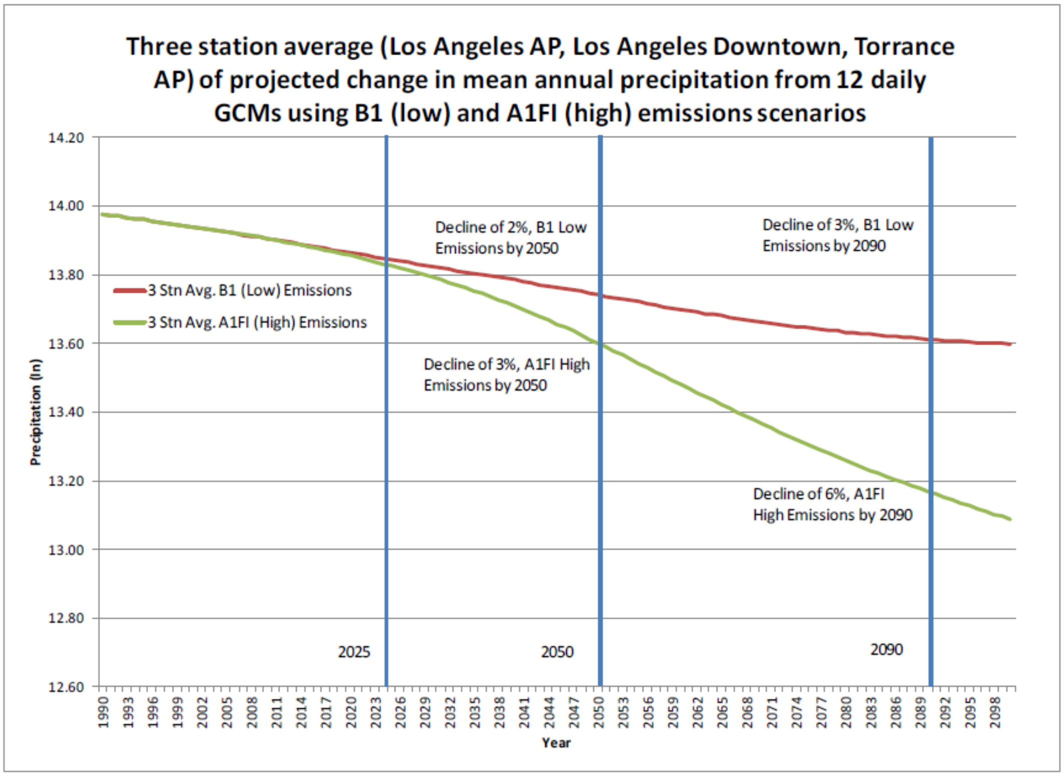


Figure 1.1 **Projected Changes in Annual Precipitation for the Los Angeles Project Area Derived from the Ensemble Median of 12 Daily GCMs and 2 SRES Emission Scenarios (Low [B1] and High [A1F1]) for the Years 1990-2100**

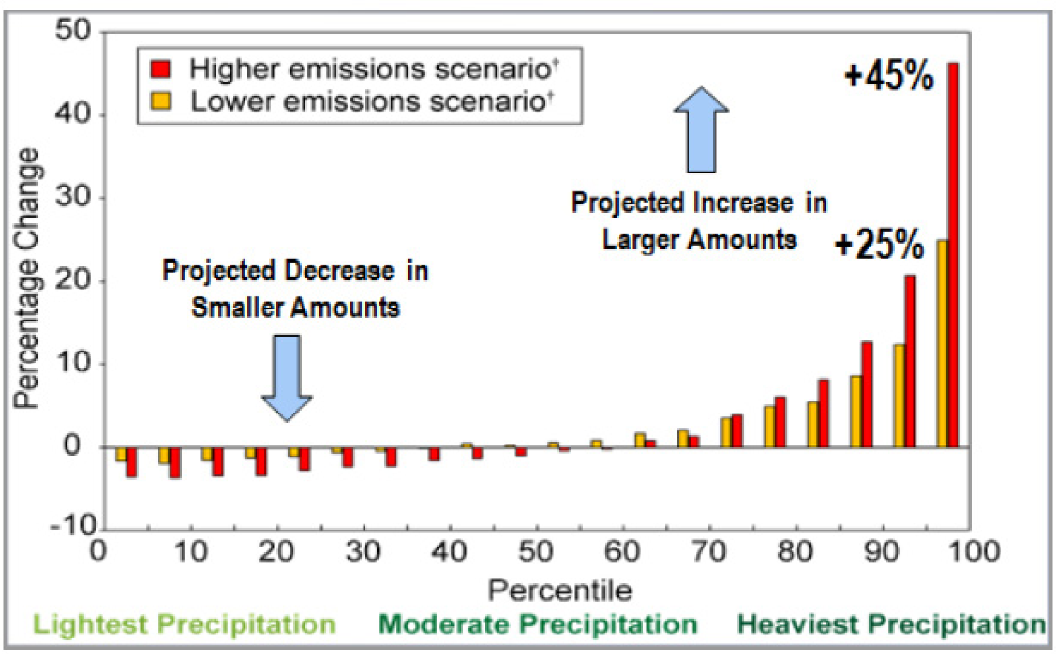


Figure 1.2 **Projected Changes in Daily Precipitation Intensity for the Years 2080-2099 for Lower (B1) and Higher (A2) Greenhouse Gas Emissions Scenarios**

(CCSP Unified Synthesis Product: Global Climate Impacts in the United States, 2009).

Figure 1.3 and Figure 1.4 show the projected three-station average precipitation amounts for year 2050 using the low and high emission scenarios.

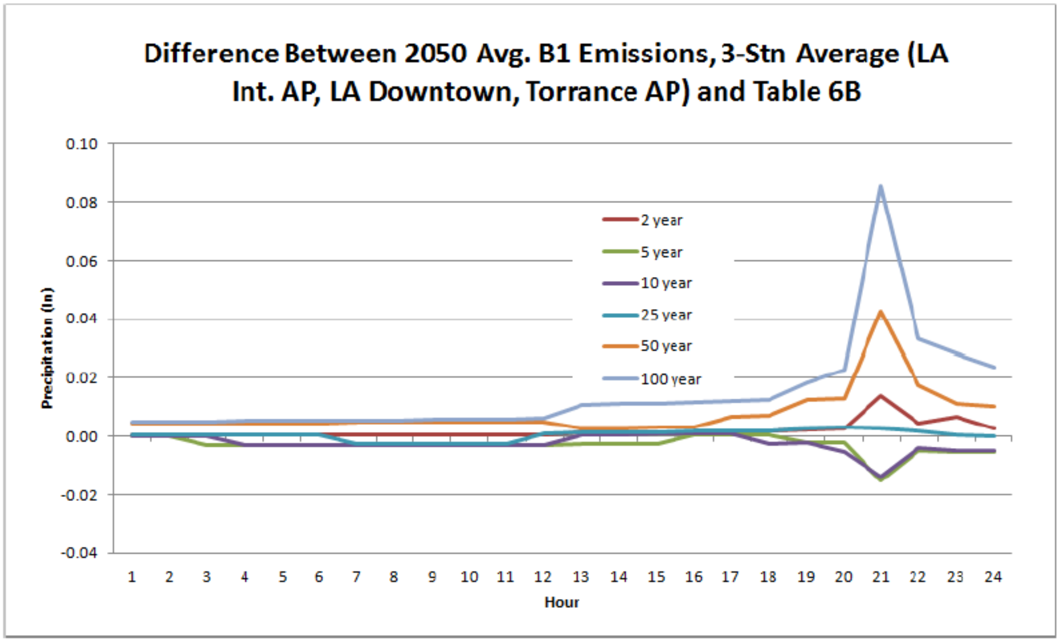


Figure 1.3 Difference between Projected 2050, B1 (Low) Emissions, from 3-Station Average for Return Periods from 2 to 100 Years

Projected hourly amounts distributed from projected daily amounts using Table B.1 hourly distribution.

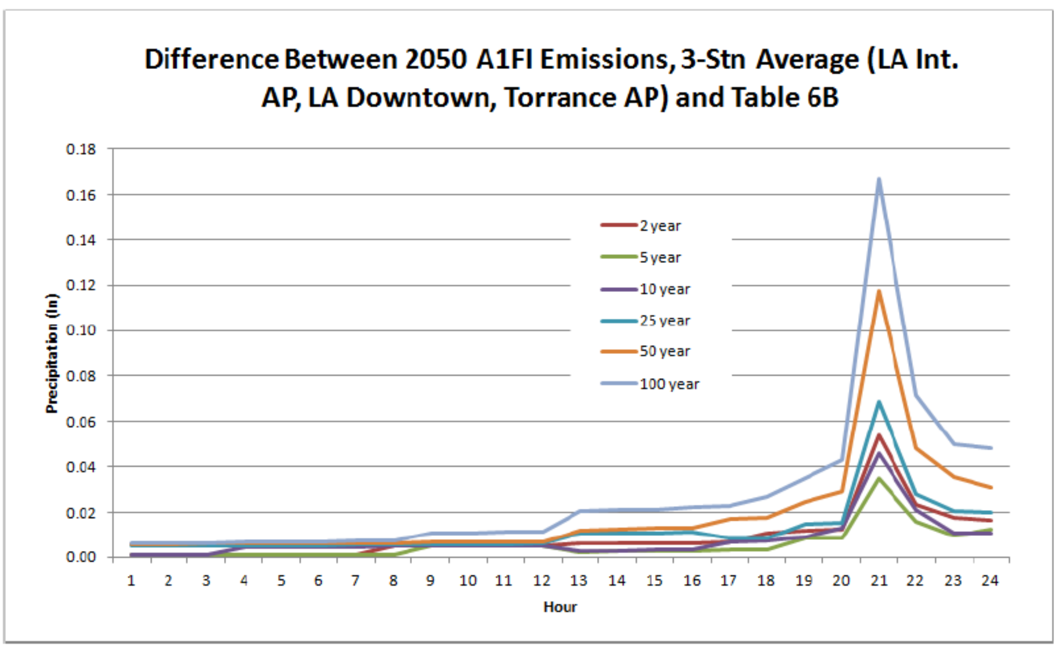


Figure 1.4 Difference between Projected 2050, A1FI (High) Emissions, from 3-Station Average for Return Periods from 2 to 100 Years

Projected hourly amounts distributed from projected daily amounts using Table B.1 hourly distribution.

Figure 1.5 and Figure 1.6 show the projected three station average precipitation amounts for year 2090 using the low and high emission scenarios. An examination of low emission (B1) results for 2090 (Figure 1.5) indicates a trend to higher amounts, however all changes are less than 0.18 inch. The high emission (A1FI) precipitation amounts (Figure 1.6) for all hours are higher than Table 1.1, and approximately 0.43 inch higher for hour-21.

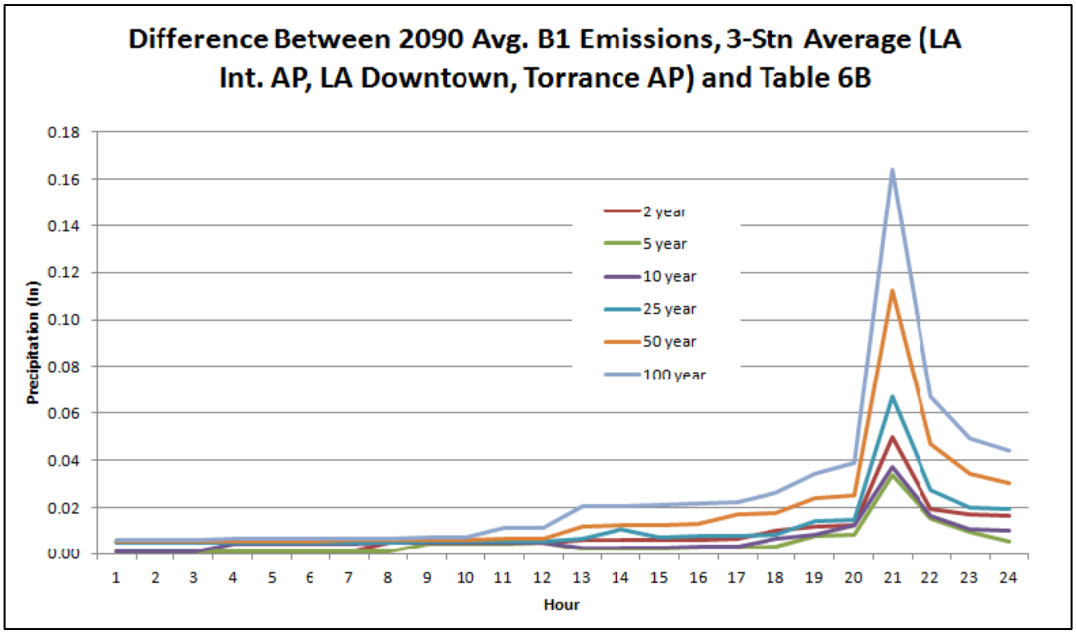


Figure 1.5 Difference between Projected 2090, B1 (Low) Emissions, from 3-Station Average for Return Periods from 2 to 100 Years

Projected hourly amounts distributed from projected daily amounts using Table 6B-D-3 hourly distribution.

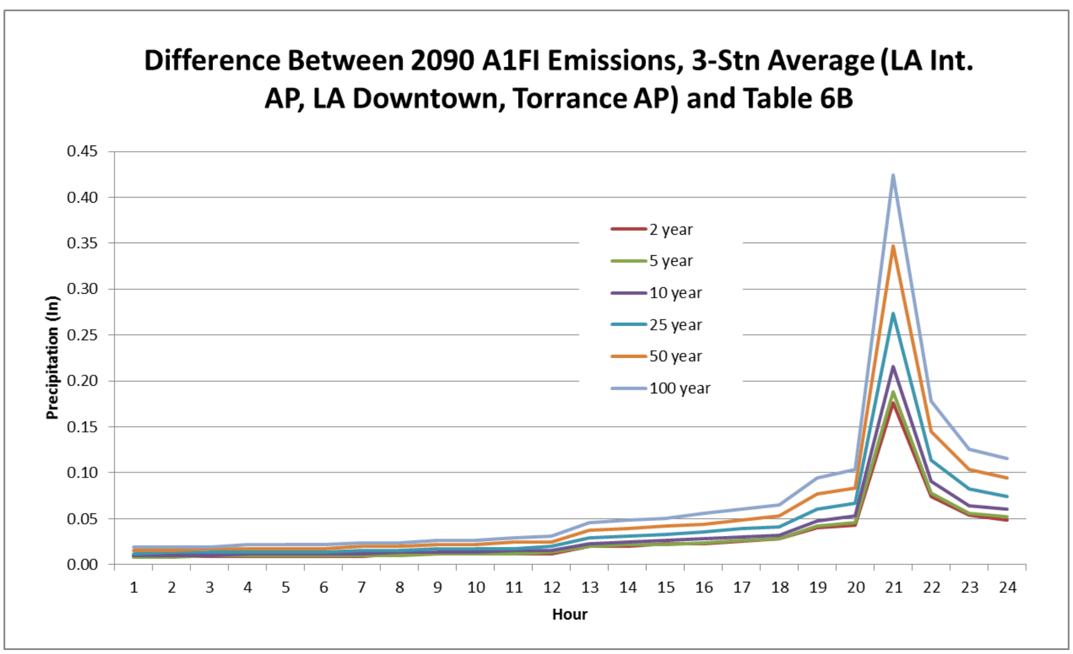


Figure 1.6 Difference between Projected 2090, B1 (High) Emissions, from 3-Station Average for Return Periods from 2 to 100 Years

Table 1.2 summarizes the differences between 3-station average projected changes in hour-21 precipitation amounts (inches) for the years 2025, 2050, and 2090 for the low and high emissions scenario from an ensemble of 12 daily GCMs for return periods from 2 to 100 years (CH2M 2012). For year 2025, differences are small, ranging from -0.06 inch for 2-year, B1 low emissions to +0.04 inch for 100-year, A1FI high emissions. For year 2050, differences range from -0.02 inch for 2-year, B1 low emissions to +0.17 inch for 100-year A1FI high emissions. For year 2090, differences are all positive and range from 0.03 inch for 2-year, B1 low emissions to +0.43 inch for 100-year A1FI high emissions.

Table 1.2 Range of Difference Summary Between The 3-station Average of Projected Changes in Hour-21 Precipitation amounts (inches)

Year	Hour-21 Precipitation Difference Range (Projected - Table 6B-D-3) B1 (Low Emissions) for 2- to 100-Year Return Period	Hour-21 Precipitation Difference Range (Projected - Table 6B-D-3) A1F1 (High Emissions) for 2- to 100-Year Return Period
2025	-0.06" to 0.03"	-0.05" to 0.04"
2050	-0.02" to 0.09"	0.03" to 0.17"
2090	0.03" to 0.17"	0.17" to 0.43"

1.5 SEA LEVEL RISE POTENTIAL FOR CITY OF LOS ANGELES, CA

In 2012 CH2M conducted a study for the City of Los Angeles Bureau of Sanitation to evaluate projected changes in sea level rise using the Intergovernmental Panel on Climate Change general circulation models (GCMs). The study focuses on sea level rise in coastal areas of Los Angeles and Santa Monica through the year 2100.

Results from 13 general circulation models that project sea level and two greenhouse gas emission scenarios (low [B1] and high [A1FI]) were used to generate projected changes in mean sea level (MSL) and mean higher high water (MHHW) for the National Oceanic and Atmospheric Administration (NOAA) Los Angeles and Santa Monica tide gauges in the Los Angeles basin area through the year 2090.

A review of peer-reviewed sea level rise research was also performed to assess recent publications that address new findings associated with ice sheet melt rates and other factors that may affect projected changes in sea level. This review included the "State of California Sea Level Rise Interim Guidance Document" which recommended estimates of future SLR from the scientific literature, publications by Vermeer and Rahmstorf (2009), and members of the Ocean Protection Council (OPC).

The 2007 Fourth Assessment Report (IPCC 4) projected century-end sea levels using the Special Report on Emissions Scenarios (SRES). The projections based on these scenarios are not predictions, but reflect plausible estimates of future social and economic factors that affect greenhouse gas emissions. This report found that sea level is expected to rise by 7.1 to 23 inches (18 to 59 cm) as shown in Table 1.3. Their projections were for the time 2090–99, relative to average sea level over the period 1980–1999. These IPCC projections represent a "likely range" which inherently allows for the possibility that the actual rise may be higher or lower, and does not include possible increased meltwater contributions from Greenland and Antarctica (Meehl et al., 2007; IPCC, 2007).

Table 1.3 Projected Global Average Surface Warming and Sea Level Rise at the End of the 21st Century (IPCC, 2007)

Case	Temperature Change (°C at 2090-2099 Relative to 1980-1999)		Sea Level Rise (m at 2090-2099 Relative to 1980-1999) Model-Based Range Excluding Future Rapid Dynamical Changes in Ice Flow
	Best Estimate	Likely Range	
Constant Year 2000 Concentrations(2)	0.6	0.3 - 0.9	NA
B1 Scenario	1.8	1.1 - 2.9	0.18 - 0.38
A1T Scenario	2.4	1.4 - 3.8	0.20 - 0.45
B2 Scenario	2.4	1.4 - 3.8	0.20 - 0.43
A1B Scenario	2.8	1.7 - 4.4	0.21 - 0.48
A2 Scenario	3.4	2.0 - 5.4	0.23 - 0.51
A1F1 Scenario	4.0	2.4 - 6.4	0.26 - 0.59

Notes:
(1) These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth System Models of Intermediate Complexity and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs)
(2) Year 2000 constant composition is derived from AOGCMs only.

The SimCLIM application (Warrick, 2005), developed by CLIMsystems in New Zealand, provides a workbench to assess the impacts of climate on the environment. SimCLIM merges historical climate information with global climate change projections to provide users with the ability to conduct sensitivity analysis and examine sector impacts of climate change.

The SimCLIM Sea Level Scenario Generator used output from 13 GCMs available from the IPCC sanctioned CMIP3, AR4 database managed by the Program for Climate Model Diagnosis and Intercomparison (PCMDI, 2009). The Sea Level Scenario Generator was run for the Los Angeles and Santa Monica tide stations using a low (B1) and high (A1FI) emissions scenarios. Based on recent research focused on ice sheet melt contribution to sea level rise, the SimCLIM model was rerun to include median AR4 ice sheet contributions of 0.85 mm/year for the B1 emissions scenario and 1.9 mm/year for the A1FI (IPCC, 2007a).

Research by Overpeck et al. (2006) compared Arctic climate during the last interglacial period with conditions projected to occur during the 21st century under a business-as-usual emissions (A2) scenario and resulted in sea level rise estimates on the order of 2.6 to 2.9 feet (0.8 to 0.9 meter). Overpeck et al. (2006) found that the Arctic would be substantially warmer before the end of the 21st century than it was during the last interglacial period. This suggests that similar areas of Greenland could melt, raising sea level by at least 6.6 feet (2 meters). Just how rapidly this melting might occur is a key question, with traditional models suggesting that it could take a thousand years. The accelerating pace of melting recently observed, suggests that this might take only centuries. Because of the exclusion of important meltwater contributions from Greenland and Antarctica in IPCC sea level estimates, sea level rise rates could already be approaching the higher end of IPCC estimates (Rahmstorf et al. (2007) and Jevrejeva et al. (2008)). Figure 1.7 and Table 1.4 show the range of global sea level rise if increased melting of ice sheets in Greenland and Antarctica is added to IPCC estimates.

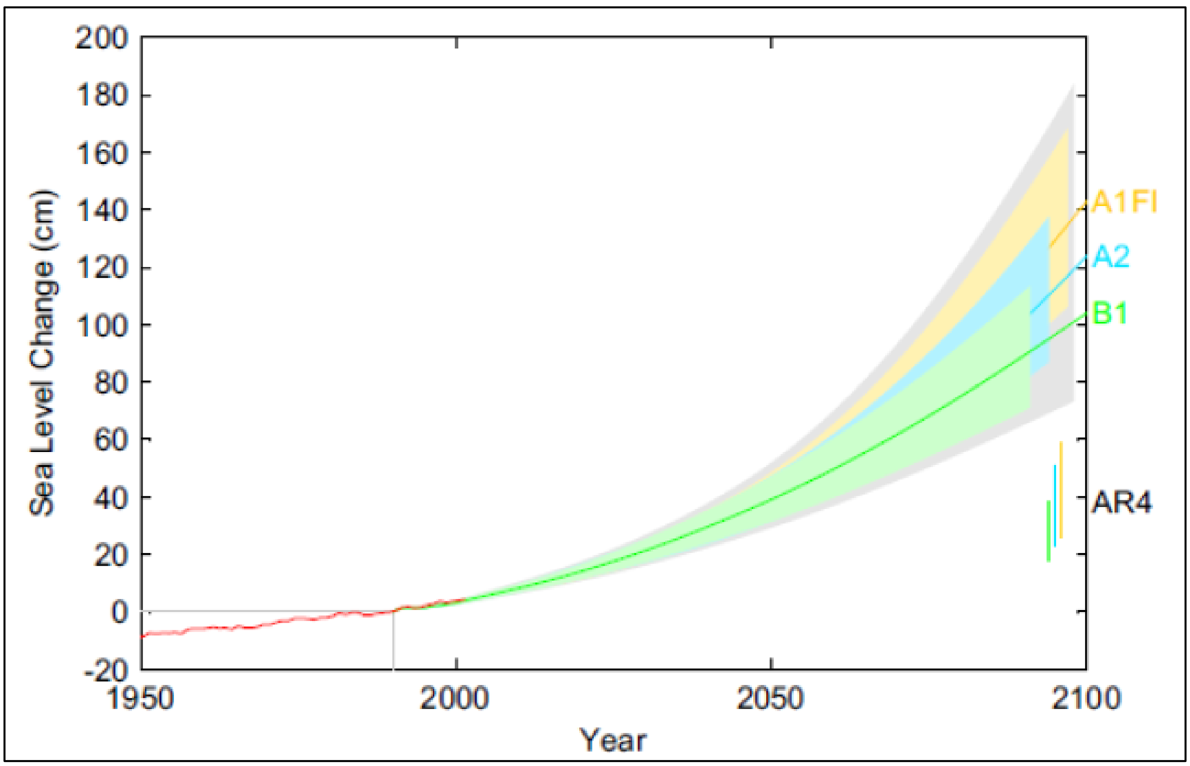


Figure 1.7 Projection of Sea-Level Rise from 1990 to 2100, Based on IPCC Temperature Projections for Three Different Emission Scenarios

Emission scenarios are labeled on right, see Projections of Future Sea Level for explanation of uncertainty ranges) (Vermeer and Rahmstorf, 2009)

Table 1.4 Temperature Ranges and Associated Sea Level Ranges by the Year 2100 for Different IPCC Emission Scenarios (Vermeer and Rahmstorf, 2009)

Scenario	Temperature Range (°C above 1980-2000)	Model Average (°C above 1980-2000)	Sea Level Range (cm above 1990)	Model Average (cm above 1990)
B1	1.4 - 2.9	2.0	81 - 131	104
A1T	1.9 - 3.8	2.6	97 - 158	124
B2	2.0 - 3.8	2.7	89 - 145	114
A1B	2.3 - 4.3	3.1	97 - 156	124
A2	2.9 - 5.3	3.9	98 - 155	124
A1F1	3.4 - 6.1	4.6	113 - 179	143

Note:

(1) The temperatures used are taken from the simple model emulation of 19 climate models as shown in figure 10.26 of the IPCC AR4 (2); they represent the mean ±1 SD across all models, including carbon cycle uncertainty. The sea-level estimates were produced by using Eq. 2 and 342 temperature scenarios and are given here excluding the uncertainty of the statistical fit, which is approximately ±7% (1 SD).

In October 2010, the State of California published a Sea Level Rise Interim Guidance Document developed by the Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), with science support provided by the Ocean Protection Council's Science Advisory Team and the California Ocean Science Trust.

The document provides guidance for incorporating sea-level rise projections into planning and decision making for projects in California with policy recommendations as follows.

> *"The SLR Task Force reached agreement on the following policy recommendations based upon recent estimates of future SLR from the scientific literature and input from scientists as described above. Use the ranges of SLR presented in the December 2009 Proceedings of National Academy of Sciences publication by Vermeer and Rahmstorf ("Vermeer and Rahmstorf publication") as a starting place and select SLR values based on agency and context-specific considerations of risk tolerance and adaptive capacity.*
>
> *Note: These projections do not account for catastrophic ice melting, so they may underestimate actual SLR. The SLR projections included in this table do not include a safety factor to ensure against underestimating future SLR."*

Table 1.5 presents SLR projections based on the Vermeer and Rahmstorf publication, adjusted to use 2000 as a baseline.

Table 1.5 Sea-Level Rise Projections Using 2000 as the Baseline (State of California Interim Sea Level Guidance)

Year	Average of Model	Range of Models
2030	7 in (18 cm)	5 - 8 in (13 - 21 cm)
2050	14 in (36 cm)	10 - 17 in (26 - 43 cm)
2070		
Low	23 in (59 cm)	17 - 27 in (43 - 70 cm)
Medium	24 in (62 cm)	18 - 29 in (46 - 74 cm)
High	27 in (69 cm)	20 - 32 in (51 - 81 cm)
2100		
Low	40 in (101 cm)	31 - 50 in (78 - 128 cm)
Medium	47 in (121 cm)	37 - 60 in (95 - 152 cm)
High	55 in (140 cm)	43 - 69 in (110 - 176 cm)

For the Los Angeles tide gauge, projected median rise in mean sea level for the year 2100 using 13 AR4 GCMs with and without ice sheet flow, two greenhouse gas scenarios (low [B1] and high [A1FI]) and Vermeer study range from 0.9 foot to 1.2 feet for AR4, 1.3 feet to 2.3 feet for AR4 using ice sheet flow, and 3.4 feet to 4.7 feet from Vermeer.

For the Santa Monica tide gauge, projected median rise in mean sea level for the year 2100 using 13 AR4 GCMs with and without ice sheet flow, two greenhouse gas scenarios (low [B1] and high [A1FI]) and Vermeer study range from 1.2 feet to 1.9 feet for AR4, 1.5 feet to 2.5 feet for AR4 using ice sheet flow, and 3.4 feet to 4.7 feet from Vermeer.

The model results were translated from MSL to NAVD (North American Vertical Datum) for both locations. A relationship between MSL and MHHW was developed for both tide locations and model results were converted to NAVD.

The corresponding NAVD MHHW values for Los Angeles for the year 2100 using 13 AR4 GCMs with and without ice sheet flow, two greenhouse gas scenarios (low [B1] and high [A1FI]) and Vermeer study range from 6.2 feet to 6.9 feet for AR4, 6.5 feet to 7.7 feet for AR4 using ice sheet flow, and 8.6 feet to 9.8 feet from Vermeer as shown in Figure 1.8.

The corresponding NAVD MSL values for Santa Monica for the year 2100 using 13 AR4 GCMs with and without ice sheet flow, two greenhouse gas scenarios (low [B1] and high [A1FI]) and Vermeer study range from 3.8 feet to 4.5 feet for AR4, 4.1 feet to 5.1 feet for AR4 using ice sheet flow, and 6.0 feet to 7.3 feet from Vermeer as shown in Figure 1.8.

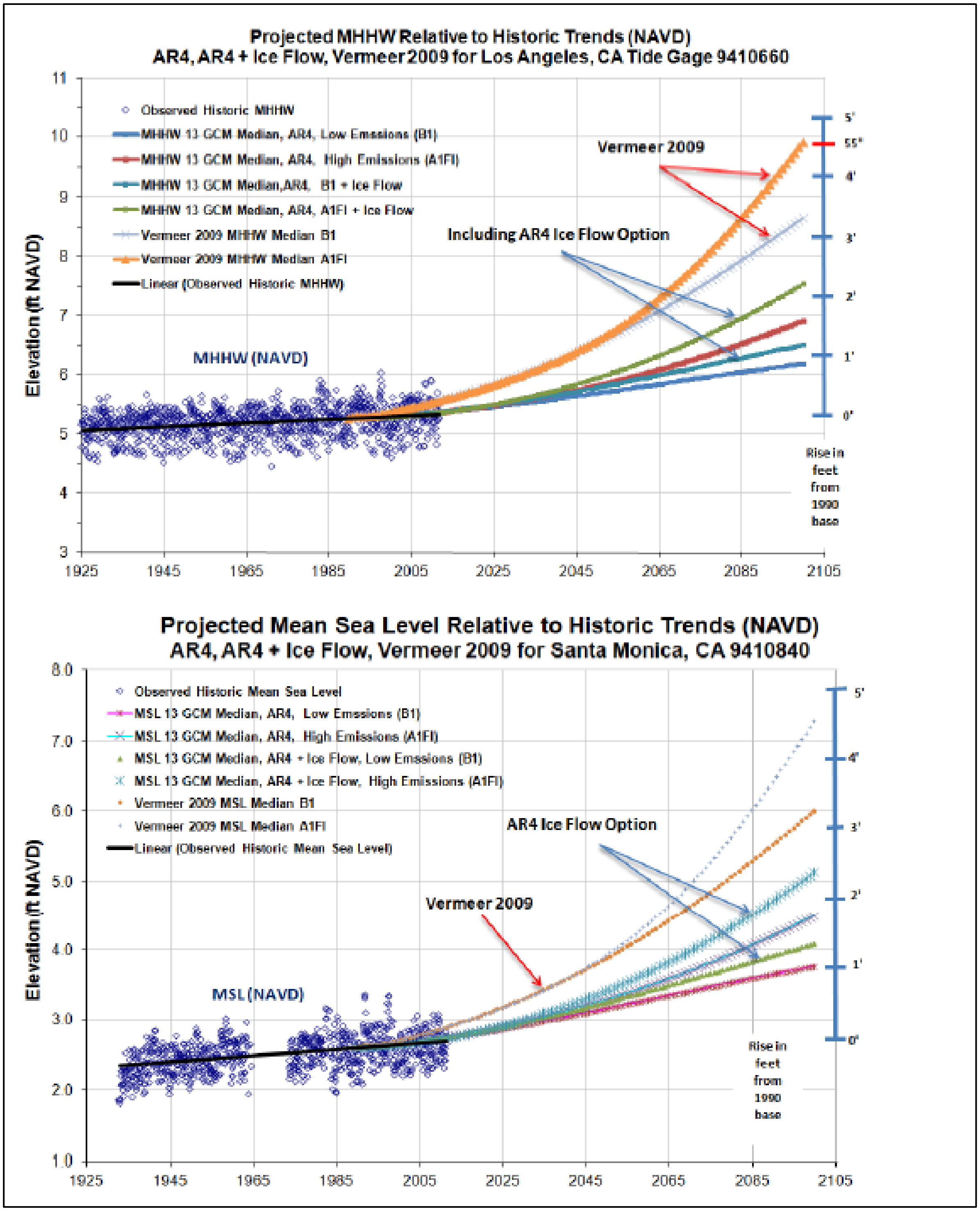


Figure 1.8 Projected MHHW (NAVD) Results from the SimCLIM AR4, SimCLIM AR4 Plus Ice Sheet Contribution, and Vermeer (2009).

All results use the B1 (low) and A1FI (high) emissions scenarios.

1.6 CITY OF LOS ANGELES WASTEWATER COLLECTION AND STORM DRAIN SYSTEM'S CLIMATE CHANGE VULNERABILITY ASSESSMENT

Climate change induced sea level rise and extreme precipitation events will significantly impact wastewater and storm drain conveyance hydraulics. The Venice Pumping Plant and San Pedro storm drain network as amongst two of the City of Los Angeles' (City) most vulnerable collection systems. These systems were identified based on historical spillage, cost of increased hydraulic loading, criticality of failure, and hydraulic relief redundancy.

Climate change impacts to these systems were studied using the City's current design storm and the modified storm generated from three local rainfall stations. The City's design storm is based on Intensity-Duration-Frequency (IDF) curves developed from historical precipitation from rain gauges as Los Angeles Civic Center, Los Angeles International Airport, and Rain Station 57A. The modified design storm was developed to reflect the effects of climate change using precipitation data from the Los Angeles Civic Center, Los Angeles International Airport, and Torrance Airport. Climate change correction factors based on the high estimate of greenhouse gas emissions were developed using the SimCLIM model. Figure 1.9 shows the modified 10-year design storm intensity.

The SimCLIM model was also used to conduct a sea-level rise analysis for a period from 1990 to 2100.

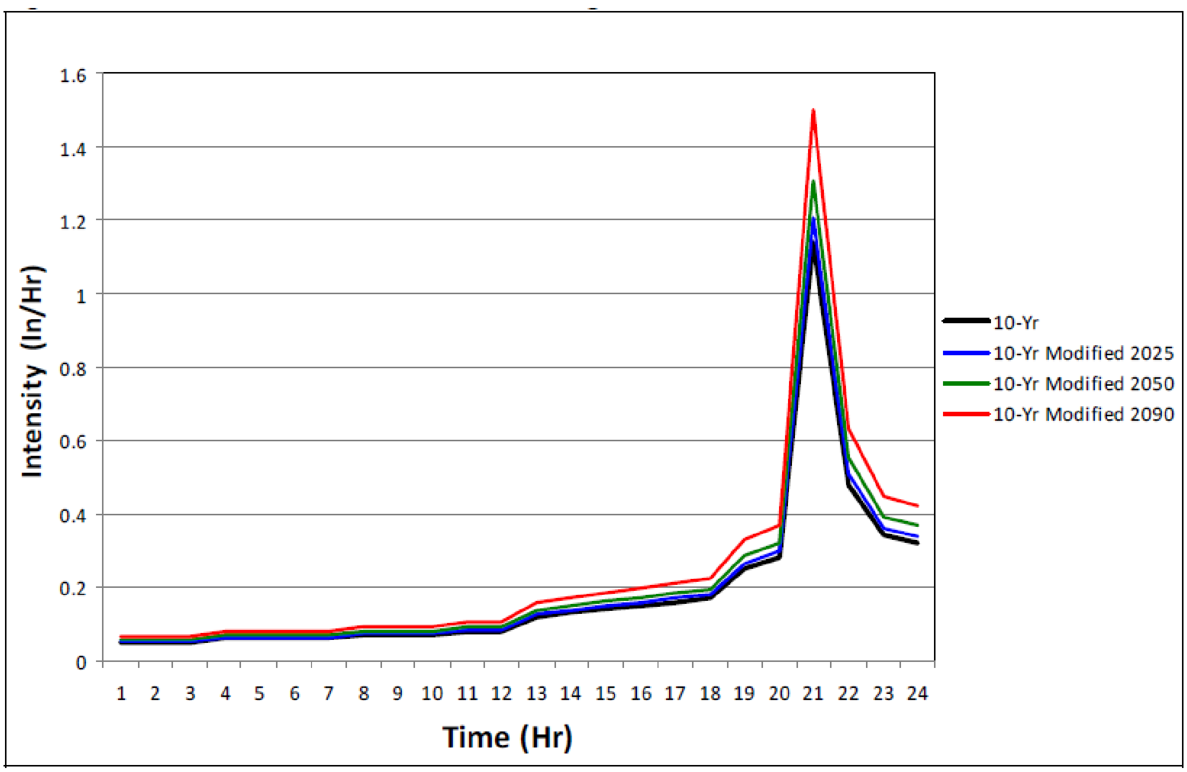


Figure 1.9 IDF Curves for Modified 10-Year Design Storms

Hydraulic models for each network were used to simulate the modified storms and wet weather flows for the target years 2010, 2025, 2050, and 2090. The City's wet weather hydrodynamic model includes the existing Venice Pumping Plant and was modified to incorporate the proposed dual force main downstream of the plan. The San Pedro storm drain network was imported into the MIKE URBAN hydrodynamic model.

To quantify the effects of climate change for the Venice Pumping Plant, the 10-year design storm and 10-year modified storms were evaluated for the year 2090. Comparison values included depth over diameter, flooding, flow rate, and discharge. While a slight increase in depth over diameter and wet-weather wastewater flows were observed upstream of the network, a significant increase in spilling at the Santa Monica area was projected. A 1.9 percent increase in peak discharge flow from the system was also projected as shown in Figure 1.10.

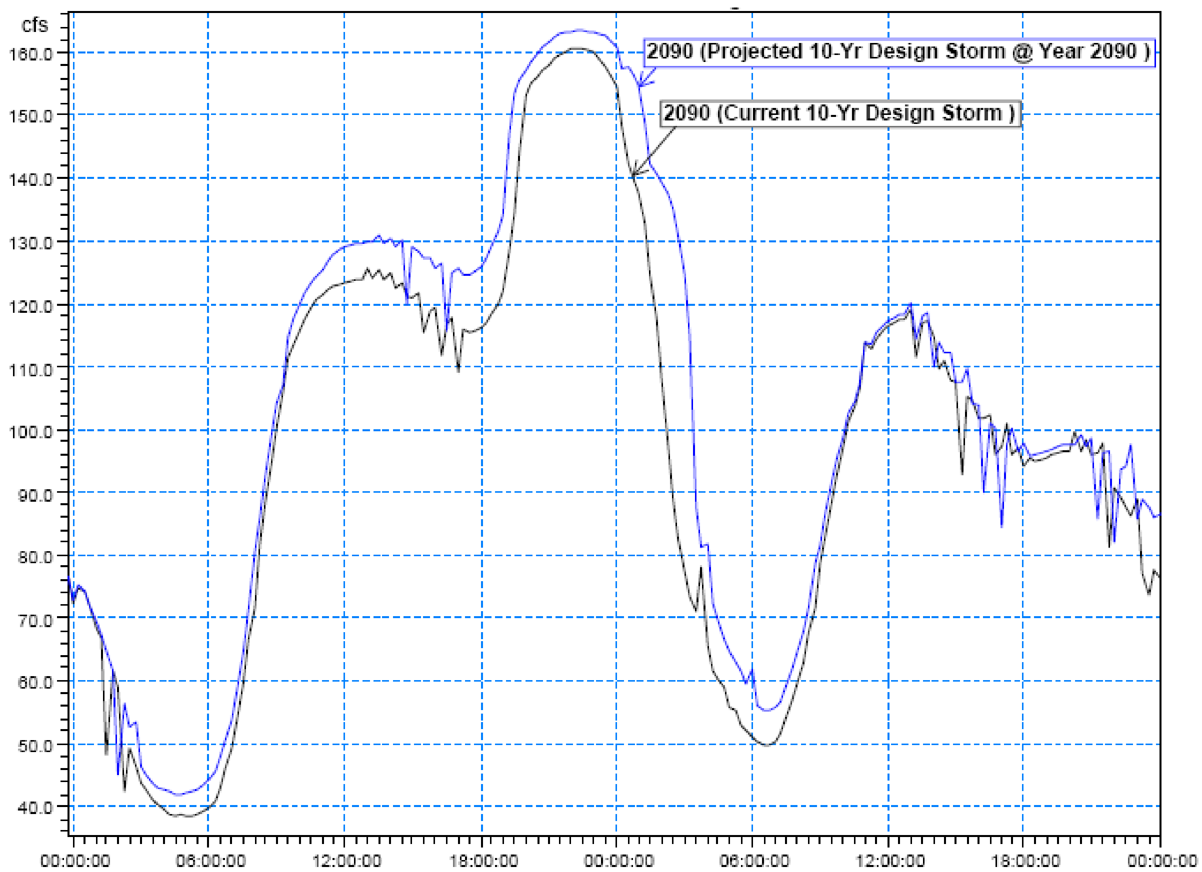


Figure 1.10 Flow Comparison at the VPP Discharge

A similar modeling effort was conducted for the San Pedro storm drain network. The results show a noticeable increase in depth over diameter, spills, and storm flows. The model predicts an 11.7 percent increase in peak outfall discharge due to climate change and the incorporation of a 1-foot sea level rise by 2090 also introduces backwater at the outfall.

1.7 REFERENCES

Bergquist, S.P., J.S. Pal, W. Trott, A. Brown, G. Wang, and S.L. Luce. 2012. Climate Change Implications for Ballona Wetlands Restoration. Report prepared for the US EPA Climate Ready Estuary Program. 65pp.

CH2M HILL. 2012. Analysis of Projected Changes in Precipitation IDF Values Based on Climate Change Projections.

City of Los Angeles, 1990. Clean Water Program Advanced Planning Report. Technical Memorandum No. 6B: Infiltration/Inflow Allowance for Design of the sanitary Sewer System, Wastewater Program Management Division.

City of Los Angeles. 2012. City of Los Angeles Wastewater Collection and Storm Drain System's Climate Change Vulnerability Assessment.

Grifman, P. M., J. F. Hart, J. Ladwig, A. G. Newton Mann, M. Schulhof. 2013. Sea Level Rise Vulnerability Study for the City of Los Angeles. USCSG-TR-05-2013.

Intergovernmental Panel on Climate Change (IPCC). 2000. Special Report on Emissions Scenarios. Cambridge: Cambridge University Press. http://www.grida.no/publications/other/ipcc%5Fsr/?src=/climate/ipcc/emission/.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, eds. Cambridge, United Kingdom and New York, New York: Cambridge University Press. p. 996.

Los Angeles Division of Tourism. 2012. Statistics provided available at: www.discoverlosangeles.com.

Overpeck, J.T., B.L Otto-Bliesner, G.H. Miller, D.R. Muhs, R.B. Alley, and J.T. Kiehl. 2006. Paleoclimatic Evidence for Future Ice-Sheet Instability and Rapid Sea level Rise. Science. Vol. 311. March 24.

PCMDI (Program for Climate Model Diagnosis and Intercomparison). 2009. Lawrence Livermore National Laboratory. https://esg.llnl.gov:8443/index.jsp

Port of Los Angeles. 2012. Statistics provided at: www.portoflosangeles.org/about/facts.asp.

Rahmstorf, S. 2007. A Semi-empirical Approach to Projecting Future Sea level Rise. Science, 315(5810), 368-370.

Rahmstorf, S., A. Cazenave, J.A. Church, J.E. Hansen, R.F. Keeling, D.E. Parker, and R.C.J. Somerville. 2007. Recent Climate Observations Compared to Projections. Science, 316(5825), 709.

Regional AdaptLA: Coastal Impacts Planning in the Los Angeles Region. (n.d.). Retrieved April 08, 2016, from http://dornsife.usc.edu/uscseagrant/adaptla/

Rohling, E.J., K. Grant, C. H. Hemleben, M. Siddall, B. A. A. Hoogakker, M. Bolshaw, and M. Kucera. 2007. High rates of sea level rise during the last interglacial period. Nature Geoscience. December 16.

USC. 2016. Climate Change & Hazard Mitigation: Local Plans and Resources. (n.d.). Retrieved April 08, 2016, from http://dornsife.usc.edu/uscseagrant/hazard-mitigation/

Vermeer, M., Rahmstorf, S. 2009. Global Sea Level Linked to Global Temperature. Proceedings of the National Academy of Sciences 106 (51): 21527–21532.

Warrick, R. 2005. Climate Proofing: A Risk-based Approach to Adaptation. Asian Development Bank. http://www.adb.org/Documents/Reports/Climate-Proofing/climate-proofing.pdf.

ATTACHMENT 2 – SUMMARY OF CITY OF LOS ANGELES CLIMATE ADAPTATION PLANNING EFFORTS

Current efforts of the City of Los Angeles to adapt to climate change are detailed below. Many studies recommended collaboration between governmental agencies, integration of climate change into all aspects of City planning, and individual-scale adaptation plans for critical assets.

2.1 CLIMATE CHANGE & HAZARD MITIGATION: LOCAL PLANS AND RESOURCES

The USC Sea Grant Program is engaging in an ongoing coordination with the Los Angeles City Emergency Management Department and other local agencies across the Los Angeles region to integrate climate change into hazard assessments, mitigation priorities, and stakeholder engagement (USC, 2016).

2.2 RISING TO THE CHALLENGE: RESULTS OF THE 2011 CALIFORNIA COASTAL ADAPTATION NEEDS ASSESSMENT

The report *Rising to the Challenge: Results of the 2011 California Coastal Adaptation Needs Assessment* presents a summary survey responses on coastal management challenges, climate change adaption, and resource and support needs within California. Survey respondents included up to 600 professionals ranging from coastal counties and communities along California including local, state, and federal agencies as well as private and nongovernmental organizations (Hart et al., 2012). The survey was intended to build upon the previous survey conducted in 2005/2006 by the National Center for Atmospheric Research (Moser and Tribbia 2006/2007; Tribbia and Moser 2008).

There are a number of current coastal management challenges which indicate the existing and near-term vulnerabilities of the area. Results from the survey found water quality, shoreline erosion, sea level rise, and loss of habitat and species were the most commonly noted challenges. These challenges are significant today and will be accelerated due to climate change. There are additional obstacles to planning and prioritizing responses when factoring in political and social influences.

Coastal managers understand the need for climate change adaptation and have become increasingly aware in recent years when compared to the 2005/2006 survey. A majority of respondents acknowledge climate change and understand the coastal impacts over the coming decades. Although some coastal professionals have started taking action to adapt to climate change, a significant amount are waiting for direction on how to do so. The largest barriers to adaptation and planning are lack of resources, tools, and information.

Most coastal professionals are familiar with data that directly relates to their organization, position, or legal requirements. Consequently, there is a lack of understanding about the socioeconomic data that can be utilized in climate change planning and vulnerability assessment. When gathering information, respondents tend to look at information readily available on the internet and less frequently utilize scientific journals or contact experts, potentially introducing less credible information. There is an apparent need and clear opportunity to connect scientific data and tools with these coastal professionals.

2.3 LOS ANGELES SANITATION – WASTEWATER ASSETS REPORT

In May 2015 the City of Los Angeles Bureau of Sanitation conducted a climate change risk assessment using the beta version of the U.S. Environmental Protection Agency (EPA) Climate Resilience Evaluation and Awareness Tool (CREAT) 3.0. The CREAT tool was developed to evaluate assets and systems by assessing risk for current and future climatic threats with climate change scenarios. Concerns for Los Angeles Sanitation included water supply management, peak service challenges, natural disasters, population/demographic changes, sector water/service needs, interdependent sector reliability, sea-level rise, liquefaction, and tsunamis. CREAT assesses future climate projections in comparison to historical data using Global Climate Model (GCM) results.

Seven at-risk facilities were identified to assess the potential effects of climate change on seven priority assets under current flooding and wet weather conditions and considering an increase in storm intensity, plus sea-level rise, projected for the year 2060 (Los Angeles Sanitation, 2016). Five wastewater pumping plants, a stormwater pumping plant, and the Terminal Island Water Reclamation Plant (DIWRP) were prioritized and evaluated for changes in temperature, precipitation sea level rise.

CREAT 3.0 provides GCM-calculated projected changes from CMIP5, RCP8.5, which is a higher trajectory for projected greenhouse gas concentrations to support assessments looking at higher potential risk futures (USEPA 2016). The CREAT projections were developed via an ensemble approach from 38 GCM runs, providing averages that represent a range of potential future climate conditions. The averages are grouped into hot and dry, central, and warm and wet future conditions as follows:

- Hotter and drier: average of five individual models that are nearest to the 5th percentile of precipitation and 95th percentile of temperature projections.
- Moderate: average of five individual models that are nearest to the median (50th percentile) of both precipitation and temperature projections; and
- Warmer and wetter: average of five individual models that are nearest to the 95th percentile of precipitation and 5th percentile of temperature projections.

CREAT and previous projections estimate a 3°F to 4°F increase in average annual temperature. The number of hot days over 95°F is also expected to increase from a current average of 6 days to 22 days by 2060, which poses a risk to power loss and transmission problems potentially affecting Los Angeles Sanitation.

CREAT-derived annual precipitation projections for the Los Angeles area based on CMIP5, RCP8.6, range from -5.5 percent to +5.7 percent by 2035 and -10.7 to +11.2 percent by 2060. Changes are variable across the service area and were selected for individual assets based on location.

Extreme wet weather events (i.e. 100-year storms) may generate landslides and localized flooding. Los Angeles Sanitation is more concerned with drainage as opposed to the pumping and process capacity of plants. The system experiences a 2.2 peaking factor during storms; although the sewer system is completely separated, the first flush of stormwater is diverted to sanitary sewers via low-flow diversions and other mechanisms. Historical daily maximum rainfalls from USEPA's CREAT are consistent with magnitudes used for planning at Los Angeles Sanitation (5 to 7 inches of rain in 24-hour period for the 100-year storm). CREAT provides ensembles of the five wettest models to describe a "Stormy Future," while ensembles of the five driest models describe a "Not as Stormy Future." In each case, these models were averaged to provide two model projections. CREAT's "warm and wet" scenario with a stormy extreme precipitation projection for the Los Angeles area is a projected increase in the 100-year storm is 15.6 percent by 2035 and 30.43 percent for the year 2060. The not-as-stormy projections are a 5.0 percent increase by 2035 and 9.6 percent increase by 2060. The warm and wet future climate was selected for projections with the 30.43 percent increase in precipitation for the 100-year storm by 2060.

Facility impacts due to sea level rise and flooding are a high concern for Los Angeles Sanitation having many wastewater, stormwater and low-flow-diversion pumping stations and two water reclamation plants in the coastal zone. Sea-level rise also poses an increased risk of flooding during coastal storms and tsunamis. The National Oceanic and Atmospheric Administration (NOAA) data for the mean sea level trend at Los Angeles is 0.08 inch/year (0.88 mm/year) based on monthly mean sea level data from 1923 to 2014 at the Port of Los Angeles. The rate of global and regional sea-level rise will increase with climate change. CREAT-provided data projects up to 2 meters (6.6 feet) of sea-level rise by 2100. Until recently, Los Angeles Sanitation was previously using the USGS Coastal Storm Modeling System (CoSMoS) 1.0 calculations for Southern California to identify coastal storm threats with climate change. CoSMoS 1.0, officially released in 2012, used 0.5 and 1.4 meters (1.6 and 4.6 feet) of sea-level rise to 2050 and 2100 respectively, in its coastal storm model calculations (Barnard et al 2014). As an example, the CoSMos base flood elevation calculations in the Port of Los Angeles at TIWRP were about 1.8 meters (5.9 feet) above NAVD88 including tide and storm surge. Adding 0.5 meter (1.6 feet) of sea-level rise to the calculation raises the mid-century flood elevation to 2.3 meters (7.5 feet) at TIWRP.

By 2100, the flood elevation may be 3.2 meters (10.5 feet) at TIWRP. CoSMoS 1.0 was being updated by the USGS as CoSMoS 3.0 and was expected to be complete in 2016. CoSMoS 3.0 provides daily, annual, 20-year, and 100-year coastal storm calculations at sea-level rise of 0 to 2 meters (0.25 meter increment), plus a 5 meter scenario. As indicated previously, since CoSMoS 3.0 has limited capabilities until its completion later this year, Los Angeles Sanitation used both CoSMoS 1.0 and CoSMos 3.0 to determine which of its assets will be inundated by the year 2100, primarily using a 1.64-foot (0.5 meter) increase in sea levels through 2060. The CoSMoS 3.0 model framework applied with a 100-year coastal storm at sea-level rise elevations (0 to 2 meters) to identify which assets would be vulnerable.

The climate data used for Los Angeles Sanitation is shown in Table 2.1.

Table 2.1 Climate Data for Los Angeles Sanitation

Location	Climate Variable	Historical Value (Observed)	Projected Value for 2060 (Observed + Changes)
Sunset Boulevard, Temescal Canyon, North Pulga Canyon and Venice Beach Pumping Plants	Average Annual Temperature	62.9°F	66.0°F
	Total Annual Precipitation	18.5 inches	22.4 inches
	100-Year Storm Event	5.4 inches in 24 hours	7.0 inches in 24 hours
	Hot Days (over 95.0°F)	6 days (1981-2000)[3]	22 days
	Sea-Level Rise	2 mm/year[4]	> 0.5 meter (1.64 feet)
22nd and Signal and Nissan Way Pumping Plants, TIWRP	Average Annual Temperature	63.2°F	66.1°F
	Total Annual Precipitation	13.7 inches	15.2 inches
	100-Year Storm Event	7.3 inches in 24 hours	9.5 inches in 24 hours
	Hot Days (over 95.0°F	6 days (1981-2000)[3]	22 days[3]
	Sea-Level Rise	2 mm/year[4]	> 0.5 meter (1.64 feet)

The assessments of the Sunset Boulevard Pumping Plant No. 632, Temescal Canyon Pumping Plant No. 634, and North Pulga Canyon Pumping Plant No. 639 indicate that they are currently not at risk to flooding but are adjacent to tsunami zones. The Venice Beach Stormwater Pumping Plant No. 647, 22nd and Signal Pumping Plant No. 680, Nissan Way Pumping Plant No. 686 are potentially at high risk currently because they are in current 500-year flood zones. The 22nd and Signal Pumping Plant No. 680, Nissan Way Pumping Plant No. 686 and TIWRP are potentially at high risk to flooding under current conditions because they are in a tsunami zone. Flooding risks increase under future conditions for all facilities with sea-level rise. Potential adaptation measures were identified in this exercise that could be implemented in the short- and long-term to reduce those risks. Priority adaptation measures may be incorporated into Los Angeles Sanitation's Capital Improvement Program. Los Angeles Sanitation plans to continue using the beta version of CREAT 3.0 to conduct additional risk assessments for other pumping plants and wastewater reclamation plants.

Upon understanding facility impacts from storm and climate change scenarios a four-step risk assessment was done using the EPA's Flood Resilience: A Basic Guide for Water and Wastewater Utilities (Flood Resilience Guide). Mitigation measures were selected from EPA's guide and evaluated for effectiveness, practicality, and cost as well as long- and short-term implementation.

2.4 LOS ANGELES SANITATION SOLID RESOURCES CLIMATE CHANGE RESILIENCY ASSESSMENT AND RECOMMENDATIONS SUMMARY

Climate change risk assessments were performed for eight solid resources facilities selected by Los Angeles Sanitation. During a two-day assessment from October 20 to 21, 2015, Los Angeles Sanitation and CH2M visited sites, discussed risks from potential climate change threats, and identified and prioritized adaptation options. The assessment included using the U.S. Environmental Protection Agency's (EPA) Climate Resilience Evaluation and Awareness Tool (CREAT) and other resources for identifying climate change scenarios. CREAT and other information gathered by Los Angeles Sanitation were used to define scenarios as projected changes in climate with respect to historical conditions (temperature and precipitation), extreme events (intense precipitation and extreme heat) and sea-level rise.

The CREAT tool enables users to consider scenarios of projected climate changes to assess the consequences of various threats to their assets. The three projected scenarios in CREAT capture the range of potential future conditions at any given location within the U.S. based on Global Climate Model (GCM) results. While all models project temperatures warming, the projected changes in precipitation vary, with some projecting wetter conditions and others projecting drier conditions. For example, concerning increased temperatures and precipitation affecting wet weather events and flooding, the CREAT "warm and wet" scenario with a stormy extreme precipitation projection was considered - the projected increase of the event rainfall volume in the 100-year storm is 30.4 percent for the year 2060. Hotter average temperatures, and more frequent hotter days (days with temperatures exceeding a particular threshold such as 95°F) combined with dry periods and strong winds increases the likelihood of wildfires encroaching on Solid Resources facilities and posing a threat to the City's solid waste collection, transportation and recycling operations.

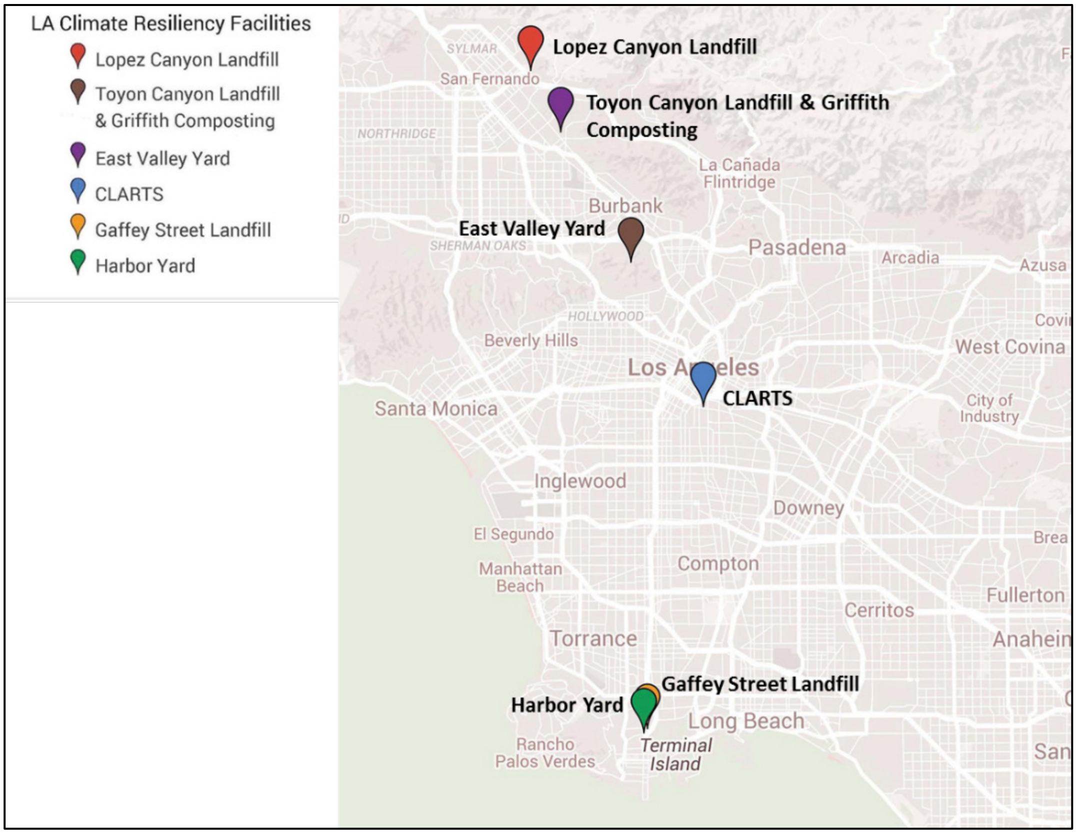


Figure 2.1 Location of Solid Resources Facilities Assessed for Climate Risk and Resiliency

Note: Harbor Yard is the location of the Harbor Collection Yard and Harbor Mulching Facility.

The overall climate-related areas of concern for Los Angeles Sanitation were found to be: sea-level rise and extreme rainfall affecting flooding; temperature increases causing blackouts due to increased energy demand; more frequent/intense/longer droughts and high winds affecting wildfires; and, all of these factors affecting the impacts of earthquakes (with subsequent landslides and liquefaction or flooding from tsunamis).

Potential short- and long-term adaptation measures were recommended for individual facilities and operations based on each facility's risks. General adaptation recommendations, including existing measures, are detailed below.

Existing adaptation measures:

- Regularly monitor climate conditions and re-evaluate temperature, precipitation (intensity, duration, and frequency), hot days, extreme events, and other metrics to determine if design standards and weather-dependent operations require updating.
- Monitor updates to FEMA flood zones and elevations and other information resources maintained by state and federal agencies on a regular basis
- Store and dispense all types of fuel for fueling of collection and yard vehicles at Solid Resources facilities throughout Los Angeles.

- Regularly backup electronic and paper files outside and separate from the facilities themselves at secure locations.
- Fill and maximize fuel levels in local fueling and backup generator storage tanks in anticipation of predicted extreme events

Overall adaptation measures:

- Ensure that backup power is available at all facilities as either permanent generators or portable generators with dedicated plans for deployment and support.
- Proactive fire prevention measures at landfills and yards
- Proactive erosion control and soil stabilization at facilities
- Identify local public, private and governmental fueling stations, purchasing additional diesel and gasoline refueling trucks, contracting with local vendors to provide onsite alternative refueling, and leasing or purchasing portable alternative fueling units
- Proactive support and implementation of the Public Works Debris Management Plan (DMP) including encouraging the formation of the Advisory Committee, implementing workshops and training programs, identifying additional debris management sites, reviewing and/or amending agreements with the Ports relating to storage and transport of debris and continually updating its list of designated Temporary Debris Storage and Reduction (TDSR) sites.

Costs of adaptation measures were estimated for each facility in Table 2.2, with methodology of estimated cost detailed in a separate attachment (Attachment 1).

Table 2.2 Cost Estimates of Replacement and Adaptation Measures for Eight LA Solid Resource Facilities

		Short- and Long-term Adaptation Measures	
Facility/Operation	Replacement Costs	Capital Costs	Annual Operational Costs
CLARTS	$1,100,000	$0	$0
Harbor Collection Yard	$6,300,000	$230,000	$11,500
Harbor Mulching Facility	$8,500,000	$0	$0
Gaffey Street Landfill	$530,000	$0	$0
Toyon Canyon Landfill	$500,000	$220,000	$31,000
Griffith Park Composting Facility	$2,200,000	$220,000	$11,000
East Valley Yard	$108,900,000	$1,540,000	$77,000
Lopez Canyon Landfill	$29,500,000	$0	$20,000
Alternative Fueling Systems	n/a	$7,040,000	$352,000
Totals	**$157,530,000**	**$9,250,000**	**$502,500**

2.5 LOS ANGELES AQUEDUCT SYSTEM CLIMATE CHANGE STUDY, LOS ANGELES DEPARTMENT OF WATER AND POWER

TetraTech helped prepare a report for the Los Angeles Department of Water and Power (LADWP) examining climate change effects on hydrologic patterns in the Eastern Sierra Watershed. The report focused on reviewing climate projections relevant to the Eastern Sierra, identifying the likely hydrologic changes from these projections including runoff and flow to the City, performing a hydraulic analysis of the Los Angeles Aqueduct (LAA) system in light of these changes, and identifying adaptation options to prepare for climate scenarios. This section aims to summarize the work done in this LADWP Report to provide background knowledge for OWLA.

The report's model-based approach examined both statistical and dynamic downscaling methodologies to render large-scale climate data meaningful over the study area. Temperature and precipitation variables in statistically downscaled data using the Bias Correction and Statistical Downscaling (BCSD) method from 16 different global climate models (GCMs) using CMIP3 projections were analyzed for early-century, mid-century, and end-of-century timeframes. Projections over Mono-Owens Watershed, shown in Figure 2.2, were compared to the historical observations from 1950-1999.

Early-century conditions suggest a warming of 0.9 to 2.7°F (0.5 to 1.5°C) and minimal change in average precipitation from 1950-1999 conditions. Mid-century conditions show a 3.6 to 5.4°F (2 to 3°C) and an average -5 percent change in average precipitation, which encompasses some models indicating increases in precipitation and some indicating decreases. End-of-century conditions indicate a warming of 2.5 to 4.5 degrees Celsius and a decrease in precipitation -10 percent. The overall narrative of the statistically downscaled data of the models selected is a warming trend with a drying trend in the latter half of the century.

Dynamic downscaling was also explored as an option to produce fine-scale climate data. A regional climate model (WRF3-CLM3.5) and two GCMs (CCSM3 and GFDL) were used to produce ten-year mean climatologies consistent with the IPCC A2 scenario future time periods 2020-2029 and 2062-2071 along with a historical simulation period of 1985-1996. Computational demand constraints prevented the development of longer periods of downscaled data, but the given periods were deemed suitable for the California statewide assessment. Dynamic downscaling results project higher summertime temperature values by about 5.4°F (3°C) in mid-century as compared to statistically downscaled data, but other parameters (wintertime temperature, precipitation, and SWE) do not depart significantly from statistically downscaled data. These results generally support statistical downscaling results, and future work that expands the length of RCM simulations would allow further assessment of the differences between statistical and dynamically downscaled data.

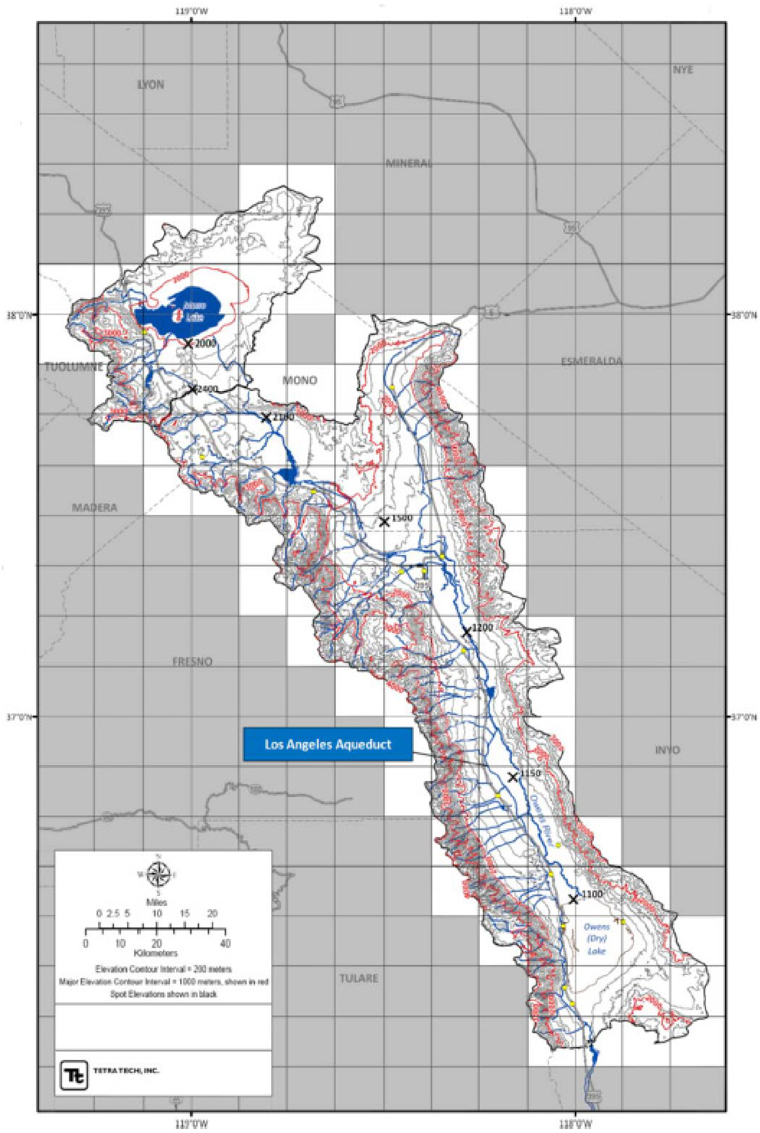


Figure 2.2 Map of the Mono-Owens Watersheds and 1/8° Grids Used for Analysis (Tetra Tech, 2010)

The Variable Infiltration Capacity (VIC) model was used in this study to translate future climate states into hydrological insights. Projections through 2099 using 30-year running means were made for each of the 16 GCMs and two emission scenarios (A2, B1) using the statistically downscaled climate data. The projected results found included temperature, precipitation, runoff, April 1 SWE, peak SWE, the ratio of April 1 SWE to precipitation, snowfall, and the ratio of rain to precipitation. This study found that GCMs found consistently higher temperatures over the course of the 21st century, which resulted in a greater fraction of precipitation falling as rain and earlier snowmelt in the season. Changes in precipitation varied by model, but the model average proved to not vary substantially from historical records. Timing of peak SWE was projected to be earlier in the season (12 to 20 days) than the historical baseline due to higher temperatures, as well as the peak SWE decreasing in quantity by 20-25 percent of the historical baseline.

The analysis was further by examining projected climate change impacts on the operation of the LAA. VIC generated base-of-mountain runoff for the Owens Valley and Mono Basin sub-watersheds from all 16 models and 2 emission scenarios were routed through the LAA using LAASM for the entire 21st century. Because operation of an aqueduct depends on many other factors other than climate change, care was take to isolate and identify historic and future climatic influence factors. A hydraulic analysis was performed on the LAA, including the estimation of flow carrying capacity of different engineered sections of the LAA system. LAASM simulations included these operational constraints, along with including minimum flow requirements and the effect of diversions.

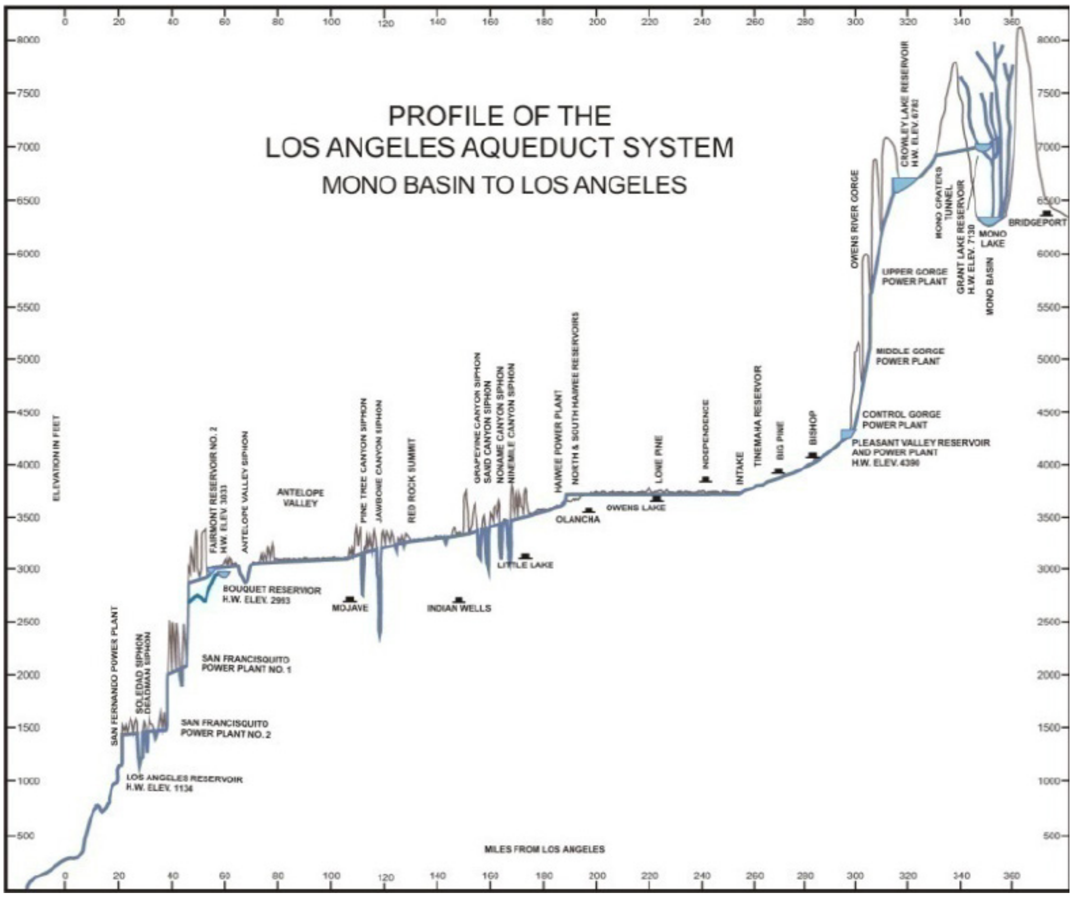


Figure 2.3 Profile of the Los Angeles Aqueduct System (Tetra Tech, 2011)

The results of this analysis reflected a hydrologic cycle that is expected to become more variable over the 21st century. Extremes in runoff were of particular concern to LADWP as upper extremes may exceed the capacity of the LAA and lower extremes may cause inadequate flow to the City (FTC). 10 percent of the years simulated are projected to have runoff below the historical minimum (216,159 acre-feet per year [AFY]) and 7 percent of the years are projected to have higher runoff than the historical maximum (885,812 AFY). Cumulative runoff results were also of interest in this Task, as the amount of runoff was projected to decrease by about 2 million acre-feet by the end of the century as compared to

1950-1999. These results support the narrative of drying conditions in the Eastern Sierra expounded upon in Task B.

Overall, Task C work revealed that 83 percent of projected flows through 2099 are expected to be within historical ranges. Current infrastructure would handle high flow conditions through controlled spills over reservoirs and/or spreading in different locations in Owens Valley. Analysis of conveyance capacity of different sections of the aqueduct showed that there are no obvious bottlenecks where capacity could be individually improved, so any increase in capacity would require a redesign of the entire aqueduct. Low flows are of special concern to LADWP, as Los Angeles is an arid area with a large population that's municipal supply depends on flows from this watershed. LAASM simulations even predicted some low runoff years where FTC may be zero once in-Valley water commitments are accounted for.

Adaptation measures to address potential impacts presented in Task A and B to the LAA were described in Task D. Measures considered were grouped into categories including Operational Changes, Modify existing infrastructure, and Add new infrastructure. Operational Changes suggested included changing Long Valley Reservoir targets, which addresses the impacts of high monthly flows noted in Task C. Modifications to existing infrastructure proposed included increasing the volume of Tinemaha, North Haiwee, Bouquet Reservoirs and increasing the volume of Long Valley Reservoir. New infrastructure proposed to address the impact of a future drying trend included a diversion of water from the State Water Project to LAA at Neenach Pumping Facility and new ground water and surface water storage near the LAA down gradient of Owens Valley. Adaptation options were evaluated by re-configuring the as-built configuration and inputting the projected GCM results into the newly configured LAASM model. FTC and hydropower generation were the main metrics by which options were evaluated. Diversion of water from the SWP is expected to produce a significant increase in FTC, as it is the only adaptation option suggested that benefits the system by using "new water." Other options do not improve FTC in the long term, but seem to be beneficial during dry years by creating a water bank during the water years.

2.6 REFERENCES

Barnard, P.L., van Ormondt, M., Erikson, L.H., Eshleman, J., Hapke, C., Ruggiero, P., Adams, P. N., and Foxgrover, A. 2014. Coastal Storm Modeling System: CoSMoS. Southern California 1.0, projected flooding hazards, http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal1.0/, doi:10.5066/F74B2ZB4

Finzi Hart, J. A., P. M. Grifman, S. C. Moser, A. Abeles, M. R. Myers, S. C. Schlosser, J. A. Ekstrom. 2012. Rising to the Challenge: Results of the 2011 Coastal California Adaptation Needs Assessment. USCSG-TR-01-2012.

Moser S.C., Tribbia J. 2006/2007. Vulnerability to inundation and climate change impacts in California: Coastal managers' attitudes and perceptions. Marine Technology Society Journal 40(4): 35-44

Tetra Tech. 2010. Task B: Evaluate the Impacts of Climate Change on the Hydrology of the Eastern Sierra Watershed. December, 2010.

Tetra Tech. 2010. Task C: Final Technical Report: LAASM and Hydraulic Analysis of Projected Climate Change on the Operation of the Los Angeles Aqueduct. March 2, 2011.

Tetra Tech. 2010. Task D Report: Identification and Analysis of Potential Measures to Address Climate Change Impacts on the Los Angeles Aqueduct. March 2, 2011.

Tribbia J., S.C. Moser. 2008. More than information: What coastal managers need to plan for climate change. Environmental Science & Policy 11: 315-28.

U.S. Environmental Protection Agency (USEPA) 2016. *Climate Resilience Evaluation and Awareness Tool, Version 3.0 Methodology Guide*. Office of Water (4608-T) EPA 815-B-16-004. Washington, DC. May 2016.

ATTACHMENT 3 – REGIONAL AND NATIONAL CLIMATE CHANGE ASSESSMENTS AND ADAPTATION

Climate change assessments performed by regional and national entities that include relevant information to Los Angeles are included below. These studies connect Los Angeles' water system to the larger water system of the American west and provide a larger framework for Los Angeles to place its' climate change assessments in.

3.1 LOS ANGELES BASIN STORMWATER CONSERVATION STUDY

The purpose of the *Los Angeles Basin Stormwater Conservation Study* is to evaluate flood control and water conservation impacts from projected population and climate changes in order to provide recommendations for balancing water supply and demand in the region (Bureau of Reclamation, n.d.). With populations projected to increase by 18 percent in Los Angeles County, and 35 percent statewide there will be added competition for imported water supply throughout California. The effects of climate change will continue to put pressure on water supply by causing more extreme hydrologic variance.

A climate-adjusted hydrologic model was developed to study the flood control and water conservation impacts resulting from changes in climate and population. For this model a climate adjusted precipitation and evaporation values were developed as input into the Los Angeles County Flood Control District's Watershed Management Modeling System. Based on the available downscaled projection sets, the baseline reference period was 1986 through 1999 and the future period was evaluated for 2011 to 2099.

The climate change projections were used to simulate hydrology in the Los Angeles River, San Gabriel River, Ballona Creek, South Santa Monica Bay, North Santa Monica Bay, Malibu Creek, and Dominguez Channel/Los Angeles Harbor watersheds. Historic hydrologic modeling was done for a period of 1987 through 2000 and projections were done for a future period of 2012 through 2095.

The model results snow a wide range of variability in stormwater runoff but overall averages indicate runoff could increase 4 to 37 percent with climate change. Highest runoff is exhibited during a "business as usual" greenhouse gas emission scenario is applied. All scenarios project a pattern of increasing stormwater supplies and there is a potential for an increase in recharge volume. Peak flows are also projected to increase along with flood flow rates. When modeling future hydrologic conditions with Low Impact Development (LID) practices, stormwater runoff to the ocean can be reduced up to 10 percent by the end of the century.

Upon development of the hydrologic model, operation of existing infrastructure under the current and future climate were evaluated. Infrastructure included 18 dams, 26 major spreading ground facilities, and 5 major channel outlets. The study found that 15 dams and 19 spreading grounds have the potential for high to moderate potential for enhancements. When modeling each watershed for flows reaching the ocean, the Ballona Creek, San Gabriel River, and Los Angeles River watersheds have a high potential for conservation. By complimenting infrastructure improvements with decentralized storm water capture, there is great potential within the Los Angeles region to manage changing hydrology amongst future climate change.

Recommendations were developed for structural and non-structural concepts to manage stormwater and aid in climate resiliency. Stakeholder and public outreach meetings were held in November 2014 to develop a list of over 500 stormwater capture concepts. The concepts were further refined into 12 project groups including Local Stormwater Capture, Low Impact Development, Complete Streets, Regional Stormwater Capture, Stormwater Conveyance Systems, Alternative Capture, Los Angeles County Flood Control District (LACFCD) Dams, Army Corps of Engineers Dams, Debris Basins, Stormwater Policies, Green Infrastructure Programs, and Regional Impact Programs. Under high projections for climate change, the greatest stormwater capture potential lies in LACFCD dams, stormwater policies, green infrastructure programs, and regional impact programs.

A tradeoff analysis was conducted to develop quantifiable and non-quantifiable costs and benefits of the stormwater concepts. Amongst the scoring criteria, climate adaptation was heavily weighted. Final scoring revealed Low Impact Development, Local Stormwater Capture, Stormwater Policies, Complete Streets, and Green Infrastructure Programs produce a high ranking combination of benefits.

3.2 SECURE WATER ACT SECTION 9503(C) – RECLAMATION CLIMATE CHANGE AND WATER 2016

The southern California region is an area with variable precipitation and intermittent drought, causing stress to the existing water supply which will become worse when factoring in climate change (Bureau of Reclamation, 2016 [SECURE]). Most of the water supplied to the coastal area of southern California is imported by the Metropolitan Water District of Southern California. In 2014, the water supply source for the area was 22 percent Colorado River, 17 percent northern California, 33 percent local supply, and 28 percent from conservation and water recycling (Bureau of Reclamation, 2015 [Moving Forward]). Although the population has rapidly increased, the water use per capita has decreased by 10 percent since 2000 due to conservation efforts.

The 2012 Bureau of Reclamation report *Colorado River basin Water Supply and Demand Study* assessed temperature and precipitation trends of the Lower Colorado River Basin (Bureau of Reclamation, 2012). The study found that by 2050 the average temperature for the Los Angeles area is expected to increase by 2 to 5°F, coastal areas could experience 2 to 5 percent less precipitation, and there will be less frequent but more intense storms. Due to climatic and population changes, the overall water demand in the area is expected to increase which will required a continued adaptation of water management and agricultural techniques.

Federal, state, local, and tribal partnerships have begun coordination to address these water challenges. The Bureau of Reclamation has participated in a number of coastal area studies including a Water Augmentation Study and the Los Angeles Basin Study to evaluate water supply and demand scenarios. The Bureau of Reclamation has also partnered with the California Energy Commission and Metropolitan Water District of Southern California to consider an integrated approach to water and energy efficiency programs (Bureau of Reclamation, 2015 [SCAO]).

3.3 LOS ANGELES REGION FRAMEWORK FOR CLIMATE CHANGE ADAPTATION AND MITIGATION

Los Angeles Region Framework for Climate Change Adaptation and Mitigation provides a structure to initiate understanding in the relationship between climate change, water resources, and water quality in order to address potential impacts through the Los Angeles Regional Water Quality Control Board planning and programming (Smith et al., 2015). The nine Regional Water Quality Controls Boards (Regional Water Boards) and State Water Resources Control Board (State Water Board) enact programs to protect and restore the state's water as required by the Federal Clean Water Act and Porter-Cologne Water Quality Control Act. Implementation programs and planning to maintain compliance with the water quality objectives need to be adapted to consider the challenges presented by climate change introduced below.

- Temperature: By 2050, Los Angeles is predicted to see a 4-5°F temperature increase and two to six times more "extreme heat days" even with reduced greenhouse gas emissions. This heat and overall warmer climate is expected to lengthen the fire season and increase the acreage burned by 20 to 30 percent. More intense wildfires will lead to greater erosion, sedimentation, pollutant runoff, and loss of habitat. Fires also introduce toxic chemicals associated with fire suppression into the environment, including dioxins.

- Precipitation and Snowpack: Although there will be a minimum 31 percent snowfall loss in the Los Angeles area mountains, the mean precipitation throughout California is not expected to change. However, weather patterns are expected to produce extreme precipitation events, amplifying flood risk. Heavy rainfall can also overload and inundate sewer systems and treatment plants as well as landfills causing contaminated flows.

- Sea Level Rise: The global sea level is expected to rise 7 to 19 inches by 2050 and 20 to 55 inches by 2100. In the Los Angeles region, this translates to an increase of 5 to 24 inches by 2050 and 17 to 66 inches by 2100. Sea level rise is expected induce coastal storms and extreme tides, increasing flooding and erosion in seaside areas. Sea level rise also increases the salinity concentrations inland posing a risk to the freshwater ecosystem.

- Water Supplies and Water Quality: Climatic impacts to temperature and snowpack when combined with drought can cause drops in groundwater and reduce the amount of available imported water, thereby affecting water supplied of the region.

- Water Quality: Drought also reduces stream flows which increases water temperatures, pollutant concentrations, and habitat loss. Increased water temperatures can be conducive to algae growth which can degrade water quality and aquatic life. Aquatic life is also impacted by changes in pH in seawater due to oceanic carbon dioxide update.

Climate change will have impacts to the physical, chemical, and biological characteristics of surface water quality and beneficial uses. Development of reference conditions in the surface water is needed to set objectives for system recovery and reconsider water quality objectives and complexity.

Groundwater is also susceptible to changes in water quality resulting from climate change. Less precipitation and snow pack reduce natural groundwater recharge. Recycled water can be used to supplement this recharge but can have impacts to the groundwater quality. Continued pumping of groundwater can lead to seawater intrusion in coastal areas, further jeopardizing water quality. The range and magnitude of these impacts need to be studied in order to develop strategies to mitigate.

Research and monitoring are needed in order to provide a basis for region-wide decisions as well as track climate change and track progress of mitigation efforts. Data collection leads to development of adaptation and mitigation measures in order to help drive climate change policy with respect to water quality protection and beneficial uses. This framework provides the foundation to facilitate future discussions on climate change adaptation and mitigation incorporation into the various Regional Water Board programs. The next steps include stakeholder involvement to identify and prioritize projects, research, monitoring, and other contract needs.

3.4 CALIFORNIA CLIMATE CHANGE ASSESSMENTS

A series of four climate change assessments have been conducted for the State of California (State of California, 2016). The first assessment was released in 2006 to evaluate climate change impacts on key state resources including water supply, public health agriculture, coastal areas, forestry, and electricity. The assessment helped to influence the 2006 California Global Warming Solutions (Assembly Bill 32).

The second assessment was released in 2009 to provide initial estimates of economic impacts from the losses and damages resulting from climate change and became instrumental in the 2009 California Climate Adaptation Strategy. The assessment found that change will have significant impacts on the economy but can be mitigated with appropriate measures to reduce risks.

The third assessment was released in 2012 to evaluate the state's vulnerability and adaptation options as an update to the 2009 California Climate Adaptation Strategy. The assessment sought to understand institutional barriers as well as water, energy, and agriculture on the state and local scales.

The fourth assessment will provide additional information to help safeguard California's people, economy, and resources. By understanding the scope, timing, cost, and feasibility of management options the state can prioritize actions and investments.

3.5 CALIFORNIA COASTAL COMMISSION SEA LEVEL RISE POLICY GUIDANCE

The Coastal Commission adopted the Sea Level Rise Policy Guidance document in 2015 to address sea level rise planning and regulatory action in conjunction with the California Coastal Act (California Coastal Commission, 2015). The average global temperature has increased by 1.4°F in the past century inducing an average global sea level rise of 7 to 8 inches (IPCC, 2013). The third National Climate Assessment indicates that doing nothing about sea level rise is 4 to 10 times more costly than adaptation (Moser *et al*. 2014). Sea level rise adaptation principles include scientific guidance, planning, and development standards updated to minimize coastal hazards, protection of public action, recreation, and resources, and maximize agency coordination and public participation.

As our understanding of sea level rise evolves, the best available science on sea level rise should be used for projections, evaluation of impacts, and understanding of future storm events. During the guidance document development, the best available data included the IPCC 5th Assessment Report (AR5) for global projections, National Climate Assessment (NCA; Melillo et al., 2014) for national projections, and the National Research Council (NRC, 2012) for state projections. Sources of uncertainty in projections come from future greenhouse gas emissions, rate of land ice loss, influence of thermal expansion on local sea level, and future vertical land motion. Scenario-based planning helps to understand these uncertainties to develop adaptation strategies under different situations.

The California Coastal Act required the coastal counties to develop Local Coastal Programs (LCPs) to govern development and protection the coastal areas. Updating LCPs to reflect sea level rise can be an essential mechanism for adaptation planning. Coastal zone development typically required a Coastal Development Permit and can be used to minimize risks and impacts of a new coastal project. By addressing sea level rise in the LCPs and Coastal Development Permits it will help to identify vulnerability's for specific projects sites as well as regional panning.

3.6 SAFEGUARDING CALIFORNIA

The 2014 Safeguarding California Plan is an updated policy guide to the 2009 California Climate Adaptation Strategy (Natural Resources Agency, 2014). Climate change risks must be incorporated into government activities to provide risk reduction measures for the state's vulnerable populations. Sustainable funding for investment and continued climate research and data tool development should be identified to reduce climate risks, human loss, and disaster spending. Return on investments can be maximized by prioritizing multi-benefit projects. Investing in climate change actions will save lives as well as provide long-term savings.

The 2016 Safeguard California: Implementation Action Plans was developed as an implementation strategy of the 2014 Safeguarding California: Reducing Climate Risk. Although California has been proactive about emission reduction, impacts from climate change including increased fires, floods, severe storms, and heat waves have already begun to occur. Plans and strategies were developed for 10 sectors including agricultural, biodiversity and habitat, emergency management, energy, forestry, land use and community development, oceans and coastal resources, public health, transportation, and water (Natural Resources Agency, 2016). Collaboration across sectors is necessary to address climate change and to resource optimization.

3.7 SACRAMENTO-SAN JOAQUIN RIVERS BASIN STUDY

The Sacramento-San Joaquin Rivers Basin Study (Basins Study) is a collaborative multi-stakeholder effort conducted by the U.S. Bureau of Reclamation to address current and future vulnerabilities to the water-dependent resources in the Central Valley and to identify adaptation strategies to reduce future risks (Bureau of Reclamation, 2016 [Sacramento and San Joaquin Basin Study]). The Basins Study is addressing future uncertainties in climate, demographics, land use, and socioeconomic conditions and their effects on future water supply and demand. To better understand future challenges, the study focuses on providing a comprehensive assessments of potential climatic and socioeconomic uncertainties for the entire Central Valley and explores various portfolios of system wide and local water management actions that could be employed to adapt to twenty-first century challenges.

The Basins Study employs a scenario-based analytical approach. Uncertainties in future climate, demographics, land use, and socioeconomics are being considered to develop over 15 scenarios of the future conditions. These uncertainties are translated into potential changes to future water supply and demand through a suite of hydrologic, agricultural, and urban water demand models. The uncertainty in future water supply, largely driven by an increasingly variable climate and changes in sea level, has been found to be the largest cause of potential future changes.

Potential future risks to resources are being evaluated within a formal vulnerability-risk assessment framework. This framework evaluates vulnerabilities to various resources by establishing performance metrics, identifies potential options such as new storage, new conveyance, demand management, reuse, water conservation, and others to reduce vulnerabilities, and evaluates the effectiveness of various strategies under a broad range of future socioeconomic-climate uncertainties.

CVP and SWP Delta Exports

The Central Valley Project (CVP) and State Water Project (SWP) Delta exports provide a portion of the water supply for two-thirds of the state's population. The CVP exports water at the C. W. "Bill" Jones Pumping Plant and SWP exports occur at the Harvey O. Banks Pumping Plant. Both pumping plants are located in the southern part of the Delta and are operated to meet state and federal operation regulations to maintain salinity. To protect the Delta from increased salinity from sea level rise, more water will be needed for Delta outflow and less will be available for export. Modeling of the Delta exports with consideration of climate change resulted in increased exports during the warm-wet scenario and significantly reduced exports during the hot-dry scenario. In a scenario with no climate change and current socioeconomic trends, the total average annual export out of the Delta was 5,522 TAF/year from 2040-2069.

Figure 3.1 shows annual exceedance of total Delta exports for the Reference-No-Climate-Change and ensemble climate scenarios with the Current Trends socioeconomic scenario. Figure 3.2 shows box plots showing total Delta exports for the Reference-No-Climate-Change and ensemble climate scenarios with the Current Trends socioeconomic scenario.

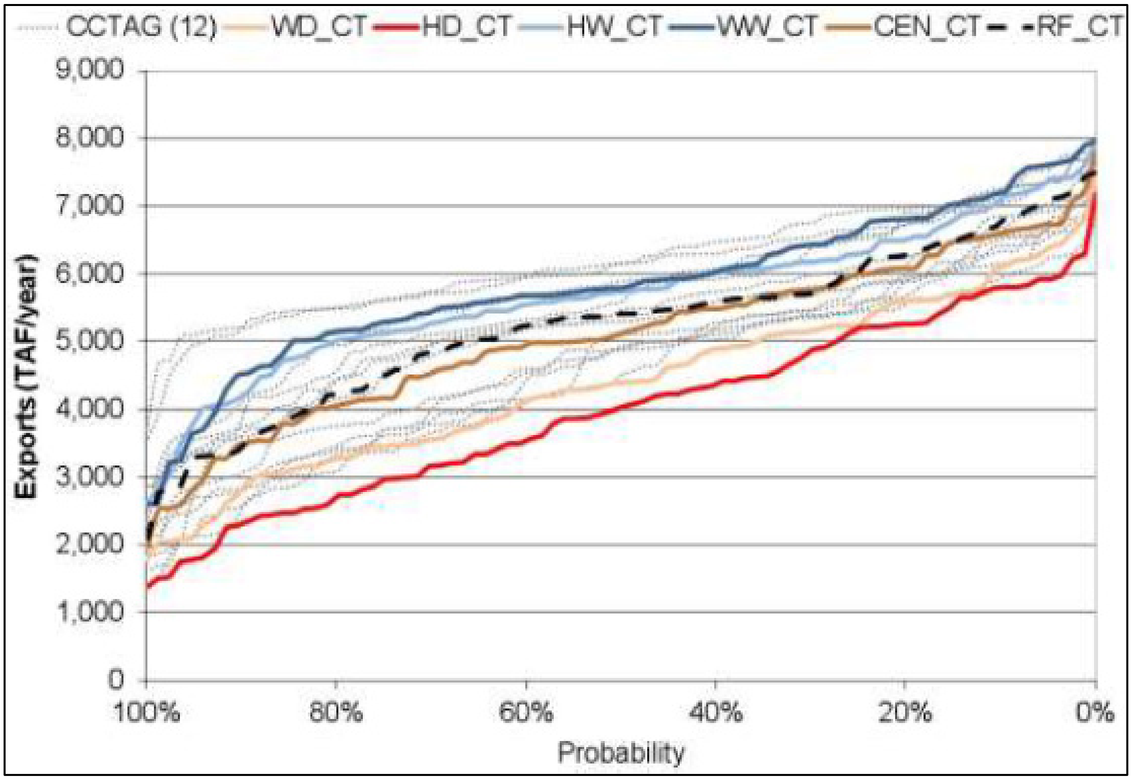


Figure 3.1 Annual Exceedance Plot of Total Delta Exports for the Reference-No-Climate-Change and Ensemble Climate Scenarios with the Current Trends Socioeconomic

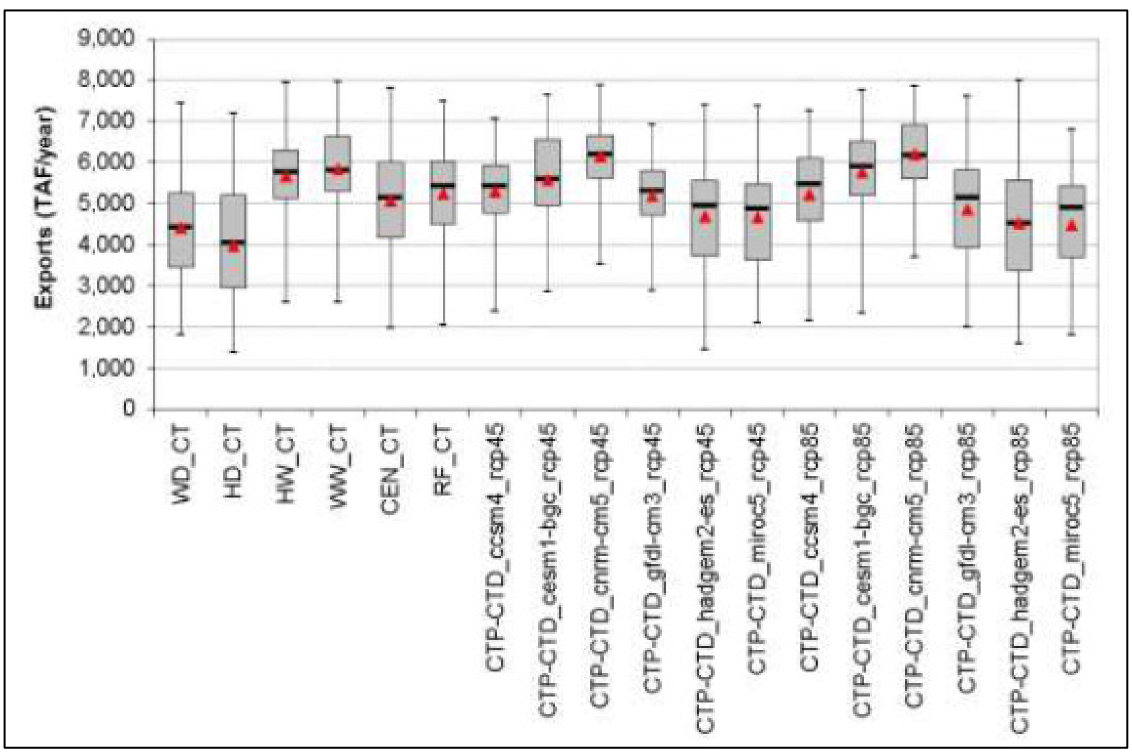


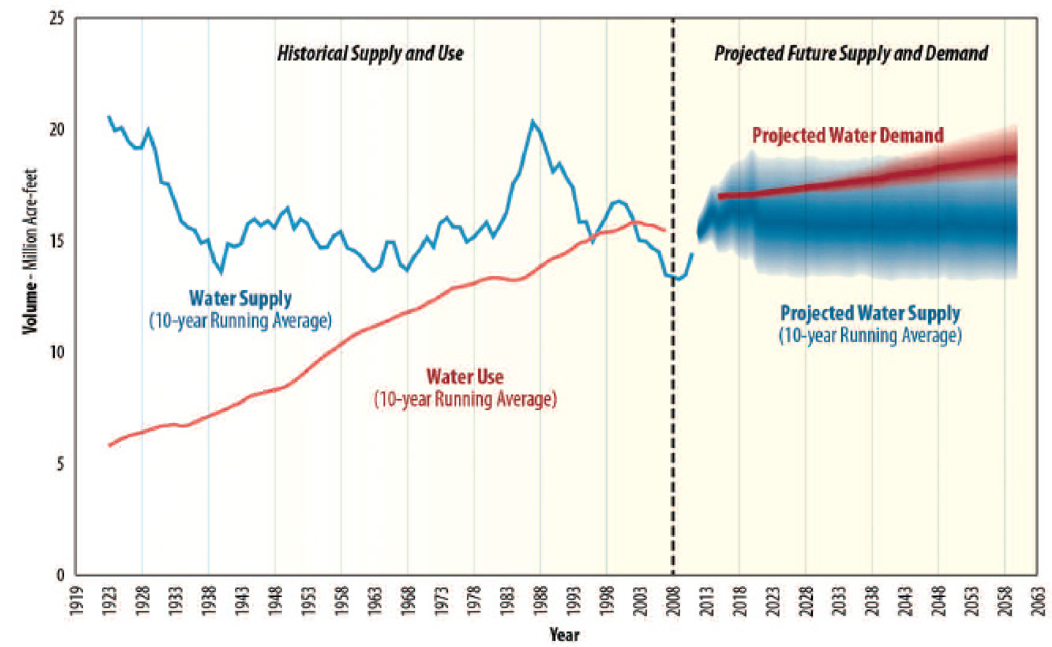
Figure 3.2 Box Plot of Average Annual Total Delta Exports for each Climate Scenario under the Current Trends Socioeconomic Scenario (TAF/year)

3.8 COLORADO RIVER BASIN STUDY

The U.S. Bureau of Reclamation, in collaboration with representatives of the seven Colorado River Basin States, conducted a comprehensive assessment of the current and future imbalances in water supply and demand in the Colorado River Basin and the adjacent areas of the Basin States that receive Colorado River water (Bureau of Reclamation, 2012 [CO Basin Study]). The Basin study addressed the uncertainty in supply and demands over the next 50 years, and developed and analyzed adaptation and mitigation strategies to resolve the imbalances.

The Colorado River supplies water to agricultural, municipal, and industrial users in the seven Basin states, to Indian tribes along the River, and to Mexico. Recent extended droughts, reduced snowpack, and declining basin runoff have demonstrated the variability and potential vulnerability of the system to changes in water supply. The river is managed for many objectives, including water deliveries for agricultural, municipal, and industrial users, hydroelectric power, recreation, fish and wildlife, flood control, and water quality. The performance of various water management strategies was evaluated against metrics developed for each of these objectives. A diverse group of stakeholders consisting of federal, state, tribal, and local interests is being assembled to define standardized metrics to evaluate risks to the various resources.

The reliability of the Colorado River system was assessed for six water demand scenarios applied to four water supply scenarios. As shown in Figure 3.3, the system was found to be insufficient to meet future water delivery needs due to declining supply and substantial demand growth for both the Upper and Lower Basins. A comparison of median supply and demand projections estimated a 3.2 million acre foot balance by 2060. To mitigate imbalances, the Basin states have begun implementing programs and strategies as well as diversifying water supply portfolios. Four unique portfolio scenarios (A, B, C, and, D) were developed to model with future water supply scenarios as shown in Figure 3.4. Comparison of the baseline condition against the portfolios shows increasing difficulty to meet basin resource needs in the coming years. Improving system reliability also comes with significant costs and trade-offs. Portfolios exhibit that there are a broad range of options available, including water conservation, reuse, and augmentation, to help reduce basin vulnerability.



[1] Water use and demand include Mexico's allotment and losses such as those due to reservoir evaporation, native vegetation, and operational inefficiencies.

Figure 3.3 Historical Supply and Use and Projected Future Colorado River Basin Water Supply and Demand

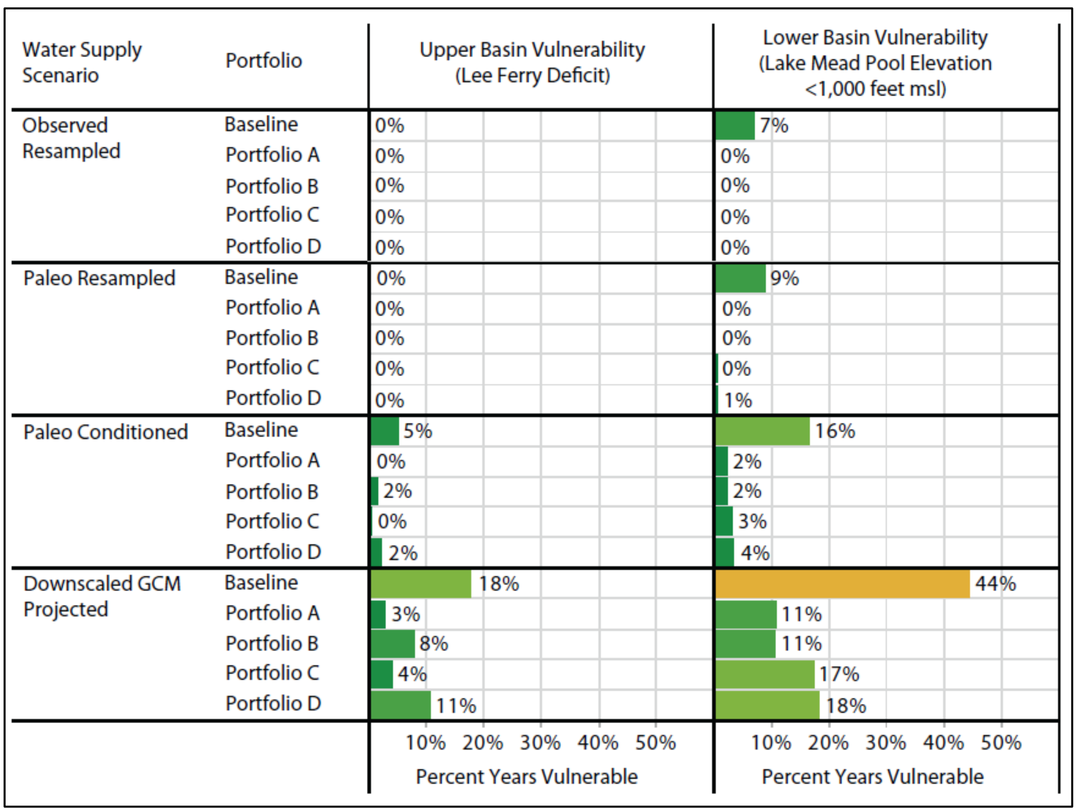


Figure 3.4 Percent of Years Vulnerable for Upper Basin (left) and Lower Basin (right) Vulnerabilities in 2041-2060 with Portfolios, by Water Supply Scenario

3.9 REFERENCES

Bureau of Reclamation. 2012. Colorado River Basin Water Supply and Demand Study. Retrieved from http://www.usbr.gov/ lc/region/programs/crbstudy/finalreport.

Bureau of Reclamation. 2015 (SCAO). Southern California Area Office. Retrieved from http://www.usbr.gov/lc/socal/aboutus.html.

Bureau of Reclamation. 2015 (Moving Forward). Moving Forward. Colorado River Basin Stakeholders Moving Forward to Address Challenges Identified in the Colorado River Basin Water Supply and Demand Study — Phase 1 Report. A Product of the Moving Forward Effort. Retrieved from http://www.usbr.gov/lc/region/ programs/crbstudy/MovingForward/Phase1Report/fullr eport.pdf.

Bureau of Reclamation. 2016 (Sacramento and San Joaquin Basin Study). Sacramento and San Joaquin Rivers Basin Study Executive Summary. Prepared by U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, Sacramento, California. [Available at http://www.usbr.gov/watersmart/bsp/docs/finalreport/sacramento-sj/Sacramento_SanJoaquin_SUMMARY.pdf]

Bureau of Reclamation. 2016. (SECURE) SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water. Prepared for United States Congress. Denver, CO: Bureau of Reclamation, Policy and Administration.

Bureau of Reclamation. (n.d.). Los Angeles Basin Stormwater Conservation Study. Retrieved from http://www.usbr.gov/lc/socal/basinstudies/LABasin.htm

California Coastal Commission. 2015. Sea Level Rise Policy Guidance. http://www.coastal.ca.gov/climate/SLRguidance.html.

Intergovernmental Panel on Climate Change (IPCC). 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change. [TF Stocker, D Qin, G Plattner, MMB Tignor, SK Allen, J Boschung, A Nauels, Y Xia, V Bex, PM Midgley (eds.)], Cambridge University Press: Cambridge, UK and New York, NY, USA. 1535pp. https://www.ipcc.ch/report/ar5/.

Melillo JM, TC Richmond, GW Yohe (eds). 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. Report for the US Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

Moser SC, MA Davidson, P Kirshen, P Mulvaney, JF Murley, JE Neumann, L Petes, D Reed. 2014. Chapter 25: Coastal Zone Development and Ecosystems. In: Climate Change Impacts in the United States: The Third National Climate Assessment, [JM Melillo, TC Richmond, GW Yohe (eds.)], US Global Change Research Program, pp. 579-618. doi:10.7930/J0MS3QNW.

National Research Council (NRC). 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Report by the Committee on Sea Level Rise in California, Oregon, and Washington. National Academies Press, Washington, DC. 250 pp. http://www.nap.edu/catalog/13389/sea-level-rise-for-the-coasts-of-california-oregon-and-washington.

Natural Resources Agency. 2014. Safeguarding California: Reducing Climate Risk.

Natural Resources Agency. 2016. Safeguarding California: Implementation Action Plans.

Smith, D. J., & Gallon, C. 2015. Los Angeles Region Framework for Climate Change Adaptation and Mitigation Current State of Knowledge & Water Quality Regulatory Program Considerations (Rep.). Los Angeles Regional Water Quality Control Board.

State of California. California Climate Change Assessments. California Climate Change Assessments. Web. Accessed 1 May 2016.

APPENDIX C – CONSEQUENCE CATEGORIES AND LEVEL DESCRIPTIONS

Table C.1 Consequence Categories for Water Reclamation Plants

Category	Utility Business Impacts	Utility Equipment Damage	Source/ Receiving Water Impacts	Environmental Impacts
Description	Revenue or operating income loss evaluated in terms of magnitude and recurrence of service interruptions	Costs of replacing the service equivalent provided by a utility or piece of equipment evaluated in terms of magnitude of damage (minimal, minor, significant, complete loss) and financial impacts (flexible cost scale, "$x," can be customized by each user)	Degradation or loss of source water or receiving water quality and/or quantity, evaluated in terms of recurrence (minimal, temporary, seasonal or episodic, long-term)	Evaluated in terms of environmental damage or loss (aside from source water or other assets) and compliance with environmental regulations (minimal, short term, persistent/permit violations, significant impact, and/or regulatory enforcement and actions)
Very High	Long-term and/or significant loss of expected revenue or operating income $11,430,001+	Complete loss of asset $9,345,001+	Long-term compromise of source water quality or quantity $77,880,001+	Significant environmental damage $12,040,001+
High	Seasonal or episodic compromise of expected revenue or operating income $7,620,001 - $11,430,000	Significant damage to equipment $3,900,001 - $9,345,000	Seasonal or episodic compromise of source water quality or quantity $32,440,001 - $77,880,000	Persistent environmental damage $5,040,001 - $12,040,000
Medium	Minor and short-term reductions in expected revenue $3,810,001 - $7,620,000	Minor damage to equipment $1,560,001 - $3,900,000t	Temporary impact on source water quality or quantity $12,960,001 - $32,440,001	Short-term damage, compliance can be quickly restored $2,000,001 - $5,040,000
Low	Minimal potential for loss of revenue or operating income $0 - $3,810,000	Minimal damage to equipment $0 - $1,560,000	No more than minimal changes to water quality $0 - $12,960,000	No impact or environmental damage $0 - $2,000,000

Table C.2 Consequence Categories for Pumping Plants and LFDs

Category	Utility Business Impacts	Utility Equipment Damage	Source/ Receiving Water Impacts	Environmental Impacts
Description	Revenue or operating income loss evaluated in terms of magnitude and recurrence of service interruptions	Costs of replacing the service equivalent provided by a utility or piece of equipment evaluated in terms of magnitude of damage (minimal, minor, significant, complete loss) and financial impacts (flexible cost scale, "$x," can be customized by each user)	Degradation or loss of source water or receiving water quality and/or quantity, evaluated in terms of recurrence (minimal, temporary, seasonal or episodic, long-term)	Evaluated in terms of environmental damage or loss (aside from source water or other assets) and compliance with environmental regulations (minimal, short term, persistent/permit violations, significant impact, and/or regulatory enforcement and actions)
Very High	Long-term and/or significant loss of expected revenue or operating income $715,001+	Complete loss of asset $623,001+	Long-term compromise of source water quality or quantity $77,880,001+	Significant environmental damage $12,040,001+
High	Seasonal or episodic compromise of expected revenue or operating income $508,001 - $715,000	Significant damage to equipment $260,001 - $623,000	Seasonal or episodic compromise of source water quality or quantity $32,440,001 - $77,880,000	Persistent environmental damage $5,040,001 - $12,040,000
Medium	Minor and short-term reductions in expected revenue $254,001 - $508,000	Minor damage to equipment $104,001 - $260,000	Temporary impact on source water quality or quantity $12,960,0001 - $32,440,000	Short-term damage, compliance can be quickly restored $2,000,001 - $5,040,000
Low	Minimal potential for loss of revenue or operating income $0 - $254,000	Minimal damage to equipment $0 - $104,000	No more than minimal changes to water quality $0 - $12,960,000	No impact or environmental damage $0 - $2,000,000

APPENDIX D – REPLACE-IN-KIND AND RESILIENCE IMPROVEMENT COST METHODOLOGIES

Several methodologies were used to estimate replace-in-kind construction costs and the costs of short- and long-term resilience improvements for Los Angeles Sanitation's assets at pumping plants, low flow diversions and water reclamation plants. The following three costing methods were used during the climate risk and resilience assessment for infrastructure:

- Conceptual-level cost curves for replace-in-kind costs.
- Association for the Advancement of Cost Engineering's (AACE) Class 5 cost estimates for replace-in-kind costs and resilience improvements.
- Scaled costs for resilience improvements based on AACE Class 5 cost estimates for adaptation measures.

The following describes the basis and methodologies for developing the cost estimates used in this climate risk and resilience assessment.

D.1 REPLACE-IN-KIND COSTS

Replace-in-kind cost estimates for pumping plants are based on One Water LA cost assumptions described in Appendix G of Technical Memorandum (TM) No. 5.1 (Carollo, 2016). The memorandum identifies a sewer lift station unit construction cost of $0.75/gallons per day (gpd) and a stormwater low flow diversion cost of $1,000,000 for basic systems and $2,000,000 for more complex diversions before markups. Sewer and stormwater pumping plant unit costs are assumed to be equivalent. Capital costs for pumping plants may be broken down into the following elements and percentages of the costs: mechanical (35-40 percent), electrical (10-15 percent), instrumentation and controls ([&C], 5 percent) and the remaining 30 to 50 percent for structural, architectural, masonry and site civil. The replace-in-kind cost is estimated to be 25 percent of the capital cost and assumes that all electrical, mechanical, and instrumentation equipment will be replaced and all mechanical process piping and concrete structures would remain. This approach was previously used in the 2015-2016 USEPA CREAT effort to estimate the costs for pumping plants that were evaluated without direct Class 5 estimating methods using as-builts. The costs represent cleaning and replacing damaged or destroyed assets, such as:

- Clean facility and demolish/remove damaged assets
- Replace electrical and power – motor control centers, backup generators, conduits, lights, etc.
- Replace heating, ventilating and air conditioning (HVAC) – fans and ducts

- Replace instrumentation and controls (I&C) – control panels, etc.
- Replace process mechanical – pumps, motors, etc.

Construction markups were also taken from Technical Memorandum No. 5.1. A 160 percent markup is applied to all replace-in-kind costs and include the following breakdown:

- 30 percent construction contingency to account for unknown or unforeseen construction costs.
- 30 percent implementation factor to account for the costs of program management and planning.
- 10 percent to account for engineering, design, and construction services.
- 10 percent to account for construction management and inspections.
- 20 percent to account for environmental documentation, permits, administration and unknown or unforeseen legal fees.
- 30 percent project contingency to account for the level of detail of the project concept.

These replace-in-kind costs were then compared to AACE Class 5 estimates calculated for two wastewater pumping plants (No. 632 Sunset Boulevard, No. 634 Temescal Canyon). These two cost estimates were performed in 2015-2016 using as-built design drawings for takeoffs with Los Angeles Sanitation for a USEPA CREAT exercise.

The existing Capital Improvement Plan (CIP) has six small to medium sized pump stations with capacities between 2,000 gallons per minute (gpm) to 18,000 gpm and estimated costs ranging from $1.4 million to $2.9 million (described further in Section D.3 below). A comparison of the CIP rehabilitation costs with the replacement estimates based on the TM 5.1 assumptions indicates the small pump station replacement costs would be underestimated if following the unit construction cost of $0.75 per gallon. Therefore, a minimum replacement cost of $1,000,000 was applied to more accurately predict small pump station damage replacement costs. The replacement cost of the Riverdale Pumping Plant No. 611 was reduced because there is no pumping equipment at the facility.

Potential damages at the water reclamation plants may vary from minor damage due to localized flooding to major destruction due to total inundation of the facilities during major flooding events. All four WRPs are in or adjacent to flood hazard zones and two are in or adjacent to tsunami zones. AACE Class 5 replace-in-kind costs for the headworks building and lift station, MCCs throughout the facility, and the effluent pumping plant including standby generators were estimated in 2015-2016 using as-built design drawings for takeoffs with Los Angeles Sanitation for a USEPA CREAT exercise. These estimates were used to inform damage estimates for all four facilities for the risks identified.

D.2 RESILIENCE IMPROVEMENT COSTS

The resilience improvement costs for Sunset Pumping Plant No. 632, Temescal Canyon Pumping Plant No. 634, and the Terminal Island Water Reclamation Plant (WRP) were estimated using the AACE Class 5 cost methodology based on line item takeoffs from design and as-built drawings for the 2015-2016 USEPA CREAT exercise. For additional pumping plants, those costs were scaled based on pumping capacity and facility size to estimate the costs for the other pumping plants. Construction cost estimates for the WRPs were made based on the 2015-2016 USEPA CREAT exercise estimates for the Terminal Island WRP and those provided by Los Angeles Sanitation staff from other ongoing facility planning projects for the Donald C. Tillman WRP. A 160 percent markup was applied to the improvement costs following the using One Water LA cost assumptions.

D.3 SUPPLEMENTAL COST DATA

Replace-in-kind and resilience improvement cost estimates can be compared to cost estimates in the current CIP to confirm that estimated costs for pumping plants are appropriate. Table D.1 shows the construction cost estimates for pumping plant projects currently in the CIP. Many of the pumping plants listed in the table are identified to be at risk to climate-based events. Rehabilitation typically includes procurement, demolition, and installation of new pumps, suction/discharge gate values, check valves, variable frequency drives (VFDs), instrumentation, and controls. Generator replacements typically include procurement, demolition, and installation of new generators and ancillary controllers, transfer switches, exhaust, and cooling system. These efforts are similar to replace-in-kind costs that would be incurred following a flooding or other damaging events.

The rehabilitation costs of pumping plants range as follows based on pumping capacity based on the projects listed above:

- Small (0 to 5,000 gpm): $1,500,000
- Medium (5,000 to 15,000 gpm): $1,500,000 to $3,000,000
- Large (>15,000 gpm): >$3,000,000

Generator replacement costs for pumping plants range as follows based on pumping capacity based on the projects listed above:

- Small (0 to 5,000 gpm): $300,000 to $700,000
- Medium (5,000 to 15,000 gpm): $700,000 to $1,500,000 Large (>15,000 gpm): $1,500,000 to $5,400,000

Table D.1 Pumping Plant CIP Construction Cost Estimates

Project Type	Project Name	Project No.	Capacity (gpm)	10-Yr Construction Cost ($)
Rehabilitation	PP604 HIGHBURY REHAB	7184	2,250	2,204,990
Rehabilitation	PP671 TERMINAL WAY REHAB	7185	10,000	2,810,000
Rehabilitation	PP691 SAN PEDRO REHAB	7186	18,000	2,334,951
Rehabilitation	PP666 FRIES REHAB	7183	7,400	1,531,855
Rehabilitation	PP677 HAWAIIAN & B REHAB	7181	5,800	1,430,105
Rehabilitation	PP676 WILMINGTON REHAB	7182	8,000	1,522,962
Rehabilitation	PP601 MANCHESTER IMPROVEMENTS	7249	20,160	650,000
Generator Replacement	PP646 VENICE GENERATORS REPL	7222	45,000	5,393,000
Generator Replacement	PP674 190 & VERMONT GEN REPL	7223	2,800	698,145
Generator Replacement	PP672 MURDOCK & I GEN REPL	7229	1,100	567,105
Generator Replacement	PP601 MANCHESTER GEN REPL	7230	20,160	1,506,540
Generator Replacement	PP606 DACOTAH GEN REPL	7231	10,000	785,820
Generator Replacement	PP669 HARRIS PL GEN REPL	7232	1,600	615,720
Generator Replacement	PP654 BALLONA CREEK GEN REPL	7244	18,000	1,793,000
Generator Replacement	PP616 CAHUENGA GEN REPL	7239	1,600	367,709
Generator Replacement	PP NORTH YARD GEN REPL	7237		941,000
Generator Replacement	PP638 PALISADES GEN REPL	7242	600	300,000
Generator Replacement	PP624 ROSCOMARE GEN REPL	7240	500	405,000
Generator Replacement	PP632 SUNSET GEN REPL	7241	10,000	662,000
Generator Replacement	PP648 THOMPSON YARD GEN REPL	7243	700	541,000
Generator Replacement	PP WEST LA YARD GEN REPL	7238		357,000
New Facility	VENICE AUXILIARY PUMPING PLANT	C922		17,029,000

Source: Carollo, 2017.

The estimated replace-in-kind costs of the pumping plants based on the TM No. 5.1 assumptions are listed below.

- Small (0 to 5,000 gpm): $3,500,000
- Medium (5,000 to 15,000 gpm): $3,500,000 to $8,500,000
- Large (>15,000 gpm): >$8,500,000

Since the assumption estimates the pumping plant cost linearly by capacity, medium and large pump stations are estimated higher than the planned rehabilitation costs. Therefore, the estimated replace-in-kind costs for pumping plants with capacities greater than 5,000 gpm may overestimate the cost for repairing damaged facilities.

D.4 REFERENCES

Carollo, 2016. Technical Memorandum No. 5.1, Basis of Planning, Draft. Prepared by Carollo for the City of Los Angeles, October 2016.

Carollo, 2017. Technical Memorandum No. 7.5, Wastewater Facilities Plan, Existing And Future Collection System, Final Draft. Prepared by Carollo, MWH and CH2M for the City of Los Angeles. February 2017.

-This Page Left Blank Intentionally-

APPENDIX E – FACILITY RISK ASSESSMENT AND ADAPTATION SUMMARY SHEETS

This appendix includes individual facility risk assessment and adaptation summary sheets developed for the wastewater reclamation plants, wastewater pumping plants, stormwater pumping plants, and low flow diversions to increase their climate resiliency over the planning horizon of the One Water LA Plan.

-This Page Left Blank Intentionally-

Pumping Plants with No or Minimal Hazards

Pumping Plants with No Hazards

The following pump stations are geographically separated from the climate change hazard areas:

- #601 MANCHESTER
- #602 UNION PACIFIC
- #604 HIGHBURY
- #605 SAN PASQUAL
- #606 DACOTAH
- #608 WASHINGTON & INDUSTRIAL
- #609 4TH & FIGUEROA
- #610 11TH & SANTA FE
- #615 SUN VALLEY PARK
- #616 CAHUENGA
- #617 LANKERSHIM
- #619 SHERMAN WAY
- #620 WOODMAN
- #621 VAN NUYS
- #622 SEPULVEDA
- #626 RIVERDALE
- #631 HAMDEN PLACE
- #654 BALLONA CREEK
- #659 NORS
- #674 190TH & VERMONT
- #675 P.C.H. & FIGUEROA
- #688 SOUTH NEPTUNE
- #693 ROBIDOUX
- #705 GARVANZA
- #710 ENTERPRISE
- #711 DOWNTOWN
- #735 SANTA MONICA CANYON
- #741 MAR VISTA
- #742 PENMAR
- #750 IMPERIAL HWY

Pumping Plants with Minimal Hazards

Lopez Canyon Pumping Plant No. 535 has short term fire and landslide hazards as shown in Figure 1. The Lopez Canyon Landfill was closed in 1996 and is still within its post-closure monitoring period of 30-years which requires monitoring and mitigation for risks including fire and landslide. Therefore, no resilience improvements are recommended at this time.

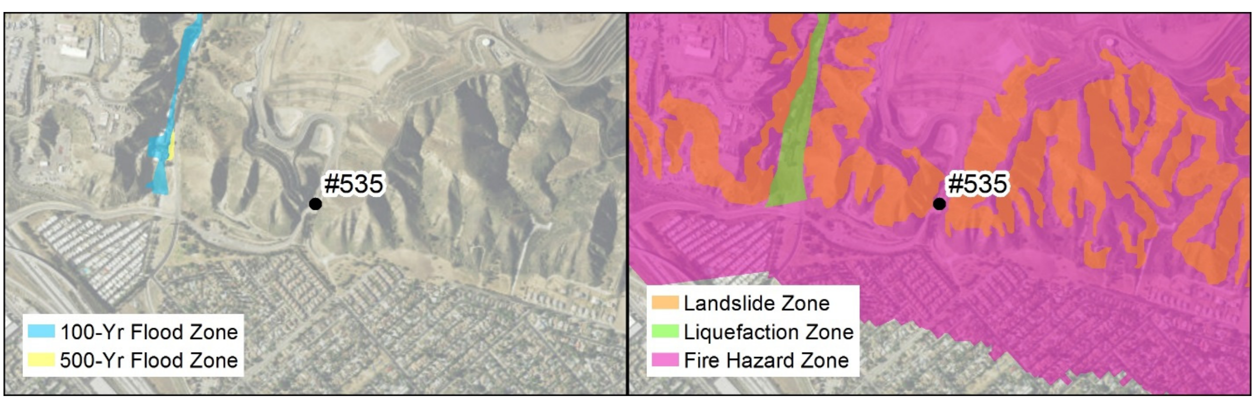


Figure 1. Hazard Zones for Lopez Canyon Pumping Plant No. 535

Sunset Pumping Plant No. 632 is located within fire and landslide hazard zones and has nearby flood, CoSMoS SLR, and tsunami inundation hazards as shown in Figure 2. The facility is located next to a parking lot, adjacent to the Pacific Coast Highway and away from vegetated areas which minimizes the potential for wildfire. The landslide hazard is also considered minimal with development of the adjacent hillsides. The facility has a flood threshold elevation of 21.0 feet NAVD88 which is higher than the estimated long-term flood elevation. Therefore, the facility is considered to have minimal hazards and no resilience improvements are recommended at this time.

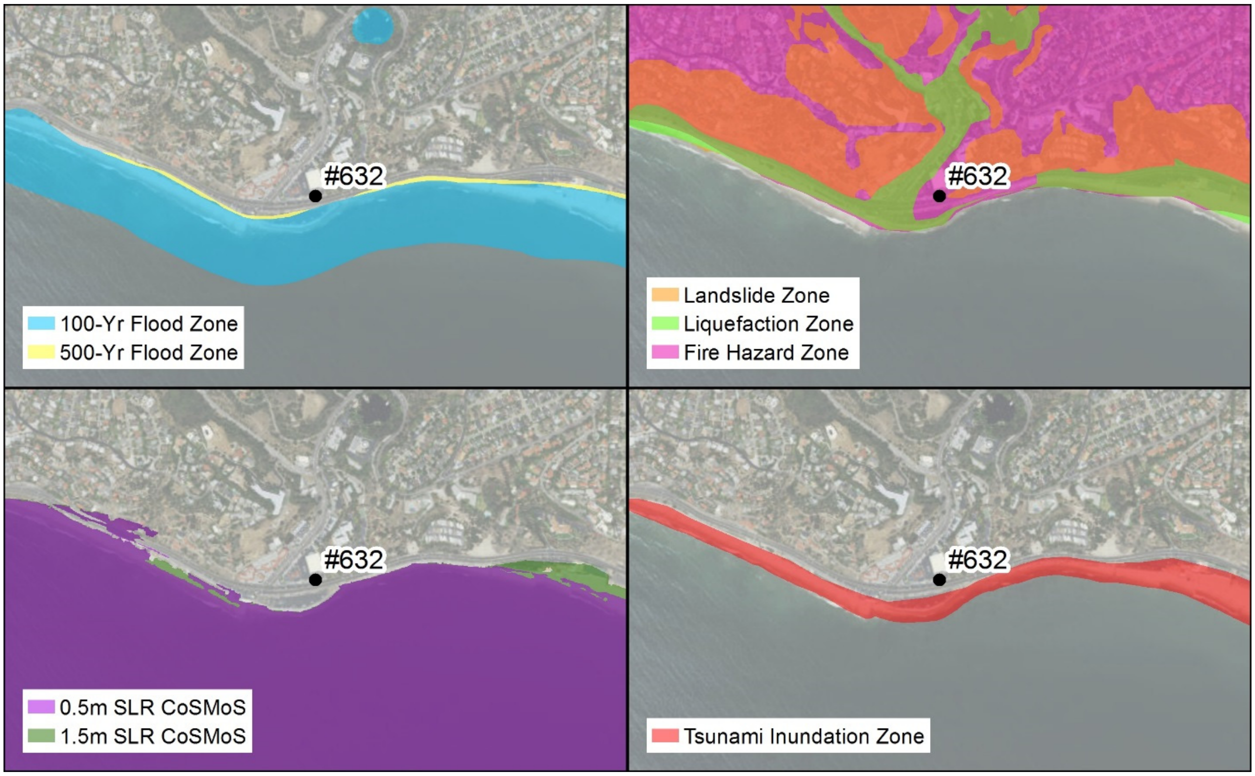


Figure 2. Hazard Zones for Sunset Pumping Plant No. 632

Chautauqua Pumping Plant No. 633 is located within landslide, liquefaction, and fire hazard zones and near flood, CoSMoS SLR, and tsunami inundation zones as shown in Figure 3. The facility has one cabinet above ground with the rest of the controls and equipment located below ground. The facility is also located between two streets and surrounded by development which minimizes the wildfire and landslide risk. The elevation of the pumping plant is above the long-term flood depths. Therefore, the facility is considered to have minimal hazards and no resilience improvements are recommended at this time.

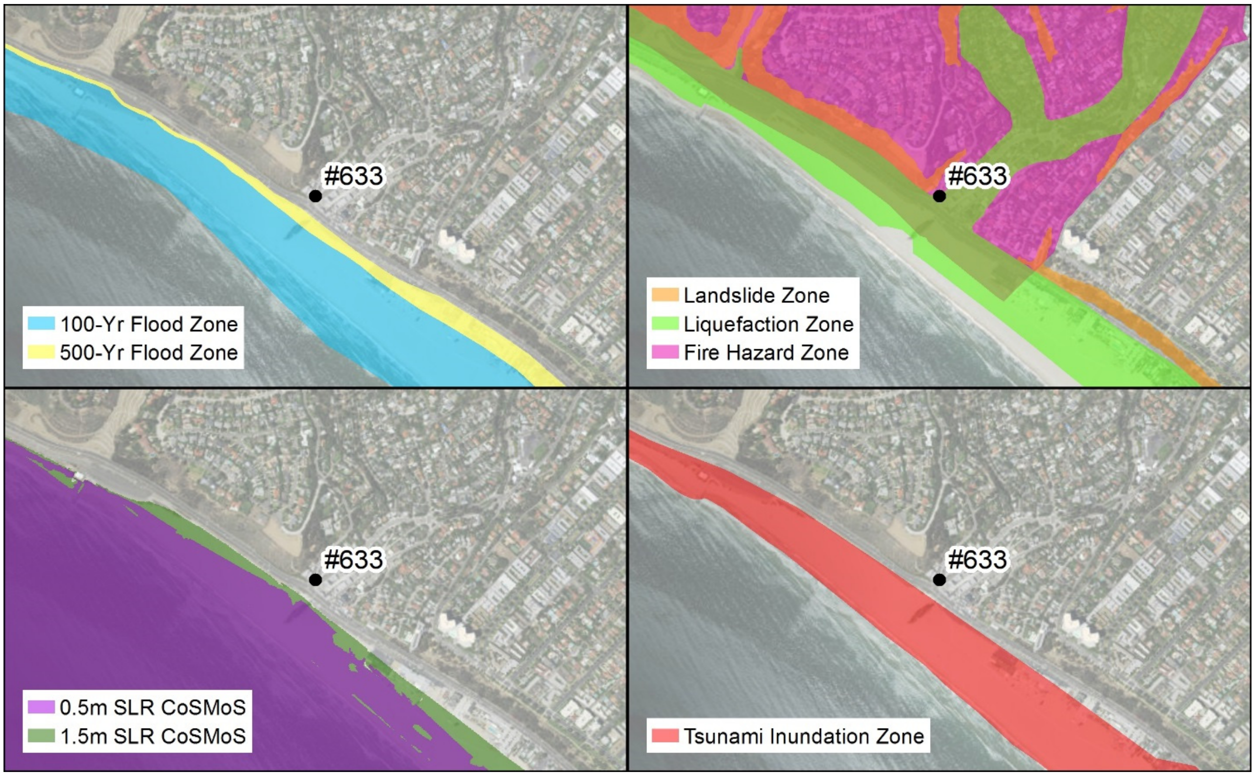


Figure 3. Hazard Zones for Chautauqua Pumping Plant No. 633

Eubank & "Q" Pumping Plant No. 678 is used to pump stormwater from the adjacent retention basin after a storm event which places the pump station near a 100-year flood zone contained within the basin as shown in Figure 4. The control cabinet is elevated above the basin and flood waters would overflow into the surrounding properties before reaching the cabinet platform. Therefore, flood risk at this location is considered minimal and no resilience improvements are recommended at this time.

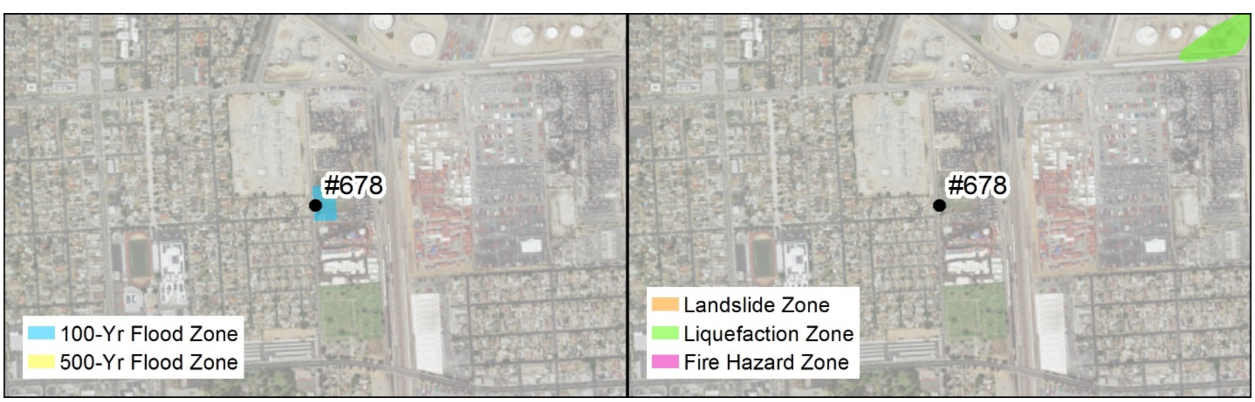


Figure 4. Hazard Zones for Eubank & "Q" Pumping Plant No. 678

South LA Wetlands Pumping Plant No. 701 is a low flow diversion located within the liquefaction hazard zone and adjacent to 500-year flood zones as shown in Figure 5. The surrounding area is developed and flat therefore the liquefaction hazard is minimal. The flooding pattern indicates the inundation is contained within adjacent roadway and there is minimal risk for this location. Therefore, no resilience improvements are recommended at this time.

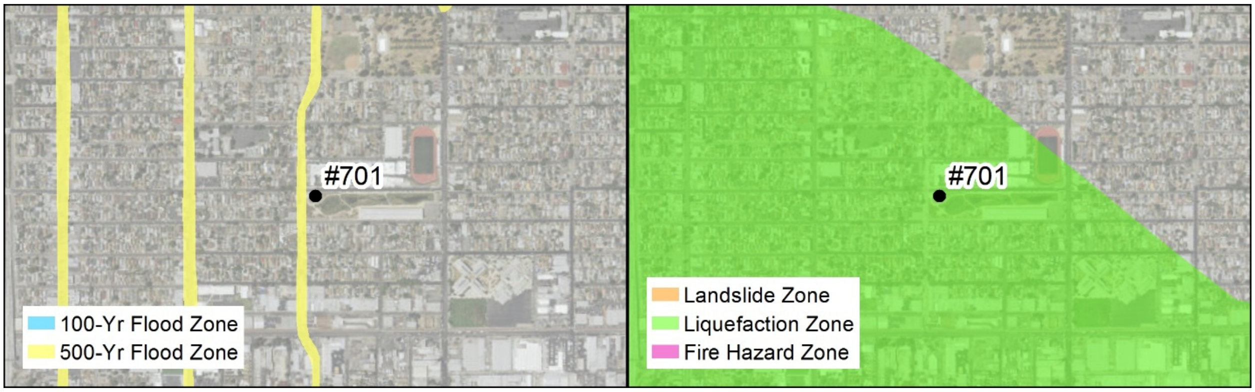


Figure 5. Hazard Zones for South LA Wetlands Pumping Plant No. 710

Echo Park Pumping Plant No. 703 is a low flow diversion to divert non-stormwater flows into Echo Park Lake as shown in Figure 6. The facility is located within the liquefaction zone and has nearby flood and landslide hazards. The facility is located in a developed area which minimizes the landslide potential. It is assumed the 100-year flood is contained within the lake minimizing the nearby flood hazard. Therefore, the facility is considered to have minimal hazards and no resilience improvements are recommended at this time.

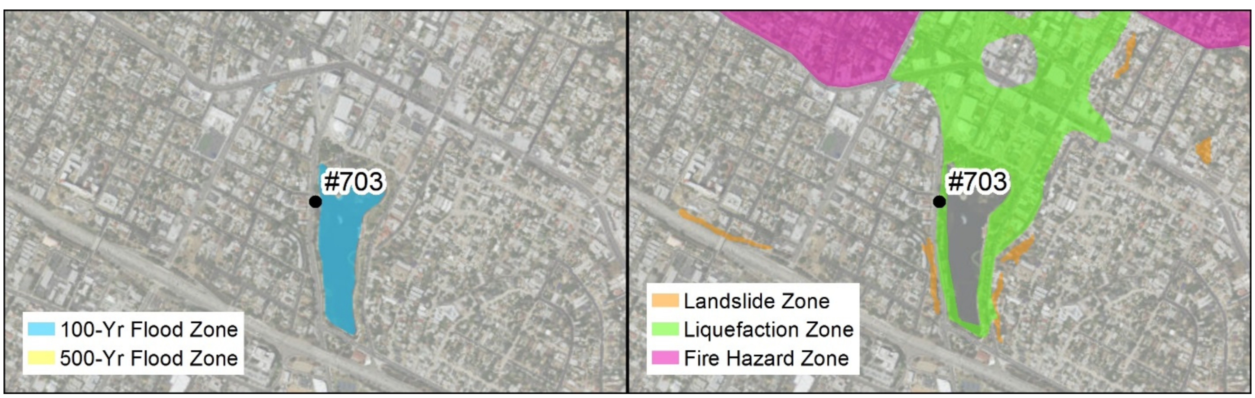


Figure 6. Hazard Zones for Echo Park Pumping Plant No. 703

Palisades Park Pumping Plant No. 730 is a low flow diversion located within the 500-year flood, fire, and liquefaction zones with nearby 100-year flood, landslide, CoSMoS SLR, and tsunami hazards as shown in Figure 7. The facility is located in a parking lot that is adjacent to Pacific Coast Highway with minimal wildfire potential. The nearby existing slopes have been developed with drainage features to minimize landslide potential. The damage threshold elevation of the facility is at the base of the control cabinet with an elevation of 24.95 feet NAVD88. The highest design flood elevation is based on the 1.5 m CoSMoS SLR scenario with an elevation of 21.92 feet NAVD88 based on a 100-year base flood elevation of 15. Therefore the facility is above long term flood inundation, has minimal hazards, and no resilience improvements are recommended at this time.

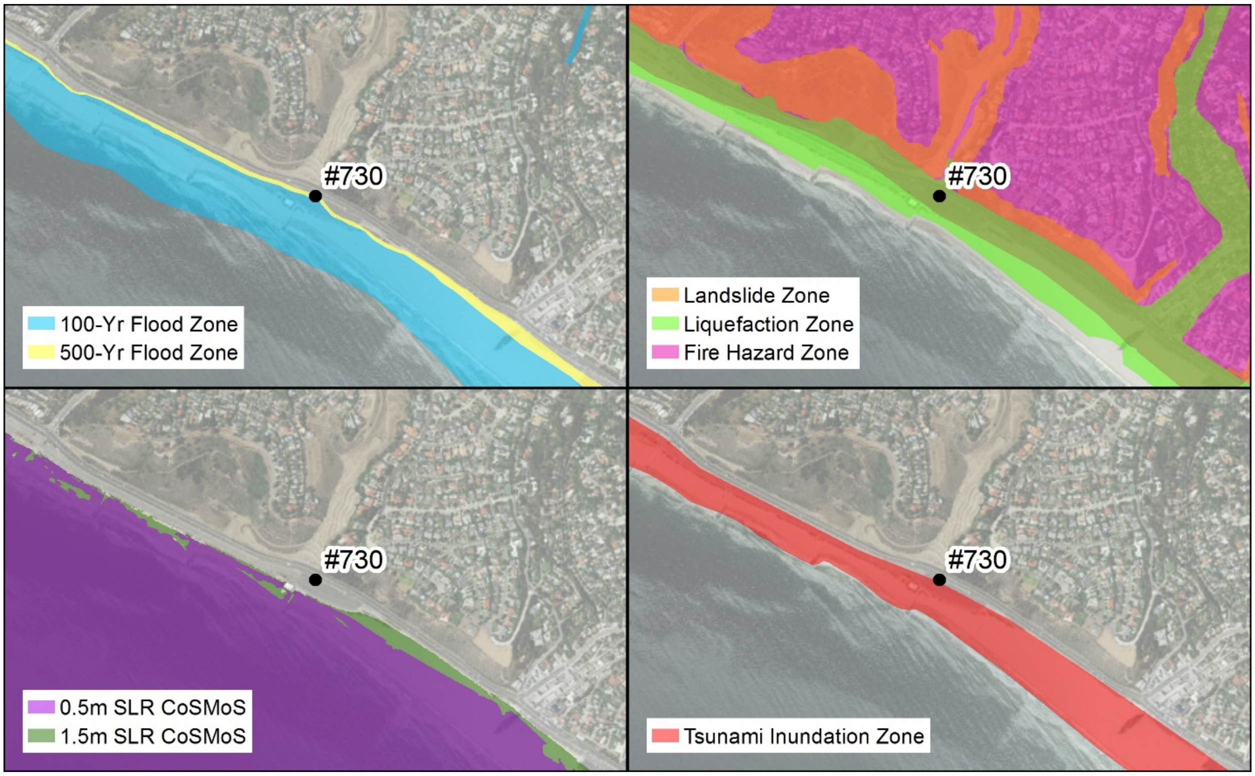


Figure 7. Hazard Zones for Palisades Park Pumping Plant No. 730

Marquez Canyon Pumping Plant No. 732 is a low flow diversion located within landslide, fire, and liquefaction zones with nearby flood, CoSMoS SLR, and tsunami hazards as shown in Figure 8. The facility is located between Pacific Coast Highway and Malibu Village Lane with minimal wildfire and landslide potential. The damage threshold elevation of the facility is at the base of the control cabinet with an elevation of 30.51 feet NAVD88. The highest design flood elevation is based on the 1.5 m CoSMoS SLR scenario with an elevation of 20.92 feet NAVD88 based on a 100-year base flood elevation of 14. Therefore the facility is above long term flood inundation, has minimal hazards, and no resilience improvements are recommended at this time.

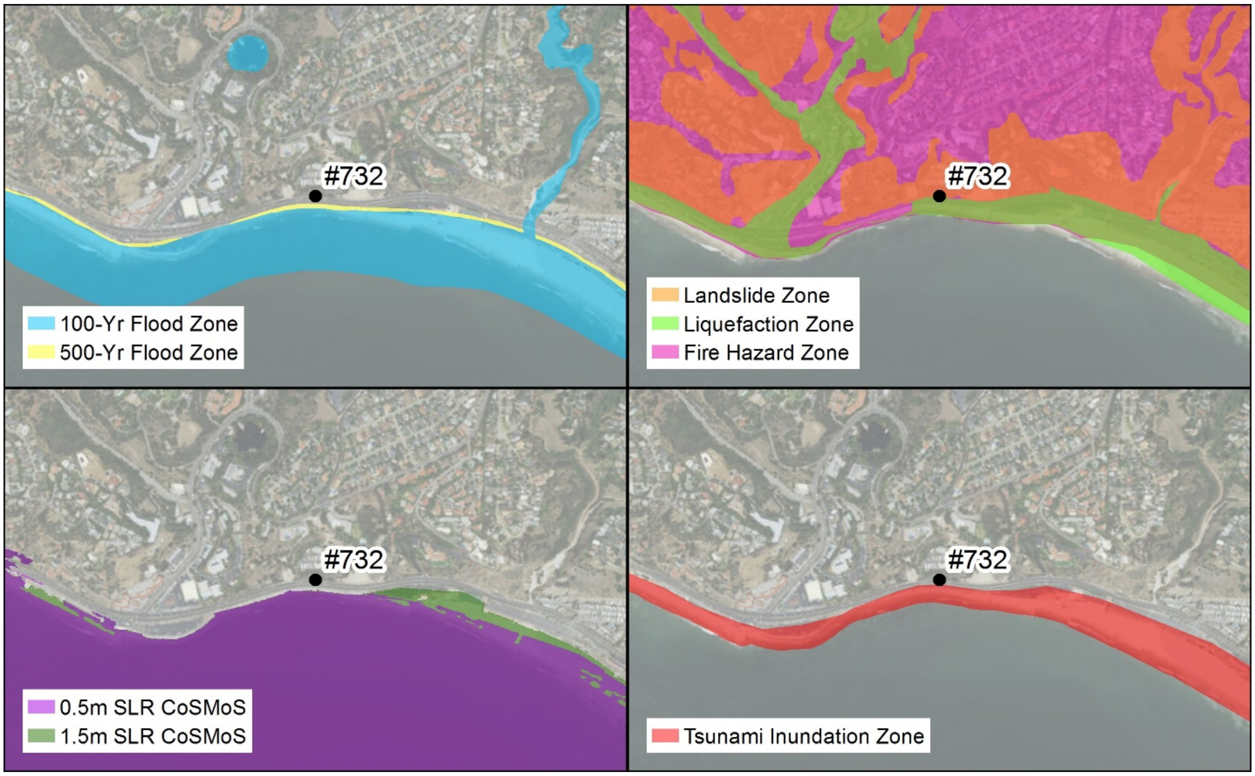


Figure 8. Hazard Zones for Marquez Canyon Pumping Plant No. 732

Temescal Canyon Pumping Plant No. 736 is a low flow diversion located within landslide and wildfire hazard areas as shown in Figure 9. The facility is located adjacent to Temescal Canyon Road within a park with managed vegetation that minimizes fire hazard. The nearby hillsides with development at the top of the canyon and the facility is located away from the base of the slope, minimizing landslide potential. The facility is above long term flood inundation, has minimal hazards, and no resilience improvements are recommended at this time.

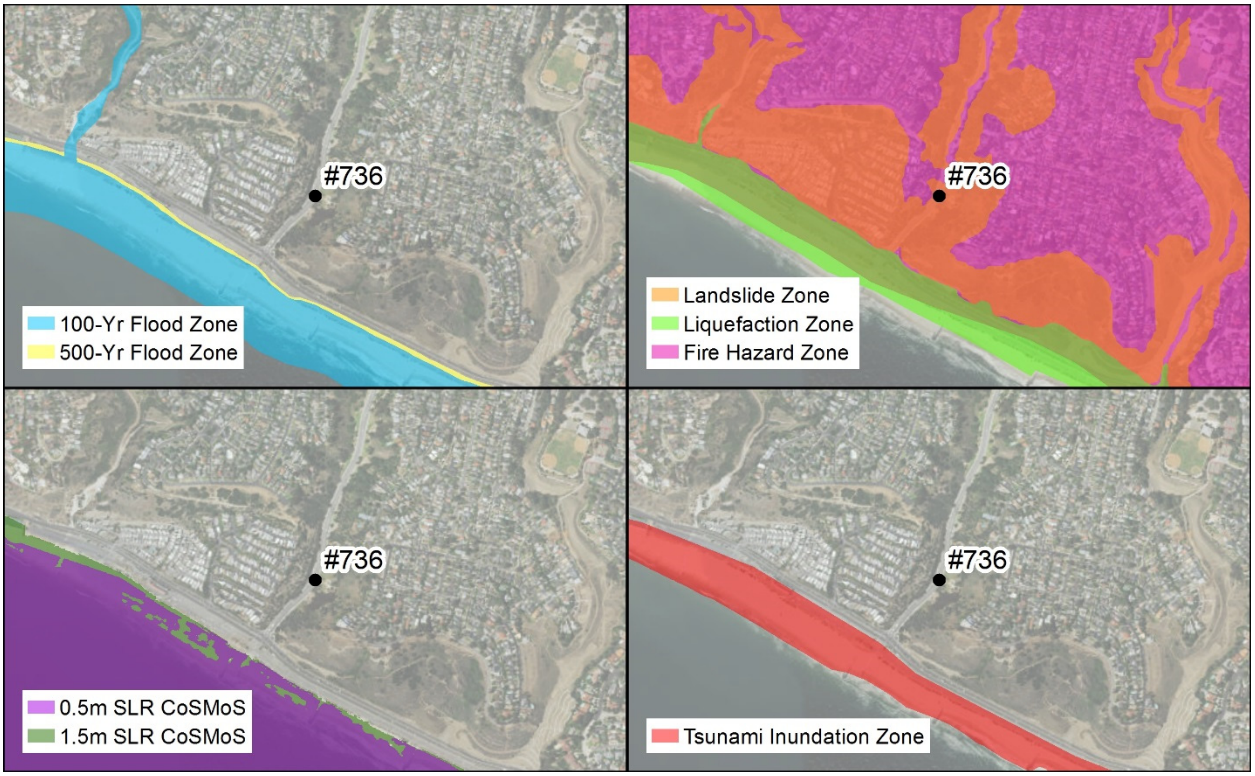


Figure 9. Hazard Zones for Temescal Canyon Pumping Plant No. 736

Bay Club Drive Pumping Plant No. 739 is a low flow diversion within fire and landslide hazard zones as seen in Figure 10. The facility is located adjacent to the Bel-Air Bay Club and the surrounding hillside has been developed minimizing the potential for wildfire and landslide. Therefore the facility is above long-term flood elevations, has minimal hazards, and no resilience improvements are recommended at this time.

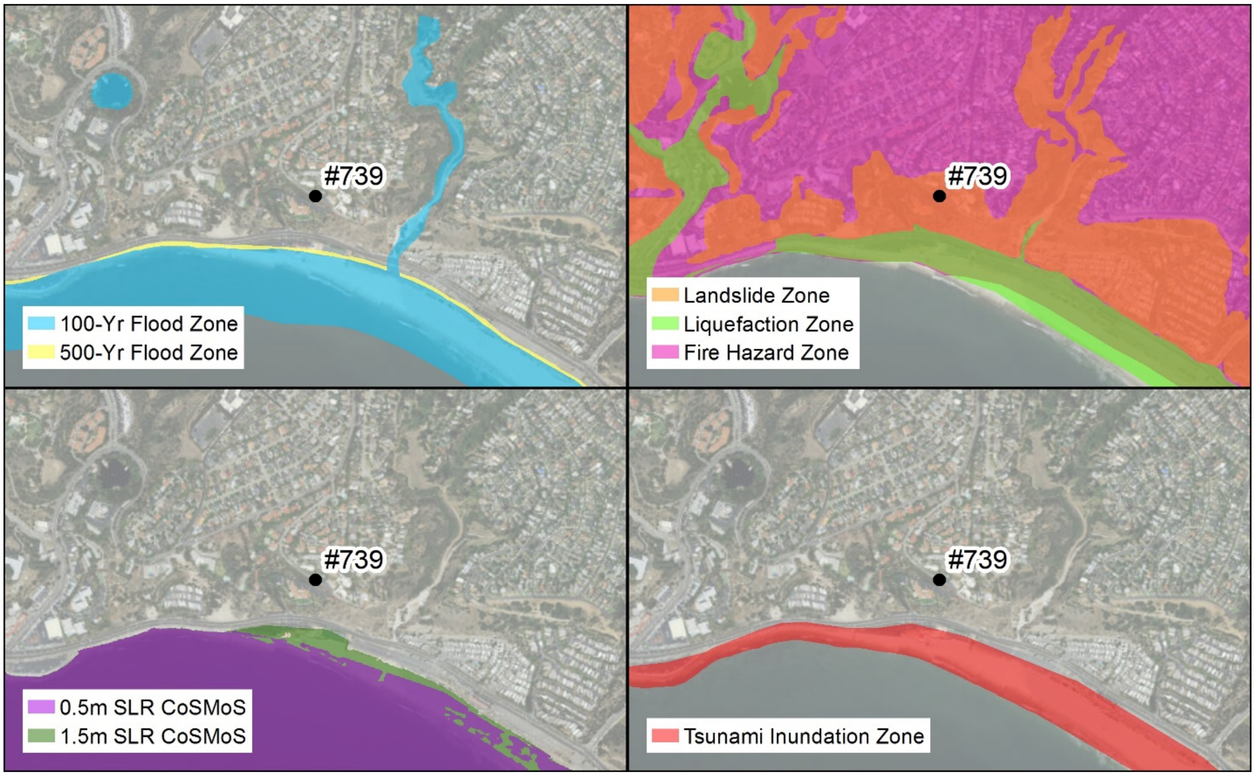


Figure 10. Hazard Zones for Bay Club Drive Pumping Plant No. 739

Thornton Pumping Plant No. 747 is a low flow diversion located within 500-year flood and liquefaction hazard zones as shown in Figure 11. The flood threshold elevation is the top of the control pad at an elevation of 21.67 feet NAVD88. The 500-year design flood elevation is 20.75 feet NAVD88 therefore the facility is above the long term inundation hazards. The surrounding area is developed and flat minimizing the liquefaction potential. Therefore, no resilience improvements are recommended at this time.

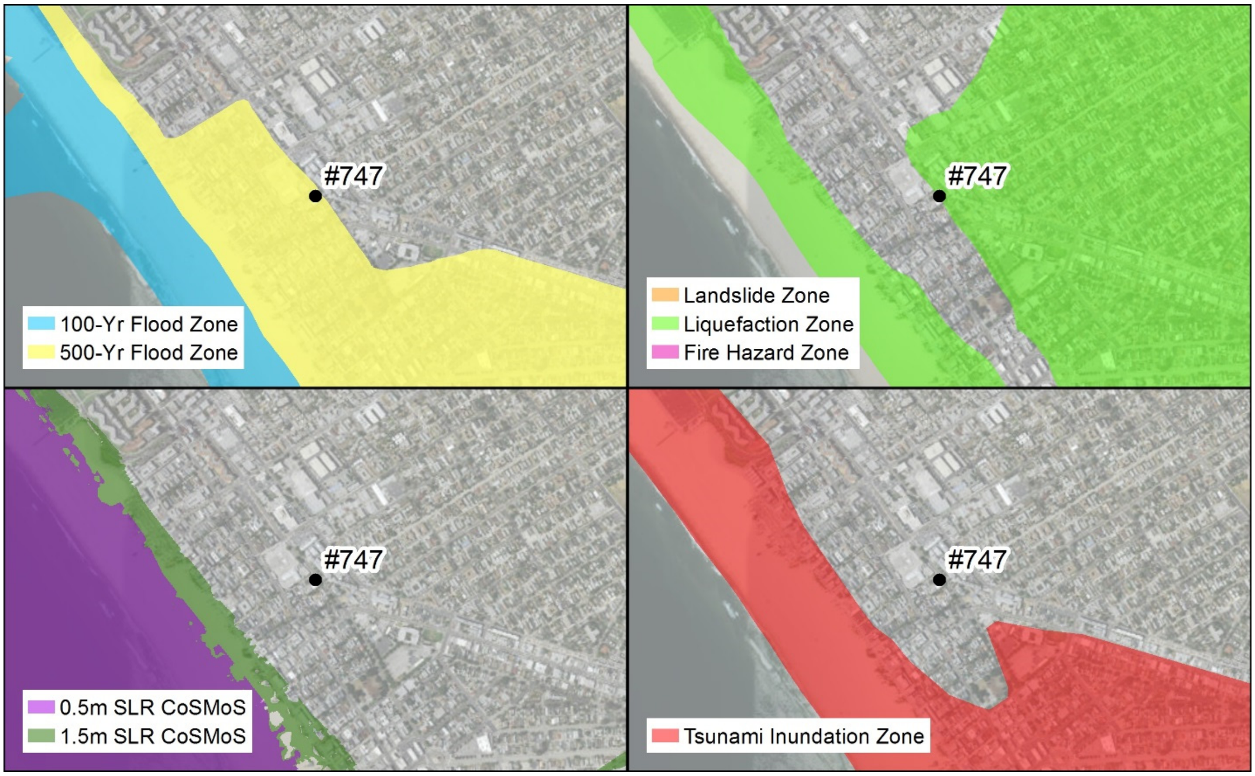


Figure 11. Hazard Zones for Thornton Drive Pumping Plant No. 747

Westminster Dog Park Pumping Plant No. 748 is a low flow diversion located within 500-year flood, liquefaction, and tsunami hazard zones as shown in Figure 12. The low flow diversion is a subgrade gravity fed system without pumping equipment. The facility does not have equipment that could become damaged during flooding. Therefore, no resilience improvements are recommended at this time.

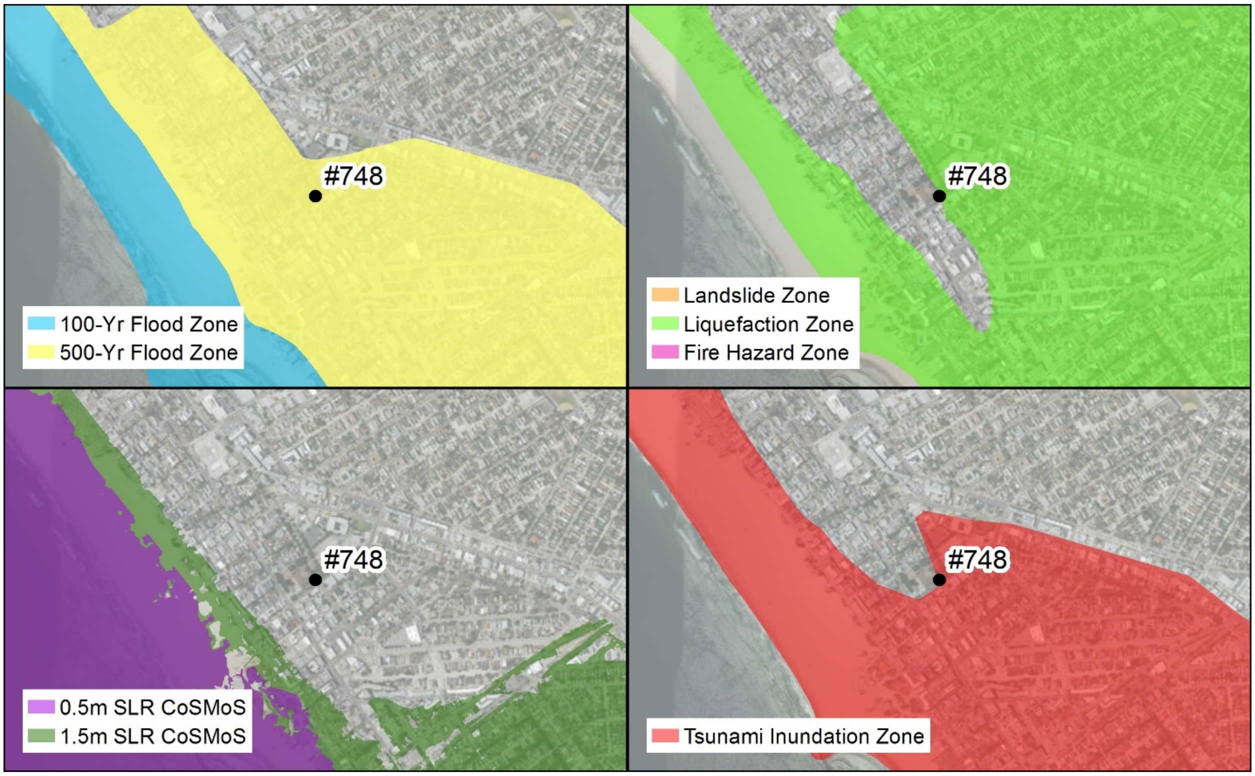


Figure 12. Hazard Zones for Westminster Dog Park Pumping Plant No. 748

Hyperion Water Reclamation Plant

Facility Location and Description

Hyperion Water Reclamation Plant (HWRP) is located along the Pacific coast on Vista Del Mar and began operation in 1894. It is the City of Los Angeles's oldest and largest wastewater treatment and water reclamation facility. The facility is designed to treat a peak wet weather flow of 800 mgd and a dry weather capacity of 450 mgd. The facility has a 1-mile outfall and a 5-mile outfall used to discharge the treated effluent. Both Los Angeles-Glendale Water Reclamation Plant and the Donald C. Tillman Water Reclamation Plant have the ability to bypass flow to HWRP, however HWRP does not have a bypass system.

Power is supplied to the HWRP via two independent power feeds. One feed is from the Scattergood Generating Station operated by the Los Angeles Department of Water and Power (LADWP) on the south side of the HWRP. An emergency generator and fuel source is available to only power four of the pumps at the Intermediate Pump Station in case of a power outage. Individual uninterruptible power supplies are distributed throughout the facility for instrumentation and controls. Full operations could not be sustained should a power failure occur. The overall total replacement value of the HWRP has been estimated to be $3 Billion (Grifman et al, 2013). Impacts to individual pieces of equipment would cost significantly less than the loss of the entire facility for a given catastrophic event.

Facility Hazards

HWRP is located along the coast and near several different hazard areas as shown in Figure 1.

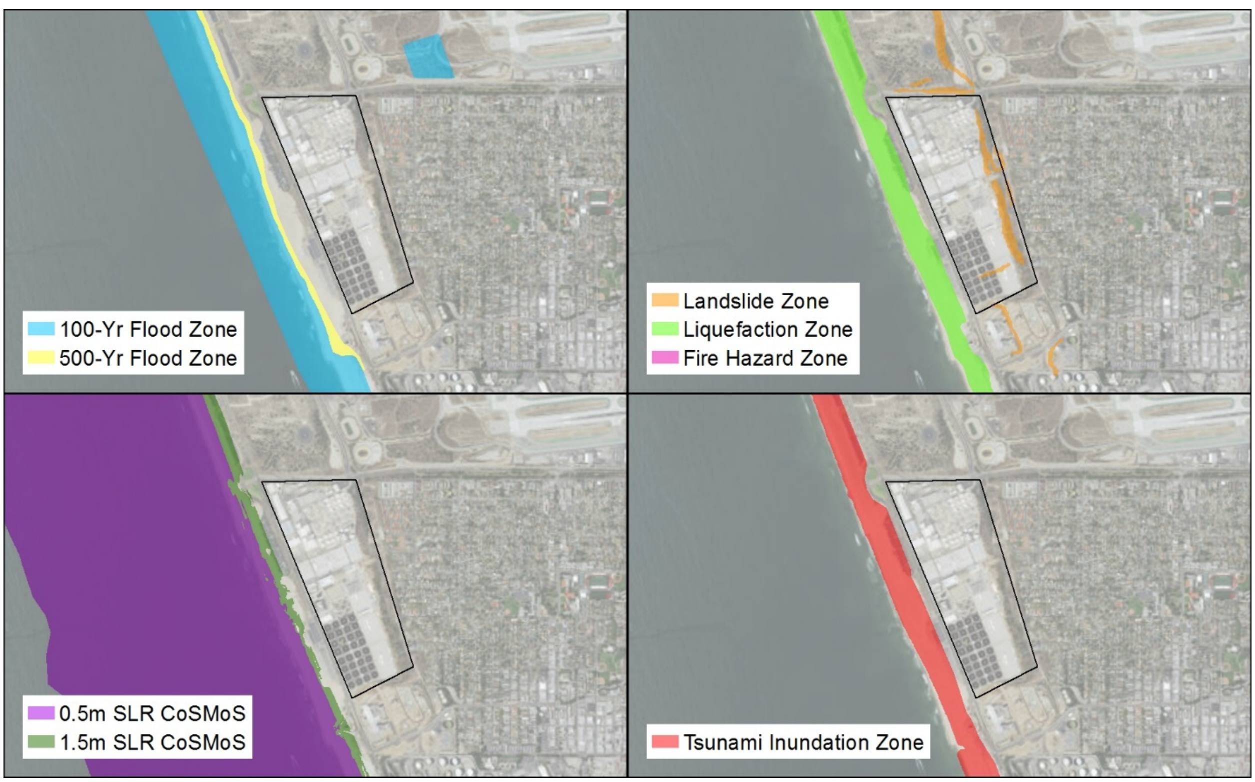


Figure 1. Hazard Zones for HWRP

Two bayside FEMA flood hazard zones meet at the HWRP. The FEMA base flood elevation (BFE) for the 100-year flood is 13 feet to 15 feet NAVD88 at the HWRP. The 500-year BFE is not calculated by FEMA but is estimated to be 16.25 to 18.75 feet NAVD88 using their suggested rule-of-thumb of multiplying the 100-year flood elevation by 1.25. The HWRP is also adjacent to but not in a tsunami zone that may have wave heights of 20 feet. Vista Del Mar, the coastal road between the HWRP and the Pacific Ocean, is at elevations ranging from 39 feet to 47 feet NAVD88. This roadway elevation provides protection against these coastal flooding hazards. Although effluent pumping assures discharge during higher tidal and coastal storm conditions, the 1- and 5-mile ocean outfalls may be susceptible to hydraulic forces during a tsunami – the outfall is inspected regularly for operational and structural integrity.

The high eastern slope at the HWRP is a landslide hazard zone that may erode during extreme wet weather or seismic events and/or may be made unstable by a seismic event. An existing retaining wall along the foot of the slope protects most assets during a landslide event. There is approximately 1,100 feet of the slope without a wall and some assets may be damaged and facility roadways may be blocked should a slide occur. A damage cost due to a landslide could total $5,000,000.

Saltwater intrusion of influent flows at the HWRP is a growing concern having observed rising influent total dissolved solids (TDS) concentrations. Observed TDS concentrations are currently below thresholds that would be problematic for water reuse. Influent TDS monitoring is ongoing.

Resilience Improvements

The FEMA FIRM map indicates the BFE for the 100-year flood at the coast is 13 feet to 15 feet NAVD88. Table 1 shows DFEs recommended based on the BFE for resilience improvements.

Table 1. HRWP Design Flood Elevations

Damage Threshold Elevation	**Short Term**	**Medium Term**	**Long Term**		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
39 ft	NA	NA	20.75	21.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 feet Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 feet Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 feet Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 feet Freeboard
[f] Tsunami DFE = 20 feet estimated tsunami wave height

Project development is underway with LADWP to provide full backup power to the facility to eliminate this risk. Capital and non-capital facility planning recommendations for the HWRP for resilience improvement considerations are as follows:

- Enhance slope stabilization and lengthen existing retaining wall approximately 1,100 feet to complete wall along eastern edge of facility - $600,000 conceptual construction cost.
- Perform a structural analysis of Vista Del Mar with Los Angeles County to determine structural stability of roadway during future flood and seismic/tsunami conditions.
- Evaluate tsunami impacts to HWRP hydraulics including tsunami magnitude needed to damage outfalls or hydraulically block effluent discharge.
- Monitor influent TDS and consider performing a cost benefit analysis of lining pipes versus treatment to mitigate higher influent TDS concentrations for reuse purposes.

For planning purposes the estimated cost of the recommended resilience improvements is $600,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for HWRP. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the HWRP

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Consequences
Without Improvements	Low	Medium	Low	Low	$5,000,000
With Improvements	Low	Low	Low	Low	$600,000

References:

Grifman, P. M., J. F. Hart, J. Ladwig, A. G. Newton Mann, M. Schulhof. 2013. Sea Level Rise Vulnerability Study for the City of Los Angeles. USCSG-TR-05-2013.

-This Page Left Blank Intentionally-

Donald C. Tillman Water Reclamation Plant

Facility Location and Description

The Donald C. Tillman Water Reclamation plant (LAGWRP) is located at 6100 Woodley Avenue in Van Nuys and began operation in 1985 to treat wastewater flows from Chatsworth and Van Nuys in the San Fernando Valley. The original facility was designed to treat 40 mgd but was later expanded to 80 mgd in 1991. Effluent from DCTWRP is discharged at different points to the Los Angeles River.

Power is supplied to the DCTWRP via two power feeds. Backup power is provided only for the headworks with 12-hours of onsite fuel. Full operations are not possible should a power failure occur. Individual uninterruptible power supplies are distributed throughout the facility for instrumentation and controls. In case of an emergency, the DCTWRP can bypass to the HWRP. Process recovery for full secondary treatment however would take approximately two weeks or longer if all processes were shut down and biomass is lost. Los Angeles Sanitation estimated in December 2015 that the cost of flooding the DCTWRP is $52,345,275 for the equipment generally below 716.72 feet NGVD29 (719.32 feet NAVD88), which is the top of wall elevation for the primary tanks (Arcadis, 2016).

Facility Hazards

DCTWRP is located in the Sepulveda Flood Control Basin administered by the USACE. The facility is between Haskell Canyon creek to the east, Woodley Creek to the west and the Los Angeles River to the south that each contain a 100-year flood within their banks according to the FEMA FIRMs. The DCTWRP is currently in a mapped flood zone but outside a 500-year flood hazard zone with no calculated base flood elevation on the FEMA FIRMs as shown in Figure 1. Earthen berms on the south and east sides, and a floodwall on the west side protect the facility from flooding for a 100-year flooding event with a base flood elevation (BFE) of 712.0 feet NGVD29 (714.6 feet NAVD88) plus freeboard. The 200- and 500-year flood elevations calculated by the USACE are 713.5 feet NGVD29 (716.1 feet NAVD88) and 714.6 feet NGVD29 (717.2 feet NAVD88), respectively. The facility is within a liquefaction zone however the surrounding flat terrain presents minimal risk of landslides/mudslides caused by current or future rainfalls.

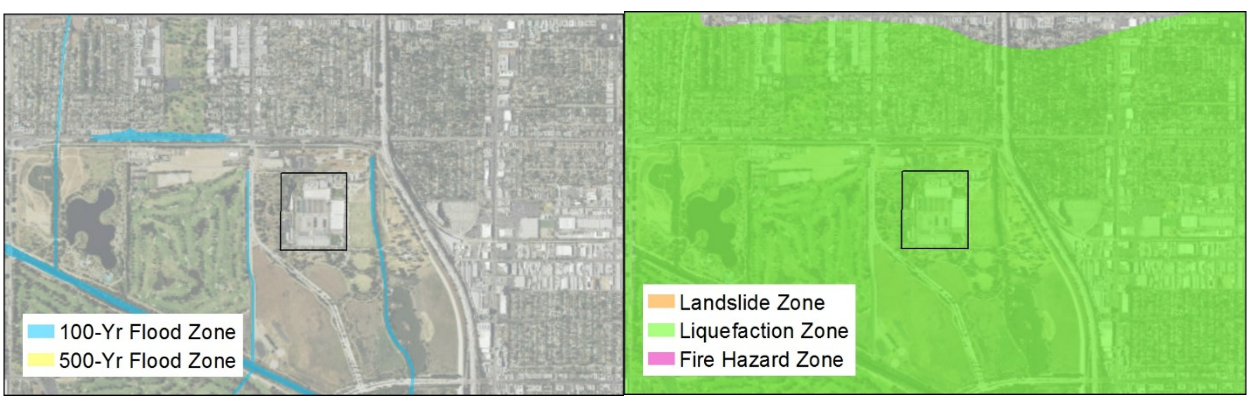


Figure 1. Hazard Zones for DCTWRP

Resilience Improvements

The USACE informed LASAN in 2014 that it requires the flood protection be raised to a Standard Project Flood elevation of 713.5 feet NGVD29 (716.1 feet NAVD88) plus 2.7 feet of freeboard. The design flood elevation would be 716.2 feet NGVD29 (718.8 feet NAVD88). Raising protective berms and improving structures and gates will be required. The implementation of the flood mitigation improvements are a short-term priority as per the USACE agreements. Capital Improvement Project (CIP) #6145, Backup Power, will provide emergency backup power for the critical load so DCTWRP will not violate its National Pollutant Discharge Elimination System (NPDES) permit in case the existing power feeders are lost for a CIP cost of $7,712,900. This ongoing project is scheduled to be completed in 2018/2019 and will also remove the existing emergency backup generator and underground tank.

The overall current climate hazards risk assessment for the DCTWRP is low with implementation of the flood protection and power improvements. Capital facility planning recommendations with conceptual construction costs for the HWRP for resilience improvement considerations are as follows:

- Add backup power generation for the critical load - $7,712,900
- Raise protective berms and add structures and gates - $4,500,000

Note: Project construction costs were provided by LASAN.

CREAT Assessment

Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 1 summarizes the results of CREAT for DCTWRP. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 1. CREAT Results for Climate Change Impacts to the DCTWRP

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Consequences
Without Improvements	Low	Very High	Very High	Very High	$52,345,275
With Improvements	Low	Low	Low	Low	$12,212,900

References

Arcadis, 2016. *Risk Assessment of Vegetation, Flood Risk Reduction System, Donald C. Tillman Water Reclamation Plant*. Prepared by Arcadis for the Los Angeles Department of Public Works, Bureau of Sanitation. March 2016.

Los Angeles-Glendale Water Reclamation Plant

Facility Location and Description

The Los Angeles-Glendale Water Reclamation plant (LAGWRP) began operation in 1976 as the first water reclamation plant in the City of Los Angeles and is co-owned by the City of Glendale. The facility is located at 4600 Colorado Boulevard in Los Angeles along the Los Angeles River. The plant has a capacity of 80 mgd and serves the east San Fernando Valley. Processes include tertiary treatment, disinfection, dechlorination, and nitrification/denitrification.

Power is supplied to the LAGWRP via two power feeds. A backup generator powers the influent pumping plant and one aeration blower only. Individual uninterruptible power supplies are distributed throughout the facility for instrumentation and controls. Full operations are not possible should a power failure occur. In case of an emergency, the LAGWRP can bypass to the HWRP. Biomass can be maintained with one blower for the aeration system in operation at low level but not for an extended period. Process recovery for full secondary treatment however would take approximately two weeks or longer if all processes were shut down and biomass is lost.

Facility Hazards

The LAGWRP is located within two different hazard zones. The facility is adjacent to the Los Angeles River. The LAGWRP is currently in a FEMA flood hazard Zone X but is outside the 500-year floodplain (FEMA FIRM number 06037C1345F, September 28, 2008). The facility is within a liquefaction zone however the surrounding flat terrain presents minimal risk of landslides/mudslides caused by current or future rainfalls.

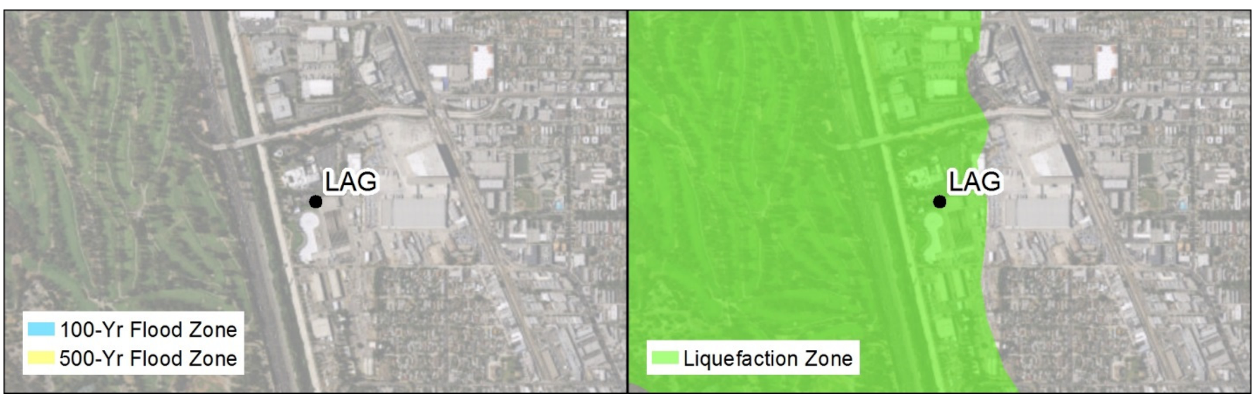


Figure 1. Hazard Zones for LAGWRP

An engineered riverbank along the Los Angeles River protects the LAGWRP from high river stages. However, the main effluent outfall to the Los Angeles River through the engineered riverbank does not have gates to prevent backflow from the river into the outfall at elevated river stages. The dechlorination effluent weir is at a high elevation such that processes are protected from backflow from the Los Angeles River. However, there is an open grate on the outfall between dechlorination and the engineered riverbank such that the river will flood the facility at river stages higher than the grate elevation. A backflow preventer on the outfall, i.e. a flap or duck-bill gate, would prevent river water from backing up and flooding the facility at the grate, but effluent would then overflow the open grate when the river elevation exceeds the effluent hydraulic grade line. Ceasing treatment processes, sealing the grate, extending the outfall through the grate chamber or other alternatives would be necessary to further prevent flooding.

A recent floodplain analysis by the USACE shows the facility will be flooded during 100- and 500-year flood events by the Los Angeles River as shown in Figure 2. Calculated inundation pathways are overland along the north side of the LAGWRP and over the levee along the west side of the LAGWRP. Four-foot high temporary barriers were positioned by the USACE along the levee in December 2015 but they are not intended as permanent protection and would not protect the facility for the 100- and 500-year events. Entrances to below-grade pipe galleries, pump rooms, and control rooms are protected by submarine doors. However, the USACE calculations are for three to five feet of water above grade in the facility for the 100-year event and five to ten feet of water above grade for the 500-year event. These depths may be higher in the future with climate change affecting future rainfalls and river flooding conditions. Subgrade structures may be protected by the existing submarine doors. The existing administration building, motor control centers and pumps, instrumentation and controls and other electrical and mechanical systems above grade are vulnerable to being damaged or destroyed by flooding.

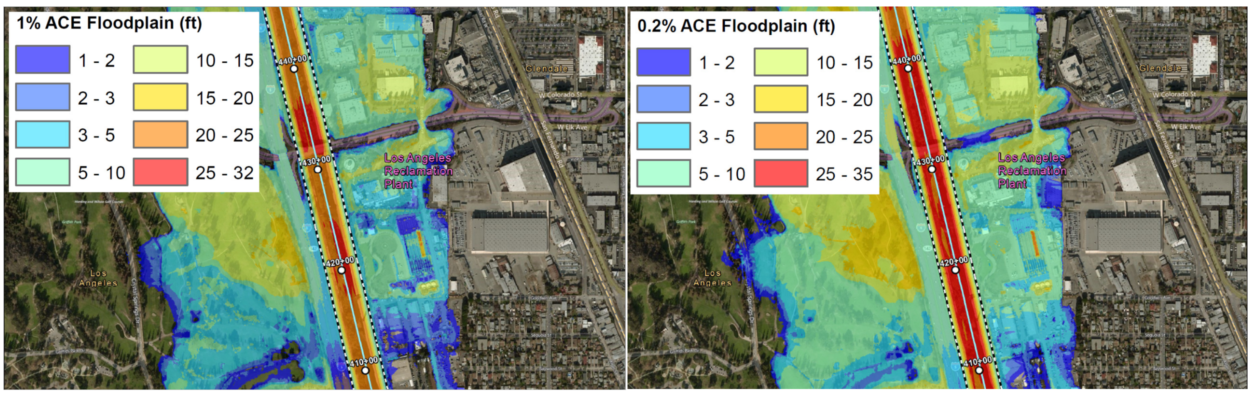


Figure 2. 100-year (left) and 500-year (right) Flood Hazard Zones for LAGWRP
Source: USACE, 2016. Modified by CH2M, 2016.

The overall current climate hazards risk assessment for the LAGWRP is very high due to the flood hazard and backup power deficiency. Therefore, LAGWRP is considered a short-term priority.

Resilience Improvements

The planned improvements at LAGWRP include administrative building renovation and a new 5 million gallon storage basin for onsite storage.

The USACE floodplain calculations show that the levee upstream and downstream of Colorado Boulevard is overtopped by three to four feet during a 100-year event. The top of the Los Angeles River channel at this location has an elevation of approximately 430 feet (NAVD88). Ground elevations around the facility range from 425 to 430 feet. Flooding depths on plant grounds could range from three to five feet in a 100-year event and would likely flood all below-ground galleries if submarine doors are not closed. Table 1 provides estimated DFEs. However, more in-depth flood modeling of the facility and design flood elevation evaluations are recommended to develop actual design guidelines.

Table 1. LAGWRP Design Flood Elevations

Damage Threshold Elevation	**Short Term**	**Medium Term**	**Long Term**		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
425	435	NA	438	NA	NA

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 feet Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 feet Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 feet Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 feet Freeboard
[f] Tsunami DFE = 20 feet estimated tsunami wave height

The following short-term resilience improvements are recommended for capital and non-capital facility planning for the LAGWRP as follows:

- Add backup power generation for entire facility - $4,000,000 construction cost.
- Install backflow prevention gates on effluent outfall to the Los Angeles River- $400,000 construction cost. Evaluate further engineering alternatives to resolve additional flooding risks at the outfall grate.
- Construct floodwalls with flood-proof gates and other structural enhancements - $10,000,000 construction cost.
- Evaluate condition of existing submarine doors and include maintenance and regular exercise of doors in the facilities SOP.

For planning purposes the estimated cost of the recommended resilience improvements is $14,400,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for LAGWRP. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the LAGWRP

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Consequences
Without Improvements	Low	Very High	Very High	Very High	$75,000,000
With Improvements	Low	Medium	Low	Medium	$14,400,000

References

U.S. Army Corps of Engineers (USACE), 2016. *Floodplain Analysis, Los Angeles River: Barham Boulevard to First Street, Flood Plain Management Services Special Study, Los Angeles, California*. U.S. Army Corps of Engineers, Los Angeles District, Engineering Division, Hydrology and Hydraulics Branch, Los Angeles, CA. October 2016.

-This Page Left Blank Intentionally-

Terminal Island Water Reclamation Plant

Facility Location and Description

Terminal Island Water Reclamation Plant (TIWRP) was constructed in 1935 and is located at 445 Ferry Street in Sap Pedro at the Port of Los Angeles. The facility produces tertiary treated water for discharge as well as recycled water through its Advanced Water Purification Facility (AWPF) with microfiltration and reverse osmosis that is being expanded. TIWRP is designed to treat an average dry weather flow of 30 mgd and a peak wet weather flow of 55 mgd. The service area of the TIWRP includes San Pedro, Harbor City, and Wilmington. TIWRP services approximately 140,000 customers, with about 35% of the flow from industrial customers.

An electrical substation is located at the TIWRP and is fed with two separate feed lines with switchgear that facilitates a power feed from one line at a time. There are two large diesel backup generators for the facility that are located at the Effluent Pumping Plant (EPP) and in the Filter Area. The EPP generators have a 1,500 kW capacity with a 23-hour run time before needing to refuel its 9,800 gallon tank. The Filter Area generators have a 500 kW capacity with a 25-hour run time before needing to refuel its 400 gallon tank. These generators do not power the entire facility, but do power the following processes and mechanical equipment: 2# Filter Influent Pump (150 hp), Filter Backwash Air Blower (250 hp), Filter Backwash Pump (125 hp), In-plant Lift Station Pump (40 hp), Grit Collector (5 hp), Bar Screen (2 hp), Compressor (20 hp), Filter Backwash Air Blower (tripped), Filter Backwash Pump (tripped), Aeration Tank Blower (1,500 hp), EPP Pump (tripped), Return Activated Sludge Pump (200 hp) and the Filter Influent Pump (150 hp). Individual uninterruptible power supplies are distributed throughout the facility for instrumentation and controls.

Facility Hazards

TIWRP is located within liquefaction, flood zones with sea level rise, and tsunami zones as shown in Figure 1.

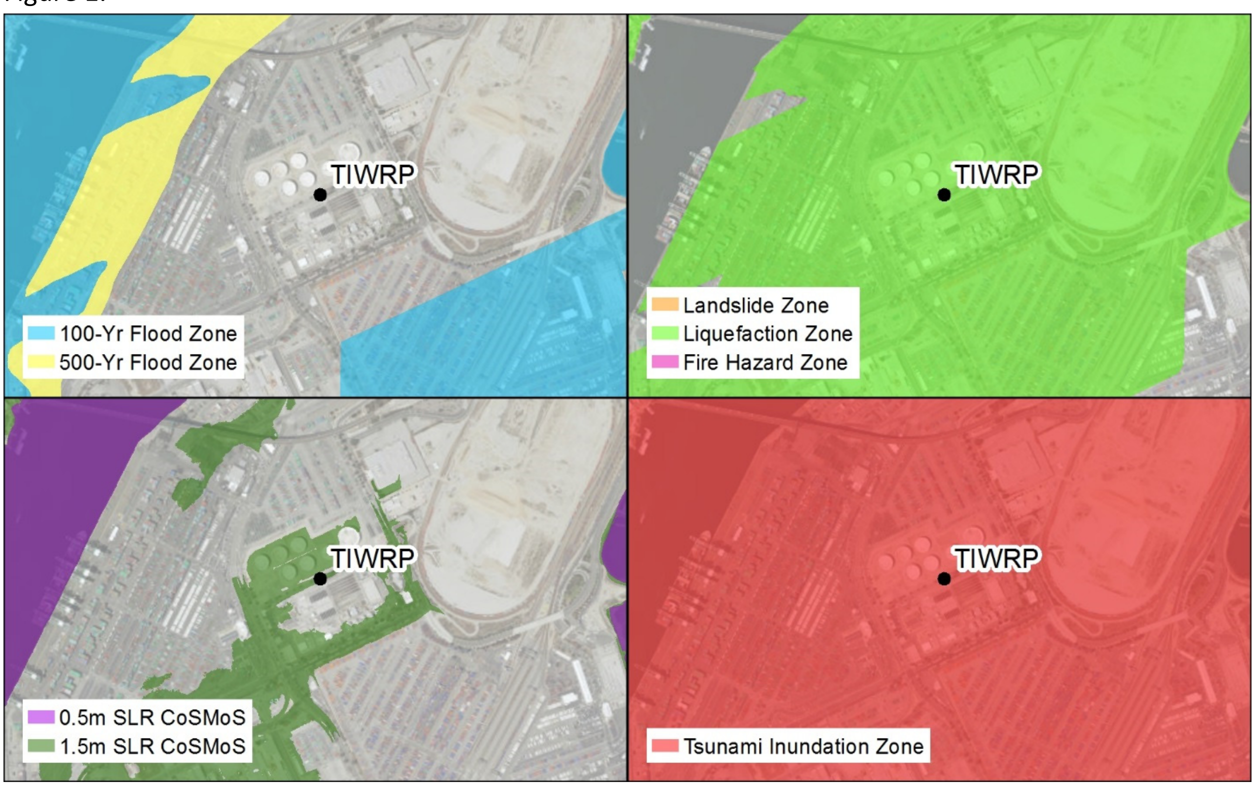


Figure 1. Hazard Zones for TIWRP

The facility is in a liquefaction zone but the terrain is flat and there are no current or future risks of landslides due to current or future rainfalls. The facility is in a FEMA flood hazard Zone X with a BFE of 9 feet (NAVD88). The average ground elevation on the property is 10 feet NAVD88, just above the BFE for the 100-year flood event. The TIWRP is expected to become inundated during the CoSMoS 100-year flood with 1.5 meters of sea level rise, and tsunami conditions. The headworks building and lift station, MCCs throughout the facility, AWPF and the effluent pumping plant are some of the facility assets at ground level. The combined replace-in-kind cost estimate for these assets should they be flooded is $52,800,000. This estimated cost does not represent the likely full value of replace-in-kind costs for the entire existing facility in a flooding event, which would likely exceed $100,000,000. In addition, the TIWRP AWPF expansion is valued at over $50,000,000, which will also be at risk to a flooding event. A likely damage cost for the entire facility could exceed $150,000,000.

Below-grade pipe galleries, pump rooms, and control rooms are unprotected for flooding. Administration buildings, MCCs and pumps, instrumentation and controls and other electrical and mechanical systems above grade throughout the facility are vulnerable to being damaged by flooding. Elevating and/or waterproofing individual assets or constructing a flood barrier system around the TIWRP would be required to protect the facility from flooding for a 500-year flood, a 100-year flood with sea level rise, or a tsunami.

Increased temperatures and extreme events may cause more frequent power interruptions at the TIWRP. Backup power generators at the Effluent Pumping Plant (EPP) and in the Filter Area do not power the entire facility. Backup generators are included for the expansion of the Advanced Water Purification Facility (AWPF) but only to power the AWPF. Additional backup power generators will be needed for the entire facility to provide emergency backup power for the critical load so TIWRP will not violate its National Pollutant Discharge Elimination System (NPDES) permit in case the existing power feeders are lost.

TIWRP is considered a medium priority due to the flood hazard and backup power deficiency.

Resilience Improvements

The existing CIP plan list several projects at TIWRP including energy efficiency improvements, expansion of the AWPF, and additional emergency generators for the AWPF. Additional backup power generation will be needed to provide emergency backup power for the critical load. Constructing floodwalls using the existing perimeter walls as a base, adding flood-proof gates and other structural enhancements to protect the entire facility for flooding. Table 1 shows the recommended DFEs to be considered for future flood resilience improvements at the TIWRP.

Table 1. TIWRP Design Flood Elevations

Damage Threshold Elevation	**Short Term**	**Medium Term**	**Long Term**		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
10.00	11.00	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88

[b] 100-yr Flood DFE = BFE + 2 feet Freeboard

[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 feet Freeboard

[d] 500-yr DFE = BFE*1.25 + 2 feet Freeboard

[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 feet Freeboard

[f] Tsunami DFE = 20 feet estimated tsunami wave height

Capital facility planning recommendations with conceptual construction costs for the TIWRP for resilience improvement considerations are as follows:

- Add backup power generation for the facility - $4,000,000.
- Construct flood walls and add structures and gates - $10,000,000.

CREAT Assessment

Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for TIWRP. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the TIWRP

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Consequences
Without Improvements	Very High	Very High	Very High	Very High	>$150,000,000
With Improvements	Low	Medium	Low	Medium	$14,000,000

-This Page Left Blank Intentionally-

Riverdale Pumping Plant No. 611

Facility Location and Description

The Riverdale Pumping Plant No. 611 was constructed in 1966 and is located at 2401 Riverdale Avenue in Los Angeles in front of the Jardin del Rio Community Garden. Although this is considered a wastewater pumping plant it is a bladder used when the North Outfall Sewer (NOS) is surcharged to prevent overflows into the surrounding neighborhood. The station is actually a storage and pump-out station. A tank truck is used to empty the bladder after large rain events.

Instruments, electrical components and controls are located in an at grade cabinet. There are no pumps. There is no bypass or backup generator at the facility. The replace-in-kind cost estimate for damaged instrumentation and controls is $21,600 for the Riverdale Pumping Plant No. 611 based on the equivalent pumping capacity including markups and contingencies.

Facility Hazards

The Riverdale Pumping Plant No. 611 is located within several different hazard zones. Figure 1 shows the facility is located outside fire and landslides hazard zones and within the liquefaction zone. Therefore, there is no risk of landslides during a seismic event caused by extreme rainfall events. Since the pumping plant is located inland, there are no coastal SLR or tsunami risks.

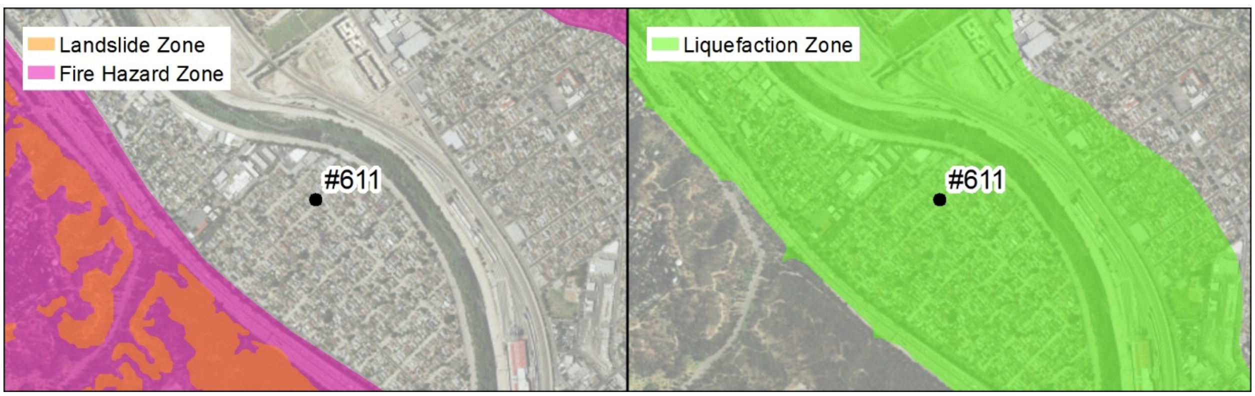


Figure 1. Non-Flood Hazard Zones for Riverdale Pumping Plant No. 611

Although the facility is adjacent to the Los Angeles River in a FEMA flood hazard Zone X, the current FEMA FIRM shows flooding is contained within the Los Angeles River (FEMA FIRM number 06037C1628F, September 26, 2008). However, a recent study by USACE shows the pumping plant will be inundated during the 100-year and 500-year flood events as shown in Figure 2 (USACE, 2016). Therefore, the Riverdale Pumping Plant No. 611 has a short term risk.

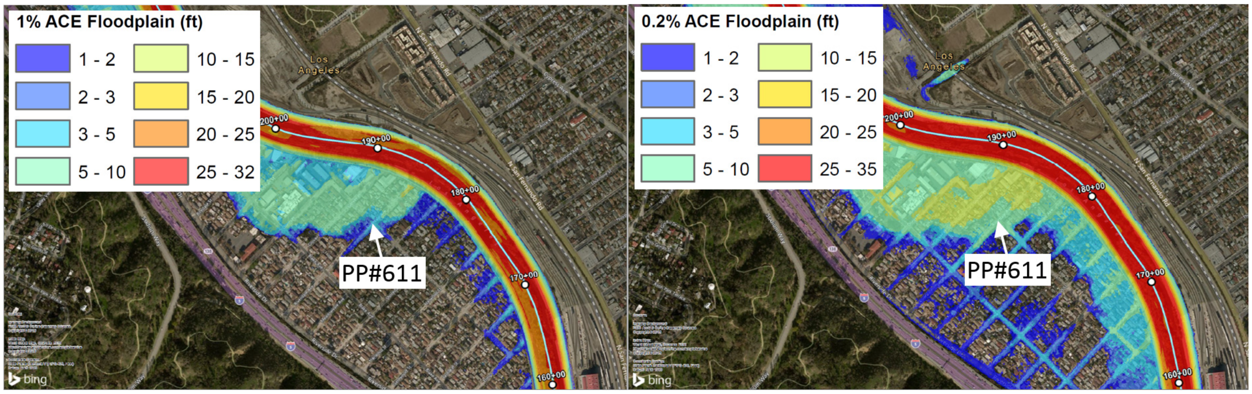


Figure 2. 100-year (left) and 500-year (right) Flood Hazard Zones for Riverdale Pumping Plant No. 611
Source: USACE, 2016. Modified by CH2M, 2016.

Resilience Improvements

The Riverdale Pumping Plant No. 611 has been identified to have short-term flood risks. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Since the facility only operates when the NOS is surcharging and the facility will likely be completely inundated during a flooding event, it is recommended to waterproof the facility for protection until flood waters subside. The following resilience improvements are recommended:

- Waterproof instrumentation and controls - $50,000

The recommended resilience improvements cost is $50,000. This exceeds the estimated damage replacement cost by more than a factor of two. Therefore, no improvement is recommended at this time. Appendix D provides more detail on the replace-in-kind and resilience improvements cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows in the residential area and to the Los Angeles River. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 1 summarizes the results of CREAT for the Riverdale Pumping Plant No. 611. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 1. CREAT Results for Climate Change Impacts to the Riverdale Pumping Plant No. 611

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Low	Medium	Medium	Medium	$21,600
With Improvements	Low	Low	Low	Low	$50,000

Roscomare Pumping Plant No. 624

Facility Location and Description

The Roscomare Pumping Plant No. 624 was constructed in 1960 and is located at 2458 Nalin Drive in Los Angeles near Stone Canyon Reservoir. The facility is a fill and drain type wastewater pump station with a capacity of 500 gpm with two pumps rated for 416 gpm. Instruments, electrical components, and controls are located in cabinets at and below grade. There is a 100 kW portable backup generator located onsite. The replace-in-kind cost estimate is $1,000,000 for the Roscomare Pumping Plant No. 624 based on the pumping capacity including markups and contingencies.

Facility Hazards

Roscomare Pumping Plant No. 624 is located inland and does not have the coastal SLR or tsunami hazards but is within several different non-flood hazard zones. Figure 1 shows the facility is near the Stone Canyon Reservoir but well outside of the existing flood zone. The pump station does have fire and landslide hazards due to the vegetated open hillsides. Therefore, the Roscomare Pumping Plant No. 624 is considered a short-term priority.

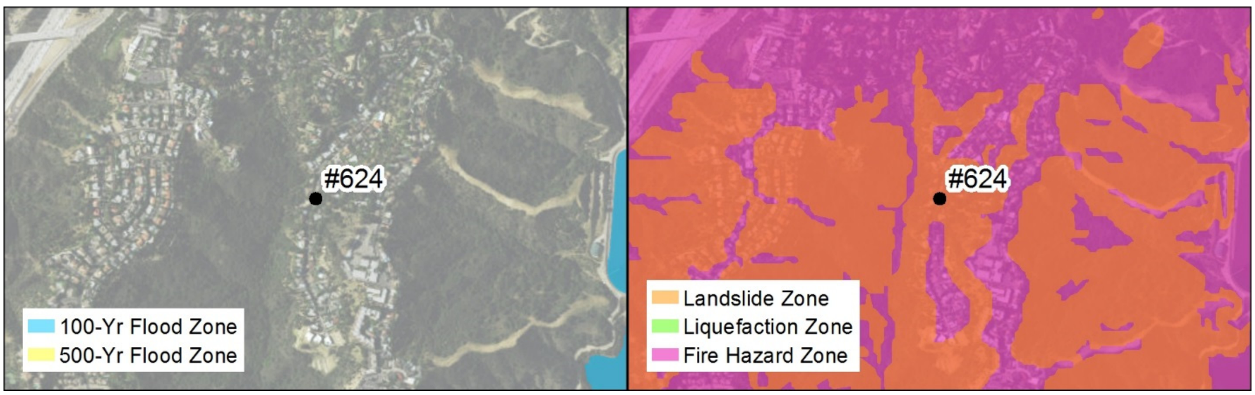


Figure 1. Hazard Zones for Roscomare Pumping Plant No. 624

Resilience Improvements

Roscomare Pumping Plant No. 624 has short-term fire and landslide hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. The existing facility has a small retaining wall to hold back the existing slope but does not provide protection from landslides or debris. The following resilience improvements are recommended:

- Increase height of existing retaining wall behind facility
- Manage nearby vegetation to minimize fire risk

For planning purposes the estimated cost of the recommended resilience improvements is $20,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to the residential area and Ballona Creek. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 1 summarizes the results of CREAT for the Roscomare Pumping Plant No. 624. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 1. CREAT Results for Climate Change Impacts to the Roscomare Pumping Plant No. 624

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Medium	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$20,000

Corbin Pumping Plant No. 628

Facility Location and Description

Corbin Pumping Plant No. 628 was constructed in 1977 and is located at 3934 Corbin Avenue in Tarzana. The facility is a fill and draw type wastewater pump station used to serve the surrounding neighborhood. The pump station does not have a bypass system.

The pump station has a capacity of 400 gpm with two pumps each rated for 200 gpm. Instruments, electrical components, and controls are located in at grade cabinets. The facility has a 60 kW portable backup generator available offsite. The replace-in-kind cost estimate is $1,000,000 for the Corbin Pumping Plant No. 628 based on the pumping capacity including markups and contingencies.

Facility Hazards

Corbin Pumping Plant No. 628 is located in an inland, hilly area and does not have flood, coastal SLR, or tsunami hazards but is within several different non-flood hazard zones. Figure 1 shows the pump station does have fire and landslide hazards due to the vegetated open hillsides. Therefore, this facility is considered a short-term priority.

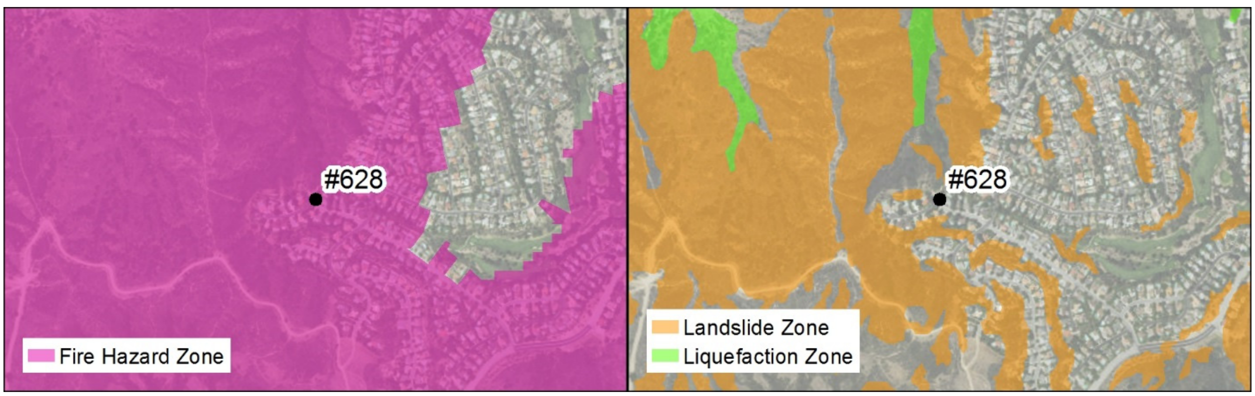


Figure 1. Hazard Zones for Corbin Pumping Plant No. 628

Resilience Improvements

Corbin Pumping Plant No. 628 has short-term fire and landslide hazards. The facility was last upgraded in 1997. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. The existing facility is not against a slope and a landslide would damage the neighboring properties before reaching the pump station. Therefore, it is recommended to evaluate and mitigate the landslide potential of the neighborhood before constructing a retaining wall around the facility. In addition, following resilience improvements are recommended:

- Manage nearby vegetation to minimize fire risk

Appendix D provides more detail on the replace-in-kind cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant will result in wastewater overflows to the residential area and it is in the Los Angeles River watershed. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 1 summarizes the results of CREAT for the Corbin Pumping Plant No. 628. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 1. CREAT Results for Climate Change Impacts to the Corbin Pumping Plant No. 628

Analysis	**Utility Business Impacts**	**Utility Equipment Damages**	**Source/Receiving Water Impacts**	**Environmental Impacts**	**Overall Cost**
Without Improvements	Medium	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$0

Temescal Pumping Plant No. 634

Facility Location and Description

The Temescal Pumping Plant No. 634 was constructed in 1956 and is located at 15733 Pacific Coast Highway in Pacific Palisades. The facility, a matched flow type wastewater pump station, is one of the 24 pumping plants within the HWRP sewershed.

Temescal Pumping Plant No. 634 has a capacity of 4,500 gpm and equipped with three dry pit submersible pumps, each rated for 3,300 gpm. Instruments, electrical components, and controls are located in above-ground cabinets. The facility does not have a bypass and there is a 150 kW backup generator located onsite. The replace-in-kind cost estimate is $3,159,000 for the Temescal Pumping Plant No. 634 based on the pumping capacity including markups and contingencies.

Facility Hazards

Temescal Pumping Plant No. 634 is located near several different hazard zones. Figure 1 shows the facility is just outside of the coastal inundation zones from flooding, SLR, and tsunami events. The flood damage threshold for the facility is 21.0 feet NAVD88 and it is outside of inundation areas. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone VE with a BFE of 13 feet NAVD88. The facility is within landslide, liquefaction, and fire hazard zones. Previous rainfall events have caused landslides of debris that entered the pump station enclosure from the neighboring hillside. The top of the facility was covered with sand and debris. An existing retaining wall that is cracked and fencing on the hillside provides minimal protection. Continual and more intense rainfall events in the future could make the hillside even more unstable, and could cause it to collapse on the pump station in a landslide. The backup generator would also be susceptible to damage in these scenarios. The pumping station would most likely be damaged and not functional until debris is cleared, assets are repaired, and electrical service and controls are restored. Therefore, the Temescal Pumping Plant No. 634 is considered a short-term priority.

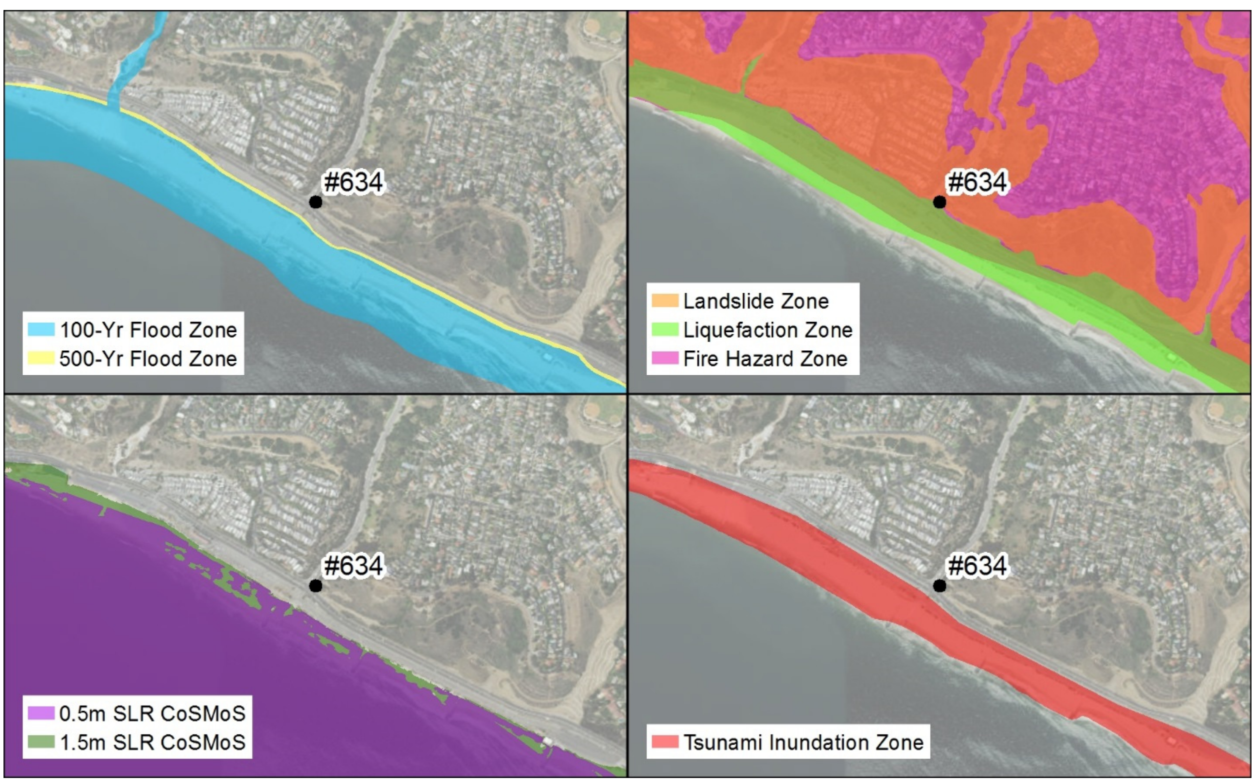


Figure 1. Hazard Zones for Temescal Pumping Plant No. 634

Resilience Improvements

The Temescal Pumping Plant No. 634 is identified as a short-term priority with landslide and fire hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. The following resilience improvements are recommended:

- Construct perimeter wall to prevent landslide debris from entering the facility
- Manage nearby vegetation to minimize fire hazards

For planning purposes the estimated cost of the recommended resilience improvements is $60,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to the neighboring roadway and Santa Monica Bay. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 1 summarizes the results of CREAT for the Temescal Pumping Plant No. 634. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 1. CREAT Results for Climate Change Impacts to the Temescal Pumping Plant No. 634

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	High	Very High	High	High	$3,159,000
With Improvements	Low	Low	Low	Low	$60,000

Palisades Pumping Plant No. 638

Facility Location and Description

The Palisades Pumping Plant No. 638 was constructed in 1977 and is located at 17425 Vereda De La Montura in Pacific Palisades. The facility is a fill and draw type wastewater pump station and was last upgraded in 1998. The pump station does not have a bypass system.

Palisades Pumping Plant No. 638 has a capacity of 600 gpm with two pumps each rated for 300 gpm. Instruments, electrical components and controls are located in an at grade cabinet. The facility has a 100 kW backup generator located onsite. The replace-in-kind cost estimate is $1,000,000 for the Palisades Pumping Plant No. 638 based on the pumping capacity including markups and contingencies.

Facility Hazards

Palisades Pumping Plant No. 638 is located inland and does not have the coastal SLR or tsunami hazards but is within several different non-flood hazard zones. Figure 1 shows the facility is within the fire hazard zone and nearby landslide and liquidation zones. The nearby development and location of the pump station minimizes the potential for landslide. The prominent climate change risk at this location is fire. Therefore, the Palisades Pumping Plant No. 638 is identified as a short-term priority.

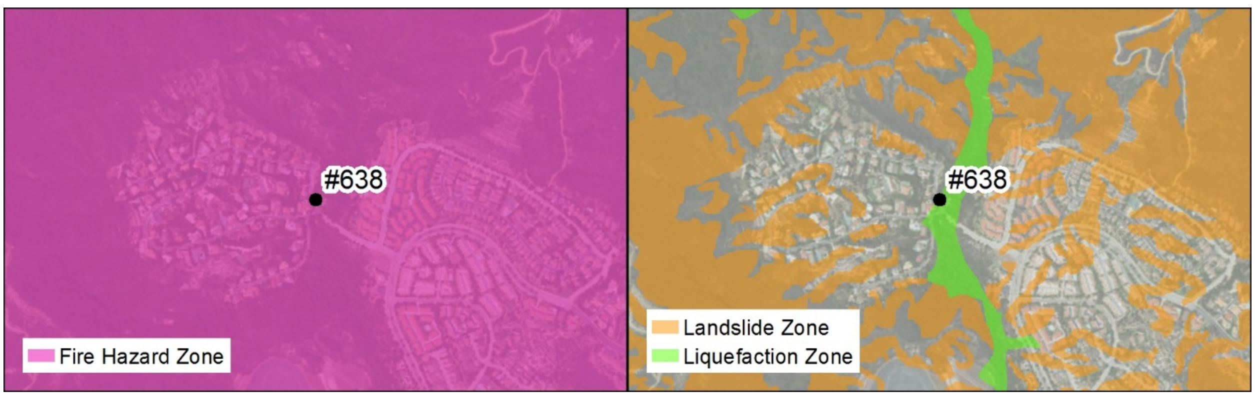


Figure 1. Hazard Zones for Palisades Pumping Plant No. 638

Resilience Improvements

Palisades Pumping Plant No. 638 has short-term fire hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. The following resilience improvement is recommended:

- Manage nearby vegetation to minimize fire risk

Appendix D provides more detail on the replace-in-kind cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to the residential area and Santa Monica Bay. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 1 summarizes the results of CREAT for the Palisades Pumping Plant No. 638. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 1. CREAT Results for Climate Change Impacts to the Palisades Pumping Plant No. 638

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Medium	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$0

North Pulga Pumping Plant No. 639

Facility Location and Description

The North Pulga Pumping Plant No. 639 was constructed in 1989 and is located at 16600 Pacific Coast Highway in Pacific Palisades. The facility is a fill and draw type wastewater pump station serving the surrounding neighborhood. The pump station does not have a bypass system.

North Pulga Pumping Plant No. 639 has a capacity of 3,000 gpm with two submersible pumps each rated for 1,600 gpm. Instruments, electrical components, and controls are located in at grade cabinets. The facility has an 85 kW backup generator located on site. The facility was last upgraded in 2007. The replace-in-kind cost estimate is $2,106,000 for the North Pulga Pumping Plant No. 639 based on the pumping capacity including markups and contingencies.

Facility Hazards

North Pulga Pumping Plant No. 639 is located across from the coastline but is just outside of the flood hazards as shown in Figure 1. The pumping plant is in fire and landslide hazard zones and adjacent to a liquefaction zone. The location is susceptible to landslides during a heavy rain event. The facility has been moved twice and repaired and upgraded in 1980 (D-25144), 1983 (D-27881), 1991 (E-1244), 2000 (D-31507), and 2002 (D-32166), due to landslides covering the facility in mud and debris. The pumping plant electrical, instrumentation and controls, switch gear and backup generator are all above ground and protected only by chain-link fencing. Continual and more intense rainfall events in the future could make the hillside even more unstable, and could cause it to collapse on the pump station in a landslide. The pumping station would most likely be damaged and not functional until electrical service and controls are restored. Therefore, this facility is considered a short-term priority.

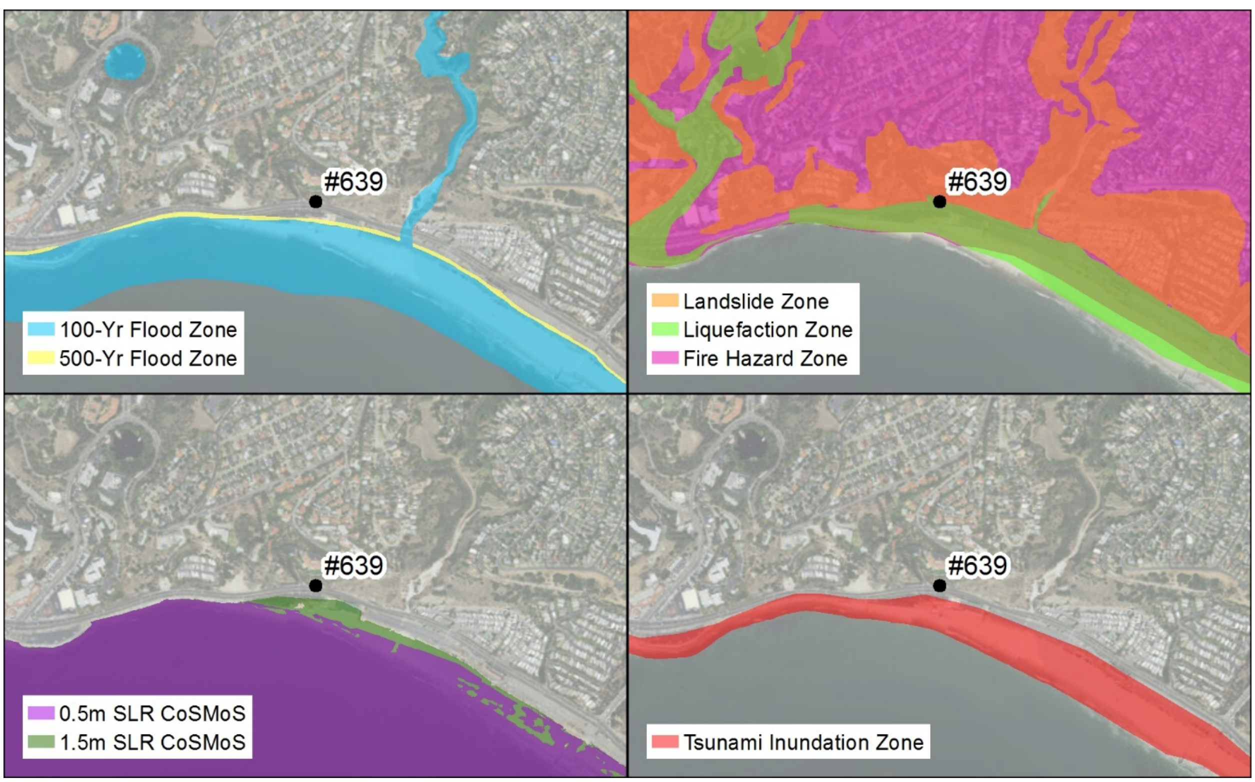


Figure 1. Hazard Zones for North Pulga Pumping Plant No. 639

Resilience Improvements

North Pulga Pumping Plant No. 639 has short-term fire and landslide hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. The following resilience improvements are recommended:

- Construct retaining wall around facility to protect from landslide
- Manage nearby vegetation to minimize fire risk

For planning purposes the estimated cost of the recommended resilience improvements is $60,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to the neighboring highway and Santa Monica Bay. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 1 summarizes the results of CREAT for the North Pulga Pumping Plant No. 639. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 1. CREAT Results for Climate Change Impacts to the North Pulga Pumping Plant No. 639

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	High	Very High	High	High	$2,106,000
With Improvements	Low	Low	Low	Low	$60,000

Venice Pumping Plant No. 646

Facility Location and Description

The Venice Pumping Plant No. 646 was constructed in 1959 and is located at 140 Hurricane Street in Venice along the Grand Canal. The facility, a matched flow type wastewater pump station, is one of the 24 pumping plants within the HWRP sewershed.

Venice Pumping Plant No. 646 is the largest of all pumping plants within the City of Los Angeles with a capacity of 45,000 gpm and equipped with five pumps each rated for 14,000 gpm. Instruments, electrical components, and controls are located below grade in a control room. There are two 750 kW backup generators and one 1.5 MW backup generator within the facility and a 150 kW portable backup generator parked outside. There is no facility bypass or diversions to perform maintenance or emergency repairs. The replace-in-kind cost estimate is $31,590,000 for the Venice Pumping Plant No. 646 based on the pumping capacity including markups and contingencies.

Facility Hazards

Venice Pumping Plant No. 646 is located within or near several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, and tsunami zones and close to the 100-year flood with 0.5 meter and 1.5 meters sea level rise hazard zones. However, development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the double doors with louvers on the southeast side of the building to the VFD room with an elevation of 7.96 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE at the ocean with a BFE of 15 feet NAVD88 and in the harbor with a BFE of 9 feet NAVD88. The facility will become inundated during the 500-year flood and tsunami events. Therefore, the Venice Pumping Plant No. 646 is considered a long-term priority.

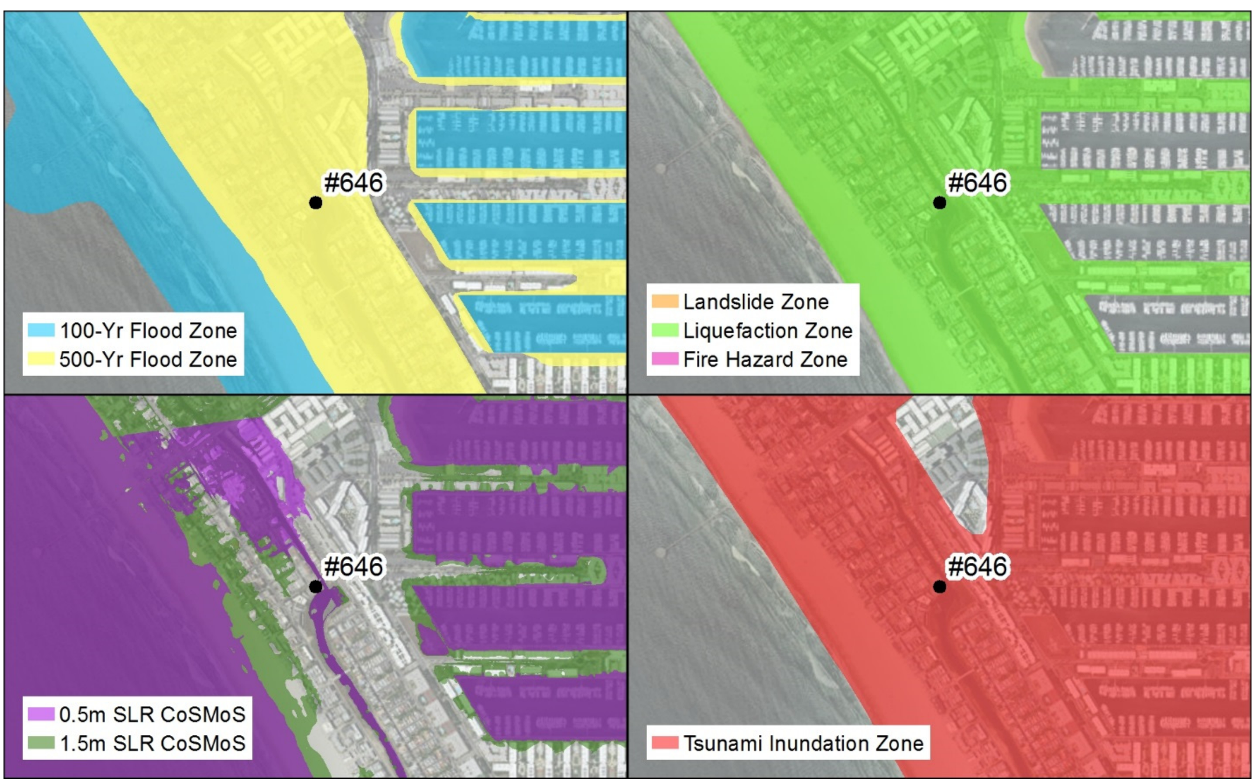


Figure 1. Hazard Zones for Venice Pumping Plant No. 646

Resilience Improvements

The Venice Pumping Plant No. 646 is identified as a long-term priority for flood risks. This facility was last expanded and upgraded in 1987 and is in the existing CIP for generator replacement in 2020 (CIP 722). At the neighboring property the Venice Auxiliary Pumping Plant (CIP C922) is currently under design and is also planned to begin construction in 2020. The purpose of the auxiliary pumping plant is to provide additional reliability and a combined capacity of 87 mgd.

Although the existing flood threshold elevation is below the neighboring 9 feet and 15 feet BFE, the pumping plant is protected from inundation by the outfall gates at the end of the lagoon and surrounding higher ground. However, inundation is expected to occur during the 500-year flood and tsunami events. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Venice Pumping Plant No. 646 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
7.96	17.00	18.64	20.75	21.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Waterproof building
- Install watertight connections
- Move portable generator stored outside the facility to higher ground

For planning purposes the estimated cost of the recommended resilience improvements is $1,600,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to the Grand Canal and Santa Monica Bay. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Venice Pumping Plant No. 646. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Venice Pumping Plant No. 646

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	High	Very High	Very High	Very High	$31,590,000
With Improvements	Low	Low	Low	Low	$1,600,000

Thompson Pumping Plant No. 648

Facility Location and Description

The Thompson Pumping Plant No. 648 was constructed in 1958 and is located at 346 Culver Boulevard in Playa Del Rey near the Ballona Wetlands Ecological Reserve. The facility is a fill and draw type wastewater pump station and is one of the 24 pumping plants within the HWRP sewershed.

Thompson Pumping Plant No. 648 has a capacity of 700 gpm and equipped with two pumps each rated for 480 gpm. Instruments, electrical components, and controls are located above ground in an elevated building. The facility does not have a bypass and there is a 125 kW portable backup generator located onsite. The replace-in-kind cost estimate is $1,000,000 for the Thompson Pumping Plant No. 648 based on the pumping capacity including markups and contingencies.

Facility Hazards

Thompson Pumping Plant No. 648 is located within several different hazard zones. Figure 1 the facility is within the liquefaction hazard zone and adjacent to fire, landslide, and 500-year flood and 100-year flood with 1.5 meters sea level rise inundation areas. Development of the area has minimized the potential for landslide, liquefaction, and wildfire.

The flood damage threshold for the facility is the control room doorway at an elevation of 12.39 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE and VE with a BFE of 9 feet in the marina and 14 feet NAVD88 along the coast. The facility will be inundated during the 500-year flood and tsunami events. Therefore, the Thompson Pumping Plant No. 648 is considered a long-term priority.

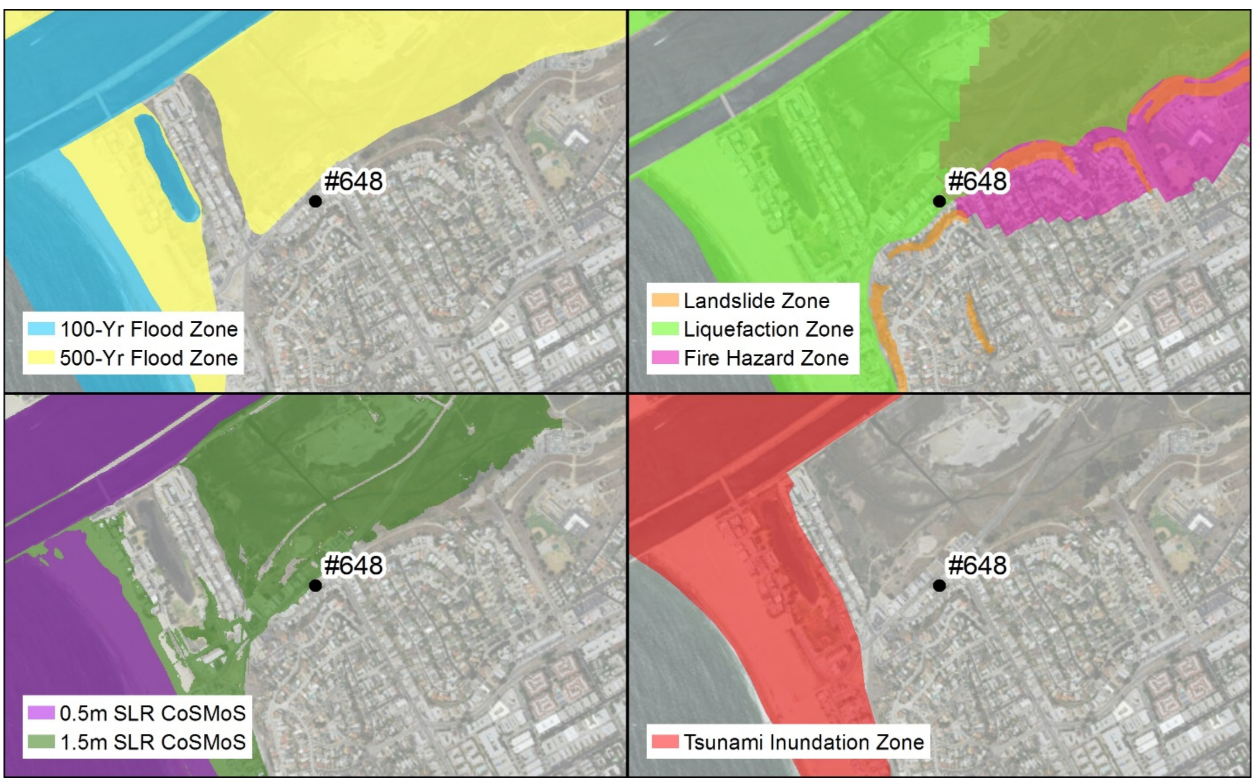


Figure 1. Hazard Zones for Thompson Pumping Plant No. 648

Resilience Improvements

The Thompson Pumping Plant No. 648 is identified as a long-term priority with flood hazards. The facility was last upgraded in 2000 and is currently listed in the CIP for generator replacement scheduled for August 2018 (CIP 7243). A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Thompson Pumping Plant No. 648 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
12.39	16.00	17.64	19.50	20.92	20.92

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections
- Waterproof instrumentation and controls
- Waterproof building
- Waterproof hatches
- Raise the portable generator to a higher elevation

For planning purposes the estimated cost of the recommended resilience improvements is $480,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to the neighboring businesses, wetlands, Ballona Creek, and Santa Monica Bay. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Thompson Pumping Plant No. 648. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Thompson Pumping Plant No. 648

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Medium	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$480,000

Jefferson Pumping Plant No. 649

Facility Location and Description

The Jefferson Pumping Plant No. 649 was constructed in 1948 and is located at 5250 West Jefferson Boulevard in Los Angeles near Baldwin Hills. The facility is a fill and drain type pump station with a 190 gpm capacity and two pumps each rated for 190 gpm. Instruments, electrical components, and controls are located below ground. The facility does not have a backup generator but does have a bypass around the facility. The replace-in-kind cost estimate is $1,000,000 for the Jefferson Pumping Plant No. 649 based on the pumping capacity including markups and contingencies.

Facility Hazards

Jefferson Pumping Plant No. 649 is located near flood hazard zones. Figure 1 shows the facility is close to the 500-year flood zone and within the liquefaction zone. The facility is located inland and does not have coastal SLR and tsunami risks. The damage threshold for the facility is the hatch located at the ground surface. The existing 100-year FEMA FIRM map does not indicate a BFE but the flood extends indicate the facility may be inundated. Therefore, the Jefferson Pumping Plant No. 649 is identified as a long-term priority.

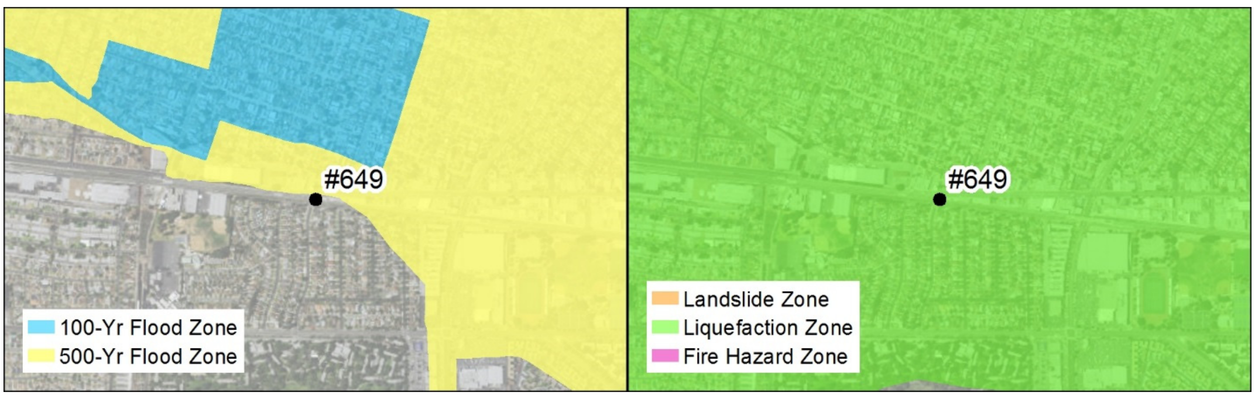


Figure 1. Hazard Zones for Jefferson Pumping Plant No. 649

Resilience Improvements

Jefferson Pumping Plant No. 649 has been identified as a long-term priority for flooding. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Exterior flood protection is recommended including the following:

- Waterproof instrumentation and controls

For planning purposes the estimated cost of the recommended long-term resilience improvements is $80,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to the surrounding area and Ballona Creek. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 1 summarizes the results of CREAT for the Jefferson Pumping Plant No. 649. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 1. CREAT Results for Climate Change Impacts to the Jefferson Pumping Plant No. 649

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Medium	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$80,000

Fries Pumping Plant No. 666

Facility Location and Description

Fries Pumping Plant No. 666 was constructed in 1948 and is located at 647 Fries Avenue in Wilmington near the Port of Los Angeles. The facility, a matched flow type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed. The Fries Pumping Plant No. 666 has a capacity of 7,400 gpm and is equipped with three pumps each rated for 3,750 gpm. Instruments, electrical components, and controls are located above ground in a control room. The facility has a 500 kW backup generator onsite and there is no facility bypass. The replace-in-kind cost estimate is $5,194,800 for the Fries Pumping Plant No. 666 based on the pumping capacity including markups and contingencies.

Facility Hazards

Fries Pumping Plant No. 666 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 0.5 meter and 1.5 meters sea level rise, and tsunami zones. However, development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the south door threshold with an elevation of 11.17 feet NAVD88 and the generator pad at 11.89 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will become partially inundated during the 100-year flood with 0.5 meter sea level rise event. Therefore, the Fries Pumping Plant No. 666 is considered a medium-term priority.

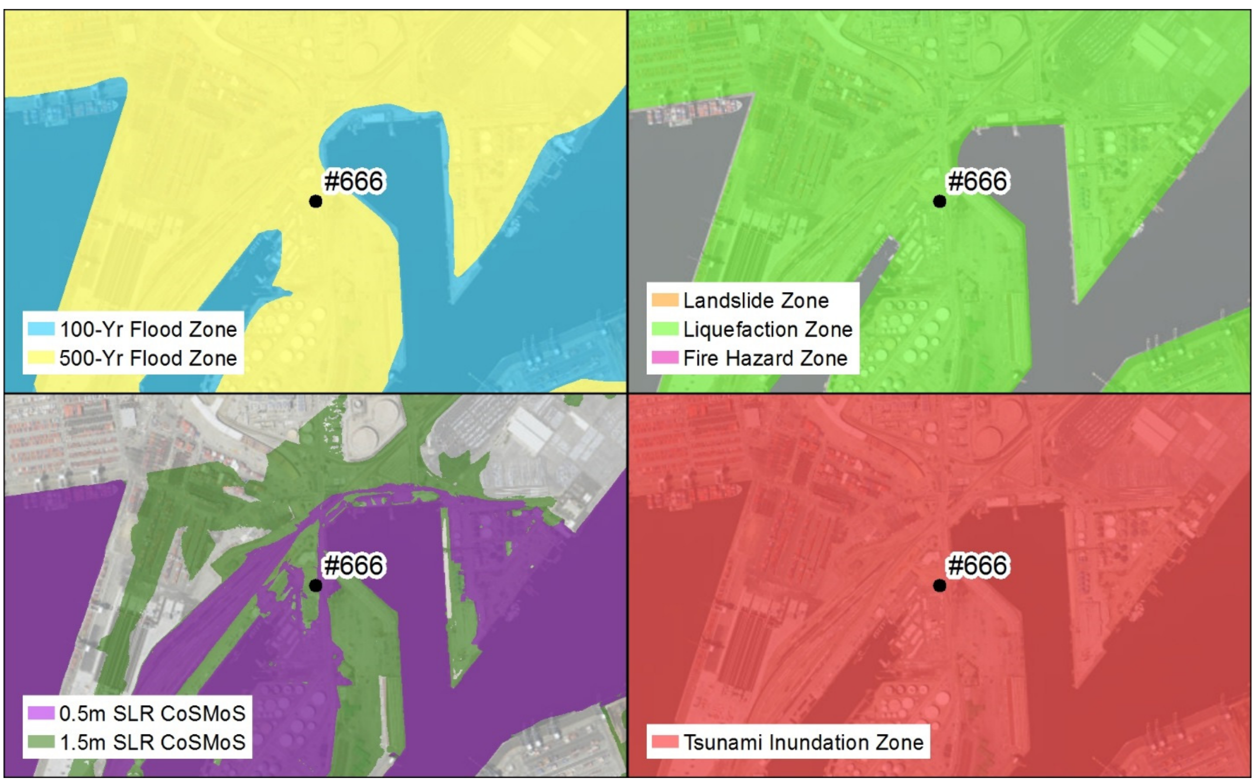


Figure 1. Hazard Zones for Fries Pumping Plant No. 666

Resilience Improvements

The Fries Pumping Plant No. 666 is identified as a medium-term priority with a flood hazard. This facility was last upgraded in 1998 and is in the existing CIP for rehabilitation in 2016 (CIP 7183). A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Fries Pumping Plant No. 666 Design Flood Elevations

Damage Threshold Elevation	**Short Term**	**Medium Term**	**Long Term**		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
11.17	NA	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88

[b] 100-yr Flood DFE = BFE + 2 ft Freeboard

[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard

[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard

[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard

[f] Tsunami DFE = 20 ft estimated tsunami wave height

The historic nature of the building may prohibit exterior modifications therefore the recommended adaptations to not include building waterproofing. The following medium-term resilience improvements are recommended:

- Raise generator pad
- Install watertight connections
- Waterproof the structure or interior instrumentation and controls to maintain its historical status
- Waterproof exterior hatches
- Construct flood wall and flood gate around building

For planning purposes the estimated cost of the recommended resilience improvements is $1,110,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Bay. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 1 summarizes the results of CREAT for the Fries Pumping Plant No. 666. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Fries Pumping Plant No. 666

Analysis	**Utility Business Impacts**	**Utility Equipment Damages**	**Source/Receiving Water Impacts**	**Environmental Impacts**	**Overall Cost**
Without Improvements	High	Very High	Very High	Very High	$5,194,800
With Improvements	Low	Low	Low	Low	$1,110,000

Henry Ford Pumping Plant No. 668

Facility Location and Description

Henry Ford Pumping Plant No. 668 was constructed in 2002 and is located at 300 Henry Ford Avenue in Wilmington near the Port of Los Angeles. The facility, a matched flow type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed. Henry Ford Pumping Plant No. 668 has a capacity of 6,800 gpm and is equipped with three pumps each rated for 4,200 gpm. Instruments, electrical components, and controls are located above ground in a control room. The facility has a 300 kW backup generator onsite and there is no facility bypass. The replace-in-kind cost estimate is $4,743,600 for the Henry Ford Pumping Plant No. 668 based on the pumping capacity including markups and contingencies.

Facility Hazards

Henry Ford Pumping Plant No. 668 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 0.5 meter and 1.5 meters sea level rise, and tsunami zones. However, development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the south door threshold with an elevation of 8.12 feet NAVD88 and a generator pad elevation of 11.13 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. Based on the shape of the 100-year and 500-year flood boundary and comparison of the flood threshold elevation against the BFE, the facility will likely become inundated in the 100-year flood. Therefore, Henry Ford Pumping Plant No. 668 is considered a short-term priority.

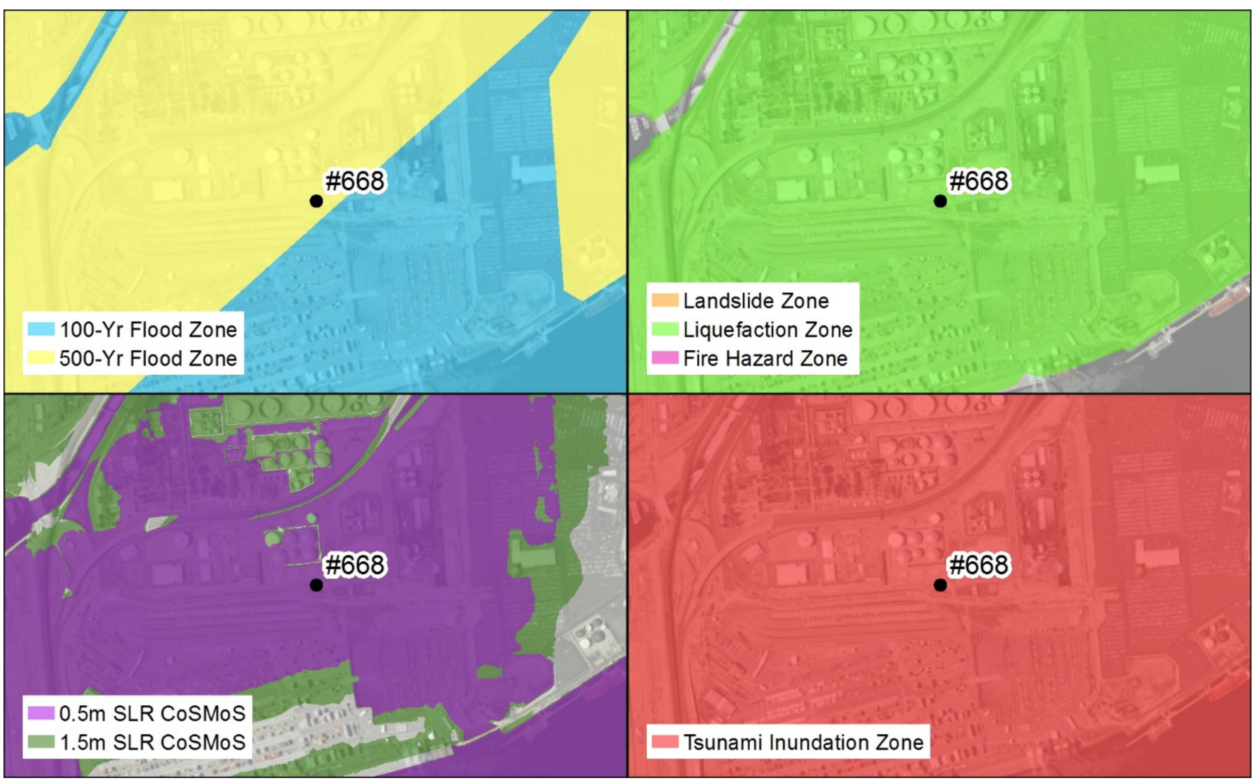


Figure 1. Hazard Zones for Henry Ford Pumping Plant No. 668

Resilience Improvements

The Henry Ford Pumping Plant No. 668 is identified as a short-term priority with 100-year flood hazards. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. This pumping plant is currently not in the existing CIP for any improvements. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Henry Ford Pumping Plant No. 668 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
8.21	11	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following short-term resilience improvements are recommended:

- Raise generator pad
- Waterproof building

For planning purposes the estimated cost of the recommended resilience improvements is $230,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to the residential area and San Pedro Bay. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Henry Ford Pumping Plant No. 668. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Henry Ford Pumping Plant No. 668

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	High	Very High	Very High	Very High	$4,743,600
With Improvements	Low	Low	Low	Low	$230,000

Harris Pumping Plant No. 669

Facility Location and Description

The Harris Pumping Plant No. 669 was constructed in 1938 and is located at 390 North Seaside Avenue on Terminal Island at the Port of Los Angeles. The facility, a fill and draw type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

Harris Pumping Plant No. 669 has a capacity of 1,600 gpm and is equipped with three pumps each rated for 1,250 gpm. Instruments, electrical components, and controls are located above ground in a control room. The facility has a 200 kW backup generator onsite and there is no facility bypass. The replace-in-kind cost estimate is $1,123,200 for the Harris Pumping Plant No. 669 based on the pumping capacity including markups and contingencies.

Facility Hazards

The Harris Pumping Plant No. 669 is located within several different hazard zones. Figure 1 shows the facility is within tsunami and liquefaction zones and near the 500-year and 100-year flood with 1.5 meters sea level rise zones. However, development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the top of the cover to the meter pit with an elevation of 13.90 feet NAVD88 and a generator pad elevation of 14.50 feet NAVD88. The facility is within an existing FEMA Zone X and is adjacent to FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will become inundated during a tsunami event. Therefore, the Harris Pumping Plant No. 669 is considered a long-term priority.

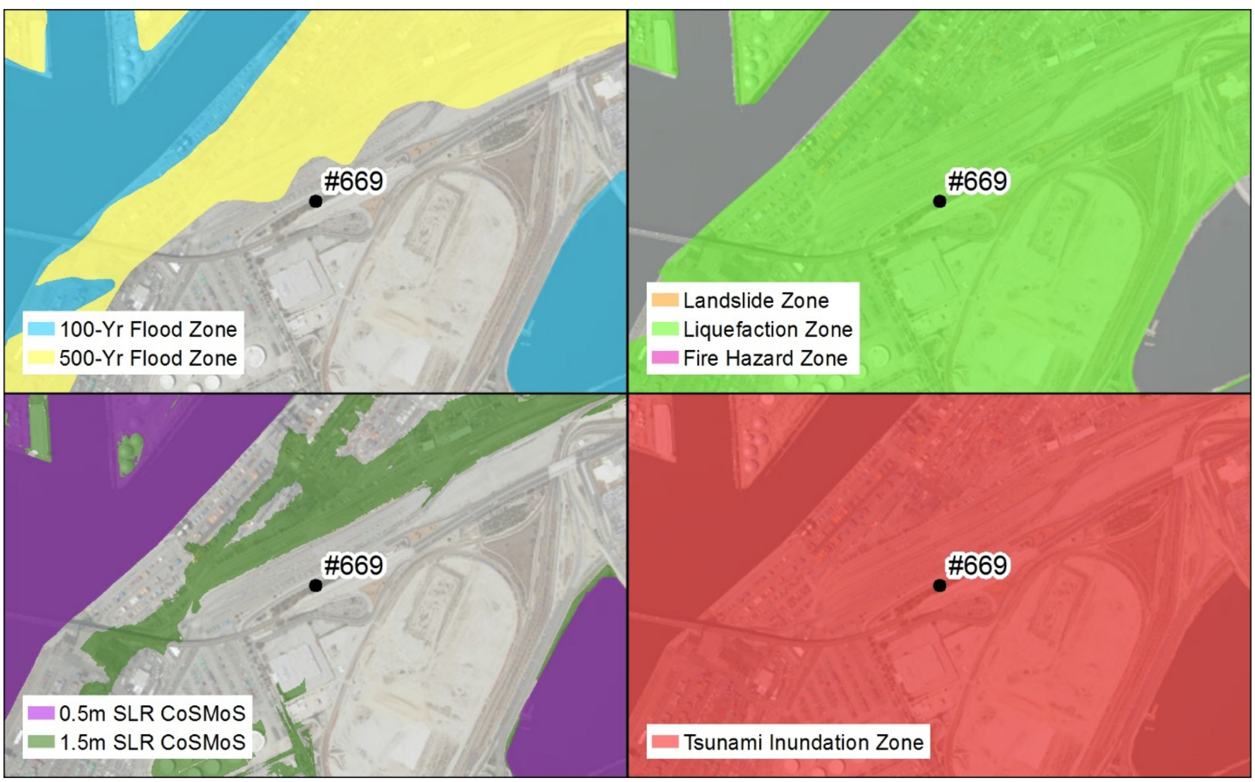


Figure 1. Hazard Zones for Harris Pumping Plant No. 669

Resilience Improvements

The Harris Pumping Plant No. 669 is identified as a long-term priority and with a flood hazard. This facility was last upgraded in 1998 and is in the existing CIP for generator replacement in 2017 (CIP 7273). A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Harris Pumping Plant No. 669 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
13.90	11.00	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88

[b] 100-yr Flood DFE = BFE + 2 ft Freeboard

[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard

[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard

[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard

[f] Tsunami DFE = 20 ft estimated tsunami wave height

The historic nature of the building may prohibit exterior modifications therefore the recommended resilience improvements do not include building waterproofing. The following long-term resilience improvements are recommended:

- Raise generator pad
- Install watertight connections
- Waterproof the structure or interior instrumentation and controls to maintain its historical status
- Waterproof exterior hatches
- Construct flood wall and flood gate around building

For planning purposes the estimated cost of the recommended resilience improvements is $810,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Bay. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Harris Pumping Plant No. 669. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Harris Pumping Plant No. 669

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	High	Very High	High	High	$1,123,200
With Improvements	Low	Low	Low	Low	$810,000

Terminal Way Pumping Plant No. 671

Facility Location and Description

The Terminal Way Pumping Plant No. 671 was constructed in 1933 and is located at 45 Terminal Way on Terminal Island in the Port of Los Angeles. The facility, a matched flow type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

Terminal Way Pumping Plant No. 671 has a capacity of 10,000 gpm and equipped with three pumps each rated for 5,000 gpm. Instruments, electrical components, and controls are located in a subgrade control room. The facility does not have a bypass and there is a 500 kW backup generator located onsite. The replace-in-kind cost estimate is $7,020,000 for the Terminal Way Pumping Plant No. 671 based on the pumping capacity including markups and contingencies.

Facility Hazards

The Terminal Way Pumping Plant No. 671 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, and tsunami zones. The facility is also close to the 100-year flood and the 100-year flood with 1.5 meters sea level rise inundation areas. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the top of the stairs to the MCC at an elevation of 14.52 feet NAVD88 and the generator pad is estimated to be at 14.78 NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will be inundated at the 1.5 m CoSMoS SLR and tsunami events. Therefore, the Terminal Way Pumping Plant No. 671 is considered a long-term priority.

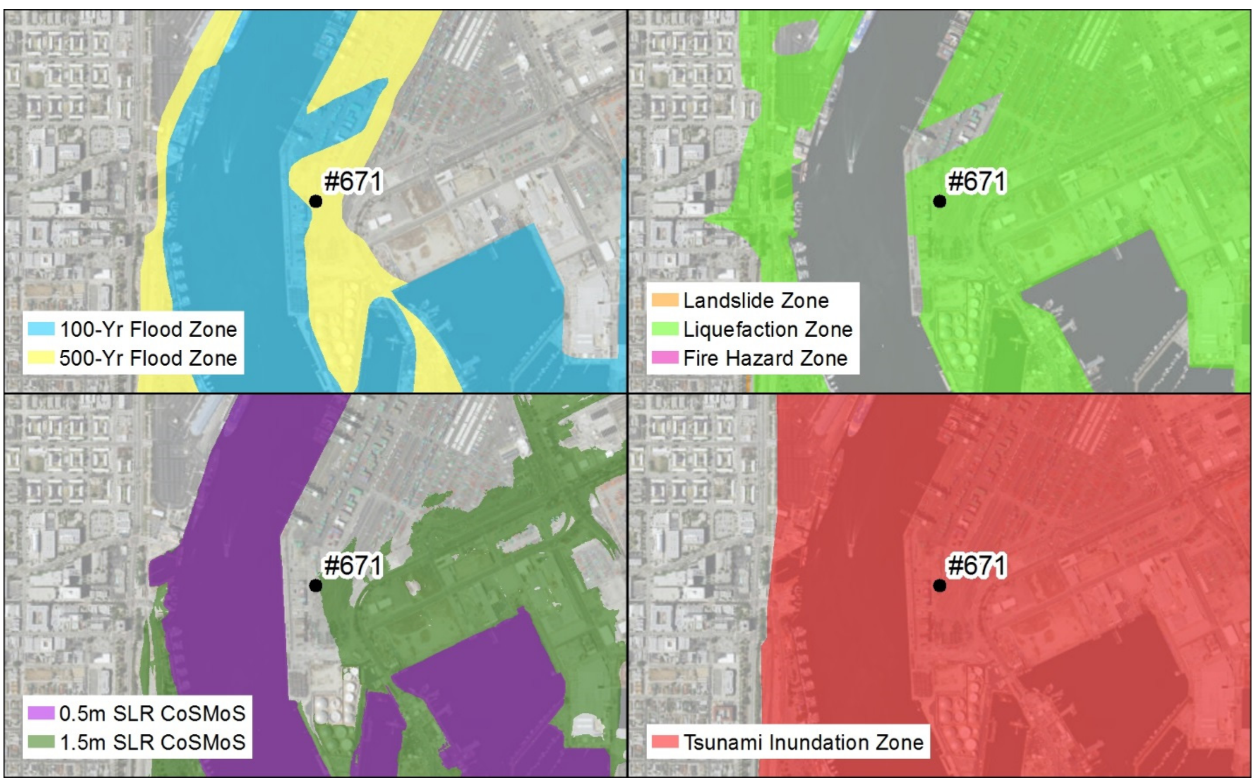


Figure 1. Hazard Zones for Terminal Way Pumping Plant No. 671

Resilience Improvements

The Terminal Way Pumping Plant No. 671 is identified as a long-term priority with flood hazards. The facility was last upgraded in 1998 and there is a rehabilitation planned in the CIP for 2018 (CIP7185). A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Terminal Way Pumping Plant No. 671 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
14.52	NA	NA	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88

[b] 100-yr Flood DFE = BFE + 2 ft Freeboard

[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard

[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard

[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard

[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor controls center
- Waterproof instrumentation and controls
- Waterproof hatches and raise vents
- Waterproof building
- Raise generator pad
- Install bollards to protect above ground structures from tsunami wave debris

For planning purposes the estimated cost of the recommended resilience improvements is $1,070,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Bay. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Terminal Way Pumping Plant No. 671. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Terminal Way Pumping Plant No. 671

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	High	Very High	High	High	$7,020,000
With Improvements	Low	Low	Low	Low	$1,070,000

Murdock & "I" Pumping Plant No. 672

Facility Location and Description

The Murdock & "I" Pumping Plant No. 672 was constructed in 1951 and is located at 1727 East "I" Street in Wilmington near the Port of Los Angeles. The facility, a fill and drain type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

Murdock & "I" Pumping Plant No. 672 has a capacity of 1,100 gpm and is equipped with three pumps each rated for 550 gpm. Instruments, electrical components, and controls are located in a subgrade control room. The facility does not have a bypass and there is an 80 kW backup generator located onsite. The replace-in-kind cost estimate is $1,000,000 for the Murdock & "I" Pumping Plant No. 672 based on the pumping capacity including markups and contingencies.

Facility Hazards

The Murdock & "I" Pumping Plant No. 672 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 1.5 meters sea level rise, and tsunami zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the top of the stairs to the motor control center at an elevation of 14.15 feet NAVD88 and the generator slab is estimated to be at 14.15 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will be inundated during the 100-year flood with 1.5 meters sea level rise and tsunami events. Therefore, the Murdock & "I" Pumping Plant No. 672 is considered a long-term priority.

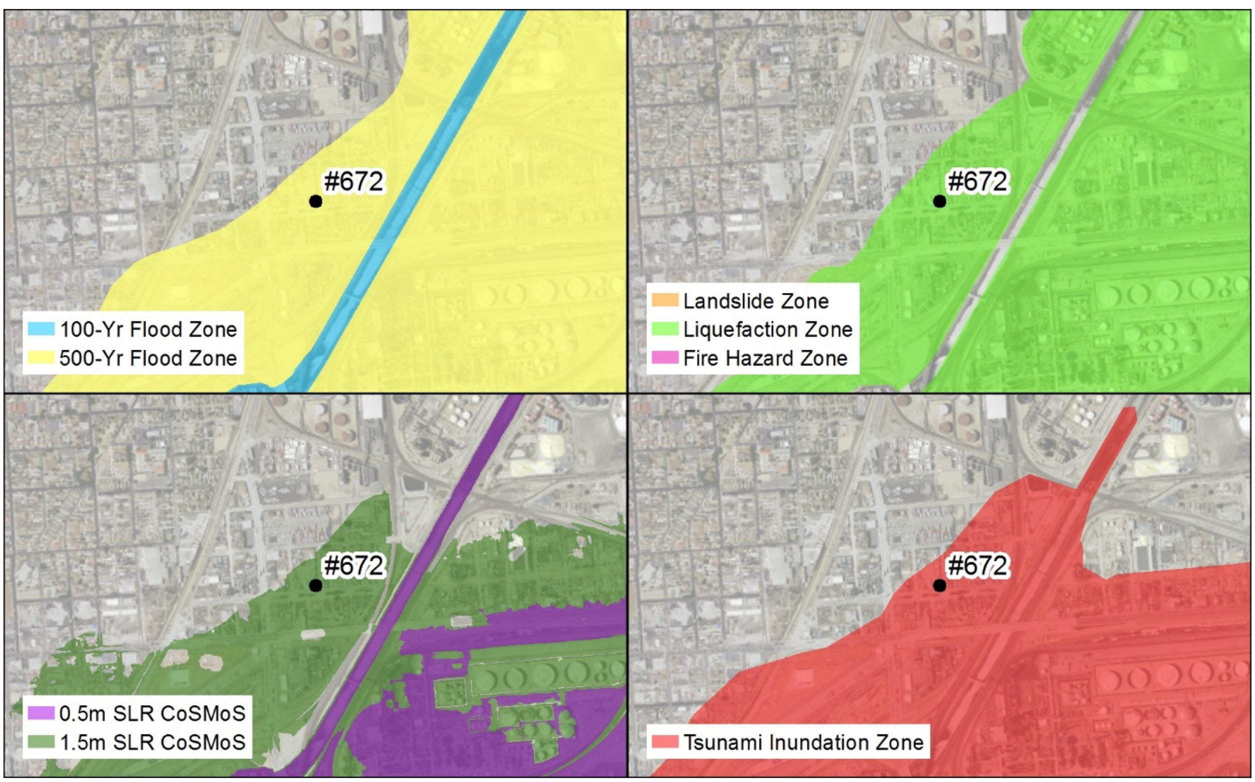


Figure 1. Hazard Zones for Murdock & "I" Pumping Plant No. 672

Resilience Improvements

The Murdock & "I" Pumping Plant No. 672 is identified as a long-term priority with flood hazards. The facility was last upgraded in 1998 and a generator replacement is planned for 2017 (CIP7229). A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Murdock & "I" Pumping Plant No. 672 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
14.15	NA	NA	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor control center
- Waterproof instrumentation and controls
- Waterproof hatches and raise vents
- Waterproof building
- Raise generator pad
- Install bollards to protect above ground structures from tsunami wave debris

For planning purposes the estimated cost of the recommended resilience improvements is $720,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Murdock & "I" Pumping Plant No. 672. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Murdock & "I" Pumping Plant No. 672

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	High	Very High	High	High	$1,000,000
With Improvements	Low	Low	Low	Low	$720,000

McFarland Pumping Plant No. 676

Facility Location and Description

The McFarland Pumping Plant No. 676 was constructed in 1968 and is located 301 McFarland Avenue in Wilmington near the Port of Los Angeles. The facility is a matched flow type wastewater pump station and is one of the 19 pumping plants within the TIWRP sewershed.

McFarland Pumping Plant No. 676 has a capacity of 8,000 gpm and equipped with three pumps each rated for 5,700 gpm. Instruments, electrical components, and controls are located in a subgrade control room. The facility does not have a bypass and there is a 750 kW backup generator located onsite. The replace-in-kind cost estimate is $5,616,000 for the McFarland Pumping Plant No. 676 based on the pumping capacity including markups and contingencies.

Facility Hazards

McFarland Pumping Plant No. 676 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 1.5 meters sea level rise, and tsunami zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the top of the stairs to the MCC at an elevation of 11.83 feet NAVD88 and the generator slab is estimated to be at 11.60 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will be inundated at the 500-year, 100-year flood with 1.5 meters sea level rise, and tsunami events. Therefore, the McFarland Pumping Plant No. 676 is considered a long-term priority.

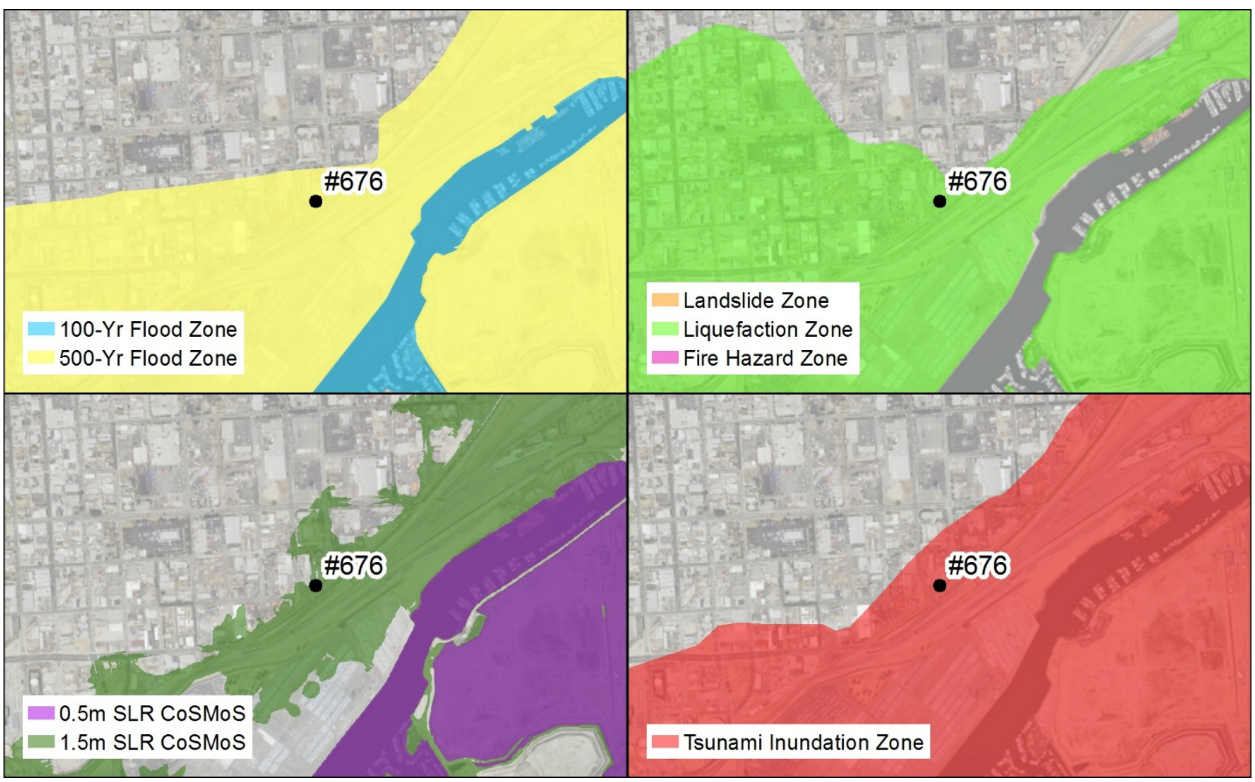


Figure 1. Hazard Zones for McFarland Pumping Plant No. 676

Resilience Improvements

The McFarland Pumping Plant No. 676 is identified as a long-term priority with flood hazards. The facility was last upgraded in 1998 and rehabilitation is planned for 2016 (CIP 7182). A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. McFarland Pumping Plant No. 676 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
11.83	NA	NA	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor control center
- Waterproof instrumentation and controls
- Waterproof hatches and raise vents
- Install submarine doors to control room
- Raise generator pad
- Install bollards to protect above ground structures from tsunami wave debris

For planning purposes the estimated cost of the recommended resilience improvements is $1,020,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the McFarland Pumping Plant No. 676. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the McFarland Pumping Plant No. 676

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	High	Very High	High	High	$5,616,000
With Improvements	Low	Low	Low	Low	$1,020,000

Hawaiian & "B" Pumping Plant No. 677

Facility Location and Description

The Hawaiian & "B" Pumping Plant No. 677 was constructed in 1969 and is located at 1220 Harry Bridges Avenue in Wilmington near the Port of Los Angeles. The facility, a matched flow type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

Hawaiian & "B" Pumping Plant No. 677 has a capacity of 5,800 gpm and is equipped with three pumps each rated for 4,000 gpm. Instruments, electrical components, and controls are located in a subgrade control room. The facility does not have a bypass and there is a 750 kW backup generator located onsite. The replace-in-kind cost estimate is $4,071,600 for the Hawaiian & "B" Pumping Plant No. 677 based on the pumping capacity including markups and contingencies.

Facility Hazards

The Hawaiian & "B" Pumping Plant No. 677 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, and tsunami zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the top of the stairs to the motor control center at an elevation of 13.64 feet NAVD88 and the generator slab is estimated to be at 13.64 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will be inundated at the 500-year, 100-year flood with 1.5 meter sea level rise, and tsunami events. Therefore, the Hawaiian & "B" Pumping Plant No. 677 is considered a long-term priority.

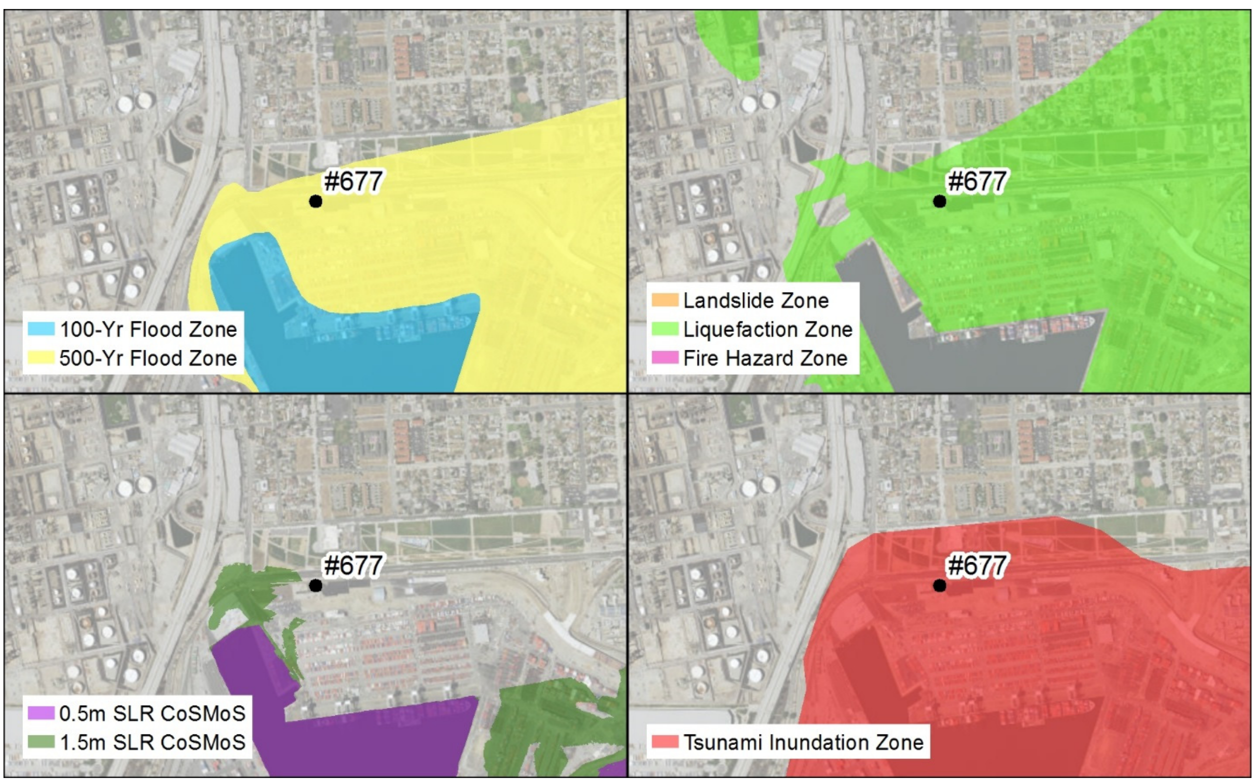


Figure 1. Hazard Zones for Hawaiian & "B" Pumping Plant No. 677

Resilience Improvements

The Hawaiian & "B" Pumping Plant No. 677 is identified as a long-term priority with flood hazards. The facility was last upgraded in 1998 and rehabilitation began in 2016 (CIP 7181). A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Hawaiian & "B" Pumping Plant No. 677 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
11.83	11.00	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88

[b] 100-yr Flood DFE = BFE + 2 ft Freeboard

[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard

[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard

[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard

[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor control center
- Waterproof instrumentation and controls
- Waterproof hatches and raise vents
- Install submarine doors to control room
- Raise generator pad
- Install bollards to protect above ground structures from tsunami wave debris

For planning purposes the estimated cost of the recommended resilience improvements is $870,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Hawaiian & "B" Pumping Plant No. 677. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Hawaiian & "B" Pumping Plant No. 677

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	High	Very High	High	High	$4,071,600
With Improvements	Low	Low	Low	Low	$870,000

22nd & Signal Pumping Plant No. 680

Facility Location and Description

The 22nd & Signal Pumping Plant No. 680 was constructed in 1951 and is located at 2121 Signal Street in San Pedro near the Port of Los Angeles. The facility, a fill and draw type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

22nd & Signal Pumping Plant No. 680 has a capacity of 100 gpm and is equipped with two submersible pumps each rated for 50 gpm. Instruments, electrical components, and controls are located in a below-ground control room. The facility has a no bypass. There is no existing backup generator onsite, but the facility has switch gear and fittings for a hookup to a portable backup generator. The replace-in-kind cost estimate is $1,000,000 for the 22nd & Signal Pumping Plant No. 680 based on the pumping capacity including markups and contingencies.

Facility Hazards

The 22nd & Signal Pumping Plant No. 680 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 1.5 meters sea level rise, and Tsunami zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

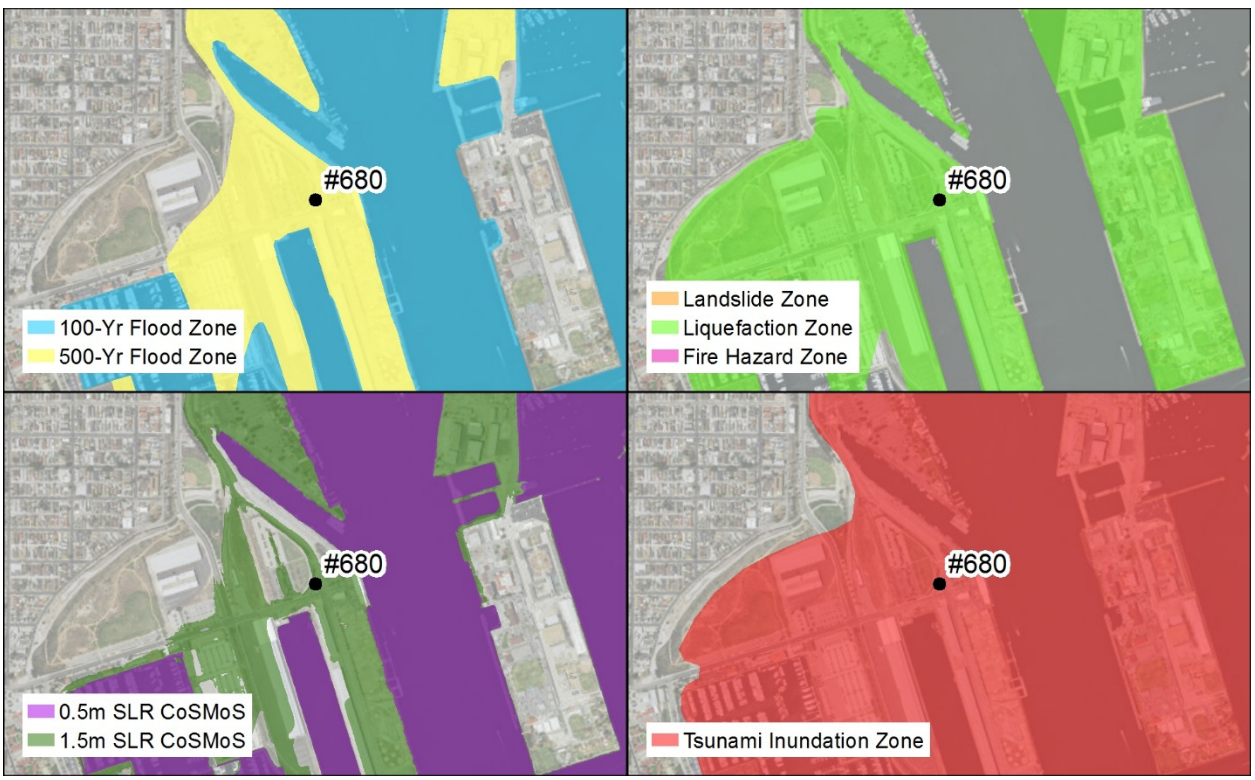


Figure 1. Hazard Zones for 22nd & Signal Pumping Plant No. 680

The flood damage threshold for the facility is at an elevation of 11.06 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will become inundated during 500-yr flood, 100-year flood with 1.5 meter sea level rise, and tsunami events. If a coastal flooding event were to occur, flood waters would enter the control room on the top level through hatches and vent holes, submerge the pumps in the dry well on the bottom level, then submerge the control room. A sump pump is located in the bottom level but only has the capacity to drain leaks and wall seepage, not to keep the pump room and control room above it dry during a flood.

The external connections for a portable generator are not in a waterproof enclosure and would also be damaged by flood waters and unusable. If a backup generator were hooked up to the pump station during a flooding event, it would also be susceptible to damage in these scenarios. The pumping station would most likely be damaged and not functional until electrical service and controls are restored. Therefore, the 22nd & Signal Pumping Plant No. 680 is considered a long-term priority.

Resilience Improvements

The 22nd & Signal Pumping Plant No. 680 is identified as a long-term priority with flood hazards. The facility was last upgraded in 1999 and there are no future planned improvements in the CIP. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. 22nd & Signal Pumping Plant No. 680 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
11.06	11.00	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor control center
- Waterproof instrumentation and controls
- Waterproof hatches
- Install watertight cover on backup power connection box, or have spare parts available on-hand if connection box is damaged by flood waters.
- Raise height of and reinforce the two shorter vent fans
- Seal holes on the outside of the pumping plant

For planning purposes the estimated cost of the recommended resilience improvements is $126,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the 22nd & Signal Pumping Plant No. 680. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the 22nd & Signal Pumping Plant No. 680

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Medium	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$126,000

Ports O' Call Pumping Plant No. 681

Facility Location and Description

The Ports O' Call Pumping Plant No. 681 was constructed in 1959 and is located at Berth 79 Nagoya Way in San Pedro near the Port of Los Angeles. The facility pumps wastewater from nearby restaurants and business to the TIWRP. The pump station does not have a bypass system.

The pump station has a capacity of 300 gpm and is equipped with three pumps each rated for 288 gpm. Instruments, electrical components, and controls are located in a cabinet at grade. There is no backup generator located onsite but there is a designated portable backup generator located at a north storage yard. The replace-in-kind cost estimate is $1,000,000 for the Ports O' Call Pumping Plant No. 681 based on the pumping capacity including markups and contingencies.

Facility Hazards

The Ports O' Call Pumping Plant No. 681 is located within or near several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 1.5 meters sea level rise, and tsunami inundation zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the control pad at an elevation of 11.35 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to the Port of Los Angeles with a FEMA Zone AE and a BFE of 9 feet NAVD88. The facility will become inundated during the 500-year flood, 100-year flood with 1.5 meters sea level rise, and tsunami events. Therefore, the Ports O' Call Pumping Plant No. 681 is considered a long-term priority.

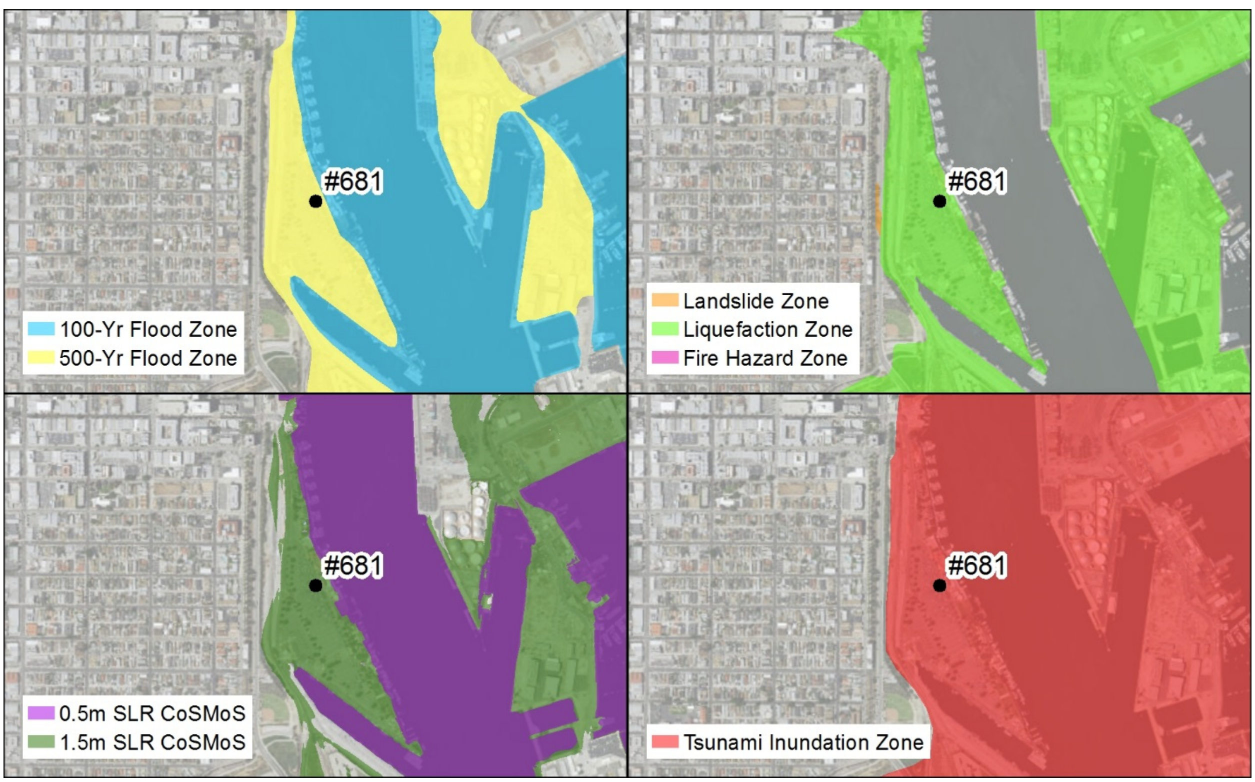


Figure 1. Hazard Zones for Ports O' Call Pumping Plant No. 681

Resilience Improvements

The Ports O' Call Pumping Plant No. 681 is identified as a long-term priority. This facility is not included in the existing CIP and there are no plans for future improvements at this time. Timing of any future improvements may be dependent on the Harbor Department. It should also be noted the pump station serves the harbor restaurants and business which will not be producing wastewater if the buildings become flooded. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Ports O' Call Pumping Plant No. 681 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
11.35	11	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88

[b] 100-yr Flood DFE = BFE + 2 ft Freeboard

[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard

[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard

[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard

[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor control center
- Waterproof instrumentation and controls
- Install bollard around facility to protect from floating debris from tsunami

For planning purposes the estimated cost of the recommended resilience improvements is $340,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Ports O' Call Pumping Plant No. 681. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Ports O' Call Pumping Plant No. 681

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Low	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$340,000

22nd Street Pumping Plant No. 683

Facility Location and Description

The 22nd Street Pumping Plant No. 683 was constructed in 1974 and is located at 191 West 22nd Street in San Pedro near the Port of Los Angeles. The facility, a fill and draw type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

22nd Street Pumping Plant No. 683 has a capacity of 900 gpm and is equipped with two pumps each rated for 750 gpm. Instruments, electrical components, and controls are located in an above-ground control room. The facility has a bypass and there is no existing backup generator onsite. The replace-in-kind cost estimate is $1,000,000 for the 22nd Street Pumping Plant No. 683 based on the pumping capacity including markups and contingencies.

Facility Hazards

The 22nd Street Pumping Plant No. 683 is located within several different hazard zones. Figure 1 shows the facility is within the liquefaction and tsunami zones and close to the 100-year flood and 100-year flood with 1.5 meters sea level rise inundation zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the top of slab at an elevation of 14.96 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will likely become inundated during a tsunami event. Therefore, the 22nd Street Pumping Plant No. 683 is considered a long-term priority.

Figure 1. Hazard Zones for 22nd Street Pumping Plant No. 683

Resilience Improvements

The 22nd Street Pumping Plant No. 683 is identified as a long-term priority with flood hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. 22nd Street Pumping Plant No. 683 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
14.96	11.00	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88

[b] 100-yr Flood DFE = BFE + 2 ft Freeboard

[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard

[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard

[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard

[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor control center
- Waterproof instrumentation and controls
- Waterproof hatches and raise vents
- Waterproof control room
- Install bollards to protect above ground structures from tsunami wave debris

For planning purposes the estimated cost of the recommended resilience improvements is $500,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the 22nd Street Pumping Plant No. 683. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the 22nd Street Pumping Plant No. 683

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Medium	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$500,000

Miner Pumping Plant No. 684

Facility Location and Description

The Miner Pumping Plant No. 684 was constructed in 1974 and is located at 2600 West Miner Street in San Pedro and the Port of Los Angeles. The facility, a fill and draw type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

Miner Pumping Plant No. 684 has a capacity of 500 gpm and is equipped with two pumps each rated for 300 gpm. Instruments, electrical components, and controls are located in an above ground control room. The facility has a bypass and there is no existing backup generator onsite. The replace-in-kind cost estimate is $1,000,000 for the Miner Pumping Plant No. 684 based on the pumping capacity including markups and contingencies.

Facility Hazards

The Miner Pumping Plant No. 684 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 1.5 meters sea level rise, and tsunami zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is top of slab at an elevation of 13.63 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will likely become inundated during a tsunami event. Therefore, the Miner Pumping Plant No. 684 is considered a long-term priority.

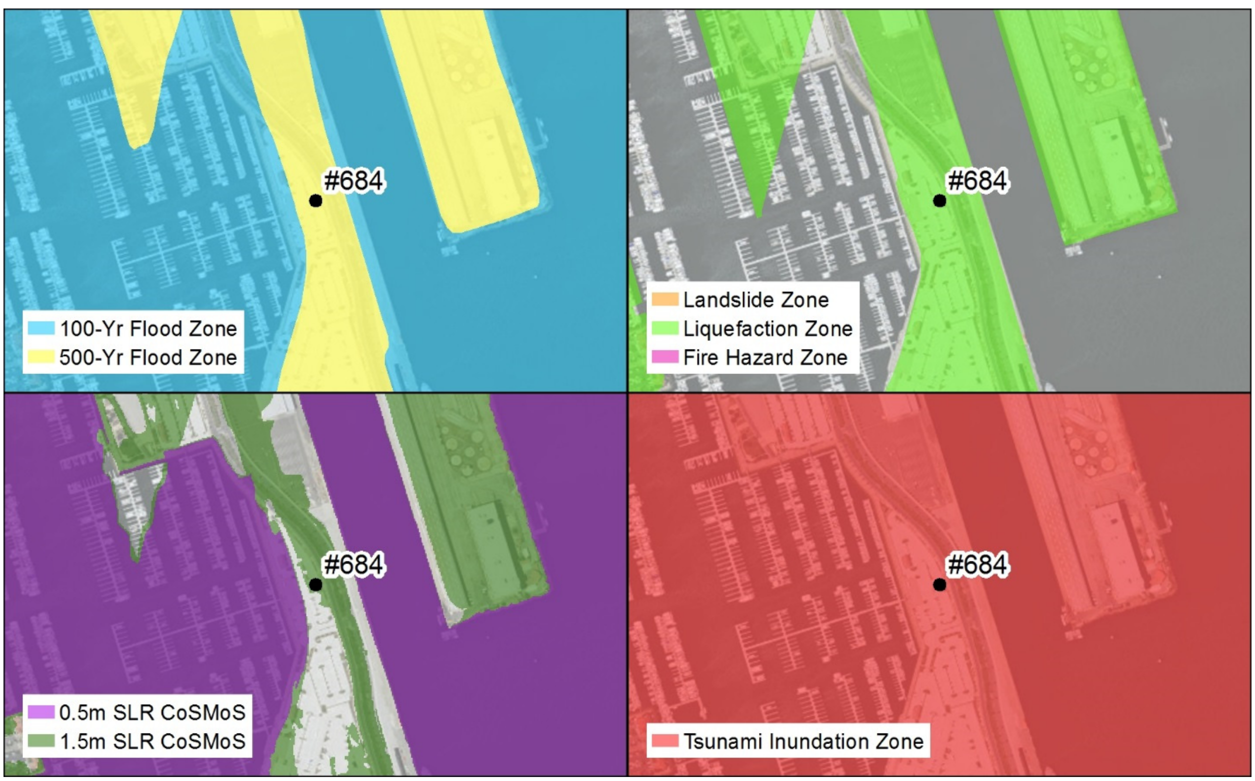


Figure 1. Hazard Zones for Miner Pumping Plant No. 684

Resilience Improvements

The Miner Pumping Plant No. 684 is identified as a long-term priority with flood hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Miner Pumping Plant No. 684 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
13.63	11.00	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor control center
- Waterproof instrumentation and controls
- Waterproof hatches and raise vents
- Waterproof control room
- Install bollards to protect above ground structures from tsunami wave debris

For planning purposes the estimated cost of the recommended resilience improvements is $500,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Miner Pumping Plant No. 684. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Miner Pumping Plant No. 684

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Medium	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$500,000

Signal Pumping Plant No. 685

Facility Location and Description

The Signal Pumping Plant No. 685 was constructed in 1962 and is located at 2400 Signal Street in San Pedro near the Port of Los Angeles. The facility, a fill and draw type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

Signal Pumping Plant No. 685 has a capacity of 200 gpm and is equipped with two pumps each rated for 250 gpm. Instruments, electrical components, and controls are located above ground in a control room. The facility does not have a bypass and there is no backup generator onsite. The replace-in-kind cost estimate is $1,000,000 for the Signal Pumping Plant No. 685 based on the pumping capacity including markups and contingencies.

Facility Hazards

The Signal Pumping Plant No. 685 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 1.5 meters sea level rise, and tsunami zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the concrete pad for the MCC at an elevation of 10.85 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will be inundated at the 500-year flood, 100-year flood with 1.5 meters sea level rise, and tsunami events. Therefore, the Signal Pumping Plant No. 685 is considered a long-term priority.

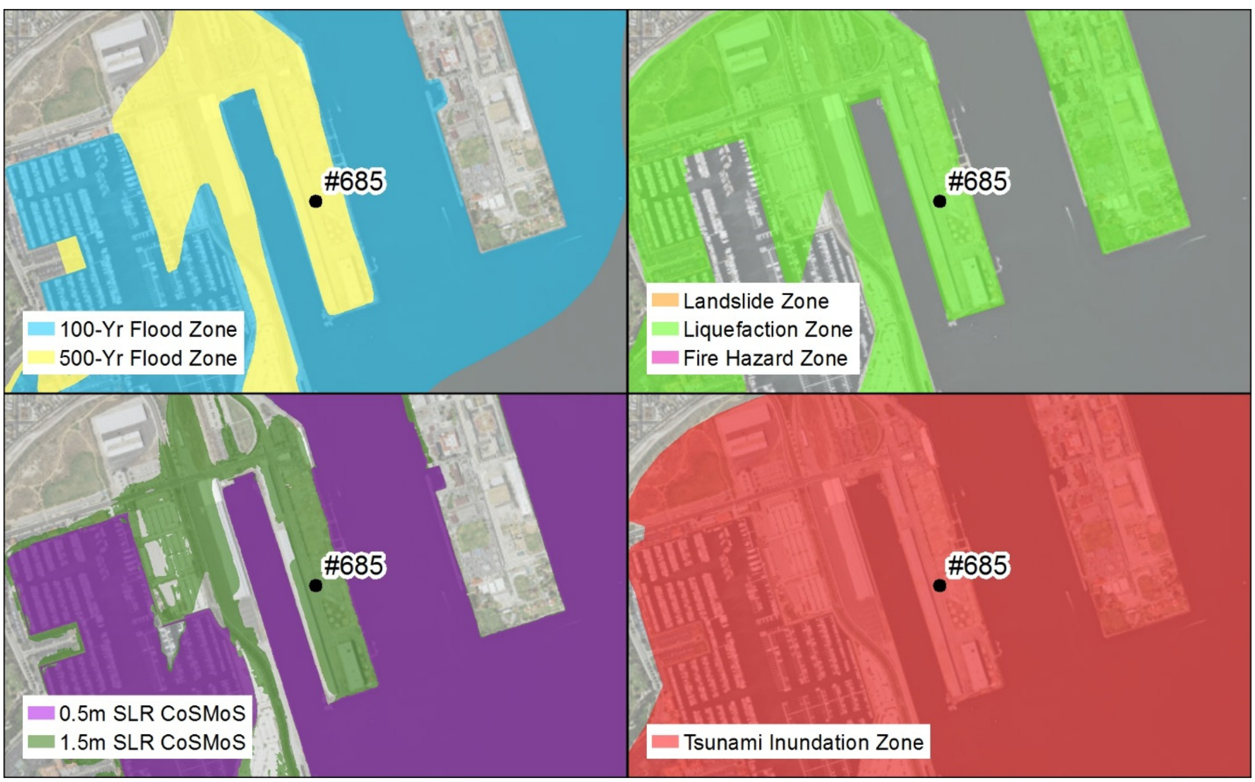


Figure 1. Hazard Zones for Signal Pumping Plant No. 685

Resilience Improvements

The Signal Pumping Plant No. 685 is identified as a long-term priority with flood hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Signal Pumping Plant No. 685 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
10.85	NA	NA	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor control room
- Waterproof instrumentation and controls
- Waterproof hatches and raise vents
- Waterproof control room
- Install bollards to protect above ground structures from tsunami wave debris

For planning purposes the estimated cost of the recommended resilience improvements is $480,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Signal Pumping Plant No. 685. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Signal Pumping Plant No. 685

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Medium	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$480000

Nissan Way Pumping Plant No. 686

Facility Location and Description

The Nissan Way Pumping Plant No. 686 was constructed in 1975 and is located at 601 Nissan Way in Wilmington and the Port of Los Angeles. The facility, a fill and draw type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

Nissan Way Pumping Plant No. 686 has a capacity of 1,700 gpm and is equipped with two submersible pumps each rated for 890 gpm. Instruments, electrical components, and controls are located in above-ground cabinets. The facility does not have a bypass. There is no existing backup generator onsite, but the facility has an elevated hookup located on the outside of the control room enclosure where a portable backup generator could be connected. The replace-in-kind cost estimate is $1,193,000 for the Nissan Way Pumping Plant No. 686 based on the pumping capacity including markups and contingencies.

Facility Hazards

The Nissan Way Pumping Plant No. 686 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 0.5 meter sea level rise, and tsunami zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

Figure 1. Hazard Zones for Nissan Way Pumping Plant No. 686

The flood damage threshold for the facility is at an elevation of 7.0 feet NAVD88. The facility is within an existing FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will become inundated during 500-year flood, 100-year flood with 0.5 meter sea level rise, and tsunami events. If a coastal flooding event were to occur, flood waters would damage or destroy the all of the pump station except for the submersible pumps. The external connections for a portable generator are not in a waterproof enclosure and would also be damaged by flood waters and unusable. If a backup generator were hooked up to the pump station during a flooding event, it would also be susceptible to damage in these scenarios. Therefore, the Nissan Way Pumping Plant No. 686 is considered a medium-term priority.

Resilience Improvements

The Nissan Way Pumping Plant No. 686 is identified as a medium term priority with flood hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Nissan Way Pumping Plant No. 686 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
11.06	11.00	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88

[b] 100-yr Flood DFE = BFE + 2 ft Freeboard

[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard

[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard

[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard

[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following medium-term resilience improvements are recommended:

- Install watertight connections and protect the motor control room
- Waterproof instrumentation and controls
- Waterproof hatches and raise vents
- Replace backup power connection box with watertight enclosure
- Seal vents and raise vent shafts
- Install bollards to protect above ground structures from tsunami wave debris

For planning purposes the estimated cost of the recommended resilience improvements is $490,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Nissan Way Pumping Plant No. 686. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Nissan Way Pumping Plant No. 686

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	High	Very High	High	High	$1,193,000
With Improvements	Low	Low	Low	Low	$490,000

North Neptune Pumping Plant No. 687

Facility Location and Description

The North Neptune Pumping Plant No. 687 was constructed in 1975 and is located at 600 South Neptune Avenue in Wilmington at the Port of Los Angeles. The facility, a fill and draw type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

North Neptune Pumping Plant No. 687 has a capacity of 880 gpm and is equipped with two pumps each rated for 880 gpm. Instruments, electrical components, and controls are located above ground in a control room. The facility does not have a bypass and there is no backup generator onsite. The replace-in-kind cost estimate is $1,000,000 for the North Neptune Pumping Plant No. 687 based on the pumping capacity including markups and contingencies.

Facility Hazards

The North Neptune Pumping Plant No. 687 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 1.5 meters of sea level rise, and tsunami zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the top of the deck to the access doors with elevation of 11.03 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will be inundated at the 500-year flood, 100-year flood with 1.5 meters sea level rise, and tsunami events. Therefore, the North Neptune Pumping Plant No. 687 is considered a long-term priority.

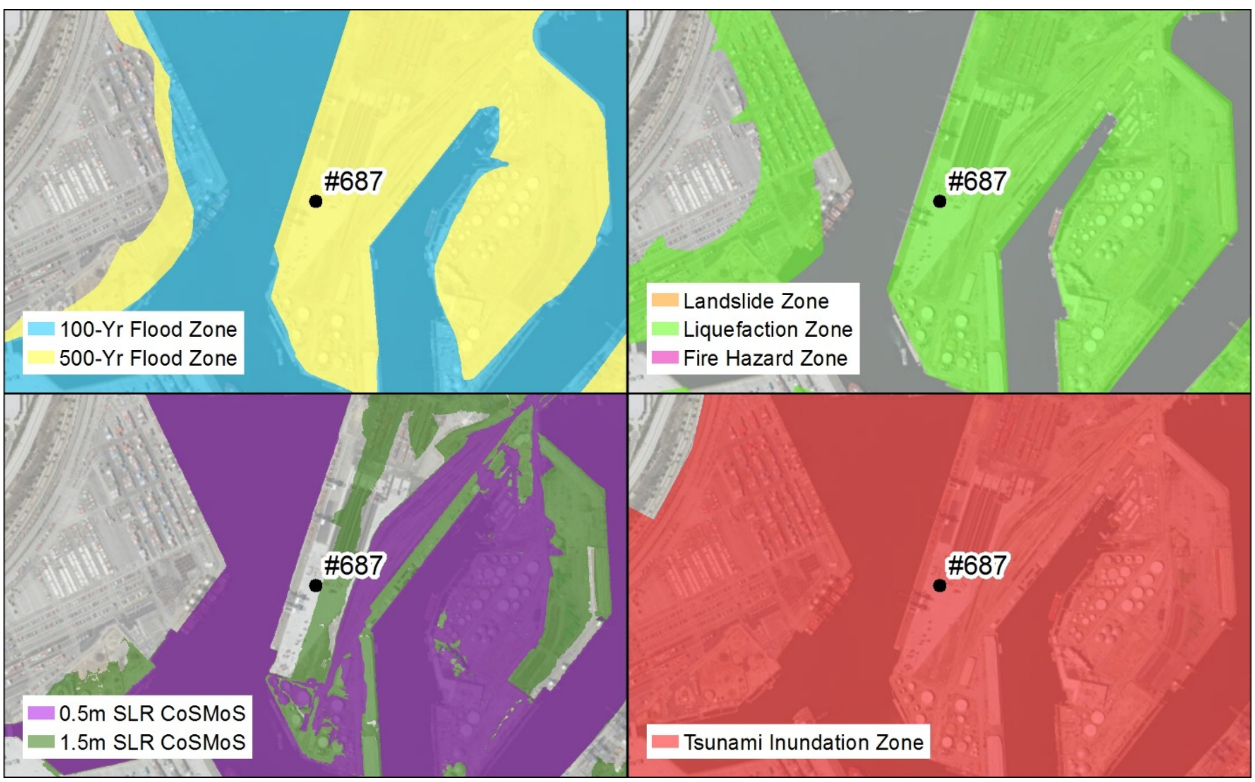


Figure 1. Hazard Zones for North Neptune Pumping Plant No. 687

Resilience Improvements

The North Neptune Pumping Plant No. 687 is identified as a long-term priority with flood hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. North Neptune Pumping Plant No. 687 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
11.03	NA	NA	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the MCC
- Waterproof instrumentation and controls (I&C)
- Waterproof hatches
- Install bollards to protect from tsunami wave debris

For planning purposes the estimated cost of the recommended resilience improvements is $400,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the North Neptune Pumping Plant No. 687. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the North Neptune Pumping Plant No. 687

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Medium	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$400,000

Seaside Pumping Plant No. 689

Facility Location and Description

The Seaside Pumping Plant No. 689 was constructed in 1976 and is located at 216 Seaside Avenue on Terminal Island in the Port of Los Angeles. The facility, a fill and draw type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

Seaside Pumping Plant No. 689 has a capacity of 1,000 gpm and is equipped with two pumps each rated for 500 gpm. Instruments, electrical components, and controls are located in an above-ground control room. The facility has a bypass and there is no existing backup generator onsite. The replace-in-kind cost estimate is $1,000,000 for the Seaside Pumping Plant No. 689 based on the pumping capacity including markups and contingencies.

Facility Hazards

The Seaside Pumping Plant No. 689 is located within several different hazard zones. Figure 1 shows the facility is within the liquefaction and tsunami zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is top of slab at an elevation of 15.33 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will likely become inundated during a tsunami event. Therefore, the Seaside Pumping Plant No. 689 is considered a long-term priority.

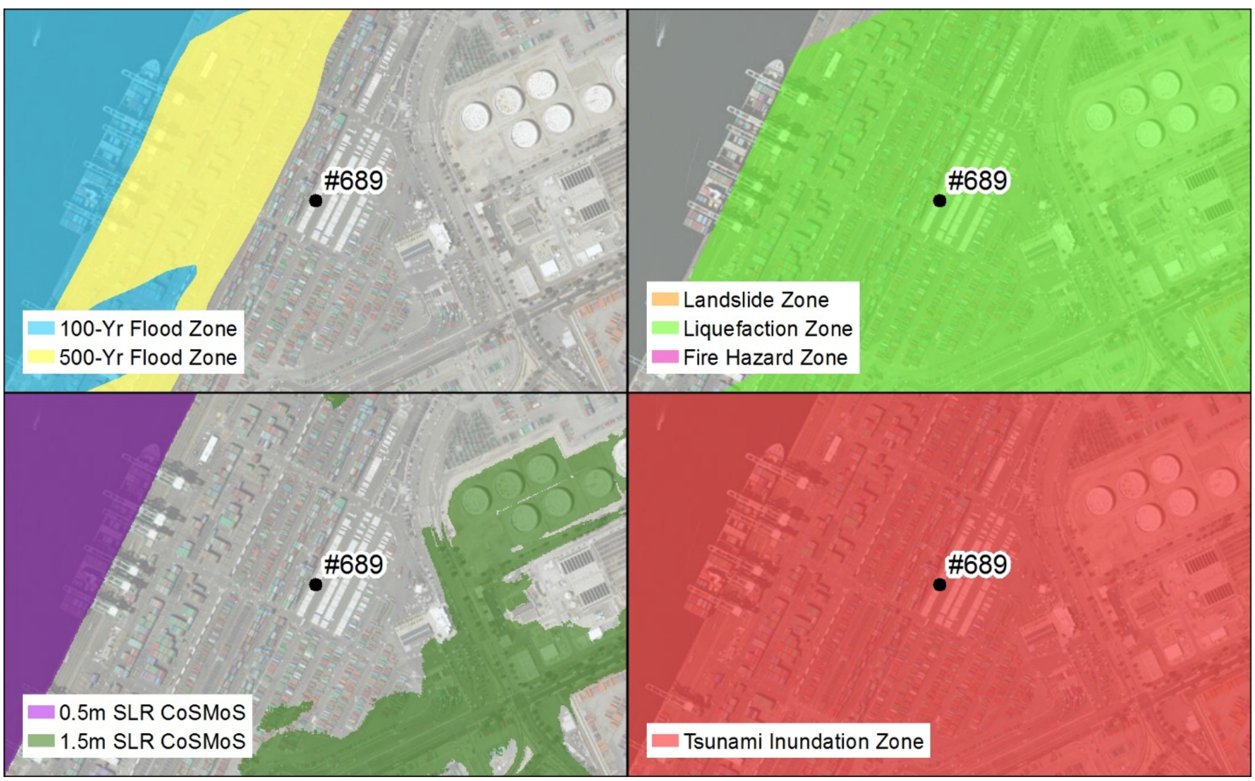


Figure 1. Hazard Zones for Seaside Pumping Plant No. 689

Resilience Improvements

The Seaside Pumping Plant No. 689 is identified as a long-term priority with flood hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Seaside Pumping Plant No. 689 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
15.33	11.00	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor control room
- Waterproof instrumentation and controls
- Waterproof hatches and raise vents
- Waterproof control room
- Install bollards to protect above ground structures from tsunami wave debris

For planning purposes the estimated cost of the recommended resilience improvements is $600,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Seaside Pumping Plant No. 689. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Seaside Pumping Plant No. 689

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	High	Very High	High	High	$1,000,000
With Improvements	Low	Low	Low	Low	$600,000

Anchorage Pumping Plant No. 690

Facility Location and Description

The Anchorage Pumping Plant No. 690 was constructed in 1976 and is located at 1251 Anchorage Road in Wilmington near the Port of Los Angeles. The facility, a fill and draw type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

Anchorage Pumping Plant No. 690 has a capacity of 520 gpm and is equipped with two pumps each rated for 250 gpm. Instruments, electrical components, and controls are located below ground in a control room. There is no backup generator onsite but the facility does have an overflow bypass. The replace-in-kind cost estimate is $1,000,000 for the Anchorage Pumping Plant No. 690 based on the pumping capacity including markups and contingencies.

Facility Hazards

The Anchorage Pumping Plant No. 690 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 1.5 meters sea level rise, and tsunami zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the concrete pad at elevation 11.19 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will be inundated at the 500-year flood, 100-year flood with 1.5 meters sea level rise, and tsunami events. Therefore, the Anchorage Pumping Plant No. 690 is considered a long-term priority.

Figure 1. Hazard Zones for Anchorage Pumping Plant No. 690

Resilience Improvements

The Anchorage Pumping Plant No. 690 is identified as a long-term priority with flood hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Anchorage Pumping Plant No. 690 Design Flood Elevations

Damage Threshold Elevation	**Short Term**	**Medium Term**	**Long Term**		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
11.19	11	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88

[b] 100-yr Flood DFE = BFE + 2 ft Freeboard

[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard

[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard

[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard

[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor control center
- Waterproof instrumentation and controls
- Waterproof hatch and raise vent
- Install bollards to protect above ground structures from tsunami

For planning purposes the estimated cost of the recommended resilience improvements is $300,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Anchorage Pumping Plant No. 690. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Anchorage Pumping Plant No. 690

Analysis	**Utility Business Impacts**	**Utility Equipment Damages**	**Source/Receiving Water Impacts**	**Environmental Impacts**	**Overall Cost**
Without Improvements	Medium	Very High	Medium	Medium	$1,000,000
With Improvements	Low	Low	Low	Low	$300,000

San Pedro Pumping Plant No. 691

Facility Location and Description

San Pedro Pumping Plant No. 691 was constructed in 1977 and is located at 675 Front Street in San Pedro near the Port of Los Angeles. The facility, a matched flow type wastewater pump station, is one of the 19 pumping plants within the TIWRP sewershed.

San Pedro Pumping Plant No. 691 has a capacity of 18,000 gpm and is equipped with three pumps each rated for 9,500 gpm. Instruments, electrical components, and controls are located in a subgrade control room. The facility does not have a bypass and there is an 800 kW backup generator located onsite. The replace-in-kind cost estimate is $12,636,000 for the San Pedro Pumping Plant No. 691 based on the pumping capacity including markups and contingencies.

Facility Hazards

San Pedro Pumping Plant No. 691 is located within several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, and tsunami zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the top of the stairs to the control room at an elevation of 19.75 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE with a BFE of 9 feet NAVD88. The facility will be inundated during the tsunami event. Therefore, the San Pedro Pumping Plant No. 691 is considered a long-term priority.

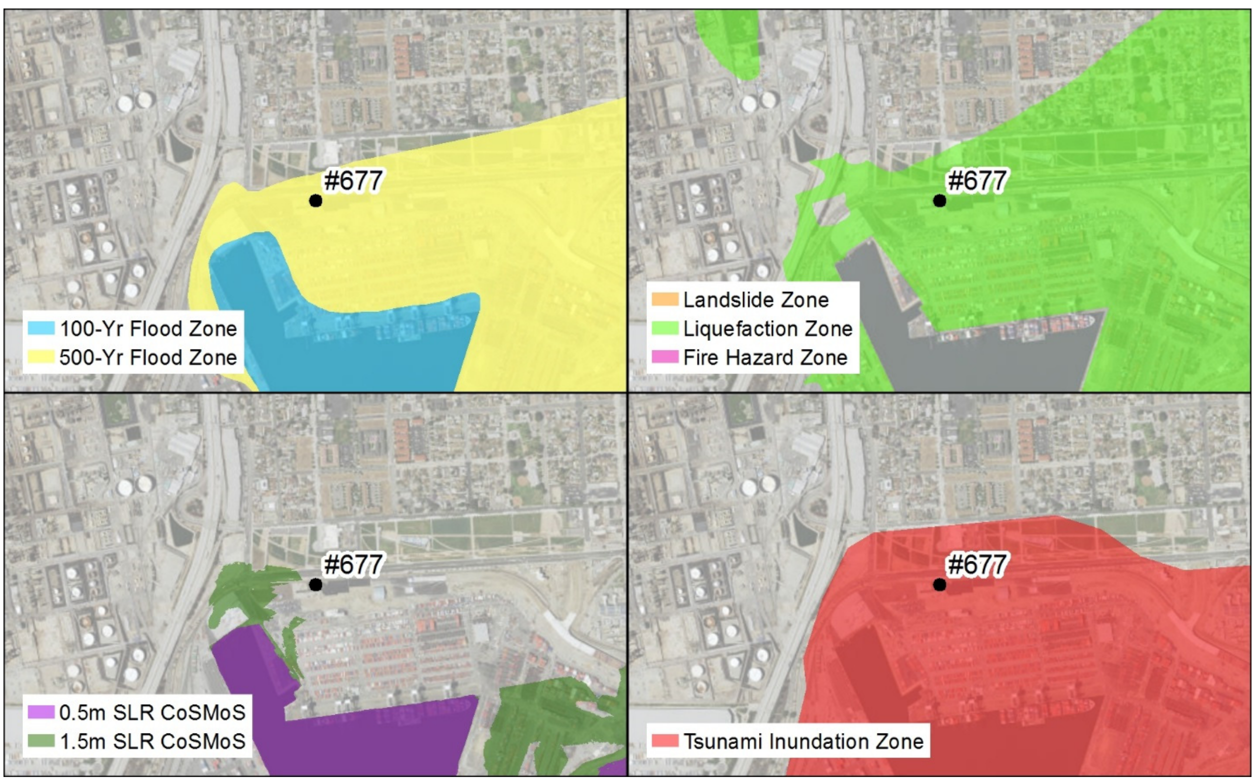


Figure 1. Hazard Zones for San Pedro Pumping Plant No. 691

Resilience Improvements

The San Pedro Pumping Plant No. 691 is identified as a long-term priority with flood hazards. The facility was last upgraded in 1999 and is currently under construction for rehabilitation listed in the CIP (CIP 7186). A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. San Pedro Pumping Plant No. 691 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
19.75	11.00	12.64	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following resilience improvements are recommended:

- Install watertight connections and protect the motor control room
- Waterproof instrumentation and controls
- Waterproof hatches and raise vents
- Install submarine doors to control room
- Raise generator pad
- Install bollards to protect above ground structures from tsunami wave debris

For planning purposes the estimated cost of the recommended resilience improvements is $1,080,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant would result in wastewater overflows to San Pedro Harbor. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the San Pedro Pumping Plant No. 691. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the San Pedro Pumping Plant No. 691

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Very High	Very High	Very High	Very High	$12,636,000
With Improvements	Low	Low	Low	Low	$1,080,000

Kinney Circle Pumping Plant No. 647

Facility Location and Description

The Kinney Circle Pumping Plant No. 647 was constructed in 1927 and is located at 1600 Main Street in Venice Beach in the middle of the traffic circle. All controls and pumps are subterranean. The facility is a fill and draw type stormwater pump station and a low flow diversion. The pump station does not have a bypass system but has storage capacity in the wet well. The stormwater part of the pump station has a capacity of 45,000 gpm and is equipped with five stormwater pumps. The low flow diversion has a 500 gpm capacity with three pumps. Instruments, electrical components, and controls are located below ground. The facility has a 125 kW portable backup generator available located at the Venice Pumping Plant No. 646.

Los Angeles Sanitation is planning an upgrade of the facility and developed a preliminary estimate of construction costs in 2015. The preliminary opinion of cost for the upgrades including the replacement of non-submersible pumps, heating and ventilation, electrical, instrumentation and controls is approximately $5,500,000. This estimate includes $750,000 in structural upgrades and the addition of a new dedicated portable backup generator for $1,000,000 (Tetra Tech, 2015). The estimated damage replacement costs of the facility is $3,750,000 assuming that the structural upgrades and the new portable generator would not be at risk to facility hazards.

Facility Hazards

Kinney Circle Pumping Plant No. 647 is located along the coast with several different hazards. Figure 1 shows the facility is within the 500-year flood, liquefaction, and tsunami zones. The facility is outside the CoSMoS SLR inundations areas.

The outfall discharges stormwater to the Pacific Ocean, and consists of an outfall box with a Tideflex tide gate device. The Tideflex device prevents back flooding into the outfall. The City does not have jurisdiction over the outfall, as it is owned and maintained by Los Angeles County. This outfall box plugs often with sand that reduces its discharge capacity. The City relies on the County to clear the outfall, which is not performed on a regular basis. Sea level rise will likely increase sand intrusion which will require more frequent monitoring and cleaning by Los Angeles County in the future.

Street flooding of the area occasionally occurs. The upgrade includes adding green infrastructure (bioretention, permeable pavements on sidewalks and bike lanes) to the drainage area. Green infrastructure will capture stormwater and reduce the bacteria count in runoff, however the City has experienced regulatory and political hurdles to implementing green infrastructure. Future changes in precipitation with climate change may involve more intense rainfalls that would exceed current design storm parameters and reduce or eliminate the benefits of the planned drainage improvements and cause more street flooding in the future.

The flood damage threshold for the facility is the surface hatches at an elevation of 9.1 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE at the ocean with a BFE of 15 feet NAVD88. The facility will become inundated during the 500-year flood and tsunami events. Therefore, the Kinney Circle Pumping Plant No. 647 is considered a long-term priority.

Figure 1. Hazard Zones for Kinney Circle Pumping Plant No. 647

Resilience Improvements

The Kinney Circle Pumping Plant No. 647 is identified as a long-term priority with flood hazards. The facility is not included in the existing CIP but planning an upgrade of the facility is underway. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience improvements.

Table 1. Kinney Circle Pumping Plant No. 647 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
9.1	17.00	18.64	20.75	21.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended for consideration in operations and the upgrade of the facility:

- Coordinate more frequent monitoring and cleaning of the outfall with Los Angeles County
- Add waterproof instrumentation and controls to planned upgrade
- Install watertight connections and protect the motor control center in planned upgrade
- Add waterproof hatches and raise vents in planned upgrade
- Check capacities of planned green infrastructure and other drainage enhancement for design storms with additional precipitation and intensity projected with climate change.

For planning purposes the estimated cost of the recommended resilience improvements is $610,000 added to the planned upgrade. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant will result in flooding of the intersection. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Kinney Circle Pumping Plant No. 647. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Kinney Circle Pumping Plant No. 647

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Medium	Very High	Medium	Medium	$3,750,000
With Improvements	Low	Low	Low	Low	$610,000

-This Page Left Blank Intentionally-

Southerland Pumping Plant No. 692

Facility Location and Description

Southerland Pumping Plant No. 692 was constructed in 1977 and is located at 900 North Southerland Avenue in Wilmington near the Port of Los Angeles. The facility pumps stormwater from the neighboring properties through the levee and into the neighboring Dominguez Channel. The pump station does not have a bypass system and the wet well has a grated cover.

The pump station has a capacity of 33,000 gpm and is equipped with five pumps, three rated for 10,500 gpm and two rated for 1,200 gpm. Instruments, electrical components, and controls are located in a cabinet at grade. The facility has a 100 kW portable backup generator located onsite. The replace-in-kind cost estimate is $23,166,000 for the Southerland Pumping Plant No. 692 based on the pumping capacity including markups and contingencies.

Facility Hazards

Southerland Pumping Plant No. 692 is located within or near several different hazard zones. Figure 1 shows the facility is within the 500-year flood, liquefaction, 100-year flood with 1.5 meters sea level rise, and tsunami inundation zones. Development of the area and flat terrain has minimized the potential for landslide or liquefaction.

The flood damage threshold for the facility is the control pad at an elevation of 7.68 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to the Dominguez Channel with a FEMA Zone AE and BFE of 9 feet NAVD88. Although the facility is lower than the flood elevation it is protected by the levee that contains the channel. Under a 500-year flood, a 100-year flood with 1.5 meters sea level rise, and tsunami events the facility is expected to become inundated. Therefore, the Southerland Pumping Plant No. 692 is considered a long-term priority.

Figure 1. Hazard Zones for Southerland Pumping Plant No. 692

Resilience Improvements

Southerland Pumping Plant No. 692 has been identified as a long-term priority for flood hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of existing adaptations that can be incorporated into maintenance practices at each pumping plant is presented in Section 3. Since this is a stormwater pumping plant with significant long-term inundation hazards, it is recommended to waterproof the facility for protection until flood waters subside. Table 1 shows the recommended DFEs to be considered for future resilience Improvements.

Table 1. Southerland Pumping Plant No. 692 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
7.68	NA	NA	13.25	15.92	20.00

Note: [a] Elevations are in NAVD88
[b] 100-yr Flood DFE = BFE + 2 ft Freeboard
[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard
[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard
[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard
[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long-term resilience improvements are recommended:

- Install watertight connections and protect the motor control center
- Waterproof instrumentation and controls
- Replace existing pumps and motors with submersibles
- Install bollard around facility to protect from floating debris from tsunami
- Move portable generator to higher ground

For planning purposes the estimated cost of the recommended long-term resilience improvements is $1,860,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant will result in flooding of the nearby area. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Southerland Pumping Plant No. 692. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Southerland Pumping Plant No. 692

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Medium	Very High	Medium	Medium	$23,166,000
With Improvements	Low	Low	Low	Low	$1,860,000

Tuxford Pumping Plant No. 614

Facility Location and Description

The Tuxford Pumping Plant No. 614 was constructed in 2007 and is located at 11502½ Tuxford Street in Sun Valley in the San Fernando Valley. The facility is a low flow diversion with a bypass to the existing storm drain system. The pump station has a capacity of 180 gpm and is equipped with two pumps rated for 90 gpm. Instruments, electrical components, and controls are located below ground. The facility does not have a backup generator. The replace-in-kind cost estimate is $650,000 for the Tuxford Pumping Plant No. 614.

Facility Hazards

Tuxford Pumping Plant No. 614 is located near flood hazard zones. Figure 1 shows the facility is within the 100-year flood zone but outside of landslide, liquefaction, and fire zones. The facility is located inland and does not have coastal SLR and tsunami risks.

The flood damage threshold for the facility is the hatches located at the ground surface. The FEMA FIRM does not indicate a 100-year BFE but the flood zone indicates the facility will be inundated. Therefore, the Tuxford Pumping Plant No. 614 is identified as a short-term priority.

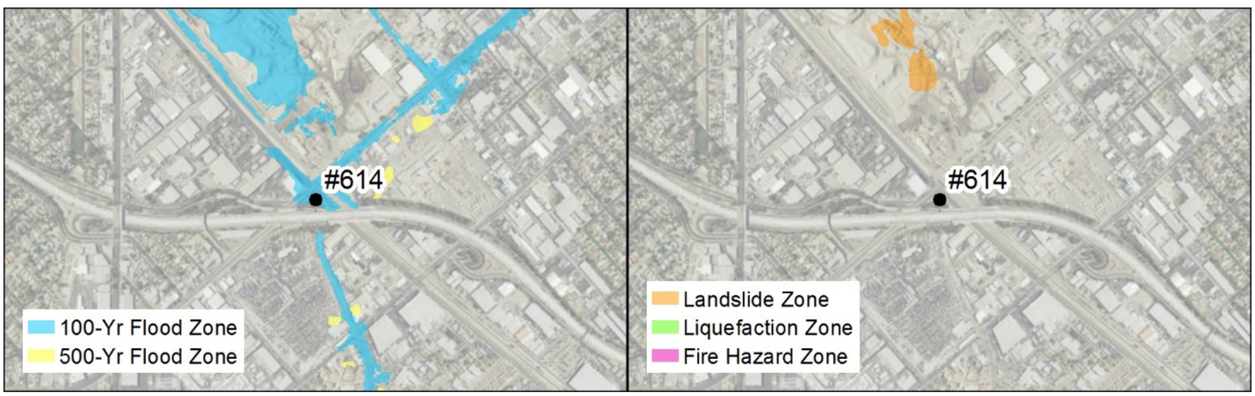


Figure 1. Hazard Zones for Tuxford Pumping Plant No. 614

Resilience Improvements

Tuxford Pumping Plant No. 614 has been identified as a short-term priority and within the 100-year flood zone. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Since the facility can bypass to the existing storm drain system the recommended resilience improvement is to waterproof the facility for protection until flood waters subside. The following resilience improvements are recommended:

- Waterproof hatches
- Waterproof instrumentation and controls

For planning purposes the estimated cost of the recommended resilience improvements is $90,000. Appendix D provides more detail on the replace-in-kind and resilience improvements cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant may have some impacts on Tujunga Wash water quality. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Tuxford Pumping Plant No. 614. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 1. CREAT Results for Climate Change Impacts to the Tuxford Pumping Plant No. 614

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Low	Very High	Low	Low	$650,000
With Improvements	Low	Low	Low	Low	$90,000

Santa Monica Pumping Plant No. 733

Facility Location and Description

Santa Monica Pumping Plant No. 733 was constructed in 2010 and is located at 14792 Pacific Coast Highway in Pacific Palisades. The facility is a low flow diversion used to divert non-stormwater flows into the sewer system and to allow high flows to bypass to Santa Monica Bay.

The pump station has a capacity of 10,000 gpm and is equipped with three pumps, two rated for 1,800 gpm and the third rated for 1,700 gpm. Instruments, electrical components and controls are located in an at grade cabinet. There is no backup generator located onsite. The replace-in-kind cost estimate is $1,300,000 for the Santa Monica Pumping Plant No. 733.

Facility Hazards

Santa Monica Pumping Plant No. 733 is located along the coast with several different hazards. Figure 1 shows the facility is within the 500-year flood, liquefaction, fire, and tsunami zones and nearby 100-year flood with 0.5 meter and 1.5 meters sea level rise inundation zones. Since the facility is located in a parking lot and neighboring a developed area, fire- and liquefaction-related hazards are minimal.

The flood damage threshold for the facility is the concrete pad for the controls with an elevation of 19 feet NAVD88. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone AE at the ocean with a BFE of 15 feet NAVD88. The facility will become inundated during the 500-year flood, 100-year flood with 1.5 meters sea level rise, and tsunami events. Therefore, the Santa Monica Pumping Plant No. 733 is considered a long-term priority.

Figure 1. Hazard Zones for Santa Monica Pumping Plant No. 733

Resilience Improvements

The Santa Monica Pumping Plant No. 733 is identified as a long term priority. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Table 1 shows the recommended DFEs to be considered for future resilience Improvements.

Table 1. Santa Monica Pumping Plant No. 733 Design Flood Elevations

Damage Threshold Elevation	Short Term	Medium Term	Long Term		
	100-yr Flood DFE[b]	0.5 m SLR DFE[c]	500-yr Flood DFE[d]	1.5 m SLR DFE[e]	Tsunami DFE[f]
19.00	17.00	18.64	20.75	21.92	20.00

Note: [a] Elevations are in NAVD88

[b] 100-yr Flood DFE = BFE + 2 ft Freeboard

[c] 0.5 m SLR DFE = BFE + 0.5 m + 2 ft Freeboard

[d] 500-yr DFE = BFE*1.25 + 2 ft Freeboard

[e] 1.5 m SLR DFE = BFE + 1.5 m + 2 ft Freeboard

[f] Tsunami DFE = 20 ft estimated tsunami wave height

The following long term resilience improvements are recommended:

- Waterproof instrumentation and controls
- Waterproof hatches

For planning purposes the estimated cost of the recommended resilience improvements is $140,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the low flow diversion would impact Santa Monica Bay water quality. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Santa Monica Pumping Plant No. 733. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 2. CREAT Results for Climate Change Impacts to the Santa Monica Pumping Plant No. 733

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Low	Very High	Medium	Medium	$1,300,000
With Improvements	Low	Low	Low	Low	$140,000

Temescal Pumping Plant No. 734

Facility Location and Description

Temescal Pumping Plant No. 734 was constructed in 2002 and is located at 15733½ Pacific Coast Highway in Pacific Palisades. The facility is a low flow diversion to divert non-stormwater flows into the sewer system.

Temescal Pumping Plant No. 734 has a capacity of 3,500 gpm and is equipped with three wet pit submersible pumps each rated for 1,300 gpm. Instruments, electrical components, and controls are located in above ground cabinets. The facility can bypass to the storm drain system and has backup power available at the neighboring Pumping Plant No. 634. The replace-in-kind cost estimate is $650,000 for the Temescal Pumping Plant No. 734.

Facility Hazards

Temescal Pumping Plant No. 734 is located near several different hazard zones. Figure 1 shows the facility is just outside of the coastal inundation zones from flooding, SLR, and tsunami events. The facility is within a FEMA flood hazard Zone X and is adjacent to a FEMA Zone VE with a BFE of 13 feet NAVD88. The damage threshold for the facility is 21.0 feet NAVD88 and outside of inundation areas. The facility is within landslide, liquefaction, and fire hazard zones. Previous rainfall events have caused debris to enter the pump station enclosure from the neighboring hillside. Therefore, the Temescal Pumping Plant No. 734 is considered a short-term priority.

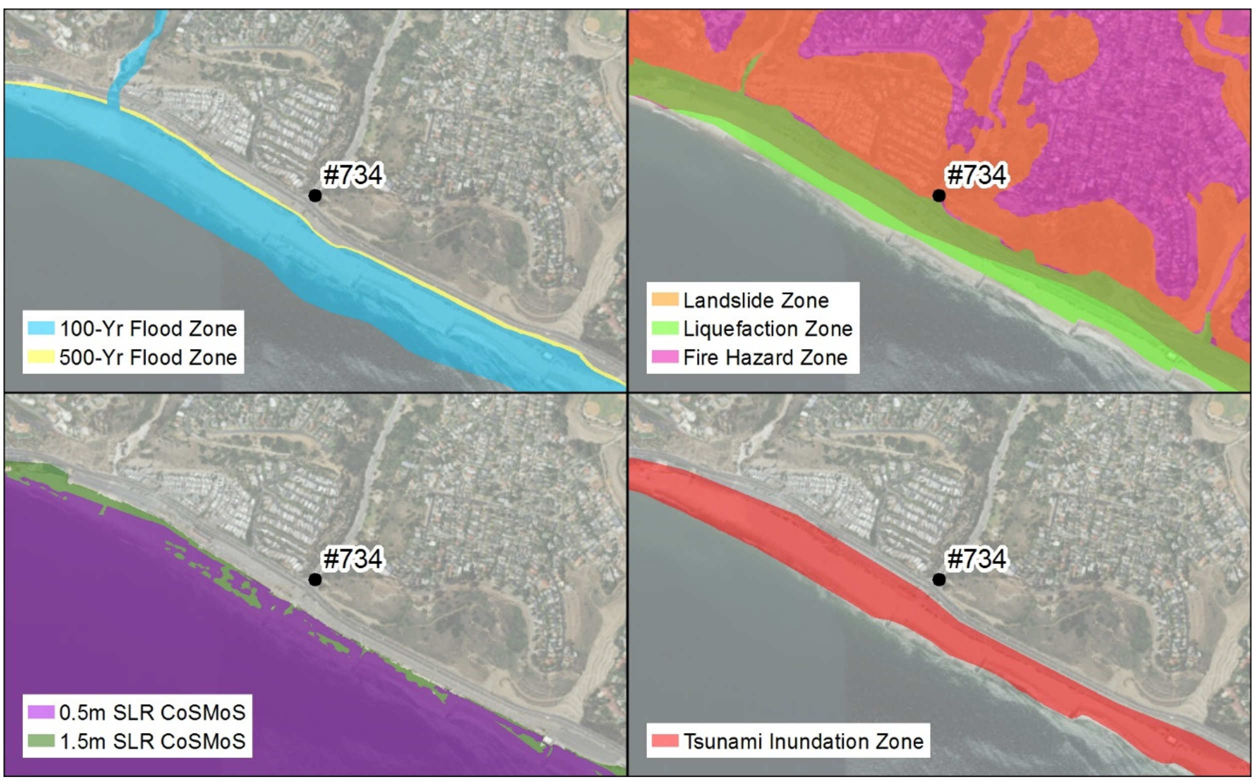


Figure 1. Hazard Zones for Temescal Pumping Plant No. 734

Resilience Improvements

The Temescal Pumping Plant No. 734 is identified as a short-term priority with landslide and fire hazards. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. The following resilience improvements are recommended:

- Construct perimeter wall around the facility
- Manage nearby vegetation to minimize fire hazards

For planning purposes the estimated cost of the recommended resilience improvements is $60,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the low flow diversion would have impacts on Santa Monica Bay water quality. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 2 summarizes the results of CREAT for the Temescal Pumping Plant No. 734. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix E.

Table 1. CREAT Results for Climate Change Impacts to the Temescal Pumping Plant No. 734

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Low	Very High	Low	Low	$650,000
With Improvements	Low	Low	Low	Low	$60,000

Westside Park Pumping Plant No. 740

Facility Location and Description

Westside Park Pumping Plant No. 740 was constructed in 2010 and is located at 2785 Clyde Avenue in Los Angeles at the Westside Neighborhood Park. The facility is a low flow diversion that pumps diverted dry weather flows through a screening process that removes floatables and sediments to reuse the treated water onsite for irrigation. The pump station has a capacity of 60 gpm and equipped with two pumps rated for 60 gpm. Instruments, electrical components, and controls are located below ground. The facility has an available 60 kW portable backup generator located offsite at the northern storage yard. The replace-in-kind cost estimate is $650,000.

Facility Hazards

Westside Park Pumping Plant No. 740 is located in flood hazard zones. Figure 1 shows the facility is within the 100-year flood zone and adjacent to the 500-year food zone, and is in a liquefaction zone. There is no potential risk for landslide during a liquefaction event. The facility is also located inland and does not have coastal SLR and tsunami risks. The flood damage threshold for the facility is the concrete pad for the control boxes. The existing 100-year FEMA FIRM does not indicate a BFE but the flood zones indicate the facility will experience inundation during the 100-year and 500-year flood events. Therefore, Westside Park Pumping Plant No. 740 is identified as a short-term priority.

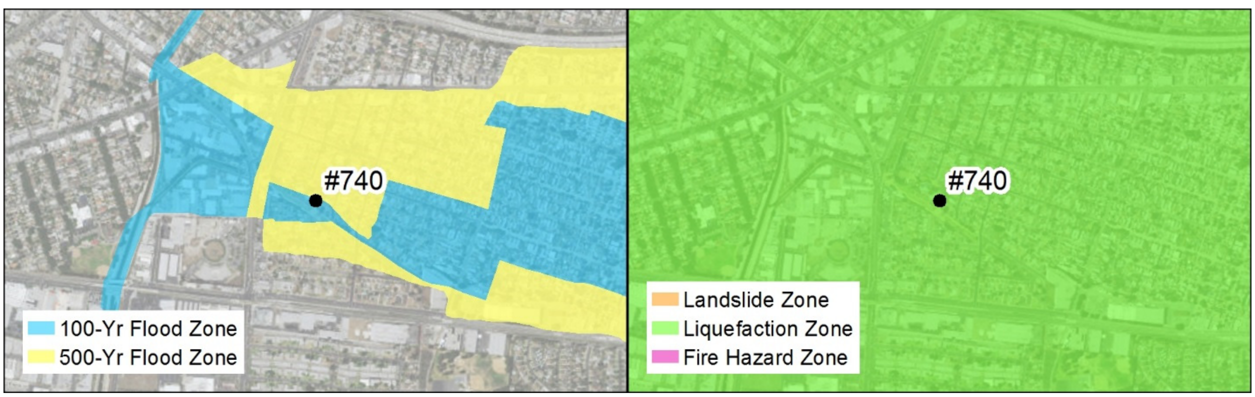


Figure 1. Hazard Zones for Westside Park Pumping Plant No. 740

Resilience Improvements

Westside Park Pumping Plant No. 740 has been identified within the 100-year flood zone. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. Since the facility can bypass to the existing storm drain system the recommended resilience improvement is to waterproof the facility for protection until flood waters subside. The following resilience improvements are recommended:

- Waterproof hatches
- Waterproof instrumentation and controls

For planning purposes the estimated cost of the recommended resilience improvements is $90,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant may have some impacts on stormwater quality discharged to Tujunga Wash. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 1 summarizes the results of CREAT for the Westside Park Pumping Plant No. 740. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

Table 1. CREAT Results for Climate Change Impacts to the Westside Park Pumping Plant No. 740

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Cost
Without Improvements	Low	Very High	Medium	Medium	$650,000
With Improvements	Low	Low	Low	Low	$90,000

Los Angeles Zoo Pumping Plant

Facility Location and Description

The Los Angeles Zoo Pumping Plant was constructed in 1993 and is located at 4700½ Western Heritage Drive in Los Angeles, east of the Los Angeles Zoo and the Autry Museum of the American West. The facility provides primary treatment to runoff and wash-down water from animal enclosures. The effluent is discharged to the Los Angeles River and captured solids are conveyed to the North Outfall Sewer for conveyance to and treatment at the HWRP.

The pump station has a capacity of 12,000 gpm with four pumps powered by 60 hp motors. Instruments, electrical components, and controls are located in a control room building at grade. The facility has a 350 kW backup generator located within the control room. The replace-in-kind cost estimate is $8,424,000 for the Los Angeles Zoo Pumping Plant based on the pumping capacity and including markups and contingencies.

Facility Hazards

The Los Angeles Zoo Pumping plant is located within several different hazard zones. Figure 1 shows the facility is located within the fire and liquefaction hazard zones and there are some nearby landslide hazards. Due to the development of the area and flat grade around the facility, the fire and landslide risks are minimal. Since the pumping plant is located inland, there are no sea level rise or tsunami risks.

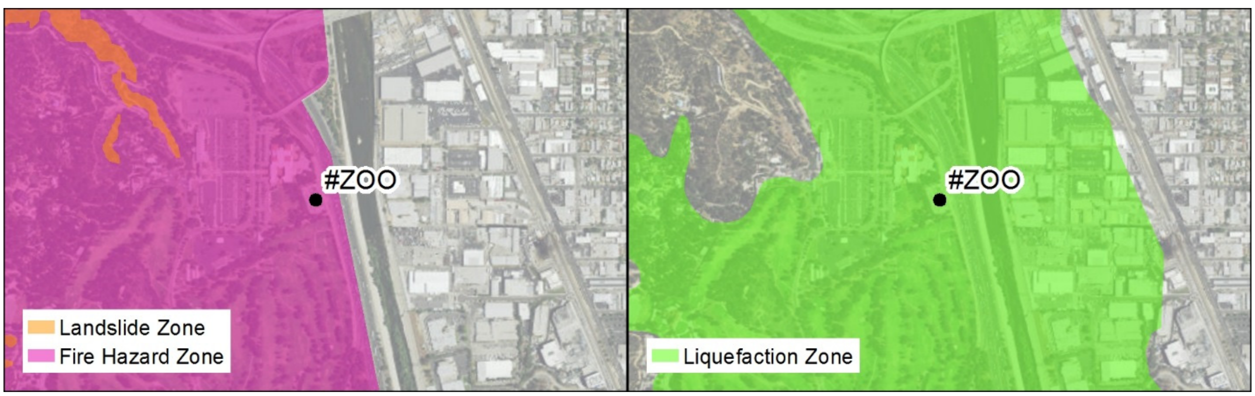


Figure 1. Non-Flood Hazard Zones for Los Angeles Zoo Pumping Plant

The facility is adjacent to the Los Angeles River and the current FEMA FIRM shows no flooding risks (FEMA FIRM number 06037C1345F, September 28, 2008). However, a recent study by USACE shows the pumping plant will be inundated during the 100- and 500-year flood events as shown in Figure 2 (USACE, 2016). Therefore, the Los Angeles Zoo Pumping Plant is identified to be a short-term priority.

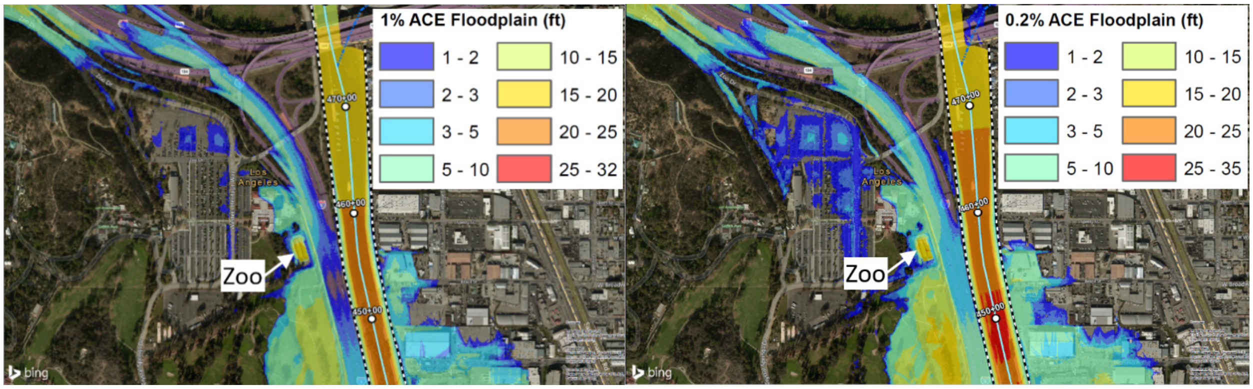


Figure 2. USACE 100-year (left) and 500-year (right) Flood Hazard Zones for Los Angeles Zoo Pumping Plant

Source: USACE, 2016. Modified by CH2M, 2016.

Resilience Improvements

The Los Angeles Zoo Pumping Plant has been identified as a short-term priority with hazards for the 100-year and 500-year flood scenarios. The facility is not included in the existing CIP and there are no plans for future improvements at this time. A list of actions that can be incorporated into existing maintenance practices is presented in Section 3. The USACE has not released calculated flood elevations that could be used for recommending design flood elevations at this time. The following resilience improvements are recommended:

- Waterproof existing wall and install flood gates at both entrances
- Install influent and effluent gates to prevent flooding from within
- Waterproof control room
- Raise diesel fuel tank

For planning purposes the estimated cost of the recommended resilience improvements is $960,000. Appendix D provides more detail on the replace-in-kind and resilience improvement cost methodology, which is consistent with the basis of cost methodology used for One Water LA.

CREAT Assessment

Failure of the pumping plant will impact Los Angeles River water quality. Application of CREAT results in a monetization of risk for each type of impact considering the asset before and after implementing resilience improvements. Table 1 summarizes the results of CREAT for the Los Angeles Zoo Pumping Plant. A description of CREAT, as well as details on the consequence categories and level descriptions, are provided in Section 3 and Appendix C.

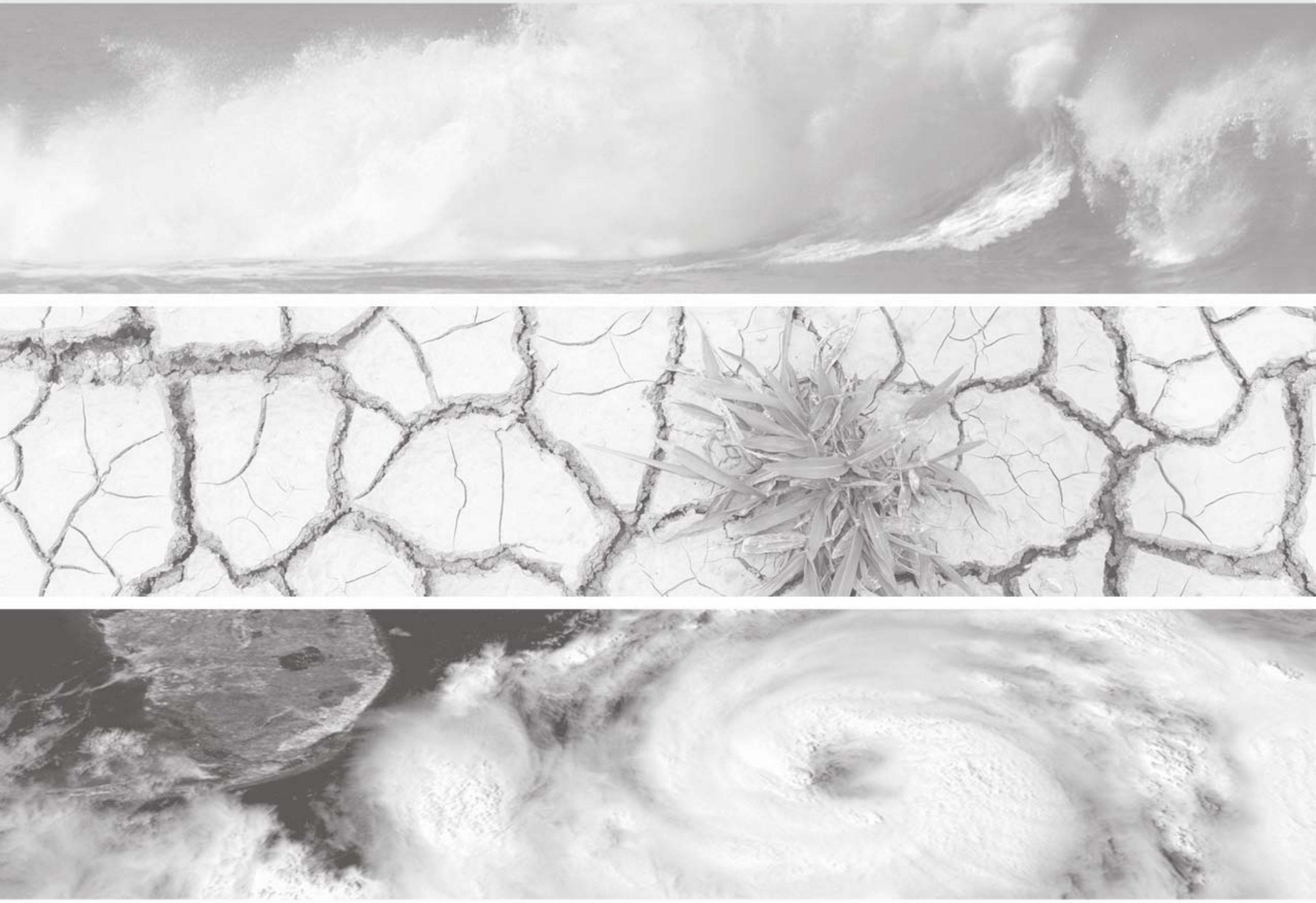
Table 1. CREAT Results for Climate Change Impacts to the Los Angeles Zoo Pumping Plant

Analysis	Utility Business Impacts	Utility Equipment Damages	Source/Receiving Water Impacts	Environmental Impacts	Overall Consequences
Without Improvements	Medium	Very High	High	High	$8,424,000
With Improvements	Low	Low	Low	Low	$960,000

APPENDIX F – EPA LOS ANGELES SANITATION CLIMATE CHANGE RISK ASSESSMENT AND ADAPTATION MEASURE RECOMMENDATIONS FOR WASTEWATER ASSETS

Climate Ready Water Utilities

Los Angeles Sanitation Climate Change Risk Assessment and Adaptation Measure Recommendations for Wastewater Assets



AUGUST 22, 2016

Table of Contents

Appendices

RESULTS SUMMARY

Table 1: Replace in-kind and Adaptation Cost Estimates for LA Sanitation Assets

		ADAPTATION COSTS	
ASSET	**REPLACE IN-KIND COSTS**	**COST ESTIMATE**	**80TH PERCENTILE FOR PLANNING**
PUMPING PLANTS			
Pumping Plant No. 632 Sunset Boulevard	$3,500,000	$732,000	$1,240,000
Pumping Plant No. 634 Temescal Canyon	$2,700,000	$718,000	$1,220,000
Pumping Plant No. 639 North Pulga Canyon	$2,200,000	$504,700	$860,000
Pumping Plant No. 647 Venice Beach (stormwater)	$1,400,000	$400,000	$680,000
Pumping Plant No. 680 22nd and Signal	$500,000	$89,300	$150,000
Pumping Plant No. 686 Nissan Way	$1,700,000	$376,700	$640,000
TERMINAL ISLAND WATER RECLAMATION PLANT			
Headworks and Lift Station	$11,000,000	$230,000	$390,000
Motor control centers (MCC)	$15,800,000	$6,470,000	$11,000,000
Advanced Water Purification Facility (AWPF)	$15,000,000	$1,060,000	$1,800,000
Effluent pumping plant, including standby generators	$11,000,000	$170,000	$310,000
Perimeter Wall Alternative	Entire Facility	$3,730,000	$6,340,000

INTRODUCTION

The City of Los Angeles, Department of Public Works, Bureau of Sanitation (LA Sanitation) has more than 6,700 miles of public sewers that collect about 400 million gallons per day (MGD) of wastewater from four million people in residences and businesses within two service areas covering over 600 square miles. LA Sanitation operates 44 pumping plants as well as four wastewater treatment and water reclamation plants. On May 13 -14, 2015 and October 19-20, 2015, LA Sanitation conducted a climate change risk assessment at an in-person meeting using the beta version of the U.S. Environmental Protection Agency's (EPA) Climate Resilience Evaluation and Awareness Tool (CREAT) 3.0[1]. Site visits were also conducted to assess the vulnerabilities of each asset. In order to meet Strategic Goal #8, Complete a Climate Change Adaptation Plan and identify projects for LA Sanitation's ten-year Capital Improvement Program for FY 2016-17, and to be in line with the City's Sustainable City Plan (pLAn)[2], LA Sanitation used CREAT to assess climate risk and resilience for several of its critical assets.

Within CREAT, LA Sanitation assessed the potential effects of climate change on seven priority assets under current flooding and wet weather conditions and considering an increase in storm intensity, plus sea-level rise, projected for the year 2060. The priority assets were:

- Sunset Boulevard Pumping Plant No. 632
- Temescal Canyon Pumping Plant No. 634
- North Pulga Canyon Pumping Plant No. 639
- Venice Beach Stormwater Pumping Plant No. 647
- 22nd and Signal Pumping Plant No. 680
- Nissan Way Pumping Plant No. 686
- Terminal Island Water Reclamation Plant (TIWRP)

The current and future climate conditions applied in the assessment are listed in **Table 2**.

The assessments of the Sunset Boulevard Pumping Plant No. 632, Temescal Canyon Pumping Plant No. 634 and North Pulga Canyon Pumping Plant No. 639 indicate that they are currently not at risk to flooding but are adjacent to tsunami zones. The Venice Beach Stormwater Pumping Plant No. 647, 22nd and Signal Pumping Plant No. 680, Nissan Way Pumping Plant No. 686 are potentially at high risk currently because they are in current 500-year flood zones. The 22nd and Signal Pumping Plant No. 680, Nissan Way Pumping Plant No. 686 and TIWRP are potentially at high risk to flooding under current conditions because they are in a tsunami zone. Flooding risks increase under future conditions for all facilities with sea-level rise. Potential adaptation measures were identified in this exercise that could be implemented in the short- and long-term to reduce those risks. Priority adaptation measures may be incorporated into LA Sanitation's Capital Improvement Program. LA Sanitation plans to continue using the beta version of CREAT 3.0 to conduct additional risk assessments for other pumping plants and wastewater reclamation plants.

---

[1] EPA Climate Resilience Evaluation and Awareness Tool: http://water.epa.gov/infrastructure/watersecurity/climate/creat.cfm
[2] Sustainable City pLAn available online at http://plan.lamayor.org/

Table 2: Climate Data for LA Sanitation

LOCATION	CLIMATE VARIABLE	HISTORICAL VALUE (OBSERVED)	PROJECTED VALUE FOR MID-CENTURY (OBSERVED + CHANGES)
Sunset Boulevard, Temescal Canyon, North Pulga Canyon and Venice Beach Pumping Plants	Average Annual Temperature	62.9°F	66.0°F
	Total Annual Precipitation	18.5 inches	22.4 inches
	100-Year Storm Event	5.4 inches in 24 hours	7.0 inches in 24 hours
	Hot days (over 95°F)	6 days (1981-2000)[3]	22 days
	Sea-Level Rise	2 mm/year[4]	0.5 meters (1.64 feet)[5]
22nd and Signal and Nissan Way Pumping Plants, TIWRP	Average Annual Temperature	63.2°F	66.1°F
	Total Annual Precipitation	13.7 inches	15.2 inches
	100-Year Storm Event	7.3 inches in 24 hours	9.5 inches in 24 hours
	Hot days (over 95°F)	6 days (1981-2000)[3]	22 days[3]
	Sea-Level Rise	2 mm/year[4]	0.5 meters (1.64 feet)

PURPOSE OF THIS DOCUMENT

The Sustainable City pLAn was released on April 8, 2015, and requires City departments to meet short- and long-term sustainability targets that include actions to build climate resilience. LA Sanitation is identifying actions they can take to meet its Strategic Goal #8, which is due summer 2016. LA Sanitation is concerned with impacts to its critical infrastructure and operations from a number of climate threats, including drought, sea-level rise, flooding due to extreme rainfall, blackouts due to increased energy demand with temperature increases, wildfires, high winds and earthquakes (with subsequent landslides and liquefaction or flooding from tsunamis). Seismic analysis is not included in this report, and drought impacts will be addressed in LA Sanitation's One Water Plan.

The overall assessment goal is to use CREAT to identify priority adaptation options that can be included in capital improvement planning for the following priority assets:

- Sunset Boulevard Pumping Plant No. 632,
- Temescal Canyon Pumping Plant No. 634,
- North Pulga Canyon Pumping Plant No. 639,
- Venice Beach Stormwater Pumping Plant No. 647,
- 22nd and Signal Pumping Plant No. 680,
- Nissan Way Pumping Plant No. 686, and
- Terminal Island Water Reclamation Plant (TIWRP).

[3] Dr. Alex Hall, UCLA Study on Climate Change in the Los Angeles Region: Temperature Results, Business As Usual Scenario
[4] Historical global sea-level rise observations, used by CoSMoS 1.0
[5] Projected sea-level rise data from – SLR from CoSMoS 1.0 for the year 2050, CoSMoS 3.0 model calculations used at 100-year storm plus 0.5m sea-level rise scenario

The purpose of this document is to describe a climate risk assessment for the aforementioned assets and provide short- and long-term risk mitigation recommendations.

CLIMATE RESILIENCE ASSESSMENT PROCESS

During a two-day meeting from May 13 to 14, 2015, the U.S. Environmental Protection Agency (EPA) provided technical assistance to LA Sanitation to assess their risk to potential climate change threats, and identify and prioritize adaptation options using a beta version of CREAT 3.0. The assessment brought together various LA Sanitation staff (**Appendix A**) to think critically about potential climate impacts, priority assets and adaptation options.

CREAT enables a utility to assess and identify risks related to climate change impacts with the purpose of raising awareness and generating sets of adaptation options for further consideration. After selecting the analysis location, climate scenarios, threats and assets of concern, users assess their overall consequences from climate change-related threats, considering both existing resources and additional capabilities from implementing adaptation measures.

CREAT provides a consequence matrix with default economic data for four categories that capture the range of impacts a utility may experience from a particular climate change-related threat (**Appendix C**). These include utility business impacts, utility equipment impacts, source and receiving water impacts, and environmental impacts. CREAT users can also assess public health consequences from climate change impacts in either a qualitative or quantitative manner. Within each of these categories, users assess the impacts on a four-point scale from Low to Very High. CREAT will calculate a monetized value of risk based on the user's selections, and calculate a reduction in that risk after implementing adaptation options. Users can evaluate the performance of potential adaptation measures to inform planning decisions based on risk reduction, cost, public health impacts, energy requirements and socio-economic factors.

LA Sanitation is using CREAT to inform their adaptation prioritization efforts, aligning the results of the CREAT analysis with the prioritization criteria and weightings that is used for capital improvement planning efforts (**Appendix D**).

CREAT ASSESSMENT

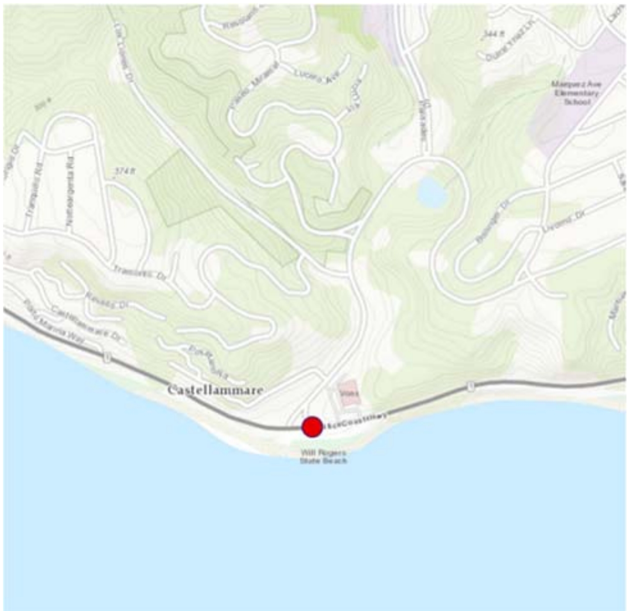
CREAT enables a utility to assess a number of challenges that may impact operations and services for its customers, including current challenges as well as those that may become exacerbated by future climate conditions. CREAT can assist in evaluating how these concerns may change under a number of possible climate scenarios and provide data to help inform planning for concerns relating to water supply management, peak service challenges, water quality management and natural disasters. The overall climate-related areas of concern for LA Sanitation were water supply management, peak service challenges, natural disasters, population/demographic changes, sector water/service needs, interdependent sector reliability and sea-level rise. LA Sanitation added earthquakes as a custom concern, in particular liquefaction and tsunamis.

For this assessment, the impacts of changes in temperature, precipitation and sea-level rise on flooding conditions due to coastal storms and earthquakes (with subsequent landslides and liquefaction or flooding from tsunamis) were assessed for the six pumping plants and TIWRP.

Climate Awareness

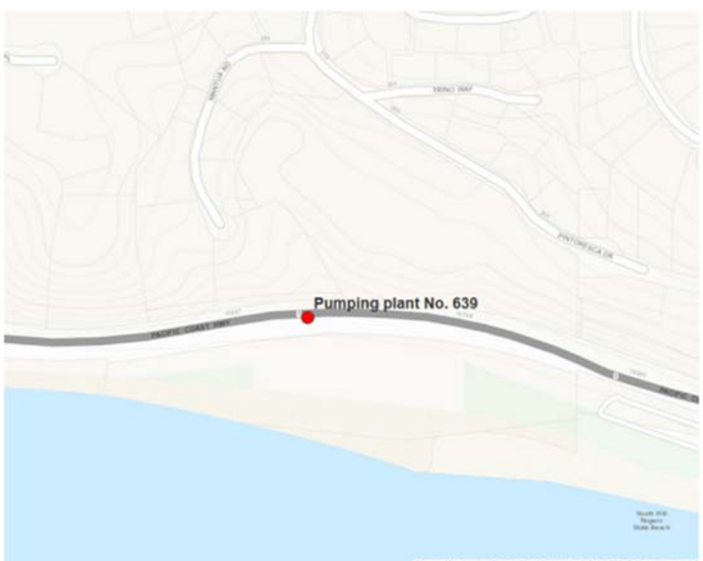
The locations of the Pumping Plants and TIWRP are shown in **Figures 1 and 2.**

Figure 1: Locations of the Assessed Pumping Plants



Sunset Boulevard Pumping Plant No. 632

Temescal Canyon Pumping Plant No. 634



North Pulga Canyon Pumping Plant No. 639

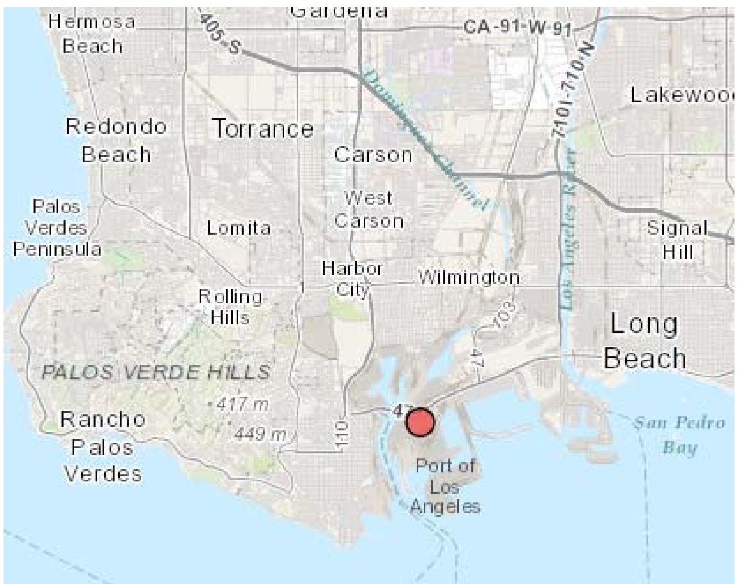
Venice Beach Stormwater Pumping Plant No. 647

Figure 1: Locations of the Assessed Pumping Plants

22nd and Signal Pumping Plant No. 680

Nissan Way Pumping Plant No. 686

Figure 2: Location of the Terminal Island Water Reclamation Plant



Climate Scenarios

Climate threats, such as floods or drought, can be driven by a number of factors, such as changes in total precipitation or average annual temperatures. The CREAT assessment uses current climate data and projections of future climate conditions to identify those threats and how they may change over time. CREAT defines a scenario as projected changes in climate with respect to historical conditions (temperature and precipitation), extreme events (intense precipitation and extreme heat) and sea-level rise.

Within CREAT, users can consider scenarios of projected climate changes to assess the consequences of various threats to their assets. The three projected scenarios in CREAT capture the range of potential future conditions at any given location within the U.S. based on Global Climate Model (GCM) results. While all models project temperatures warming, the projected changes in precipitation vary, with some projecting wetter conditions and others projecting drier conditions. Because they were mainly concerned with wet weather events and flooding, the LA Sanitation group focused on CREAT's "warm and wet" scenario with a stormy extreme precipitation projection (**Table 3**). In this scenario, the projected increase in the 100-year storm is 30.43% for the year 2060. For more information on LA Sanitation climate data, see **Appendix B**.

Table 3: LA Sanitation Climate Data Sources

SCENARIO	DATA
Current Conditions Scenario	CREAT-provided historical data based on PRISM (http://www.prism.oregonstate.edu/)
	Onsite weather station data (for comparison with CREAT-provided data)
	FEMA Flood Data — 100- and 500-year FEMA base flood elevations
	U.S. and California Geological Survey tsunami zones and earthquake conditions
	Dr. Alex Hall, UCLA Study on Climate Change in the Los Angeles Region: Temperature Results, Business As Usual Scenario
	Historical sea-level rise observations, used by CoSMoS.
Projected Climate Scenario	Warm/wet scenario in CREAT with Stormy Extreme Precipitation
	UCLA Temperature Projection 2041-2060
	Sea-level rise – CoSMoS 1.0 and 3.0 model calculations with 100-year storm and incremental sea level rise from 0.5 meters to 2.0 meters, and at 5.0 meters.
Other Climate and Weather Data	Extreme event data – California Emergency Management Agency (CalEMA)
	Earthquake data – California Geological Survey
	Wildfire data – California Department of Forestry and Fire Protection (CAL FIRE)

CREAT provides historical and projected climate change data. The following data and how it could be used by LA Sanitation were discussed:

- Annual average temperature: CREAT-provided temperature data were generally consistent with LA Sanitation's information. CREAT reported an average annual historical temperature of approximately 63°F with a projected increase of 3°F over the next few decades (average for the period 2050-2070). Increases in average temperatures are already being seen in the area.
- Number of hot days: Hot days increase chances of losing power, having transmission problems and introducing health and safety concerns for staff. For LA Sanitation, the total number of days over a temperature threshold (95°F), as well as the number of consecutive hot days, is used for planning purposes. The projected number of hot days for the Temescal Pumping Station and TIWRP locations are minimal and will increase modestly (2 days for the 2060 time

period). The measured number of days with maximum temperatures greater than or equal to 95°F for three different climate stations in 2011 to 2014 are summarized in **Table 4** below.

Table 4. Number of Hot Days from 2011 to 2014 for Different Climate Stations in yhe Los Angeles Area.

CLIMATE STATION	NUMBER OF DAYS OVER 95°F			
	2011	2012	2013	2014
Long Beach[6]	1	5	0	12
Pierce College/ Woodland Hills[7]	48	80	65	69
Santa Monica[6]	0	2	4	2

- Annual average precipitation: Historical data show 14 to 18 inches per year, but total annual precipitation has been about 6.8 inches for the past few years due to the drought. Rainy season is typically October 15 – April 15, which is consistent with CREAT-provided data.
- Extreme precipitation data: 100-year storms may generate landslides and localized flooding. LA Sanitation is more concerned with drainage as opposed to the pumping and process capacity of plants. The system experiences a 2.2 peaking factor during storms; although the sewer system is completely separated, the first flush of stormwater is diverted to sanitary sewers. Historical daily maximum rainfalls from CREAT are consistent with magnitudes used for planning at LA Sanitation (5 to 7 inches of rain in 24-hour period for the 100-year storm).
- Coastal Flooding and Earthquakes/tsunami zone: The Sunset Boulevard, Temescal Canyon, and Pulga Canyon Pumping Plants and TIWRP are not in the current Federal Emergency Management Agency (FEMA) 100- and 500-year flood zones shown on the current Flood Rate Insurance Map (FIRM). These pumping plants are just outside the tsunami and liquefaction zone but TIWRP is in a tsunami and liquefaction zone, as shown in a GIS data layer provided by the U.S. Geological Survey (USGS) (**Figure 3**). The Venice Beach Stormwater, 22nd and Signal, and Nissan Way Pumping Plants are in the FEMA 500-year flood zone and the tsunami and liquefaction zone. The potential maximum mean wave height resulting from a local seismic event is approximately 0.75 meters (2.5 feet).[8]
- Sea-level rise: Historical global sea-level rise is estimated as 2 mm/year over the past century. The National Oceanic and Atmospheric Administration (NOAA) reports the mean sea level trend at Los Angeles is 0.88 mm/year based on monthly mean sea level data from 1923 to 2014 (see **Appendix B**). The rate of global and regional sea-level rise will increase with climate change. CREAT-provided data projects up to 2 meters (6.6 feet) of sea-level rise by 2100. Until recently, LA Sanitation was using the USGS Coastal Storm Modeling System (CoSMoS) 1.0 calculations for Southern California to identify coastal storm threats with climate change. CoSMoS 1.0, officially released in 2012, used 0.5 and 1.4 meters (1.6 and 4.6 feet) of sea-level rise to 2050 and 2100 respectively, in its coastal storm model calculations.[9] As an example, the CoSMos base flood elevation calculations in the Port of Los Angeles at TIWRP were about 1.8

[6] Data from the University of California Agricultural and Natural Resources Department: http://www.ipm.ucdavis.edu/WEATHER/index.html

[7] Data from the Pierce College Weather Station: http://piercecollegeweather.com/data/monthly-historical-data/

[8] *Tsunami Hazard Assessment for The Ports of Long Beach And Los Angeles*, Final Report. Prepared for the Port of Long Beach and Port of Los Angeles by Moffatt & Nichol, April 2007.

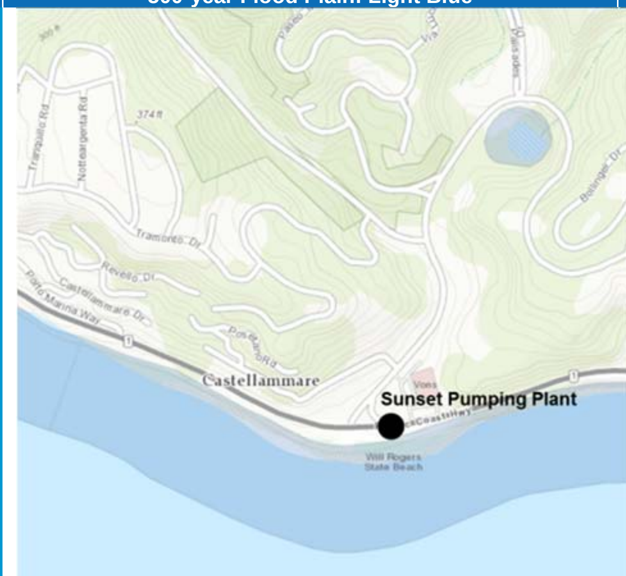
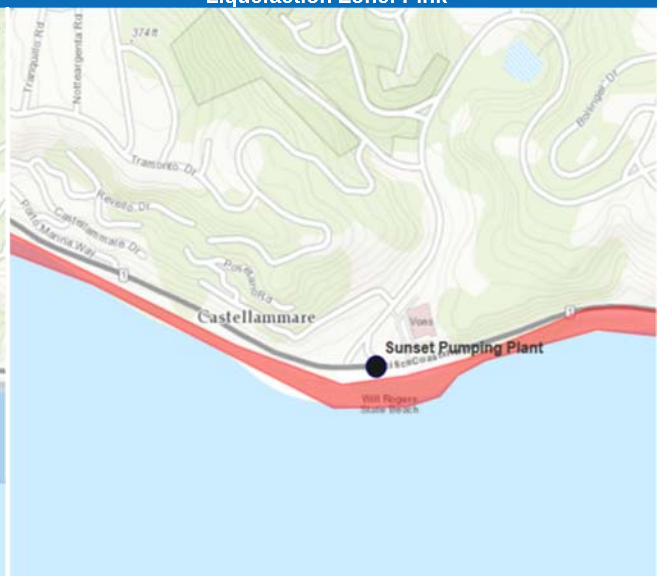
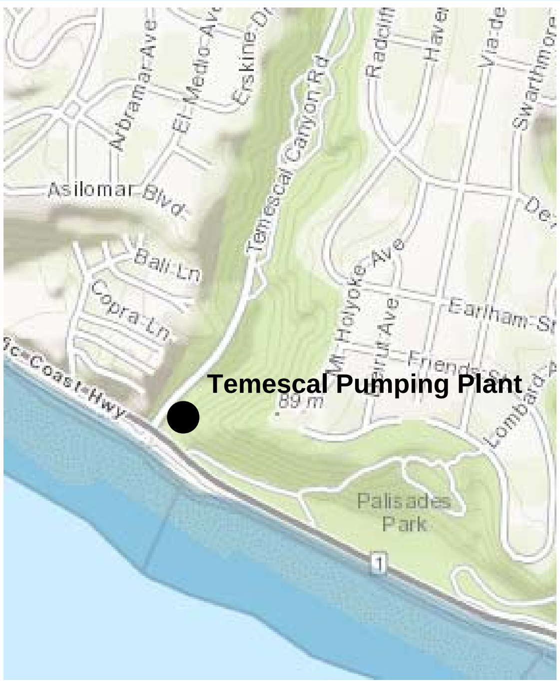
[9] Barnard, P.L., van Ormondt, M., Erikson, L.H., Eshleman, J., Hapke, C., Ruggiero, P., Adams, P. N., and Foxgrover, A. 2014. Coastal Storm Modeling System: CoSMoS. Southern California 1.0, projected flooding hazards, http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal1.0/, doi:10.5066/F74B2ZB4

meters (5.9 feet) above NAVD88 including tide and storm surge. Adding 0.5 meters (1.6 feet) of sea-level rise to the calculation raises the mid-century flood elevation to 2.3 meters (7.5 feet) at TIWRP. By 2100, the flood elevation may be 3.2 meters (10.5 feet) at TIWRP. CoSMoS 1.0 is being updated by the USGS as CoSMoS 3.0 and is expected to be complete by mid-2016. CoSMoS 3.0 provides daily, annual, 20-year, and 100-year coastal storm calculations at sea-level rise of 0 to 2 meters (0.25 meter increment), plus a 5 meter scenario. As indicated previously, since CoSMoS 3.0 has limited capabilities until its completion later this year, LA Sanitation used both CoSMoS 1.0 and CoSMos 3.0 to determine which of its assets will be inundated by the year 2100. It should be noted that the CoSMoS 3.0 model framework applied with a 100-year coastal storm at sea-level rise elevations (0 to 2 meters) to identify which assets would be vulnerable.

The key threats were identified to be coastal storm surges that could inundate facilities and high intensity rainfall events that could overwhelm the drainage systems within the facilities.

Figure 3: Inundation and Hazard Maps for the Pumping Plants and TIWRP.[10]

100- and 500-year FEMA flood zones and hazard areas for tsunami and liquefaction following earthquakes

	FEMA Flood Zones **100-year Flood Plain: Dark Blue** **500-year Flood Plain: Light Blue**	**Tsunami / Liquefaction Zones** **Tsunami Zone: Red Shade** **Liquefaction Zone: Pink**
Sunset Boulevard Pumping Plant No. 632		
Temescal Canyon Pumping Plant No. 634		

---

[10] EPA Storm Surge Inundation Map: http://www.epa.gov/crwu/see-coastal-storm-surge-scenarios-water-utilities

Figure 3: Inundation and Hazard Maps for the Pumping Plants and TIWRP.10

100- and 500-year FEMA flood zones and hazard areas for tsunami and liquefaction following earthquakes

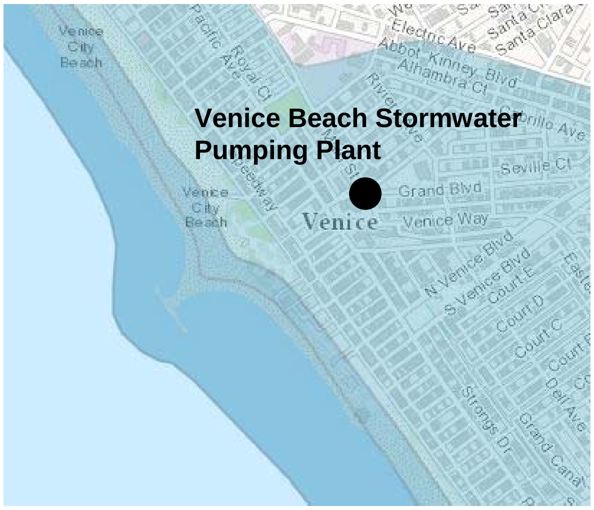
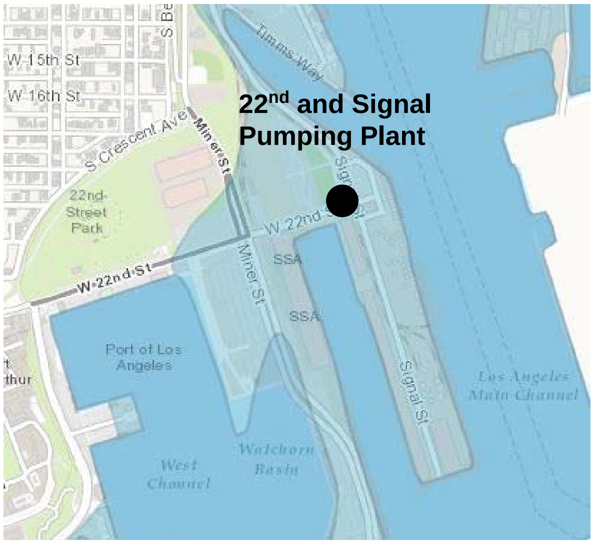
<table>
<tr><th></th><th>FEMA Flood Zones
100-year Flood Plain: Dark Blue
500-year Flood Plain: Light Blue</th><th>Tsunami / Liquefaction Zones
Tsunami Zone: Red Shade
Liquefaction Zone: Pink</th></tr>
<tr><td>North Pulga Canyon Pumping Plant No. 639</td><td>
</td><td>
</td></tr>
<tr><td>Venice Beach Stormwater Pumping Plant No. 647</td><td>
</td><td>
</td></tr>
</table>

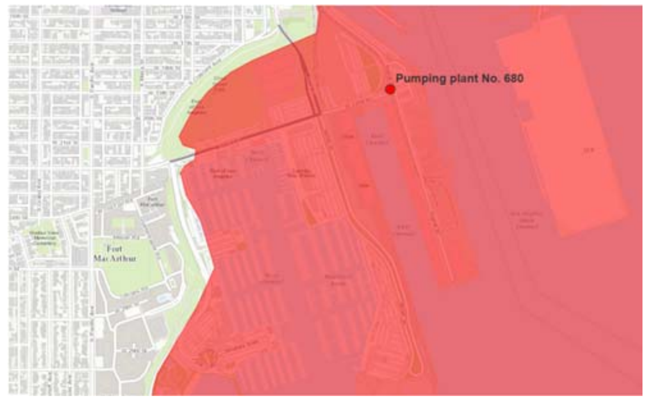
Figure 3: Inundation and Hazard Maps for the Pumping Plants and TIWRP.10

100- and 500-year FEMA flood zones and hazard areas for tsunami and liquefaction following earthquakes

	FEMA Flood Zones 100-year Flood Plain: Dark Blue 500-year Flood Plain: Light Blue	Tsunami / Liquefaction Zones Tsunami Zone: Red Shade Liquefaction Zone: Pink

22nd and Signal Pumping Plant No. 680

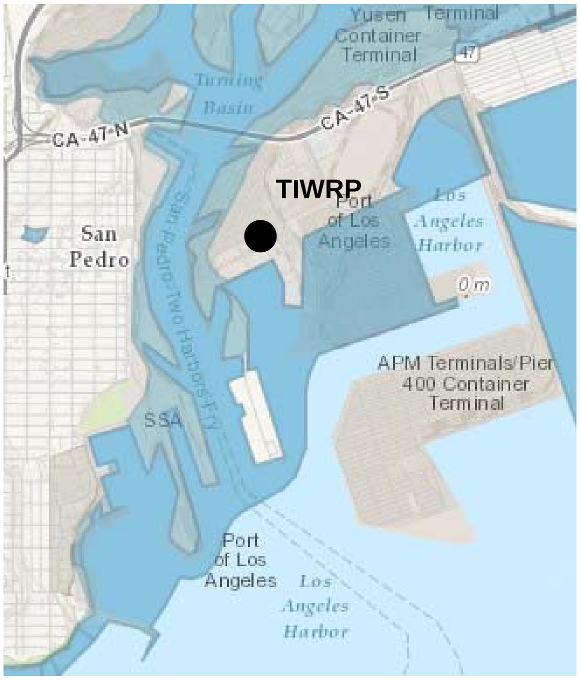
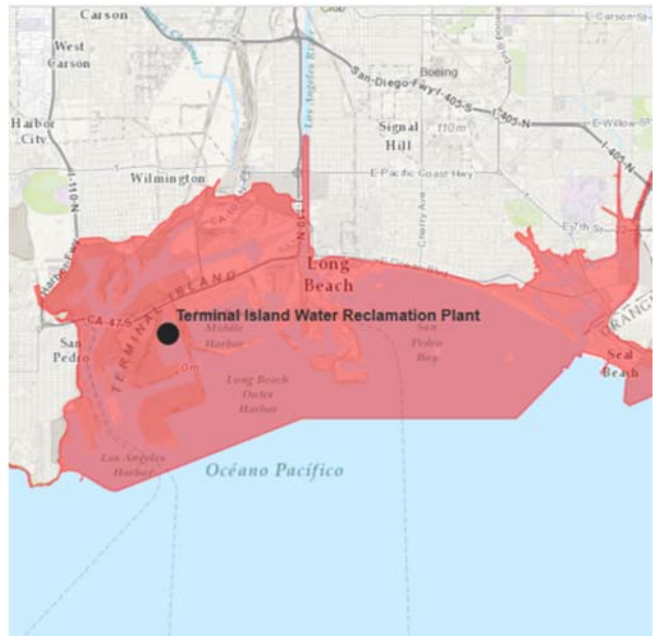




Nissan Way Pumping Plant No. 686

Figure 3: Inundation and Hazard Maps for the Pumping Plants and TIWRP.10

100- and 500-year FEMA flood zones and hazard areas for tsunami and liquefaction following earthquakes

	FEMA Flood Zones 100-year Flood Plain: Dark Blue 500-year Flood Plain: Light Blue	Tsunami / Liquefaction Zones Tsunami Zone: Red Shade Liquefaction Zone: Pink
Terminal Island Water Reclamation Plant		

LA Sanitation Assets Climate Risks

Climate risk assessments were performed for five wastewater pumping plants, one stormwater pumping plant, and the Terminal Island Water Reclamation Plant (TIWRP). Event-based threats were established for each facility for existing and future climate conditions described above. A risk analysis identified the assets at risk from flooding, debris strikes, power loss and surge, and the potential damage or destruction to specific assets. Anticipated replacement costs (replace-in-kind costs) to clean and replace damaged or destroyed assets were then estimated assuming that all damaged assets would have to be replaced. The cost estimates were not developed to entirely replace a facility. A detailed description of the cost methodologies is presented in **Appendix H**. Pumping plant damage threshold elevations (the elevation at which water will damage equipment), as well as current and future risk from coastal flooding, using CoSMos 3.0 data, are summarized in **Table 5**. Descriptions of each facility, the threat and risk analyses, and the estimated replacement costs for those risks are below.

Table 5. Pumping plant elevation data, and current and future risk from coastal flooding.

PUMPING PLANT	DAMAGE THRESHOLD ELEVATION (FEET)	CURRENT FEMA FLOOD ZONE*	COSMOS 3.0 100-YEAR FLOOD DATA + SEA-LEVEL RISE UP TO 2 METERS BY 2100
Pumping Plant No. 632 Sunset Boulevard	21.0	None (Adjacent AE and VE is 14 feet)	N/A, outside of inundation zone up to 2 meters of sea-level rise
Pumping Plant No. 634 Temescal Canyon	21.0	None (Adjacent AE is 13 feet and VE is 14 feet)	N/A, outside of inundation zone up to 2 meters of sea-level rise
Pumping Plant No. 639 North Pulga Canyon	20.5	None (Adjacent VE is 13 feet)	N/A, outside of inundation zone up to 2 meters of sea-level rise
Pumping Plant No. 647 Venice Beach (stormwater)	9.1	X (Adjacent VE is 15 feet)	Inundated at 2 meters of sea-level rise
Pumping Plant No. 680 22nd and Signal	11.6	X (Adjacent AE is 9 feet)	Inundated at 1 meter of sea-level rise
Pumping Plant No. 686 Nissan Way	7.0	X (Adjacent AE is 9 feet)	Inundated at 0 meters of sea-level rise

*FEMA Flood Zone Definitions:

Zones AE and VE have a 1-percent annual chance of flood, also referred to as the base flood or 100-year flood. A VE zone includes wave action.

Zone X is a 0.2-percent-annual-chance flood, also referred to as the 500-year flood. It is often not given a flood elevation but a rule of thumb can be used to approximate it as 1.25 times the 100-year elevation.

Sunset Boulevard Pumping Plant No. 632

The Sunset Boulevard Pumping Plant is in the Hyperion Water Reclamation Plant (HWRP) system. The facility is located on the Pacific Coast Highway at Sunset Boulevard and pumps wastewater to a high point, where it then flows by gravity to the Temescal Pumping Plant. All controls and pumps are subterranean (dry well submersible pumps are two levels below grade). Instruments, electrical components and controls are located in an electric room below ground level and isolated from the dry well pump room. The wet well is isolated from the pump room. A 350 kW backup generator is above grade on-site with a day tank that can power the pump station for 24 hours.

The Sunset Boulevard Pumping Plant has a capacity of 10,000 gallons per minute (gpm), or about 14.4 MGD. The pumping plant consists of four 3,000 gpm dry pit submersible pumps. In the event of a catastrophic plant failure, the system can overflow to a one million gallon storage tank across the street. The storage tank has not been used to date. However, once the tank is filled, the facility would have to be bypassed with portable pumping equipment.

The Sunset Boulevard Pumping Plant is also located across Pacific Coast Highway from the Pacific Ocean and it has sufficient elevation such that it is not in a 100- or 500-year flood zone on 2008 FEMA FIRM. The Zone AE flood elevation (100-year storm) is 13 feet at the beach, and flood waters would have to exceed an elevation of 22 feet to enter the facility or damage the backup power generator. The facility is not projected to flood using the CoSMoS 3.0 scenarios with a 100-year storm and sea-level rise up to 2 meters by 2100.

Although not in the 100- or 500-year flood zones presently, a tsunami or a coastal storm occurring in the future with sea-level rise above the elevation of the pumping station may put the pumping plant at risk. If a coastal flooding event were to occur, flood waters would enter the electric room on the top level and the pumps in the dry well on the bottom level. A sump pump is located in the bottom level, but only has the capacity to drain leaks and wall seepage, not to keep the pump room and control room above it dry during a flood. The backup generator would also be susceptible to damage in these scenarios. The pumping station would most likely be damaged and not functional until electrical service and controls are restored. If the pumping plant needed to be temporarily bypassed due to facility damage, it was estimated by LA Sanitation staff that those costs would exceed $2M per year.

A cost analysis was performed to determine the anticipated replacement costs if the Sunset Boulevard Pumping Plant No. 632 is inundated by a coastal flooding event. In the event that no protective measures are taken and the facility becomes inundated, systems critical to the operation of the facility will be damaged or destroyed by the flood waters and debris. In order to determine the full financial consequences of a flood at the facility, should no remedial measures be implemented and a severe flood event strikes the area, a Class 5 cost estimate was conducted to identify the value of work to repair or replace electrical, instrumentation, control and mechanical assets that would be affected by flood waters. Design drawings from previous projects were used to identify the assets and the costs to replace them in today's dollars. A detailed description of the cost estimate is provided in **Appendix E**. The replace-in-kind cost estimate is $3,500,000 for the Sunset Boulevard Pumping Plant No. 632 using an 80th percentile of the possible range of costs including markups and contingencies.

Temescal Canyon Pumping Plant No. 634

The Temescal Canyon Pumping Plant is one of 24 pumping plants in the HWRP system. The facility is located on the Pacific Coast Highway at Temescal Canyon Road, and pumps wastewater to a high point, where it then flows by gravity through Santa Monica to the Venice Pumping Plant. Upgraded in 2006, all controls and pumps are subterranean (dry well submersible pumps are two levels below grade). Instruments, electrical components and controls are located on the top level, although not isolated from the dry well. The wet well is isolated from the pump room. A 150 kW backup generator is above grade on-site with a day tank that can power the pump station for 24 hours.

The Temescal Canyon Pumping Plant has a capacity of 5.7 MGD, but pumps an average 800,000 gallons per day of sewage to the Coastal Interceptor Sewer (CIS) for treatment at the HWRP. The pumping plant consists of three 3,300 gpm dry pit submersible pumps. In the event of a catastrophic plant failure, the system would have to be bypassed with portable pumping equipment.

The site also includes a separate Low Flow Diversion (LFD) Pumping Plant No. 734 which diverts and pumps runoff to the CIS. The LFD diverts an average of 200,000 gallons per day dry weather runoff to the CIS for treatment at the HWRP. This LFD consists of three 1,300 gpm wet pit submersible pumps with an above ground control cabinet. It is powered from the same utility service and emergency backup generator as the Temescal Canyon Pumping Plant.

The location is susceptible to landslides during a heavy rain event. During a previous rain event, the top of the facility was covered with sand and debris from the adjacent hillside. Although located across the street from the Pacific Ocean, the facility has sufficient elevation such that it is not in a 100- or 500-year flood zone on 2008 FEMA FIRMs. The Zone AE flood elevation (100-year storm) is 13 feet at the beach, and flood waters would have to exceed an elevation of 21 feet to enter the facility or damage the backup power generator. The location is also on the edge but not within the tsunami impact zone. The facility is not modeled to flood using the CoSMoS 3.0 scenarios with a 100-year storm and sea-level rise up to 2 meters by 2100.

Although not in the 100- or 500-year flood zones at present, a tsunami or a coastal storm occurring in the future with projected sea-level rise above the elevation of the pumping plant may put it at risk. If a coastal flooding event were to occur, flood waters would enter the control room on the top level and the pumps in the dry well on the bottom level. A sump pump is located in the bottom level but only has the capacity to drain leaks and wall seepage, not to keep the pump room and control room above it dry during a flood. Continual and more intense rainfall events in the future could make the hillside even more unstable, and could cause it to collapse on the pump station in a landslide. The backup generator would also be susceptible to damage in these scenarios. The pumping station would most likely be damaged and not functional until electrical service and controls are restored.

A cost analysis was performed to determine the anticipated replacement costs if the Temescal Canyon Pumping Plant No. 634 is inundated by a coastal flooding event or by a landslide. In the event that no protective measures are taken and the facility becomes inundated, systems critical to the operation of the facility will be damaged or destroyed by the flood waters and debris. In order to determine the full financial consequences of a flood at the facility, should no remedial measures be implemented and a severe flood event strikes the area, a Class 5 cost estimate was conducted to identify the value of work to repair or replace electrical, instrumentation, control and mechanical assets that would be affected by flood waters. Design drawings from previous projects were used to identify the assets and the costs to replace them in today's dollars. A detailed description of the cost estimate is provided in Appendix E. The replace-in-kind cost estimate is $2,700,000 for the Temescal Canyon Pumping Plant No. 634 using an 80th percentile of the possible range of costs including markups and contingencies.

North Pulga Canyon Pumping Plant No. 639

The North Pulga Canyon Pumping Plant is located on Pacific Coast Highway south of Sunset Boulevard. The pumping plant was upgraded in 1998 and 2007. The facility controls and on-site backup generator are located above grade, and the two submersible pumps (1,688 gpm capacity each) are subterranean. The on-site 85 kW backup generator will automatically switch on if power is lost, and has a day tank with enough fuel to power the plant for 15 to 16 hours. Another backup generator can be hooked up to the pumping plant, if needed, and would be brought in from West L.A.

The North Pulga Canyon Pumping Plant has a capacity of 3,000 gpm, but pumps an average of 259 gpm and has a minimum 30 minute down time. This facility does not have a bypass.

The location is susceptible to landslides during a heavy rain event. The facility has been moved twice and repaired and upgraded in 1980 (D-25144), 1983 (D-27881), 1991 (E-1244), 2000 (D-31507), and 2002 (D-32166), due to landslides covering the facility in mud and debris. The current location may still be at risk from landslides, however above the loose landscape lies a sidewalk and well-kept field, which appears to be level and relatively stable. More information is needed to confirm the level of risk from a landslide.

Although located across the street from the Pacific Ocean, the facility has sufficient elevation such that it is not in a 100- or 500-year flood zone on 2008 FEMA FIRMs. The Zone AE flood elevation (100-year storm) is 13 feet at the beach, and flood waters would have to exceed an elevation of 20.5 feet to inundate the facility or damage the backup power generator. The location is also on the edge but not within the tsunami impact zone. The facility is not modeled to flood using the CoSMoS 3.0 scenarios with a 100-year storm and sea-level rise up to 2 meters by 2100. Although not in the 100- or 500-year flood zones at present, a tsunami or a coastal storm occurring in the future with projected sea-level rise above the elevation of the pumping plant may put it at risk. The pumping plant electrical, instrumentation and controls, switch gear and backup generator are all above ground and protected only by chain-link fencing. The enclosure cabinets are not rated for submersion. If a coastal flooding event were to occur, flood waters and/or debris carried by the flood waters would damage or destroy the pump station except for the submersible pumps. Continual and more intense rainfall events in the future could make the hillside even more unstable, and could cause it to collapse on the pump station in a landslide. The pumping station would most likely be damaged and not functional until electrical service and controls are restored.

A cost analysis was performed to determine the anticipated replacement costs if the North Pulga Canyon Pumping Plant No. 639 is inundated by a coastal flooding event or by a landslide. In the event that no protective measures are taken and the facility becomes inundated, systems critical to the operation of the facility will be damaged or destroyed by the flood waters and debris. In order to determine the full financial consequences of a flood at the facility should no remedial measures be implemented and a severe flood event strikes the area, Class 5 cost estimates for the Temescal Canyon and Sunset Boulevard pumping plants and cost curves were used to estimate the value of work to repair or replace electrical, instrumentation, control and power assets that would be affected by flood waters and mudslides. The replace-in-kind cost estimate is $2,200,000 for the North Pulga Canyon Pumping Plant No. 639 using an 80th percentile of the possible range of costs including markups and contingencies.

Venice Beach Stormwater Pumping Plant No. 647

The Venice Beach Stormwater Pumping Plant is located in the middle of a traffic circle in on Main Street in Venice Beach. This pumping plant was constructed in 1929 (DL-366 thru 374) and refurbished (except for the five largest pumps) in 2000 (D-31882), and is LA Sanitation's only subterranean stormwater pump station. All controls and pumps are subterranean. The pump station features low flow diversion pumps and stormwater duty pumps. At low flow conditions, this station pumps stormwater to the CIS using three submersible low flow pumps. If the levels in the 80,000 gallon wet well (which is isolated from the pump room) exceed 5.25 feet, the low flow pumps will automatically switch off and five larger non-submersible pumps will switch on and pump stormwater through an outfall to the Pacific Ocean. If the water levels are too high in the wet well to pump water out, the pumps will be shut off and the wet well will be used for storage, up to 1 million gallons. LA Sanitation has not needed to use the wet well in this way. If this condition were to occur, the low flow pumps would be used to pump the stored stormwater back into the CIS. A backup generator is not on-site at the pumping plant, but a portable, trailer-mounted 125-kW generator would be brought in from Pumping Plant No. 646, located in nearby Marina del Ray. To date, the pumping plant has not experienced a power outage.

The outfall discharges stormwater to the Pacific Ocean, and consists of an outfall box with a Tideflex tide gate device. This outfall box plugs often with sand, and requires maintenance. LA Sanitation does not have jurisdiction over the outfall, as it is owned and maintained by L.A. County. The Tideflex device prevents back flooding into the outfall. The City requests that the outfall box be dug out by L.A. County before storms.

The existing stormwater pumping capacity of the five pumps in the dry well is 100 cubic feet per second (cfs). However, the City of Los Angeles Storm Drain Design Manual requires a 50-year storm pumping capacity, which was calculated to be 163 cubic feet per second (cfs). The station can only pump 40% of the flow with no redundancy and the manual also requires a 50% redundancy. Therefore, LA Sanitation has planned to upgrade the pumping plant, add a dedicated portable generator and add green infrastructure (bioretention, permeable pavements on sidewalks and bike lanes) to the drainage area. The low flow diversion pumps and stormwater duty pumps would be replaced with dry well submersible pumps. Green infrastructure will capture stormwater and reduce the bacteria count in runoff, however LA Sanitation has experienced regulatory and political hurdles to implementing green infrastructure. The LA Sanitation stormwater group is looking to partner with other local organizations such as schools to encourage or assist in constructing green infrastructure projects on-site.

Street flooding of the area occasionally occurs. The pumping plant is in the current 500-year flood zone and tsunami zone. The facility is projected to flood using the CoSMoS 3.0 scenarios with a 100-year storm and sea-level rise of 1.5 meters by 2100. A tsunami or a coastal storm occurring in the future with projected sea-level rise above the elevation of the pumping plant may put it at additional risk. If a coastal flooding event were to occur now, flood waters would enter the control room on the top level and the non-submersible pumps in the dry well on the bottom level. The pumping station would most likely be damaged and not functional until pumps, instrumentation and controls were replaced and power was restored. Furthermore, the portable back-up generator dedicated for this pumping plant is located at Pumping Plant No. 646, which is projected to be inundated in 0.5 and 1.0 meter sea-level rise scenarios from CoSMoS 3.0.

In the event that the upgrade to the pumping plant is implemented but no protective measures are added to protect the facility from flooding, systems critical to plant operation will be damaged or destroyed by flood waters. Including a 25% contingency, the preliminary opinion of cost to complete the pumping plant upgrades is approximately $5.5 million, although this includes structural upgrades that would not be damaged during a flooding event. The control room will most likely be flooded and all electrical, instrumentation and controls would be damaged. The preliminary opinion of costs for the upgrades of ventilation, electrical, instrumentation and controls is approximately $550,000. The replace-in-kind cost estimate is therefore $1,400,000 for the Venice Beach Pumping Plant No. 647 using an 80th percentile of the possible range of costs including markups and contingencies.

22nd and Signal Pumping Plant No. 680

The 22nd and Signal Pumping Plant is located in a commercial area at the Port of Los Angeles in Los Angeles Harbor, south of the I-110 freeway. The facility has a 100 gpm capacity, with an average capacity of 70 gpm and a 3 hour downtime. The facility was rehabilitated in 1997-1998 with a cost of $566,000. A backup generator is not stored onsite at the pumping plant, but the facility has switch gear and fittings for a hookup to a portable generator, which would be brought in from West L.A. This facility does not have a bypass.

The facility has two subterranean submersible pumps (50 gpm capacity each) in the wet well. All controls and dry well pumps are located below grade. Three air vents from the control room and dry well are located above grade.

The facility is located in the 500-year flood zone and in the tsunami zone. A 500-year flood or a tsunami would most likely flood the facility. The facility is projected to flood using the CoSMoS 3.0 scenarios with a 100-year storm and sea-level rise of 1.0 meter by 2100. The facility will be at additional risk to these conditions and most likely a 100-year flood occurring in the future with projected sea-level rise. If a coastal flooding event were to occur, flood waters would enter the control room on the top level through hatches and vent holes, submerge the pumps in the dry well on the bottom level, then submerge the control room. A sump pump is located in the bottom level but only has the capacity to drain leaks and wall seepage, not to keep the pump room and control room above it dry during a flood. The external connections for a portable generator are not in a waterproof enclosure and would also be damaged by flood waters and unusable. If a backup generator were hooked up to the pump station during a flooding event, it would also be susceptible to damage in these scenarios. The pumping station would most likely be damaged and not functional until electrical service and controls are restored.

A cost analysis was performed to determine the anticipated replacement costs if the 22nd and Signal Pumping Plant No. 680 is inundated by a coastal flooding event. In the event that no protective measures are taken and the facility becomes inundated, systems critical to the operation of the facility will be damaged or destroyed by the flood waters and debris. In order to determine the full financial consequences of a flood at the facility should no remedial measures be implemented and a severe flood event strikes the area, Class 5 cost estimates for the Temescal Canyon and Sunset Boulevard pumping plants and cost curves were used to estimate the value of work to repair or replace electrical, instrumentation, control and power assets that would be affected by flood waters. The replace-in-kind cost estimate is $500,000 for the 22nd and Signal Pumping Plant No. 680 using an 80th percentile of the possible range of costs including markups and contingencies.

Nissan Way Pumping Plant No. 686

The Nissan Way Pumping Plant is located in an industrial area east of the I-110 freeway at the Port of Los Angeles in Los Angeles Harbor. The facility pumps wastewater to TIWRP and has a 1,700 gpm capacity, with an average capacity of 10 gpm and a 6 hour downtime. The facility was replaced in 1997-1998 with a cost of $419,000. A backup generator is not stored on-site at the pumping plant, but the facility has an elevated hookup located on the outside of the control room enclosure where a generator could be connected. Due to the long downtime, power outages are not of high concern to the facility. This facility does have a bypass.

The control room is a mobile enclosure located above grade. The pumping plant is connected to the SCADA system at Pumping Plant No. 646 with 24/7 monitoring. The facility has two submersible pumps in the dry well. A sump pump is located below the dry well. Two vents are located above grade.

The facility is located in the 500-year flood zone and in the tsunami zone. A 500-year flood or a tsunami would most likely flood the facility. The facility is projected to flood using the CoSMoS 3.0 scenarios with a 100-year storm without sea-level rise by 2100. The facility will be at additional risk to these conditions and most likely a 100-year flood occurring in the future with projected sea-level rise. The pumping plant electrical, instrumentation and controls, switch gear and backup generator are all above ground. The enclosure cabinets are not rated for submersion. If a coastal flooding event were to occur, flood waters would damage or destroy the all of the pump station except for the submersible pumps. The external connections for a portable generator are not in a waterproof enclosure and would also be damaged by flood waters and unusable. If a backup generator were hooked up to the pump station during a flooding event, it would also be susceptible to damage in these scenarios. The pumping station would most likely be damaged and not functional until electrical service and controls are restored.

A cost analysis was performed to determine the anticipated replacement costs if the Nissan Way Pumping Plant No. 686 is inundated by a coastal flooding event. In the event that no protective measures are taken and the facility becomes inundated, systems critical to the operation of the facility will be damaged or destroyed by the flood waters and debris. In order to determine the full financial consequences of a flood at the facility should no remedial measures be implemented and a severe flood event strikes the area, Class 5 cost estimates for the Temescal Canyon and Sunset Boulevard pumping plants and cost curves were used to estimate the value of work to repair or replace electrical, instrumentation, control, and power assets that would be affected by flood waters and mudslides. The replace-in-kind cost estimate is $1,700,000 for the Nissan Way Pumping Plant No. 686 using an 80th percentile of the possible range of costs including markups and contingencies.

Terminal Island Water Reclamation Plant

TIWRP is an advanced wastewater treatment plant with tertiary treatment for its primary discharge and an Advanced Water Purification Facility (AWPF) with microfiltration and reverse osmosis (RO) for water reclamation purposes. The service area for TIWRP consists of the Harbor area of the City located approximately 20 miles south of downtown Los Angeles. This area includes the communities of Wilmington and San Pedro, Terminal Island and a portion of Harbor City. TIWRP services approximately 140,000 customers, with about 35% of the flow from industrial customers.

TIWRP is designed to treat an average dry weather flow of 30 MGD and a peak wet weather flow of 55 MGD. Influent flows are currently averaging 15 MGD. Currently, the plant only uses 4 or 5 of the primary settling tanks at a time because of the low flows entering the plant. The primary settling tanks that are not being used provide 5 to 7 MG of available tank storage on site that could be used for storage or equalization during peak wet weather flows or in an emergency. The Plant currently discharges 12 MGD of treated wastewater to surface waters and injects 3 MGD of reclaimed water from the RO plant as a saltwater intrusion barrier in the harbor. LA Sanitation is expanding the microfiltration and RO capabilities within the next two years in an upgrade to eliminate its effluent discharge to surface waters. The plant has three effluent pumps and a bypass to the harbor.

An electrical substation is located on-site at TIWRP and is fed with two separate feed lines with switchgear that facilitates a power feed from one line at a time. There are two large diesel backup generators for the facility that are located at the Effluent Pumping Plant (EPP) and in the Filter Area. The EPP generators have a 1,500 kW capacity with a 23-hour run time before needing refueling its 9,800 gallon tank. The Filter Area generators have a 500 kW capacity with a 25-hour run time before needing refueling its 400 gallon tank. These generators do not power the entire facility, but do power the following processes and mechanical equipment: 2# Filter Influent Pump (150 HP), Filter Backwash Air Blower (250 HP), Filter Backwash Pump (125 HP), In-plant Lift Station Pump (40 HP), Grit Collector (5 HP), Bar Screen (2 HP), Compressor (20 HP), Filter Backwash Air Blower (tripped), Filter Backwash Pump (tripped), Aeration Tank Blower (1500 HP), EPP Pump (tripped), Return Activated Sludge Pump (200 HP) and the Filter Influent Pump (150 HP).

The City's Biosolids Environmental Management System manages its wastewater biosolids in an environmentally sound, socially acceptable and cost-effective manner to maximize beneficial uses. Biosolids are currently disposed of and beneficially reused by a variety of methods including land application, composting and injection. TIWRP is currently ground-injecting all 50 tons per day of its biosolids as well as 150 tons per day received from the HWRP as part of its Terminal Island Renewable Energy (TIRE) project. The project is a critical part of not only TIWRP's operation, but the City's entire Biosolids Environmental Management System and maintaining 100 percent beneficial use of biosolids produced at its wastewater treatment plants. The TIWRP also uses captured methane to run its digesters and flares the rest. LA Sanitation is looking for ways to generate power with the remaining biogas, and would consider adding those capabilities to a future upgrade. In the event that biosolids operations are ever disrupted, an empty digester can be used as biosolids storage.

TIWRP is located at an average of 10 feet elevation. TIWRP is in a tsunami zone but not in the 100- or 500-year flood zone on 2008 FEMA FIRMs (the Los Angeles Harbor Zone AE elevation is 9 feet). The facility is projected to flood using the CoSMoS 3.0 scenarios with a 100-year storm and sea-level rise of 1.5 meters by 2100. The headworks building, motor control centers (MCC) throughout the facility, AWPF, EPP including standby generators, compressor building, LA Department of Water and Power (DWP) substations and anaerobic digesters are all at the 10-foot elevation. The elevations for all of TIWRP's critical assets are summarized in **Table 6**. Considering increased frequency and magnitude of storm events, the consequences of failures in these assets due to flooding would include total process shutdowns. Ingress and egress from the facility may be restricted. Sea-level rise will put these assets at a higher risk of inundation and may put the entire site at risk of a coastal flood in the future. There is a concern that during a tsunami, shipping containers from the harbor could wash into TIWRP property and damage assets. LA Sanitation may consider installing submarine doors in pipe galleries, since serious flooding in those areas would disable non-submersible pumps and disable primary processes.

Table 6. Elevation Data and Flooding Risks for Critical TIWRP Assets

STRUCTURE	DAMAGE THRESHOLD ELEVATION (FEET)	DESCRIPTION	EQUIPMENT AT RISK
Lift Station	10.50	Doors to facility	Control room, sample room, pump room
	9.60	Control room	MCC, Variable Frequency Drive (VFD), pump controls, meters, electrical feeds
	0.13	Sampling room	UPS battery, sample ports, grinders
	-9.25	Pump room	Influent pumps
Headworks	21.00	Second floor – main floor and doorways	Grit pumps and motors, all equipment below
	19.00	Electrical room	Electric service
	8.00	Hopper truck floor	Truck parking under hopper
	2.50	Grit pump gallery	Grit pump
MCCs	+/- 10.00	MCCs throughout facility	MCCs
AWPF	10.10	MCC building, control room	MCCs, facility controls
	12.50	MF feed water wet well and pumps	Pumps
	+/- 8.00	Chemical storage area	Chemical storage and feeds
	9.50	Air compressors	Air compressors
	11.00	RO facility	RO filters

STRUCTURE	DAMAGE THRESHOLD ELEVATION (FEET)	DESCRIPTION	EQUIPMENT AT RISK
Effluent Pumping Plant	11.00	Standby generator room floor	Backup generators
	11.00	MCC, double doors to enter	MCCs
	10.00	Access hatch for major equipment installation and removal	Entrance
	7.00	Motor room floor	Pump motors

A cost analysis was performed to determine the anticipated replacement costs if TIWRP is inundated by a coastal flooding event. In the event that no protective measures are taken and the facility becomes inundated, systems critical to the operation of the facility will be damaged or destroyed by the flood waters and debris. In order to determine the full financial consequences of a flood at the facility should no remedial measures be implemented and a severe flood event strikes the area, a Class 5 cost estimate was conducted to identify the value of work to repair or replace electrical, instrumentation, control and mechanical assets that would be affected by flood waters. Replace-in-kind cost estimates using an 80th percentile of the possible range of costs including markups and contingencies were developed for the inundation of the following facility assets prioritized by LA Sanitation as follows:

- Headworks building and lift station - $11,000,000
- Motor control centers (MCC) throughout the facility - $15,800,000
- AWPF - $15,000,000
- Effluent pumping plant including standby generators - $11,000,000

Design drawings from previous projects were used to identify the assets and the costs to replace them in 2015 dollars. A detailed description of the cost estimate is provided in Appendix E. The replace-in-kind cost of the AWPF was estimated by taking 75% of the original $20,000,000 construction cost. The combined replace-in-kind cost estimate for the headworks building and lift station, MCCs throughout the facility, AWPF and the effluent pumping plant is $52,800,000. Additional replace-in-kind costs would be incurred from inundation of other assets at the facility or damage from debris washing through the facility such as containers from the port.

Adaptation Planning Recommendations and Estimated Costs

LA Sanitation identified and evaluated potential adaptive measures to reduce consequences from climate change threats by applying the 4-step risk assessment process in EPA's *Flood Resilience: A Basic Guide for Water and Wastewater Utilities (Flood Resilience Guide)*[11]. Adaptive measures suggested in the Flood Resilience Guide for preventing intrusion of flood waters, protecting assets and operations and ensuring power reliability were screened and evaluated based on effectiveness, practicality and cost. Tables showing the evaluations for all of the facilities are provided in **Appendix F**. A final set of recommended mitigation measures were then divided into two adaptation plans: Short-term and Long-term. Recommended short-term adaptation measures are assumed to be implemented in one to five years. Long-term mitigations are assumed to be implemented in five or more years, which will allow LA Sanitation to monitor weather patterns, extreme events, and the performance of their facilities and operations. LA Sanitation can use this monitoring data to determine when to implement the needed recommended actions. LA Sanitation should also consider that all

[11] *Flood Resilience, A Basic Guide for Water and Wastewater Utilities*. EPA 817-B-14-006. September 2014.

facilities must remain accessible to maintenance and construction vehicles and equipment, while determining which adaptive measures to implement.

The identified mitigation measures for the recommended short- and long-term measures are summarized in **Table 7**. The table includes direct (as-reported) Class 5 cost estimates of recommended long-term measures including markups and contingencies. Recommended cost using an 80th percentile of the possible range of costs, for planning purposes, is not included in these values, but is further described below for each facility.

Temescal Canyon Pumping Plant No. 634

The Temescal Canyon Pumping Plant was last upgraded in 2006 and there are no plans to make improvements to the facility at this time. The near-term risks are a landslide onto the facility during extreme rains, however, the elevation of the facility compared to the current coastal flood zone extant and elevations and the tsunami zone indicate a low risk. However, there is a higher long-term risks from landslides due to projected extreme rainfalls and coastal flooding risks caused by sea-level rise by the year 2100. The Flood Resilience Guide was used to evaluate possible mitigation measures for buildings, instrumentation and electrical controls, power supply, and lift stations.

Recommended short-term adaptive measures include updating the utility’s Wet Weather Plan and deploying temporary flood barriers at the facility that the utility owns. The barriers should protect the facility from potential landslides due to heavy rainfall and inundation during a coastal storm event. Short-term measures are considered operational and are assumed to have insignificant cost implications. Short-term capital and operational costs are therefore shown as $0 cost. Additional short-term measures are recommended for inclusion in the Wet Weather Plan as follows including those already being performed and noted as existing.

Existing Measures

- Train staff on how and when to shut down and start up power and gas supplies, electrical controls, operating systems and other equipment in system facilities prior to a flood to minimize damage (May need to be updated).
- Maintain a cache of spare parts to restart operations as soon as possible (May need to be updated annually).
- Regularly backup electronic and paper files outside the flood zone. Include all permits and compliance documentation, designs and as-built drawings, process diagrams, operations and maintenance (O&M) records, standard operating procedures, process and equipment manuals, material safety data sheets, asset management data, purchasing records, operations data, customer records and other critical information (May need to be updated).
- Establish interconnections or other partnership opportunities such as Water/Wastewater Agency Response Network (WARN) to share resources with neighboring water utilities (existing with City departments only).
- Fill backup generator fuel storage tank in anticipation of flooding.
- Perform an energy audit of your facility to identify energy saving opportunities via operations and equipment modifications. Implement recommendations of the audit (e.g., replace equipment with energy efficient models) to extend the life of your backup power supply.

Potential Short-term Measures:

- Store on-site documents in water-tight containers.
- Develop “start and connect” checklists specific to each piece of equipment.
- Train staff on and plan for manual operation of the facility.
- Conduct half-day tabletop exercises and drills to exercise shut down procedures, providing backup power and refueling portable generators, restoring normal operations and performing post-event assessments after an event.
- Identify locations outside the flood zone where utility equipment (e.g., heavy equipment, vehicles, replacement parts, backup generators, pumps) can be stored safely, permanently or temporarily, to prevent damage from flood waters or debris.
- Have an alternative access plan in case normal access to buildings is blocked. Consult with other entities (e.g., Department of Transportation) to consider alternate road/transportation options (e.g., watercraft) during and immediately after an event.
- Purchase and have available portable equipment if permanent equipment becomes disabled.
- Check and confirm the capabilities and limitations of operating remotely in case the facility is inaccessible.

- Provide local emergency management agency and power company with location of this facility such that during an outage it will expedite electricity restoration.
- For electrical requirements, document the size and type of existing backup generator including voltage, phase configuration, horsepower/amperage, fuel, etc. in case the generator is damaged and/or inoperable.
- Arrange to get portable generators in an emergency by maintaining a call list of multiple vendors that rent portable generators, entering into an agreement with a particular vendor or joining a mutual aid network (WARN) to allow sharing of backup generators.
- Establish an agreement with your fuel supplier and provide estimates of fuel needs (e.g., volume and frequency) in the event of a power outage. Also, secure a list of alternative fuel suppliers. Maintain communication with your local emergency management agencies for priority in getting and transporting fuel supplies.
- Investigate purchasing fuel transport vehicles and train staff in moving the utility's fuel in an emergency.
- Maintain a call list of multiple vendors that can provide "pump around" services in an emergency or enter into an agreement with one.

Recommended long-term adaptive measures include waterproofing the facility, implementing additional backup power capabilities and constructing a perimeter wall around the facility to protect it up to a design flood elevation high enough for the tsunami threat as well as landslides from the adjoining hill. Class 5 cost estimates were made for these long-term measures; detailed descriptions of the estimates are provided in **Appendix G**. LA Sanitation may work in the future towards stabilizing the adjoining slope but that was not considered in this assessment. The recommended long-term measures are as follows:

- Install waterproof protection for building entry points.
- Caulk or seal wall and floor penetrations.
- Replace vulnerable electrical, instrumentation, control and mechanical components with submersible alternatives.
- Replace or upgrade electrical connections, motor controls or junction boxes with watertight panels.
- Procure a portable generator and wire the facility to accept a portable generator. Ensure that "quick connect" capability is installed and ready, and that staff are trained.
- Install unions in the conduit system to reduce the time required to repair damaged sections.
- Extend vent lines above anticipated flood stage to prevent floodwater from entering the lift station.
- Construct a perimeter wall around the facility for flood protection.

The direct (as-reported) Class 5 cost estimate of recommended long-term measures is $718,000 including markups and contingencies for the Temescal Pumping Plant No. 634. However, considering the uncertainties of the estimate, the recommended cost for planning purposes is $1,220,000 using the 80th percentile of the possible range of costs, as described in Appendix G.

Sunset Boulevard Pumping Plant No. 632

There are no plans to make improvements to the Sunset Boulevard Pumping Plant at this time. The near-term risks are low considering the elevation of the facility compared to the current coastal flood zone extent and elevations and the tsunami zone but the long term risks are for coastal flooding risks caused by sea-level rise by the year 2100. The Flood Resilience Guide was again used to evaluate possible mitigation measures for buildings, instrumentation and electrical controls, power supply, and lift stations (wastewater).

Recommended short- and long-term adaptive measures for the Sunset Boulevard Pumping Plant are the same as those for the Temescal Canyon Pumping Plant with the exception of constructing a flood wall around the facility, which would be impractical at its location. Class 5 cost estimates were made for these long-term measures; detailed descriptions of the estimates are also provided in Appendix G.

The direct (as-reported) Class 5 cost estimate of recommended long-term measures is $732,000 including markups and contingencies for the Sunset Boulevard Pumping Plant No. 632. However, considering the uncertainties of the estimate, the recommended cost for planning purposes is $1,240,000 using the 80th percentile of the possible range of costs, as described in Appendix G.

North Pulga Canyon Pumping Plant No. 639

There are no plans to make improvements to the North Pulga Canyon Pumping Plant at this time. The near-term risks are a landslide onto the facility during extreme rains, however, the elevation of the facility compared to the current coastal flood zone extent and elevations and the tsunami zone indicate a low risk, however, there are higher long-term risks from landslides due to projected extreme rainfalls and coastal flooding risks caused by sea-level rise by the year 2100. The Flood Resilience Guide was again used to evaluate possible mitigation measures for buildings, instrumentation and electrical controls, power supply and lift stations (wastewater).

Recommended short- and long-term adaptive measures for the North Pulga Canyon Pumping Plant are similar to those for the Temescal Canyon Pumping Plant with the exception of constructing a wall around the facility, a smaller wall around the back of the facility would most likely be sufficient to protect it from landslides. Cost estimates were made for these long-term measures.

Additional short-term measures are recommended for inclusion in the Wet Weather Plan as follows:

- Stabilize the slope, in partnership with the country club at the top of the slope.
- Determine if the slope behind the current pumping plant location is at risk from landslides.
- Replace components with watertight equipment.

Recommended long-term adaptive measures include waterproofing the facility, implementing additional backup power capabilities and constructing a perimeter wall around the facility to protect it up to a design flood elevation high enough for the tsunami threat as well as landslides from the adjoining hill. Cost estimates were made for these long-term measures. LA Sanitation may work in the future towards stabilizing the adjoining slope but that was not considered in this assessment. The specific recommended long-term measures are as follows:

- Construct a retaining wall behind the pumping plant to prevent damage from landslides to the pumping station enclosure.
- Replace electrical, instrumentation, control and mechanical components with submersible alternatives.
- Replace or upgrade electrical connections, motor controls or junction boxes with watertight panels.
- Ensure that waterproof “quick connect” capability is installed and ready, and that staff are trained.

Class 5 cost estimates for the Temescal Canyon and Sunset Boulevard pumping plants were used to estimate the value of the work to perform the long-term recommendations. The cost estimate of recommended long-term measures is $505,000 including markups and contingencies for the North Pulga Canyon Pumping Plant No. 639. However, considering the uncertainties of the estimate, the recommended cost for planning purposes is $860,000 using the 80th percentile of the possible range of costs.

Venice Beach Stormwater Pumping Plant No. 647

Improvements and upgrades to the Venice Beach Stormwater Pumping Plant are planned at this time, as described in a previous section. The near-term risks are from a coastal flooding event which will increase with sea-level rise. The outfall is often filled with sand thus reducing its conveyance capacity. Stormwater drainage is currently problematic in the drainage area with localized street flooding; the frequency and extent of flooding will increase with more frequent and intense storm events in the future. The planned upgrades do not protect the pumping plant from inundation during current or future flooding events. The Flood Resilience Guide was used to evaluate possible adaptation measures for buildings, instrumentation and electrical controls, power supply and lift stations (wastewater).

Recommended short- term adaptive measures for the Venice Beach Stormwater Pumping Plant are the same as those for the Temescal Canyon Pumping Plant.

Long-term adaptive measures include waterproofing the facility and improving drainage. Since the facility is to be upgraded in the near future, the following recommendations are suggested in addition to the planned upgrades of the facility:

- Replace hatches with watertight hatches.
- Add venting to elevations above future design flood elevation.

- Use watertight enclosures on electrical, instrumentation and controls and MCCs.
- Resize green infrastructure and other drainage enhancements for design storms with additional precipitation and intensity projected in climate change.
- Capture and re-use stormwater for irrigation or other non-potable uses.

Class 5 cost estimates for the Temescal Canyon and Sunset Boulevard pumping plants were used to estimate the value of the work to perform the long-term recommendations for the pumping plant itself, not drainage enhancements. The cost estimate of recommended long-term measures is $400,000 including markups and contingencies for the Venice Beach Stormwater Pumping Plant No. 647. However, considering the uncertainties of the estimate, the recommended cost for planning purposes is $510,000 using the 80th percentile of the possible range of costs.

22nd and Signal Pumping Plant No. 680

There are no plans to make improvements to the 22nd and Signal Pumping Plant at this time. The near-term risks are for a coastal flooding event which will increase with sea-level rise by mid-century. The long term risks are for coastal flooding from sea-level rise. The Flood Resilience Guide was used to evaluate possible adaptation measures for buildings, instrumentation and electrical controls, power supply and lift stations (wastewater).

Recommended short- and long-term adaptive measures for the 22nd and Signal Pumping Plant are the same as those for the North Pulga Canyon Pumping Plant with the exception of constructing a flood wall around the facility, which would be impractical at its location. Cost estimates were made for these long-term measures.

The specific recommended long-term measures are as follows:

- Replace doors for two hatches to the control room/dry well with watertight doors.
- Seal vent holes on the outside of the pumping plant.
- Install watertight cover on backup power connection box, or have spare parts available on-hand if connection box is damaged by flood waters.
- Raise height of and reinforce the two shorter vent fans for future design flood elevation.

The direct (as-reported) Class 5 cost estimate of recommended long-term measures is $89,300 including markups and contingencies for the 22nd and Signal Pumping Plant No. 680. However, considering the uncertainties of the estimate, the recommended cost for planning purposes is $150,000 using the 80th percentile of the possible range of costs.

Nissan Way Pumping Plant No. 686

There are no plans to make improvements to the Nissan Way Pumping Plant No. 686 at this time. The near-term risks are for a coastal flooding event now that will be made worse with sea-level rise. The Flood Resilience Guide was used to evaluate possible adaptation measures for buildings, instrumentation and electrical controls, power supply and lift stations (wastewater).

Recommended short- and long-term adaptive measures for the Nissan Way Pumping Plant are the same as those for the Temescal Canyon Pumping Plant with the exception of constructing a flood wall around the facility, which would be impractical at its location. Cost estimates were made for these long-term measures.

The specific recommended long-term measures are as follows:

- Replace backup power connection box with watertight enclosure.
- Replace doors to the pump room with watertight doors.
- Replace electrical, instrumentation and control cabinet with a watertight enclosure.
- Install stylized bollards around pumping station to protect from floating debris from a tsunami wave.
- Seal vents and raise vent shafts to above future design flood elevation.

The direct (as-reported) Class 5 cost estimate of recommended long-term measures is $376,700 including markups and contingencies for the Nissan Way Pumping Plant No. 686. However, considering the uncertainties of the estimate, the recommended cost for planning purposes is $640,000 using the 80th percentile of the possible range of costs.

Terminal Island Water Reclamation Plant (TIWRP)
There are plans to make improvements to TIWRP at this time including expansion and improvement of existing advanced treatment processes and adding backup power generation. The near-term risks are for a 500-year coastal flooding event. The facility is projected to be flooded during a 100-year flooding event by the year 2100 with 1.5 meters of sea-level rise. Recommended short-term adaptive measures for TIWRP include updating the utility's Wet Weather Plan, deploying temporary flood barriers to protect buildings and exposed process assets and adding backup power for the AWPF. The barriers should protect some facility assets from inundation during a coastal storm event. Short-term measures except for adding backup power for the AWPF are considered operational and are assumed to have insignificant cost implications. Many additional short-term recommendations are the same as for the pumping plants. Additional short-term measures are recommended for inclusion in the Wet Weather Plan as follows including those already being performed and noted as existing.

Existing measures

- Train staff how and when to shut down and start up power and gas supplies, electrical controls, operating systems and other equipment in system facilities prior to a flood to minimize damage (May need to be updated).
- Maintain a cache of spare parts to restart operations as soon as possible (May need to be updated annually).
- Establish interconnections or other partnership opportunities such as Water/Wastewater Agency Response Network (WARN) to share resources with neighboring water utilities (Existing with City departments only).
- For electrical requirements, document the size and type of existing backup generator including voltage, phase configuration, horsepower/amperage, fuel, etc. in case the generator is damaged and/or inoperable.
- Fill backup generator fuel storage tanks in anticipation of flooding.
- Perform an energy audit of your facility to identify energy saving opportunities via operations and equipment modifications. Implement recommendations of the audit (e.g., replace equipment with energy efficient models) to extend the life of your backup power supply.

Potential Measures

- Develop "start and connect" checklists specific to each piece of equipment.
- Train staff and plan for manual operation of the facility.
- Identify locations outside the flood zone where utility equipment (e.g., heavy equipment, vehicles, replacement parts, backup generators, pumps) can be stored safely, permanently or temporarily, to prevent damage from flood waters or debris.
- Have an alternative access plan (in addition to an evacuation plan) in case normal access to the site and specific buildings is blocked. Consult with other entities (e.g., Department of Transportation) to consider alternate road/transportation options (e.g., watercraft) during and immediately after an event.
- Purchase and have available portable equipment if permanent equipment becomes disabled.
- Regularly backup electronic and paper files outside the flood zone. Include all permits and compliance documentation, designs and as-built drawings, process diagrams, operations and maintenance (O&M) records, standard operating procedures, process and equipment manuals, material safety data sheets, asset management data, purchasing records, operations data, customer records and other critical information (existing, but may need to be updated).
- Investigate the capabilities and limitations of operating remotely in case the facility is inaccessible.
- Provide local emergency management agency and power company with location of this facility such that during an outage it will expedite electricity restoration.
- Investigate and document the size and type of backup generators that will be needed to power the equipment not on the feeds of the existing EPP and Filter Area generators (include voltage, phase configuration, horsepower/amperage, fuel, etc.).
- Arrange to get portable generators in an emergency by maintaining a call list of multiple vendors that rent portable generators, entering into an agreement with a particular vendor or joining a mutual aid network (WARN) to allow sharing of backup generators.

- Establish an agreement with the fuel supplier and provide estimates of fuel needs (e.g., volume and frequency) in the event of a power outage. Also, secure a list of alternative fuel suppliers. Maintain communication with your local emergency management agencies for priority in getting and transporting fuel supplies.
- Investigate purchasing fuel transport vehicles and training staff in moving the utility's fuel in an emergency.
- Maintain a call list of multiple vendors that can provide "pump around" services in an emergency or enter into an agreement with one.

Several climate adaptation measures are already included in LA Sanitation's capital improvement plans for TIWRP. LA Sanitation is considering making energy efficiency improvements in Fiscal Years 2017-2020 that include detailed monitoring of energy usage. These improvements could be made during a future upgrade to the AWPF. LA Sanitation is constructing an expansion of the AWPF to meet user demand for high purity water and to comply with the TIWRP National Pollutant Discharge Elimination System (NPDES) permit goal of eliminating its ocean outfall. The $50.7M project with a planned construction completion date of December 2016 will increase water production by 6 MGD to a total of 12 MGD with a $5M annual operating cost. Dedicated emergency generators will be added to the AWPF by mid-2017 at a cost of $10M that will provide backup power to the AWPF alone.

The long-term recommendations protect the assets prioritized by LA Sanitation from floodwater inundation alone are as follows:

- Headworks Building – seal building.
- Motor control centers (MCC) throughout the facility – raise or waterproof.
- AWPF – seal MCC building, waterproof electrical panels and controls and secure chemical storage.
- Effluent Pumping Plant including standby generators – seal building.

These recommendations would likely protect the equipment inside the Headworks Building, the EPP and the AWPF MCC building from damage by debris carried by flood waters. However, MCCs throughout the facility and the AWPF are in the open and would not be protected by debris, as would pumps, electrical panels, chemical storage, and other assets throughout the facility.

TIWRP currently has a low concrete perimeter wall with a mounted fence around the south and east sides of the facility, chain link fencing on the north side of the facility, and buildings and fencing on the west side for security purposes that provides some protection to assets on the facility property. The concrete wall and mounted fence could be reconstructed and extended around the entire facility with integrated barrier-enhanced entrances to increase the level of protection from damage by debris carried by flood waters. The cost was developed to construct a 6-foot above grade 12-inch thick concrete wall, on a 6-foot wide by 2-foot deep footer, and utilize watertight swing doors to allow for passage.

Table 7. Potential Adaptive Measures Identified with Estimated Capital and Operations & Maintenance (O&M) Costs

Capital cost estimates are direct (as-reported) AACE Class 5 estimates not adjusted for planning.

	PP 632		PP 634		PP 639		PP 647		PP 680		PP 686		TIWRP (prioritized)	
ADAPTIVE MEASURE	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Short-term Plan														
Temporary Flood Barriers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Wet Weather Plan	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Long-term Plan														
Waterproof Assets	$186,000		$272,000		$156,200		$200,000		$79,300		$123,100		$7,930,000	$100,000
Improve and Protect Backup Power	$546,000	$10,000	$406,000	$10,000	$308,500	$10,000	$200,000	$10,000	$10,000	$10,000	$203,600	$10,000		
Construct Perimeter Wall			$40,0000		$40,000								$3,730,000	$20,000
Other Infrastructure Options /Upgrades											$50,000			
In Existing Capital Improvement Plans														
Energy Efficiency Improvements													$4M	$10 – 40K
AWPF Expansion													$50.7M	$5M
AWPF Emergency Generators													$10M	$50 – 100K

Shaded boxes indicate the adaptive measure is not applicable to the facility.

EPA

Risk Assessment

CREAT provides climate data within a risk assessment framework to help utilities understand climate change, assess risks, and evaluate adaptation. Leveraging the information from CREAT, LA Sanitation discussed several potential impacts of a changing climate on their assets.

CREAT provides a consequence matrix of four categories that capture the range of impacts a utility may experience from a climate change-related threat occurring. These include utility business impacts, utility equipment impacts, source and receiving water impacts, and environmental impacts. CREAT provides suggested monetized values for these categories. CREAT users can also assess public health consequences from climate change impacts in either a qualitative or quantitative manner (Appendix C). Within each of these categories, users assess the impacts on a four-point scale from Low to Very High. CREAT will calculate a monetized value of risk based on the user's selections, and a reduction in that risk after implementing adaptation options.

LA Sanitation's assets are currently vulnerable to storm surge and will be at increased risk in the future from sea-level rise. It was determined that the greatest concern was the potential for flooding events coupled with rising sea level that would directly damage equipment and interrupt operations. Therefore, LA Sanitation decided to focus their analysis on the impacts of flooding from storm surge and sea-level rise on the Sunset Boulevard Pumping Plant, Temescal Canyon Pumping Plant, and TIWRP. CREAT assessments have not been conducted on the four other pumping plants at this time.

Sunset Boulevard Pumping Plant No. 632 Assessment

In their risk analysis, LA Sanitation considered the potential consequences of both current and future flooding events at the Sunset Boulevard Pumping Plant. To assess each of these potential threats, LA Sanitation considered how the potential adaptive measures grouped into the Short- and Long-term Adaptation Plans would help lower their consequences. The implementation of these potential adaptive measures in the two recommended plans may lower LA Sanitation's consequences from threats (see **Table 8** for assessment results; for detail on level definitions, see Appendix C).

Based on the assessments, CREAT provided monetized risk for each condition, both before and after implementing their adaptation plans. For Sunset Boulevard Pumping Plant No. 632, the additional actions taken as part of the short-term plan enhances resiliency considering that flooding is not an anticipated risk at this time. The $1.24M recommended long-term plan provides a significant reduction in risk with an anticipation of future tsunami flooding with sea level rise ($3.5M per event).

Table 8: LA Sanitation Analysis Results for Flooding Impacts to the Sunset Boulevard Pumping Plant No. 632

ANALYSIS	Utility Business Impacts	Utility Equipment Damages	Source/ Receiving Water Impacts	Environmental Impacts	Overall Consequences (millions of $)
Current Flooding (no potential adaptive measures)	Low	High	Low	High	$0
Future Flooding (no potential adaptive measures)	Medium	High	Medium	High	$3.5
Short Term Adaptation Plan Implemented	Low	Medium	Low	Medium	$3.5

ANALYSIS	Utility Business Impacts	Utility Equipment Damages	Source/ Receiving Water Impacts	Environmental Impacts	Overall Consequences (millions of $)
Long Term Adaptation Plan Implemented	Low	Low	Low	Low	$0

Temescal Canyon Pumping Plant No. 634 Assessment

In their risk analysis, LA Sanitation considered the potential consequences of both current and future flooding events at the Temescal Canyon Pumping Plant. To assess each of these potential threats, LA Sanitation considered how the potential adaptive measures grouped into the Short- and Long-term Adaptation Plans would help lower their consequences. Implementing these potential adaptive measures in the two recommended plans may lower LA Sanitation's consequences from threats (see **Table 9** for assessment results; for detail on level definitions, see Appendix C).

CREAT provided monetized risk for each assessment, both before and after implementing their adaptation plans. For Temescal Canyon Pumping Plant No. 634, the additional actions taken as part of the short-term plan enhances resiliency considering that flooding is not an anticipated risk at this time. The $1.22M recommended long-term plan provides a significant reduction in risk with an anticipation of future tsunami flooding with sea level rise ($2.7M per event).

Table 9: LA Sanitation Analysis Results for Flooding Impacts to the Temescal Canyon Pumping Plant No. 634

ANALYSIS	Utility Business Impacts	Utility Equipment Damages	Source/ Receiving Water Impacts	Environmental Impacts	Overall Consequences (millions of $)
Current Flooding (no potential adaptive measures)	Low	High	Low	High	$0
Future Flooding (no potential adaptive measures)	Medium	High	Medium	High	$2.7
Short Term Adaptation Plan Implemented	Low	Medium	Low	Medium	$2.7
Long Term Adaptation Plan Implemented	Low	Low	Low	Low	$0

Terminal Island Water Reclamation Plant (TIWRP) Assessment

In their risk analysis, LA Sanitation considered the potential consequences of both current and future flooding events at TIWRP for their prioritized assets of the Headworks Building, MCCs throughout the facility, the AWPF and the Effluent Pumping Plant. To assess each of these potential threats, LA Sanitation considered how the potential adaptive measures grouped into the Short and Long Term Plans would help lower their consequences. Given the implementation of these potential adaptive measures in the two plans, LA Sanitation may potentially be able to lower their consequences (see **Table 10** for assessment results).

Based on the assessments, CREAT provided monetized risk for each condition, both before and after implementing their adaptation plans. For the prioritized assets at TIWRP, the additional actions taken as part of the short-term plan enhances resiliency considering that flooding is not an anticipated risk at this time. The $13.51M recommended long-term plan of waterproofing the prioritized assets in addition to existing capital improvement plans ($10.4M for energy efficient improvements and AWPF emergency generators) provides a significant reduction in risk for the prioritized assets with an anticipation of future tsunami flooding with sea level rise ($35.8M per event) for the prioritized assets. However, these mitigation measures would not protect the facility from debris and possibly shipping containers carried by future floodwaters. Reconstructing and extending the existing perimeter wall and fence around the entire facility at an estimated cost of $6.34M would most likely provide a much higher level of protection from debris for the entire facility.

Table 10: LA Sanitation Analysis Results for Flooding Impacts to TIWRP

ANALYSIS	Utility Business Impacts	Utility Equipment Damages	Source/ Receiving Water Impacts	Environmental Impacts	Overall Consequences (millions of $)
Current Flooding (no potential adaptive measures)	Low	High	Low	High	$0
Future Flooding (no potential adaptive measures)	Medium	High	Medium	High	$35.8
Short Term Adaptation Plan Implemented	Low	Medium	Low	Medium	$35.8
Long Term Adaptation Plan Implemented	Low	Medium	Low	Medium	$0*

* Not including the cost of replacement due to destruction from debris carried by floodwaters.

ASSESSMENT STATUS AND NEXT STEPS

The assessments of the Temescal Canyon Pumping Plant No. 634, Sunset Boulevard Pumping Plant No. 632 and TIWRP indicate that the facilities are at a mix of low to high consequential risks due to flooding impacts. Those risks increase under future flooding and sea-level rise scenarios. The four additional pumping plants may also be at risk from flooding impacts. The adaptation measures in the conceptual Short- and Long-term Adaptation Plans identified in this exercise reduce those risks for the six pumping plants and the prioritized assets at TIWRP. The results of the CREAT analysis will be used to meet LA Sanitation's strategic goal #8 for FY 2016-17 and develop a guidance for LA Sanitation to assess potential climate risk and resilience for its critical assets.

APPENDIX A: EXERCISE PARTICIPANTS

NAME	CONTACT INFORMATION	AFFILIATION
Varouj Abkian		LA Sanitation
Matthew Bequette		LA Sanitation
Barry Berggren		LA Sanitation
Karl Breitenstein		LA Sanitation
Cecile Buncio	cecile.buncio@lacity.org	LA Sanitation
Jon Chang		LA Sanitation
Terry Dickinson		LA Sanitation
Kris Flaig	kris.flaig@lacity.org	LA Sanitation
Diane Gilbert Jones	diane.gilbert@lacity.org	LA Sanitation
Azya Jackson		LA Sanitation
Carmelo Martinez		LA Sanitation
Shandiz Mohammadi		LA Sanitation
Mark Starr		LA Sanitation
Hassan Rad	Hassan.Rad@lacity.org	LA Sanitation
Melody Reid		LA Sanitation
Michael Ruiz		LA Sanitation
Amy Sen	amy.sen@lacity.org	LA Sanitation
Mikael Parlow		NYC DEP
Curt Baranowski	Baranowski.curt@epa.gov	EPA Headquarters
Steve Fries	Fries.Steve@epa.gov	EPA Headquarters
John Kemmerer		EPA Region 9
Amy Posner	Amy.Posner@csra.com	CSRA
Dan Basoli	Dan_Basoli@abtassoc.com	Abt Associates
Bill McMillin	william.mcmillin@CH2M.com	CH2M

APPENDIX B: CLIMATE DATA SOURCES – DESCRIPTION OF CLIMATE MODELS

Climate Model Selection for LA Sanitation

This scatter plot of model run results provides a visual of how the CREAT-provided projections were selected. Each point represents the projected changes in average annual temperature and total annual precipitation in the year 2060 for the ½ degree cell containing Los Angeles, California. For each projection, a cluster of models were selected to represent the projection based on their proximity to the following targets:

- **Hot and dry model projection** — models nearest the 5th percentile of precipitation and 95th percentile of temperature projections (larger increase in temperature with lower total precipitation)
- **Central model projection** — models nearest the 50th percentile of both precipitation and temperature projections (central condition, among the models, for temperature and total precipitation)
- **Warm and wet model projection** — models nearest the 95th percentile of precipitation and 5th percentile of temperature projections (smaller increase in temperature with larger total precipitation)

The terms “dry” and “wet” are used here relative to the range of total precipitation projected for this location in the 2060 time period. For example, dry does not always indicate a reduction in total precipitation relative to today; dry simply indicates projected total precipitation on the lower end of distribution of projected precipitation. A horizontal line on the plot indicates no projected change in precipitation (i.e., 0%), to help distinguish the models projecting increases in annual total precipitation from those projecting decreases.

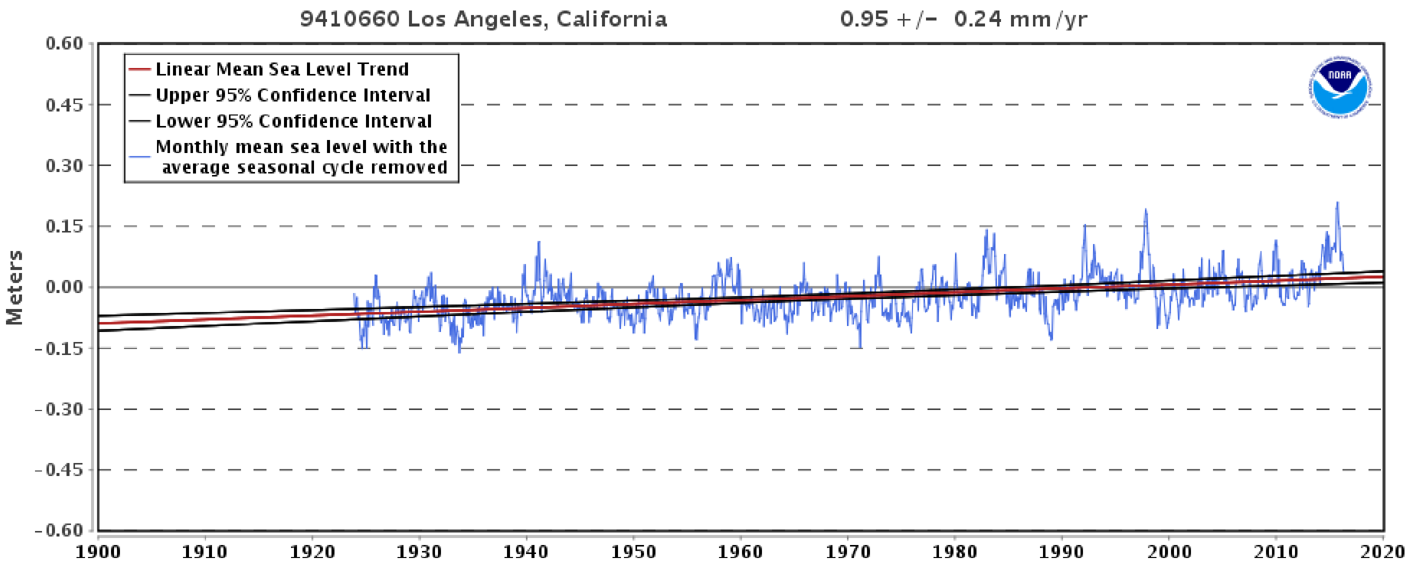
Sea-Level Rise

The mean sea level trend at Los Angeles is 0.04 inches per year (0.95 millimeters per year) with a 95% confidence interval of +/- 0.01 inches/year (0.24 mm per year) based on monthly mean sea level data from 1923 to 2015 which is equivalent to a change of 0.33 feet in 100 years. The figure below provides sea level trend data from NOAA tide gage number 9410660 at the end of Signal Street at the Port of Los Angeles in Los Angeles, California.

Until recently, LA Sanitation was using the USGS Coastal Storm Modeling System (CoSMoS) 1.0 calculations for Southern California to identify coastal storm threats with climate change. CoSMoS 1.0, released in 2014, used 0.5 and 1.4 meters (1.6 and 4.6 feet) of sea-level rise to 2050 and 2100 respectively, in its coastal storm model calculations.[12] CoSMoS 1.0 was also applied to the El Niño-fueled storm of January 18–25, 2010 that produced large waves (offshore deep-water waves up to 9 meters high) with sea-level rise. LA Sanitation was using calculated water elevations for these scenarios for flood risk planning. However, CoSMoS 1.0 is being updated by the USGS as CoSMoS 3.0 and is expected to be complete by mid-2016. CoSMoS 3.0 is more refined with daily, annual, 20-year, and 100-year coastal storm calculations at sea level increases from 0 meters to 2.0 meters (0.25 meter increment), plus a 5 meter scenario. Preliminary calculations have been released up to 2.0 meters sea-level rise, but not finalized. LA Sanitation resolved to evaluate flooding risks using the CoSMoS 3.0 model framework applied with a 100-year coastal storm at sea-level rise elevations (0 to 2 meters) to identify which assets would be vulnerable.

[12] Barnard, P.L., van Ormondt, M., Erikson, L.H., Eshleman, J., Hapke, C., Ruggiero, P., Adams, P. N., and Foxgrover, A. 2014. Coastal Storm Modeling System: CoSMoS. Southern California 1.0, projected flooding hazards, http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal1.0/, doi:10.5066/F74B2ZB4

Mean Sea Level Trend



Source: http://www.tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=9410660 accessed August 3, 2016

APPENDIX C: CHARACTERIZATION OF RISK: CONSEQUENCE CATEGORIES AND LEVEL DESCRIPTIONS

Temescal Canyon Pumping Plant No. 634

Consequence Levels	Consequence Descriptions			
	Utility Business Impacts	**Utility Equipment Damage**	**Source/ Receiving Water Impacts**	**Environmental Impacts**
	Revenue or operating income loss evaluated in terms of magnitude and recurrence of service interruptions	Costs of replacing the service equivalent provided by a utility or piece of equipment evaluated in terms of magnitude of damage (minimal, minor, significant, complete loss) and financial impacts (flexible cost scale, "$x," can be customized by each user)	Degradation or loss of source water or receiving water quality and/or quantity, evaluated in terms of recurrence (minimal, temporary, seasonal or episodic, long-term)	Evaluated in terms of environmental damage or loss (aside from source water or other assets) and compliance with environmental regulations (minimal, short term, persistent/permit violations significant impact and/or regulatory enforcement and actions)
Very High	Long-term and/or significant loss of expected revenue or operating income $715,001+	Complete loss of asset $623,001+	Long-term compromise of source water quality or quantity $77,880,001+	Significant environmental damage $12,040,001+
High	Seasonal or episodic compromise of expected revenue or operating income $508,001 - $715,000	Significant damage to equipment $260,001 - $623,000	Seasonal or episodic compromise of source water quality or quantity $32,440,001 - $77,880,000	Persistent environmental damage $5,040,001 - $12,040,000
Medium	Minor and short-term reductions in expected revenue $254,001 - $508,000	Minor damage to equipment $104,001 - $260,000	Temporary impact on source water quality or quantity $12,960,0001 - $32,440,000	Short-term damage, compliance can be quickly restored $2,000,001 - $5,040,000
Low	Minimal potential for loss of revenue or operating income $0 - $254,000	Minimal damage to equipment $0 - $104,000	No more than minimal changes to water quality $0 - $12,960,000	No impact or environmental damage $0 - $2,000,000

Terminal Island Water Reclamation Plant (TIWRP)

Consequence Levels	Consequence Descriptions			
	Utility Business Impacts	**Utility Equipment Damage**	**Source/ Receiving Water Impacts**	**Environmental Impacts**
	Revenue or operating income loss evaluated in terms of magnitude and recurrence of service interruptions	Costs of replacing the service equivalent provided by a utility or piece of equipment evaluated in terms of magnitude of damage (minimal, minor, significant, complete loss) and financial impacts (flexible cost scale, "$x," can be customized by each user)	Degradation or loss of source water or receiving water quality and/or quantity, evaluated in terms of recurrence (minimal, temporary, seasonal or episodic, long-term)	Evaluated in terms of environmental damage or loss (aside from source water or other assets) and compliance with environmental regulations (minimal, short term, persistent/permit violations significant impact and/or regulatory enforcement and actions)
Very High	Long-term and/or significant loss of expected revenue or operating income $11,430,001+	Complete loss of asset $9,345,001+	Long-term compromise of source water quality or quantity $77,880,001+	Significant environmental damage $12,040,001+
High	Seasonal or episodic compromise of expected revenue or operating income $7,620,001 - $11,430,000	Significant damage to equipment $3,900,001 - $9,345,000	Seasonal or episodic compromise of source water quality or quantity $32,440,001 - $77,880,000	Persistent environmental damage $5,040,001 - $12,040,000
Medium	Minor and short-term reductions in expected revenue $3,810,001 - $7,620,000	Minor damage to equipment $1,560,001 - $3,900,000t	Temporary impact on source water quality or quantity $12,960,001 - $32,440,001	Short-term damage, compliance can be quickly restored $2,000,001 - $5,040,000
Low	Minimal potential for loss of revenue or operating income $0 - $3,810,000	Minimal damage to equipment $0 - $1,560,000	No more than minimal changes to water quality $0 - $12,960,001	No impact or environmental damage $0 - $2,000,000

APPENDIX D: CAPITAL IMPROVEMENT PLANNING PROJECT PRIORITIZATION CRITERIA AND PRELIMINARY WEIGHTINGS

	CRITERIA	PRELIMINARY WEIGHTING
1	Physical Condition	16%
2	Performance/Process Condition	15%
3	Regulatory/Environmental	15%
4	O&M and Service Level/Reliability	12%
5	Safety	16%
6	Public Benefit/Perception and Community/Growth	7%
7	Financial	11%
8	Efficiency/Energy and Process Effectiveness/Institutional Knowledge	8%
	TOTAL	100%

APPENDIX E: REPLACE-IN-KIND COST ESTIMATES

MEMORANDUM CH2MHILL®

Preliminary Estimates: LASAN – Pumpstations – Replace in Kind

PREPARED FOR: WILLIAM MCMILLIN/NJO
PREPARED BY: Robert Wells/PDX
DATE: SEPTEMBER 22, 2015

Background

The purpose of the estimates is to determine the value of work to repair or replace facility and process components likely destroyed by water ingress due to a tsunami event. The estimates for facilities at Class V level of definition (per request) have been prepared based on several assumptions. The drawings from previous projects were utilized to provide a characterization of the work. The value of the work is determined in 2015 dollars with no escalation for future dates. The assumption is that labor resources, whether local or imported, will be costed at 2015 union rates.

The estimate assumes that all electrical, mechanical and instrumentation equipment would be replaced. Mechanical process piping, concrete structures would remain. Some amount of facility metal components, site work, roofing and painting is assumed to be necessary. The facility is assumed to be pumped by this contract, washed and cleaned up including site.

Costs

The estimates for Sunset PP and Temescal PP were based on line item takeoffs from the drawings. The estimate includes cost allocations of indirect costs, general requirements, markups, bond and taxes. The costs in the attached estimate reports do not include an allowance for market conditions. RSMeans cost data reference suggests an additional 30% based on presumed labor and subcontractor availability, and a generally unfavorable market. Additionally, there is likely a premium for emergency work affecting the local or regional market and thus the basis of contract. It is very likely that emergency scope such as temporary connections to be installed and removed, working around owner's operation personnel, additional material expedition and freight costs, as well as unknown work calendar and the consequential overtime costs. It is reasonable then, to move from 30% suggested by RSMeans, to 50% additional, to cover factors likely present given this situation.

Generally, our method cost presentation is to determine a single project cost and advise the likely range of accuracy for the level of definition. In this case, it is best to base the likely range of accuracy on a two project costs, the low as given in the attached reports, and the high with the 50% additional for project factors. Class V estimates can be minus 50% to plus 100% of the single project cost. In this case, we will assume the accuracy to be minus 50% of the cost given in the attached reports, and plus 100% of the reported cost with the 50% project factor. This results in a much wider range, and the uncertainty associated with it should help inform the decision maker regarding expected costs.

The markups included in the reported cost are as follows: Subcontractor and Prime Contractor general requirements, overhead and profit (total), 44%; Bonds and Insurance, 2%, Estimating Contingency, 15%.

Table 1: Estimated Project Costs (Class V Range)

Project	-50% accuracy limit	As reported cost	Reported cost with 50% additional	+100% accuracy limit
Sunset PP	$0.7M	**$1.4M**	**$2.1M**	$4.2M
Temescal PP	$0.5M	**$1.1M**	**$1.6M**	$3.2M

In order to standardize a value by which to compare alternatives, it is advisable and an industry standard for municipalities to use the 80th percentile of the range of costs. For these projects, the following values represent the 80th percentile:

Sunset: $3.5M

Temescal: $2.7M

Attachments

The attached reports are organized by Facility and Work Activity, which generally represents a portion or component of the facility or process.

- Detail Reports, 5pp
- AACE Classification System, 3pp

Spreadsheet Level		Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
01 SUNSET PP									
RFW090 GROUNDING									
Grounding repair or replacement		1.00 LS	40.0	5,142	7,089	-	-	12,231.66 /LS	12,232
RFW090 GROUNDING			**40.0**	**5,142**	**7,089**			**/LS**	**12,232**
RFW100 MCC									
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 1		4.00 ea	11.9	1,524	13,293	-	-	3,704.06 /ea	14,816
RVSS 75HP		4.00 ea	49.2	6,329	68,058	-	-	18,596.76 /ea	74,387
Circuit breaker, light contactor, type B, 30 Amp, NEMA 1		1.00 ea	3.0	381	3,323	-	-	3,704.07 /ea	3,704
Circuit breaker, light contactor, type B, 100 amp, NEMA 1		1.00 ea	8.0	1,028	5,804	-	-	6,832.88 /ea	6,833
Fusible switch, type A, 30 Amp, NEMA 1		9.00 ea	13.6	1,746	16,350	-	-	2,010.70 /ea	18,096
Motor control center, structures, 22,000 rms, takes any combination of starters, 600 amp, up to 72" high		10.00 ea	100.0	12,856	33,675	-	-	4,653.03 /ea	46,530
Motor control center, for copper bus add per structure		10.00 ea		-	4,697	-	-	469.67 /ea	4,697
Motor control center, for 42,000 rms, add per structure		10.00 ea		-	3,527	-	-	352.70 /ea	3,527
Motor control center, for pilot lights, add per starter		8.00 ea	4.0	514	1,687	-	-	275.19 /ea	2,202
Motor control center, for push button, add per starter		8.00 ea	4.0	514	1,687	-	-	275.19 /ea	2,202
Motor control center, for auxiliary contacts, add per starter		8.00 ea	4.0	514	2,510	-	-	377.98 /ea	3,024
Metering, surge arrestor, TVSS		1.00 ea	0.5	64	11,520	-	-	11,584.52 /ea	11,585
Automatic transfer switches, enclosed, 3 pole, 480 volt, 600 amp		1.00 ea	16.0	2,057	15,242	-	-	17,299.09 /ea	17,299
RFW100 MCC			**214.1**	**27,528**	**181,373**			**/EA**	**208,901**
RFW101 STARTERS IN FIELD									
Motor starter, magnetic, FVNR, size 00, 480 volt, 2 HP, NEMA 1, incl enclosure & heaterS, n12		8.00 ea	18.3	2,351	16,944	-	-	2,411.80 /ea	19,294
RFW101 STARTERS IN FIELD			**18.3**	**2,351**	**16,944**			**/EA**	**19,294**
RFW105 DISTRIBUTION EQUIPMENT									
Transformer, dry-type, nonventilated, single phase 480 V primary 120/240 V secondary, 25 kVA		1.00 ea	17.8	2,285	3,899	-	-	6,184.62 /ea	6,185
Panelboards, 3 phase 4 wire, main circuit breaker, 277/480 V, 100 amp, 30 circuits, NEHB, incl 20 A 1 pole plug-in breakers		1.00 ea	21.1	2,706	4,874	-	-	7,580.41 /ea	7,580
RFW105 DISTRIBUTION EQUIPMENT			**38.8**	**4,992**	**8,773**			**/LS**	**13,765**
RFW110 SWITCHBOARD									
Switchboards, main circuit breaker, 3 pole, 4 wire, 277/480 volt, 600 amp		1.00 ea	14.5	1,870	7,134	-	-	9,003.62 /ea	9,004
Switchboards, metering section 24", add		1.00 ea	8.9	1,143	1,950	-	-	3,092.31 /ea	3,092
Switchboards, Nema 3R, add		1.00 ea	8.0	1,028	798	-	-	1,826.01 /ea	1,826
Switchboards, TVSS, add		1.00 ea	1.0	129	1,595	-	-	1,723.67 /ea	1,724
RFW110 SWITCHBOARD			**32.4**	**4,170**	**11,476**			**/EA**	**15,646**
RFW120 EM GEN									
Generator set,diesel,3 phase 4 wire,277/480 v,300 kw,incl battery,charger,muffler,automatic transfer switch&day tank,excl conduit,wiring,& concrete		1.00 ea	90.9	11,657	86,136	-	828	98,621.58 /ea	98,622
RFW120 EM GEN			**90.9**	**11,657**	**86,136**		**828**	**/EA**	**98,622**
RFW130 FEEDERS									
Wire, copper, stranded, 600 volt, #3, type THWN-THHN, in raceway		1.50 clf	2.4	309	343	-	-	434.31 /clf	651
Wire, copper, stranded, 600 volt, 500 kcmil, type THWN-THHN, in raceway		6.00 clf	30.0	3,857	12,495	-	-	2,725.29 /clf	16,352
Rigid galvanized steel conduit, 4" diameter, to 15' H, incl 2 terminations, 2 elbows & 11 beam clamps per 100 LF		50.00 lf	20.0	2,571	2,038	-	-	92.19 /lf	4,609
RFW130 FEEDERS			**52.4**	**6,736**	**14,876**			**/LS**	**21,613**
RFW140 MCC LOADS									
Wire, copper, stranded, 600 volt, #12, type XHHW, in raceway		26.00 clf	18.9	2,431	880	-	-	127.35 /clf	3,311
Wire, copper, stranded, 600 volt, #6, type XHHW, in raceway		2.50 clf	3.1	396	326	-	-	288.50 /clf	721
Wire, copper, stranded, 600 volt, #4, type XHHW, in raceway		1.50 clf	2.3	291	300	-	-	394.31 /clf	591
Wire, copper, stranded, 600 volt, 1/0, type XHHW, in raceway		6.00 clf	14.5	1,870	3,190	-	-	843.36 /clf	5,060
Rigid galvanized steel conduit, 3/4" diameter, to 15' H, incl 2 terminations, 2 elbows & 11 beam clamps per 100 LF		550.00 lf	55.0	7,071	2,495	-	-	17.39 /lf	9,566
Rigid galvanized steel conduit, 1" diameter, to 15' H, incl 2 terminations, 2 elbows & 11 beam clamps per 100 LF		150.00 lf	18.5	2,373	981	-	-	22.36 /lf	3,354

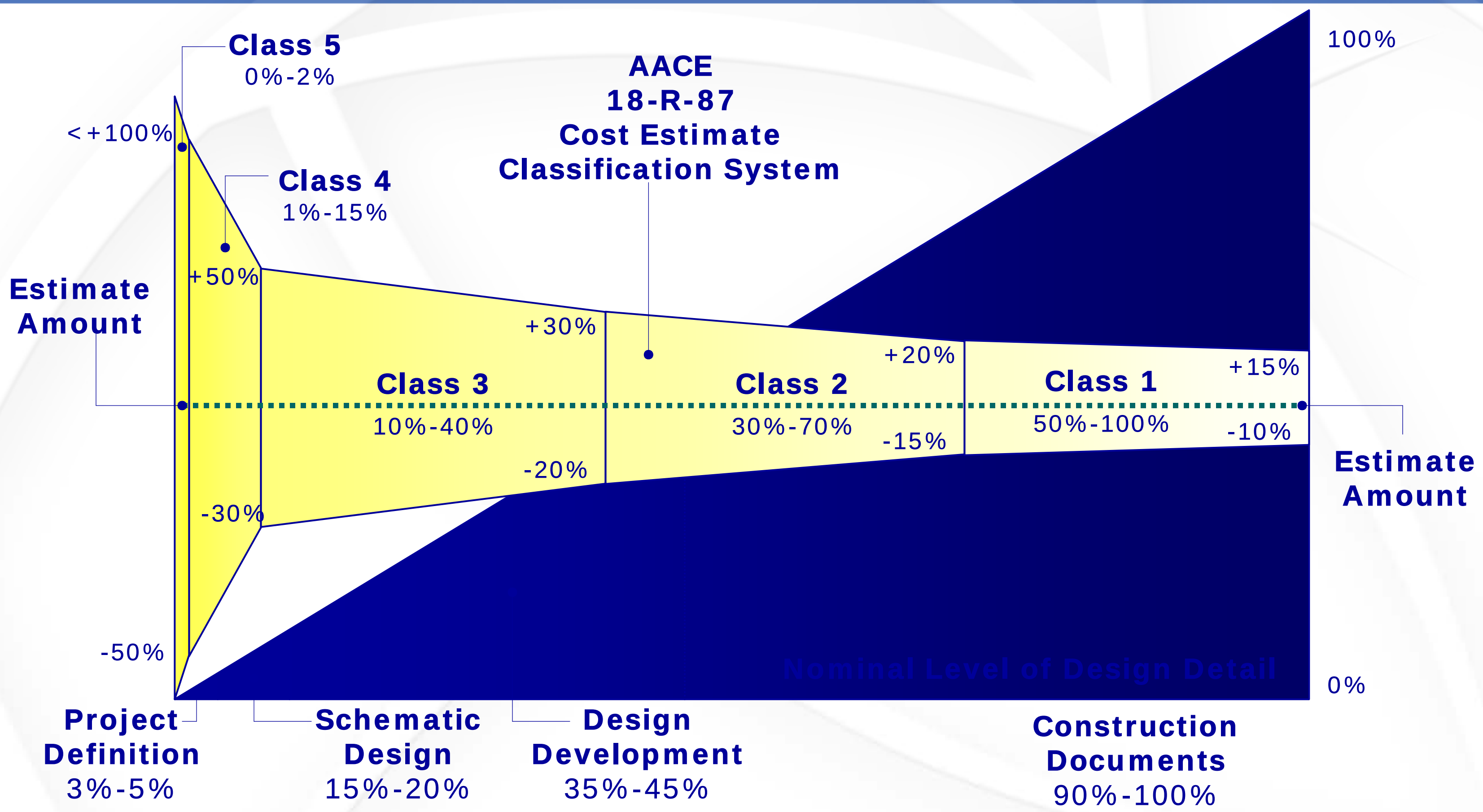
Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
RFW140 MCC LOADS								
Rigid galvanized steel conduit, 2" diameter, to 15' H, incl 2 terminations, 2 elbows & 11 beam clamps per 100 LF	200.00 lf	35.6	4,571	2,641	-	-	36.06 /lf	7,212
Motor connections, flexible conduit and fittings, 3 phase, 460 volt, 5 HP motor	12.00 ea	12.0	1,543	165	-	-	142.29 /ea	1,708
Motor connections, flexible conduit and fittings, 3 phase, 460 volt, 75 HP motor	4.00 ea	9.1	1,175	276	-	-	362.97 /ea	1,452
Safety switches, 3 pole, fusible, 600 volt, 30 amp, NEMA 12	2.00 ea	5.2	664	1,418	-	-	1,040.71 /ea	2,081
RFW140 MCC LOADS		**174.1**	**22,384**	**12,673**			**/LS**	**35,057**
RFW150 FACILITY LOADS								
Motor connections, flexible conduit and fittings, 1 phase, 115 volt, up to 1 HP motor	3.00 ea	3.0	386	39	-	-	141.41 /ea	424
RFW150 FACILITY LOADS		**3.0**	**386**	**39**			**/LS**	**424**
RFW160 FACILITY LIGHTING AND RECPTS								
Lighting allowance	1.00 ls	200.0	25,711	35,447		-	61,158.34 /ls	61,158
Receptacle allowance	1.00 ls	100.0	12,856	14,179		-	27,034.48 /ls	27,034
RFW160 FACILITY LIGHTING AND RECPTS		**300.0**	**38,567**	**49,626**			**/LS**	**88,193**
RFW170 OTHER ELECTRICAL - COMM-LS-SEC								
Security allowance	1.00 ls	120.0	15,433	14,179	3,545	-	33,156.50 /ls	33,157
Life Safety allowance	1.00 ls	80.0	10,285	-	8,862	-	19,146.30 /ls	19,146
Comm allowance	1.00 ls	40.0	5,142	-	8,862	-	14,004.01 /ls	14,004
RFW170 OTHER ELECTRICAL - COMM-LS-SEC		**240.0**	**30,860**	**14,179**	**21,268**		**/LS**	**66,307**
RFW200 PLC-HMI, PROG, START, CX								
Programming, per hour, subcontract, all expenses	200.00 hr		-	-	62,032	-	310.16 /hr	62,032
DCS, Operator Workstation	1.00 ea	40.0	5,078	35,447	-	-	40,524.94 /ea	40,525
PLC Cabinet	1.00 ea	80.0	10,156	70,894	-	-	81,049.87 /ea	81,050
ICP Cabinet	1.00 ea	80.0	10,156	70,894	-	-	81,049.87 /ea	81,050
RFW200 PLC-HMI, PROG, START, CX		**200.0**	**25,390**	**177,234**	**62,032**		**/LS**	**264,657**
RFW210 INSTRUMENTS								
FT / FIT - Flow Transmitter - Magnetic, 12"	1.00 ea	9.5	1,206	35,447	-	-	36,652.94 /ea	36,653
LT / LIT - Level Transmitter	2.00 ea	4.5	571	8,153	-	-	4,362.03 /ea	8,724
LS - Level Switch Ultrasonic	2.00 ea	6.0	762	4,254	-	-	2,507.67 /ea	5,015
LS - Level Switch - Float Type	2.00 ea	6.0	762	1,241	-	-	1,001.17 /ea	2,002
RFW210 INSTRUMENTS		**26.0**	**3,301**	**49,094**			**/EA**	**52,395**
RFW220 INSTR CIRCUITS								
3/4" conduit and instr circuit	30.00 ea	360.0	46,281	-	26,585	-	2,428.86 /ea	72,866
RFW220 INSTR CIRCUITS		**360.0**	**46,281**		**26,585**		**/LS**	**72,866**
RFW300 PUMPS								
75HP pump	4.00 ea	128.0	17,467	83,655	-	-	25,280.36 /ea	101,121
RFW300 PUMPS		**128.0**	**17,467**	**83,655**			**/EA**	**101,121**
RFW310 FANS AND DUCTS								
Ductwork, fabrication cost stainless steel, rectangular, 20 ga.	400.00 lb		-	8,507		-	21.27 /lb	8,507
Ductwork, fabrication cost, stainless steel, round, 20 ga.	200.00 lb		-	4,254		-	21.27 /lb	4,254
Ductwork, installation cost, stainless steel, rectangular, 20 ga.	400.00 lb	13.3	1,703	-		-	4.26 /lb	1,703
Ductwork, installation cost, stainless steel, round, 20 ga.	200.00 lb	6.7	851	-		-	4.26 /lb	851
Fans, prop exh, wl shtr, 1/4" S.P., v-belt dr, 3 ph, 10,100 CFM, 1 HP	2.00 ea	8.9	1,135	3,722	-	-	2,428.52 /ea	4,857
RFW310 FANS AND DUCTS		**28.9**	**3,689**	**16,483**			**/LS**	**20,172**
RFW900 MISC FACILITY								
Temp power	1.00 ls		-	-	11,793	-	11,792.59 /ls	11,793
Cleaning up	1.00 ls			-	15,723	-	15,723.46 /ls	15,723
Demo based on percentage of install MH, includes disposal	1.00 LS	444.0	47,215	17,723	-	4,431	69,369.58 /LS	69,370
Hazardous W cln/pu/dspl, liq pickup, vac trk,min charge,4hr,2compt,500	240.00 hr		-	-	72,312	-	301.30 /hr	72,312
Hazardous W cln/pu/dspl, liq pickup, vac trk, transp in 6900gal bulk t	60.00 mile		-	-	744	-	12.41 /mile	744
Clean up site detritus	1.00 acre	66.7	6,889	-	-		6,888.54 /acre	6,889
Metal deck, cellular units, galvanized, 1-1/2" deep, 16-18 gauge	100.00 sf	2.4	373	1,382	-	31	17.86 /sf	1,786
Ladder, steel, bolted to concrete, without cage	15.00 lf	6.0	914	798	-	-	114.10 /lf	1,711
Stair, steel, saf nosing, stl strg, grating trd & pipe rail, 3'-6" W	30.00 risr	27.4	4,259	14,941	-	352	651.74 /risr	19,552
Railing, pipe, stainless steel, 2 rail, 1-1/4" diam. #4 finish	200.00 lf	46.8	7,269	33,320	-	601	205.95 /lf	41,191

Spreadsheet Level		Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
RFW900 MISC FACILITY									
Repair roof		1.00 ls		-		17,723	-	17,723.45 /ls	17,723
Coml st doors, fl, full pnl, hol met 1-3/8" thk, 20 Ga., 3'-0" x 7'-0"		8.00 ea	7.5	895	4,892	-	-	723.33 /ea	5,787
Steel channel frame, C6, 8.2#/lnft, to 3' x 7' opening		8.00 ea	19.7	3,059	2,878	-	63	750.11 /ea	6,001
Painting, floors, concrete, spray, latex, block filler, 1st coat		20,000.00 sf	60.0	5,968	6,026	-	-	0.60 /sf	11,994
Painting, floors, concrete, spray, latex, block filler, 2nd coat		20,000.00 sf	40.0	3,979	3,190	-	-	0.36 /sf	7,169
Misc. Mechanical allowance		1.00 ls		-	-	8,862	-	8,861.71 /ls	8,862
Misc Electrical allowance		1.00 ls		-	-	17,723	-	17,723.45 /ls	17,723
I&C misc allowance		1.00 ls		-	-	15,723	-	15,723.45 /ls	15,723
RFW900 MISC FACILITY			**720.5**	**80,820**	**85,151**	**160,604**	**5,479**	**/LS**	**332,053**
01 SUNSET PP		**1.00 LS**	**2,667.6**	**331,720**	**814,799**	**270,490**	**6,307**	**1,423,316.39 /LS**	**1,423,316**

Spreadsheet Level		Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
02 TEMESCAL PP									
RFW090 GROUNDING									
Grounding repair or replacement		1.00 LS	24.0	3,085	4,431	-	-	7,516.23 /LS	7,516
RFW090 GROUNDING			**24.0**	**3,085**	**4,431**			**/LS**	**7,516**
RFW100 MCC									
Transformer, dry-type, ventilated, 3 phase 480 V primary 120/208 V secondary, 15 kVA		1.00 ea	14.5	1,870	1,905	-	-	3,775.20 /ea	3,775
Panelboards, 3 phase 4 wire, main circuit breaker, 277/480 V, 100 amp, 30 circuits, NEHB, incl 20 A 1 pole plug-in breakers		1.00 ea	21.1	2,706	4,874	-	-	7,580.42 /ea	7,580
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 1		3.00 ea	8.9	1,143	9,969	-	-	3,704.06 /ea	11,112
RVSS 75HP		3.00 ea	36.9	4,747	51,044	-	-	18,596.76 /ea	55,790
Circuit breaker, light contactor, type B, 30 Amp, NEMA 1		1.00 ea	3.0	381	3,323	-	-	3,704.06 /ea	3,704
Circuit breaker, light contactor, type B, 60 amp, NEMA 1		1.00 ea	4.0	514	3,811	-	-	4,324.77 /ea	4,325
Motor control center, structures, 22,000 rms, takes any combination of starters, 600 amp, up to 72" high		7.00 ea	70.0	8,999	23,572	-	-	4,653.03 /ea	32,571
Motor control center, for copper bus add per structure		7.00 ea		-	3,288	-	-	469.67 /ea	3,288
Motor control center, for 42,000 rms, add per structure		7.00 ea		-	2,469	-	-	352.70 /ea	2,469
Motor control center, for pilot lights, add per starter		6.00 ea	3.0	386	1,265	-	-	275.19 /ea	1,651
Motor control center, for push button, add per starter		6.00 ea	3.0	386	1,265	-	-	275.19 /ea	1,651
Motor control center, for auxiliary contacts, add per starter		6.00 ea	3.0	386	1,882	-	-	377.99 /ea	2,268
Metering, surge arrestor, TVSS		1.00 ea	0.5	64	11,520	-	-	11,584.51 /ea	11,585
RFW100 MCC			**167.9**	**21,581**	**120,188**			**/EA**	**141,769**
RFW110 SWITCHBOARD									
Switchboards, main circuit breaker, 3 pole, 4 wire, 277/480 volt, 400 amp		1.00 ea	14.0	1,804	5,671	-	-	7,475.83 /ea	7,476
Switchboards, metering section 24", add		1.00 ea	8.9	1,143	1,950	-	-	3,092.32 /ea	3,092
Switchboards, Nema 3R, add		1.00 ea	8.0	1,028	798	-	-	1,826.02 /ea	1,826
RFW110 SWITCHBOARD			**30.9**	**3,976**	**8,419**			**/EA**	**12,394**
RFW120 EM GEN									
Generator set,diesel,3 phase 4 wire,277/480 v,150 kw,incl battery,charger,muffler,automatic transfer switch&day tank,excl conduit,wiring,& concrete		1.00 ea	76.9	9,864	60,083	-	701	70,647.23 /ea	70,647
RFW120 EM GEN			**76.9**	**9,864**	**60,083**		**701**	**/EA**	**70,647**
RFW130 FEEDERS									
Wire, copper, stranded, 600 volt, #3, type THWN-THHN, in raceway		1.50 clf	2.4	309	343	-	-	434.32 /clf	651
Wire, copper, stranded, 600 volt, 500 kcmil, type THWN-THHN, in raceway		6.00 clf	30.0	3,857	12,495	-	-	2,725.29 /clf	16,352
Rigid galvanized steel conduit, 4" diameter, to 15' H, incl 2 terminations, 2 elbows & 11 beam clamps per 100 LF		50.00 lf	20.0	2,571	2,038	-	-	92.19 /lf	4,609
RFW130 FEEDERS			**52.4**	**6,736**	**14,876**			**/LS**	**21,613**
RFW140 MCC LOADS									
Wire, copper, stranded, 600 volt, #12, type XHHW, in raceway		20.00 clf	14.5	1,870	677	-	-	127.35 /clf	2,547
Wire, copper, stranded, 600 volt, #6, type XHHW, in raceway		2.00 clf	2.5	316	261	-	-	288.50 /clf	577
Wire, copper, stranded, 600 volt, #1, type XHHW, in raceway		6.00 clf	12.0	1,543	2,573	-	-	686.02 /clf	4,116
Rigid galvanized steel conduit, 3/4" diameter, to 15' H, incl 2 terminations, 2 elbows & 11 beam clamps per 100 LF		500.00 lf	50.0	6,428	2,269	-	-	17.39 /lf	8,696
Rigid galvanized steel conduit, 1-1/2" diameter, to 15' H, incl 2 terminations, 2 elbows & 11 beam clamps per 100 LF		200.00 lf	29.1	3,740	2,038	-	-	28.89 /lf	5,778
Motor connections, flexible conduit and fittings, 3 phase, 460 volt, 5 HP motor		4.00 ea	4.0	514	55	-	-	142.29 /ea	569
Motor connections, flexible conduit and fittings, 3 phase, 460 volt, 75 HP motor		3.00 ea	6.9	882	207	-	-	362.97 /ea	1,089
Safety switches, 3 pole, fusible, 600 volt, 30 amp, NEMA 12		2.00 ea	5.2	664	1,418	-	-	1,040.70 /ea	2,081
RFW140 MCC LOADS			**124.1**	**15,956**	**9,498**			**/LS**	**25,454**
RFW150 FACILITY LOADS									
Motor connections, flexible conduit and fittings, 1 phase, 115 volt, up to 1 HP motor		1.00 ea	1.0	129	13	-	-	141.42 /ea	141
RFW150 FACILITY LOADS			**1.0**	**129**	**13**			**/LS**	**141**
RFW160 FACILITY LIGHTING AND RECPTS									
Lighting allowance		1.00 ls	160.0	20,569	21,268	-	-	41,837.30 /ls	41,837
Receptacle allowance		1.00 ls	80.0	10,285	8,862	-	-	19,146.32 /ls	19,146

Spreadsheet Level		Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
RFW160 FACILITY LIGHTING AND RECPTS			**240.0**	**30,854**	**30,130**			**/LS**	**60,984**
RFW170 OTHER ELECTRICAL - COMM-LS-SEC									
Security allowance		1.00 ls	120.0	15,433	14,179	3,545	-	33,156.49 /ls	33,156
Life Safety allowance		1.00 ls	80.0	10,285	-	8,862	-	19,146.31 /ls	19,146
Comm allowance		1.00 ls	40.0	5,142	-	4,431	-	9,573.14 /ls	9,573
RFW170 OTHER ELECTRICAL - COMM-LS-SEC			**240.0**	**30,860**	**14,179**	**16,837**		**/LS**	**61,876**
RFW200 PLC-HMI, PROG, START, CX									
Programming, per hour, subcontract, all expenses		200.00 hr		-	-	62,032	-	310.16 /hr	62,032
DCS, Operator Workstation		1.00 ea	40.0	5,078	35,447	-	-	40,524.94 /ea	40,525
PLC Cabinet		1.00 ea	80.0	10,156	70,894	-	-	81,049.85 /ea	81,050
RFW200 PLC-HMI, PROG, START, CX			**120.0**	**15,234**	**106,341**	**62,032**		**/LS**	**183,607**
RFW210 INSTRUMENTS									
FT / FIT - Flow Transmitter - Magnetic, 12"		1.00 ea	9.5	1,206	35,447	-	-	36,652.94 /ea	36,653
LT / LIT - Level Transmitter		2.00 ea	4.5	571	8,153	-	-	4,362.04 /ea	8,724
LS - Level Switch Ultrasonic		2.00 ea	6.0	762	4,254	-	-	2,507.67 /ea	5,015
LS - Level Switch - Float Type		2.00 ea	6.0	762	1,241	-	-	1,001.17 /ea	2,002
RFW210 INSTRUMENTS			**26.0**	**3,301**	**49,094**			**/EA**	**52,395**
RFW220 INSTR CIRCUITS									
3/4" conduit and instr circuit		23.00 ea	276.0	35,482	-	20,382	-	2,428.86 /ea	55,864
RFW220 INSTR CIRCUITS			**276.0**	**35,482**		**20,382**		**/LS**	**55,864**
RFW300 PUMPS									
75HP pump		3.00 ea	96.0	13,100	62,741	-	-	25,280.36 /ea	75,841
RFW300 PUMPS			**96.0**	**13,100**	**62,741**			**/EA**	**75,841**
RFW310 FANS AND DUCTS									
Ductwork, fabrication cost stainless steel, rectangular, 20 ga.		800.00 lb		-	17,015		-	21.27 /lb	17,015
Ductwork, fabrication cost, stainless steel, round, 20 ga.		400.00 lb		-	8,507		-	21.27 /lb	8,507
Ductwork, installation cost, stainless steel, rectangular, 20 ga.		800.00 lb	26.7	3,406	-		-	4.26 /lb	3,406
Ductwork, installation cost, stainless steel, round, 20 ga.		400.00 lb	13.3	1,703	-		-	4.26 /lb	1,703
Fans, prop exh, wl shtr, 1/4" S.P., v-belt dr, 3 ph, 10,100 CFM, 1 HP		3.00 ea	13.3	1,703	5,583	-	-	2,428.52 /ea	7,286
RFW310 FANS AND DUCTS			**53.3**	**6,811**	**31,105**			**/LS**	**37,916**
RFW900 MISC FACILITY									
Temp power		1.00 ls		-	-	11,793	-	11,792.58 /ls	11,793
Cleaning up		1.00 ls		-	-	9,434	-	9,434.07 /ls	9,434
Demo based on percentage of install MH, includes disposal		1.00 LS	350.0	37,219	14,179		3,545	54,942.68 /LS	54,943
Hazardous W cln/pu/dspl, liq pickup, vac trk,min charge,4hr,2compt,500		240.00 hr		-	-	72,312	-	301.30 /hr	72,312
Hazardous W cln/pu/dspl, liq pickup, vac trk, transp in 6900gal bulk t		60.00 mile		-	-	744	-	12.41 /mile	744
Clean up site detritus		1.00 acre	66.7	6,889	-	-		6,888.54 /acre	6,889
Metal deck, cellular units, galvanized, 1-1/2" deep, 16-18 gauge		100.00 sf	2.4	373	1,382	-	31	17.86 /sf	1,786
Ladder, steel, bolted to concrete, without cage		15.00 lf	6.0	914	798	-	-	114.10 /lf	1,711
Stair, steel, saf nosing, stl strg, grating trd & pipe rail, 3'-6" W		30.00 risr	27.4	4,259	14,941	-	352	651.74 /risr	19,552
Railing, pipe, stainless steel, 2 rail, 1-1/4" diam. #4 finish		200.00 lf	46.8	7,269	33,320	-	601	205.95 /lf	41,191
Repair roof		1.00 ls		-	-	8,862	-	8,861.73 /ls	8,862
Coml st doors, fl, full pnl, hol met 1-3/8" thk, 20 Ga., 3'-0" x 7'-0"		5.00 ea	4.7	559	3,057	-	-	723.33 /ea	3,617
Steel channel frame, C6, 8.2#/lnft, to 3' x 7' opening		5.00 ea	12.3	1,912	1,799	-	40	750.11 /ea	3,751
Painting, floors, concrete, spray, latex, block filler, 1st coat		10,000.00 sf	30.0	2,984	3,013	-	-	0.60 /sf	5,997
Painting, floors, concrete, spray, latex, block filler, 2nd coat		10,000.00 sf	20.0	1,989	1,595	-	-	0.36 /sf	3,584
Misc. Mechanical allwoance		1.00 ls		-	-	8,862	-	8,861.73 /ls	8,862
Misc Electrical allowance		1.00 ls		-	-	8,862	-	8,861.73 /ls	8,862
I&C misc allowance		1.00 ls		-	-	7,862	-	7,861.72 /ls	7,862
RFW900 MISC FACILITY			**566.3**	**64,367**	**74,084**	**128,730**	**4,569**	**/LS**	**271,750**
02 TEMESCAL PP		**1.00 LS**	**2,094.9**	**261,336**	**585,180**	**227,981**	**5,270**	**1,079,766.60 /LS**	**1,079,767**

AACE – Classification System



Construction Cost Estimate Accuracy Ranges

CH2MHILL

Estimate Class	Class 5	Class 4	Class 3	Class 2	Class 1
LEVEL OF PROJECT DEFINITION Expressed as a % of complete definition	0% to 2%	1% to 15%	10% to 40%	30% to 70%	50% to 100%
END USAGE Typical Purpose of Estimate	Concept Screening	Study or Feasibility	Budget Authorization, or Control	Control or Bid / Tender	Check Estimate or Bid / Tender
METHODOLOGY Typical estimating method	Capacity Factored, Parametric Models, Judgment, or Analogy	Equipment Factored or Parametric Models	Semi-Detailed Unit Costs with Assembly Level Line Items	Detailed Unit Cost with Forced Detailed Take-Off	Detailed Unit Cost with Detailed Take-Off
EXPECTED ACCURACY RANGE Typical variation in low and high ranges [a]	L: -20% to -50% H: +30% to +100%	L: -15% to -30% H: +20% to +50%	L: -10% to -20% H: +10% to +30%	L: -5% to -15% H: +5% to +20%	L: -3% to -10% H: +3% to +15%
PREPARATION EFFORT Typical degree of effort relative to least cost index of 1 [b]	1	2 to 4	3 to 10	4 to 20	5 to 100
REFINED CLASS DEFINITION	Class 5 estimates are generally prepared based on very limited information, and subsequently have very wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systematic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with very little effort expended - sometimes requiring less than 1 hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation.	Class 4 estimates are generally prepared based on very limited information, and subsequently have very wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 5% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems and preliminary engineered process and utility equipment lists. Level of Project Definition Required: 1% to 15% of full project definition.	Class 3 estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. As such, they typically form the initial control estimate against which all actual costs and resources will be monitored. Typically, engineering is from 10% to 40% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, preliminary piping and instrument diagrams, utility flow diagrams, preliminary piping and instrument diagrams, plot plan, developed layout drawings, and essentially complete engineering process and utility equipment lists. Level Of Project Definition Required: 10% to 40% of full project definition.	Class 2 estimates are generally prepared to form a detailed control baseline against which all project work is monitored in terms of cost and progress control. For contractors, this class of estimate is often used as the "bid" estimate to establish contract value. Typically, engineering is from 30% to 70% complete, and would comprise at a minimum the following: Process flow diagrams, utility flow diagrams, piping and instrument flow diagrams, heat and material balances, final plot plan, final layout drawings, complete engineered process and utility equipment lists, single line diagrams for electrical, electrical equipment and motor schedules, vendor quotations, detailed project execution plans, resourcing and work force plans, etc.	Class 1 estimates are generally prepared for discrete parts or sections of the total project rather than generating this level of detail for the entire project. The parts of the project estimated at this level of detail will typically be used by subcontractors for bids, or by owners for check estimates. The updated estimate is often referred to as the current control estimate and becomes the new baseline for cost/schedule control of the project. Class 1 estimates may be prepared for parts of the project to comprise a fair price estimate or bid check estimate to compare against a contractor's bid estimate, or to evaluate/dispute claims. Typically, engineering is from 50% to 100% complete, and would comprise virtually all engineering and design documentation of the project, and complete project execution and commissioning plans. Level for Project Definition Required: 50% to 100% of full project definition.
END USAGE DEFINED	Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.	Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.	Class 3 estimates are typically prepared to support full project funding requests, and become the first of the project phase "control estimate" against which all actual costs and resources will be monitored for variations to the budget. They are used as the project budget until replaced by more detailed estimates. In many owner organizations, a Class 3 estimate may be the last estimate required and could well form the only basis for cost/schedule control.	Class 2 estimates are typically prepared as the detailed control baseline against which all actual costs an resources will now be monitored for variation to the budget, and form a part of the change/variation control program.	Class 1 estimates are typically prepared to form a current control estimate to be used as the final control baseline against which all actual coasts and resources will now be monitored for variations to the budget, and form a part of the change/variation control program. They may be used to evaluate bid checking, to support vendor/contractor negotiations, or for claim evaluations and dispute resolution.
ESTIMATING METHODS USED	Class 5 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques.	Class 4 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques.	Class 3 estimates usually involve more deterministic estimating methods that stochastic methods. They usually involve a high degree of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring and other stochastic methods may be used to estimate less-significant areas of the project.	Class 2 estimates always involve a high degree of deterministic estimating methods. Class 2 estimates are prepared in great detail, and often involve tens of thousands of unit cost line items. For those areas of the project still undefined, an assumed level of detailed takeoff (forced detail) may be developed to use as line items in the estimate instead of relying on factoring methods.	Class 1 estimates involve the highest degree of deterministic estimating methods, and require a great amount of effort. Class 1 estimates are prepared in great detail, and thus are usually performed on only the most important or critical areas of the project. All items in the estimate are usually unit cost line items based on actual design quantities.
EXPECTED ACCURACY RANGE	Typical accuracy ranges for Class 5 estimates are -20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 3 estimates are -10% to -20% on the low side, and +10% to +30% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 2 estimates are -5% to -15% on the low side, and +5% to +20% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 1 estimates are -3% to 10% - on the low side, and +3% to +15% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.
EFFORT TO PREPARE (for US$20MM project):	As little as 1 hour or less to prepare to perhaps more than 200 hours, depending on the project and the estimating methodology used.	Typically, as little as 20 hours or less to perhaps more than 300 hours, depending on the project and the estimating methodology used.	Typically, as little as 150 hours or less to perhaps more than 1500 hours, depending on the project and the estimating methodology used.	Typically, as little as 300 hours or less to perhaps more than 3000 hours, depending on the project and the estimating methodology used. Bid Estimates typically require more effort than estimates used for funding or control purposes	Class 1 estimates require the most effort to create, and as such are generally developed for only selected areas of the project, or for bidding purposes. A complete Class 1 estimate may involve as little as 600 hours or less, to perhaps more than 6,000 hours, depending on the project and the estimating methodology used. Bid estimate typically require more effort than estimates used for funding or control purposes.
ANSI Standard Reference Z94.2-1989 name; Alternate Estimate Names, Terms, Expressions, Synonyms:	Order of Magnitude Estimate; Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of thumb.	Budget Estimate; Screening, top-down, feasibility, authorization, factored, pre-design, pre-study.	Budget Estimate; Budget, scope, sanction, semi-detailed, authorization, preliminary control, concept study, development, basic engineering phase estimate, target estimate.	Definitive Estimate; Detailed Control, forced detail, execution phase, master control, engineering, bid, tender, change order estimate.	Definitive Estimate; Full detail, release, fall-out, tender, firm price, bottoms-up, final, detailed control, forced detail, execution phase, master control, fair price, definitive, change order estimate.

Estimate Class	Class 5	Class 4	Class 3	Class 2	Class 1
Estimate Input Checklist and Maturity Index	**Class 5**	**Class 4**	**Class 3**	**Class 2**	**Class 1**
GENERAL PROJECT DATA					
Project Scope Description	General	Preliminary	Defined	Defined	Defined
Plant Production / Facility Capacity	Assumed	Preliminary	Defined	Defined	Defined
Plant Location	General	Approximate	Specific	Specific	Specific
Soils & Hydrology	None	Preliminary	Defined	Defined	Defined
Integrated Project Plan	None	Preliminary	Defined	Defined	Defined
Project Master Schedule	None	Preliminary	Defined	Defined	Defined
Escalation Strategy	None	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	None	Preliminary	Defined	Defined	Defined
Project Code of Accounts	None	Preliminary	Defined	Defined	Defined
Contracting Strategy	Assumed	Assumed	Preliminary	Defined	Defined

ENGINEERING DELIVERABLES:	Class 5	Class 4	Class 3	Class 2	Class 1
Block Flow Diagrams	Started / Preliminary	Preliminary / Complete	Complete	Complete	Complete
Plot Plans		Started	Preliminary / Complete	Complete	Complete
Process Flow Diagrams (PFDs)		Started / Preliminary	Preliminary / Complete	Complete	Complete
Utility Flow Diagrams (UFDs)		Started / Preliminary	Preliminary / Complete	Complete	Complete
Piping & Instrument Diagrams (P&IDS)		Started	Preliminary / Complete	Complete	Complete
Heat and Material Balances		Started	Preliminary / Complete	Complete	Complete
Process Equipment List		Started / Preliminary	Preliminary / Complete	Complete	Complete
Utility Equipment List		Started / Preliminary	Preliminary / Complete	Complete	Complete
Electrical One Line Drawings		Started / Preliminary	Preliminary / Complete	Complete	Complete
Specifications and Datasheets		Started	Preliminary / Complete	Complete	Complete
General Equipment Arrangement Drawings		Started	Preliminary / Complete	Complete	Complete
Spare Parts Lists			Started / Preliminary	Preliminary	Complete
Architectural Details / Schedules		Started	Preliminary / Complete	Complete	Complete
Structural Details		Started	Preliminary / Complete	Complete	Complete
Mechanical Discipline Drawings			Started	Preliminary	Preliminary / Complete
Electrical Discipline Drawings			Started	Preliminary	Preliminary / Complete
System Discipline Drawings			Started	Preliminary	Preliminary / Complete
Civil/Site Discipline Drawings			Started	Preliminary	Preliminary / Complete
Demolition Details		Started	Preliminary / Complete	Complete	Complete

Preliminary Estimates: LASAN – Terminal Island Water Reclamation Plant – Replace in Kind

PREPARED FOR: WILLIAM MCMILLIN/NJO

PREPARED BY: Robert Wells/PDX

DATE: OCTOBER 8, 2015

Background

The purpose of the estimates is to determine the value of work to repair or replace facility and process components likely destroyed by water ingress due to a tsunami event. The estimates for facilities at Class V level of definition (per request) have been prepared based on several assumptions. The value of the work is determined in 2015 dollars with no escalation for future dates. The assumption is that labor resources, whether local or imported, will be costed at 2015 union rates.

The estimate assumes that all electrical, mechanical and instrumentation equipment would be replaced. Mechanical process piping, concrete structures would remain. Some amount of facility metal components, and some site work, is assumed to be necessary. The facilities are assumed to be pumped by this contract, washed and cleaned up including site. The MCCs-Electrical estimate is for electrical as listed per facility.

Cost Basis

The drawings from previous projects were utilized to provide a characterization of the work. These drawings and the scope included are as follows:

- **Headworks**
    - Microfilm scans in MS Word document: Headworks D-34202-120612 as-bids. Scope from these drawings includes site cleanup, temp power, demolition of ruined components, replacements or repair of metal doors, stairs, railings, floor plates and planks, HVAC components, lighting and receptacles and their associated circuits, grounding, security, comm, life-safety systems, motor drives, electrical distribution panels and equipment, MCCs, process gates and screens, wash press, grit classifiers, grit pumps and related instrumentation and control systems and their associated panels and programming of same.
    - Microfilm scans in MS Word document: Lift Station D-29274 PIE as-builts. Scope from these drawings includes site cleanup, temp power, demolition of ruined components, replacements or repair of lighting and receptacles and their associated circuits, grounding, security, comm, life-safety systems, motor drives, electrical distribution panels and equipment, MCCs, and related instrumentation and control systems and their associated panels and programming of same.
- **MCCs – Electrical**
    - Microfilm scans in MS Word documents: Biosolids D-32313 PIE as-builts, Digesters D-25078-80-750428 PIE as-builts, Filters D-30738-40-940331 PIE as-bid, LASAN-TI-Admin_Building, LASAN-TI-AerationTanks, LASAN-TI-Biosolids, LASAN-TI-CompressorBldg, LASAN-TI-FinalTanks, TI power & MCCs-1972 plant.
    - Scope includes: site cleanup, temp power, demolition of ruined components, replacements or repair of lighting and receptacles and their associated circuits, grounding, security, comm, life-safety systems, motor drives, electrical distribution panels and equipment, MCCs, and

related instrumentation and control systems and their associated panels and programming of same.

- **Effluent Pumping Plant**
  - Microfilm scans in MS Word document: EPP & Em Gen D-23942-720420 as-bids. Scope from these drawings includes site cleanup, temp power, demolition of ruined components, replacements or repair of metal doors, stairs, railings, lighting and receptacles and their associated circuits, grounding, security, comm, life-safety systems, motor drives, electrical distribution panels and equipment, MCCs, process pumps and related instrumentation and control systems and their associated panels and programming of same.

Costs

The estimate is based on line item takeoffs from the drawings. The estimate includes cost allocations of indirect costs, general requirements, markups, bond and taxes. The costs in the attached estimate reports do not include an allowance for market conditions. RSMeans cost data reference suggests an additional 30% based on presumed labor and subcontractor availability, and a generally unfavorable market. Additionally, there is likely a premium for emergency work affecting the local or regional market and thus the basis of contract. It is very likely that emergency scope such as temporary connections to be installed and removed, working around owner's operation personnel, additional material expedition and freight costs, as well as unknown work calendar and the consequential overtime costs. It is reasonable then, to move from 30% suggested by RSMeans, to 50% additional, to cover factors likely present given this situation.

Generally, our method cost presentation is to determine a single project cost and advise the likely range of accuracy for the level of definition. In this case, it is best to base the likely range of accuracy on a two project costs, the low as given in the attached reports, and the high with the 50% additional for project factors. Class V estimates can be minus 50% to plus 100% of the single project cost. In this case, we will assume the accuracy to be minus 50% of the cost given in the attached reports, and plus 100% of the reported cost with the 50% project factor. This results in a much wider range, and the uncertainty associated with it should help inform the decision maker regarding expected costs.

The markups included in the reported cost are as follows: Subcontractor and Prime Contractor general requirements, overhead and profit (total), 44%; Bonds and Insurance, 2%, Estimating Contingency, 15%.

Table 1: Estimated Project Costs (Class V Range)

Project	-50% accuracy limit	As reported cost	Reported cost with 50% additional	+100% accuracy limit
HEADWORKS	$2.2M	**$4.4M**	**$6.6M**	$13.2M
MCCs- electrical	$3.2M	**$6.3M**	**$9.5M**	$19.0M
EFFLUENT PP	$2.2M	**$4.4M**	**$6.6M**	$13.2M

In order to standardize a value by which to compare alternatives, it is advisable and an industry standard for municipalities to use the 80th percentile of the range of costs. For this project, the following values represent the 80th percentile:

HEADWORKS: $11.0M

MCCs – electrical $15.8M

EFFLUENT PP $11.0M

Attachments

The attached reports are organized by Facility and Work Activity, which generally represents a portion or component of the facility or process.

- Detail Reports, 16pp
- AACE Classification System, 3pp

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
03 TI WRP 01 HEADWORKS								
A-1 001 Platforms on A-1			17,686	44,216		1,769	/LS	63,671
A-3-A Metals Detail A on A-3		150.1	19,198	37,778		301	/LS	57,277
A-3-B Door Detail B on A-3		3.0	324	2,679			/LS	3,003
A-3-C Door Detail C on A-3		13.3	1,861	3,316			/LS	5,177
A-4-D Stair and Railing Detail D on A-4		63.3	8,915	38,395		378	/LS	47,688
A-5 001 Additional Doors on A-5		2.0	216	1,786			/LS	2,002
C-2 001 Pullboxes on C-2		5.9	691	1,380			/EA	2,071
D-E-3 001 Hazardous Area		993.5	114,743	191,322			/LS	306,066
E-13 001 Conduit/Cable Sched (E13/E14)			230,100	314,818			/LS	544,917
E-2 001 MCC A - MCC B		580.1	67,043	154,725			/LS	221,768
E-3 001 Electrical Room		51.6	5,993	15,166			/LS	21,159
E-6 001 Facility Electrical			44,216	70,746			/LS	114,961
E-7 001 Panels and loads		96.8	11,176	25,937			/LS	37,113
FS-1 001 Slide Gates		560.0	57,323	280,506			/EA	337,829
FS-1 002 Bar Screens		72.0	7,370	21,224			/EA	28,594
FS-1 003 Wash Press		52.0	5,323	78,432			/EA	83,755
FS-1 004 Grit Classifiers		64.0	6,551	58,040			/EA	64,591
FS-1 005 Grit Pumps		48.0	4,913	15,686			/EA	20,600
HV-1 001 H2S Filter on HV-1			177	2,299			/EA	2,476
HV-1 002 Roof Fan on HV-1		4.0	463	2,653			/EA	3,116
HV-1 003 Split unit on HV-1		16.0	1,957	2,653			/EA	4,610
I-4 001 Life Safety Systems		160.0	18,427	70,746				89,172
PI-1 001 Instruments on PI-1		28.5	3,282	24,761			/LS	28,043
PI-2 001 Instruments on PI-2		1.0	115	1,061			/LS	1,176
PI-3 001 Instruments on PI-3		24.0	2,764	26,530			/LS	29,294
PI-4 001 Instruments on PI-4		24.0	2,764	26,530			/LS	29,294
PI-5 001 Instruments on PI-5		28.0	3,225	80,650			/LS	83,875
PI-6 001 Instruments on PI-6		33.0	3,801	18,760			/LS	22,561
PI-7 001 Instruments on PI-7		12.0	1,382	3,537			/LS	4,919
PI-8 001 Instruments on PI-8		3.0	345	53,059			/LS	53,405
RFW090 GROUNDING		40.0	4,665	7,075			/LS	11,740
RFW170 OTHER ELECTRICAL - COMM-LS-SEC		240.0	27,996	14,149	21,224		/LS	63,369
RFW200 PLC-HMI, PROG, START, CX		200.0	23,034	176,864	61,902		/LS	261,800
RFW900 MISC FACILITY		1,066.7	112,367	35,373	333,907	4,422	/LS	486,069
S-1 001 Expansion joint resealing on S-1		4.7	492	139			/LS	631
S-2 001 Aluminum Checkered Plate on S-2		40.0	5,636	14,697		566	/LS	20,900
S-2 002 Aluminum Plank on S-2		114.8	16,183	153,792		686	/LS	170,661
S-4 001 Stair and Railing on S-4		36.9	5,193	22,665		220	/LS	28,078
03 TI WRP 01 HEADWORKS	**1.00 LS**	**4,832.2**	**837,909**	**2,094,143**	**417,033**	**8,340**	**3,357,426.57 /LS**	**3,357,427**

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
04 TI WRP 04 EFFLUENT PUMP PLANT								
A2/A3 Doors		39.1	5,138	16,271			/LS	21,409
A4 Window		2.6	357	1,698			/LS	2,055
E-1 401 E-1 Site Electrical			8,843	13,265			/LS	22,108
E-13 001 Conduit/Cable Sched (E13/E14)			114,431	157,409			/LS	271,840
E-2 401 E-2 Panels, Ltg		12.0	27,929	57,923			/LS	85,852
E-3 001 Electrical Room		15.0	1,728				/LS	1,728
E-3 401 MCC distribution		1,020.5	117,926	1,926,582		18,012	/LS	2,062,520
PI-1 001 Instruments on PI-1		200.0	23,034	176,864			/LS	199,898
RFW-401 Metals		74.5	28,189	89,254		2,214	/LS	119,657
RFW-403 Allowances for undefined electrical		153.6	35,373	53,059			/LS	88,432
RFW090 GROUNDING		40.0	4,665	7,075			/LS	11,740
RFW170 OTHER ELECTRICAL - COMM-LS-SEC		240.0	27,996	26,530	21,224		/LS	75,749
RFW200 PLC-HMI, PROG, START, CX		200.0	23,034	176,864	61,902		/LS	261,800
RFW405 Pumps		661.4	73,773	611,686			/LS	685,459
RFW503 Filters		80.0	9,213	70,746			/LS	79,959
RFW900 MISC FACILITY		794.7	83,776	52,891	233,766	4,422	/LS	374,854
04 TI WRP 04 EFFLUENT PUMP PLANT	**1.00 LS**	**3,533.4**	**585,405**	**3,438,116**	**316,892**	**24,647**	**4,365,059.19 /LS**	**4,365,059**

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
05 TI WRP MCCs - ELECTRICAL EQUIPMENT								
RFW170 OTHER ELECTRICAL - COMM-LS-SEC		842.9	98,299	176,864	21,224		/LS	296,386
RFW501 Biosolids		1,456.8	168,438	635,168			/LS	803,605
RFW502 Digesters		494.9	57,236	218,343			/LS	275,578
RFW503 Filters		3,132.7	363,243	2,371,324	8,489	15,924	/LS	2,758,980
RFW504 Aeration Tanks		479.0	55,255	130,227			/LS	185,482
RFW505 Compressor		481.6	55,592	146,593			/LS	202,185
RFW506 Final Tanks		111.7	12,890	27,617			/LS	40,507
RFW507 Primary Tanks		94.7	10,952	24,938			/LS	35,889
RFW508 Chlorination		779.6	89,989	354,877		1,178	/LS	446,045
RFW509 Sludge Treat		279.2	32,242	92,101			/LS	124,343
RFW510 Administration		884.5	102,022	227,251			/LS	329,273
RFW900 MISC FACILITY		1,200.0	127,342	35,373	326,381	4,422	/LS	493,517
05 TI WRP MCCs - ELECTRICAL EQUIPMENT	**1.00 LS**	**10,237.4**	**1,173,499**	**4,440,676**	**356,094**	**21,523**	**5,991,791.53 /LS**	**5,991,792**

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
03 TI WRP 01 HEADWORKS								
A-1 001 Platforms on A-1								
Allowance for platforms and metals not shown on details/missing plans (A-5)	1.00 ls		17,686	44,216	-	1,769	63,670.98 /ls	63,671
A-1 001 Platforms on A-1			**17,686**	**44,216**		**1,769**	**/LS**	**63,671**
A-3-A Metals Detail A on A-3								
Stair, shop fabricated, steel, 3'-6" W, incl pipe railing, stringers, grating treads w/ safety nosing, per riser	29.00 risr	26.5	3,736	16,926	-	158	717.94 /risr	20,820
Stair, landing, steel pan, conventional	20.00 sf	4.0	564	2,335	-	24	146.11 /sf	2,922
Ladder, steel, 20" wide, bolted to concrete, with cage	22.00 vlf	14.1	1,984	2,490	-	84	207.20 /vlf	4,558
Railing, pipe, steel, galvanized, 3 rails, 3'-6" high, posts @ 5' O.C., 1-1/2" dia, shop fabricated	25.00 lf	5.8	823	2,675	-	35	141.31 /lf	3,533
Aluminum roof panels, corrugated or ribbed, painted, .0155" thick	650.00 sf	17.3	1,808	1,655	-	-	5.33 /sf	3,463
Mansard panels, colored aluminum roofing, with battens, stock units, straight surfaces, .032" thick	960.00 sf	66.8	8,173	6,435	-	-	15.22 /sf	14,608
Fire door, st, fl, "A" lbl, 3 hr, full pnl, 18 Ga., 3'-0" x 7'-0"	2.00 ea	2.0	216	1,786	-	-	1,001.02 /ea	2,002
Doors, rolling service, steel, manual, 20 gauge, 12' x 12' high, incl. hardware	1.00 ea	13.3	1,861	3,316	-	-	5,176.78 /ea	5,177
Windows, steel sash, custom units, picture window, excl. glazing and trim	3.00 sf	0.2	34	159	-	-	64.22 /sf	193
A-3-A Metals Detail A on A-3		**150.1**	**19,198**	**37,778**		**301**	**/LS**	**57,277**
A-3-B Door Detail B on A-3								
Fire door, st, fl, "A" lbl, 3 hr, full pnl, 18 Ga., 3'-0" x 7'-0"	3.00 ea	3.0	324	2,679	-	-	1,001.01 /ea	3,003
A-3-B Door Detail B on A-3		**3.0**	**324**	**2,679**			**/LS**	**3,003**
A-3-C Door Detail C on A-3								
Doors, rolling service, steel, manual, 20 gauge, 12' x 12' high, incl. hardware	1.00 ea	13.3	1,861	3,316	-	-	5,176.81 /ea	5,177
A-3-C Door Detail C on A-3		**13.3**	**1,861**	**3,316**			**/LS**	**5,177**
A-4-D Stair and Railing Detail D on A-4								
Stair, shop fabricated, steel, 3'-6" W, incl pipe railing, stringers, grating treads w/ safety nosing, per riser	51.00 risr	46.6	6,570	29,766	-	278	717.94 /risr	36,615
Stair, landing, steel pan, conventional	40.00 sf	8.0	1,127	4,669	-	48	146.11 /sf	5,844
Railing, pipe, steel, galvanized, 3 rails, 3'-6" high, posts @ 5' O.C., 1-1/2" dia, shop fabricated	37.00 lf	8.6	1,218	3,959	-	52	141.31 /lf	5,228
A-4-D Stair and Railing Detail D on A-4		**63.3**	**8,915**	**38,395**		**378**	**/LS**	**47,688**
A-5 001 Additional Doors on A-5								
Fire door, st, fl, "A" lbl, 3 hr, full pnl, 18 Ga., 3'-0" x 7'-0"	2.00 ea	2.0	216	1,786	-	-	1,001.02 /ea	2,002
A-5 001 Additional Doors on A-5		**2.0**	**216**	**1,786**			**/LS**	**2,002**
C-2 001 Pullboxes on C-2								
Wiring boxes, dust tight & drip tight, 24" L x 36" W x 8" D, NEMA 12, J.I.C.	2.00 ea	5.9	691	1,380	-	-	1,035.33 /ea	2,071
C-2 001 Pullboxes on C-2		**5.9**	**691**	**1,380**			**/EA**	**2,071**
D-E-3 001 Hazardous Area								
PVC RGS XP circuit	64.00 E	768.0	88,449	113,193	-	-	3,150.66 /E	201,642
Nema 7 enclosed motor/switch/control	31.00 ea	225.5	26,294	78,130	-	-	3,368.50 /ea	104,423
D-E-3 001 Hazardous Area		**993.5**	**114,743**	**191,322**			**/LS**	**306,066**
E-13 001 Conduit/Cable Sched (E13/E14)								
3/4" P/C sched	72.00 ea		101,874	127,342	-	-	3,183.55 /ea	229,216
1" P/C sched	28.00 ea		49,522	74,283	-	-	4,421.60 /ea	123,805
1.5" P/C sched	11.00 ea		29,183	38,910	-	-	6,190.24 /ea	68,093
2" P/C sched	5.00 ea		17,686	26,530	-	-	8,843.19 /ea	44,216
2.5" P/C sched	3.00 ea		13,265	21,224	-	-	11,496.15 /ea	34,488
3" P/C sched	3.00 ea		18,571	26,530	-	-	15,033.43 /ea	45,100

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
E-13 001 Conduit/Cable Sched (E13/E14)			**230,100**	**314,818**			**/LS**	**544,917**
E-2 001 MCC A - MCC B								
PVC RGS XP load circuit	17.00 E	340.0	39,157	45,100	-	-	4,956.33 /E	84,258
PVC RGS MCC feed	2.00 E	80.0	9,213	17,686	-	-	13,449.94 /E	26,900
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	7.00 ea	21.5	2,512	23,523	-	-	3,719.26 /ea	26,035
Motor starter, size 2, FVNR, type B, circuit breaker, NEMA 12	2.00 ea	8.4	982	7,605	-	-	4,293.63 /ea	8,587
Circuit breaker, light contactor, type B, 30 Amp, NEMA 12	1.00 ea	3.1	359	3,582	-	-	3,940.36 /ea	3,940
Circuit breaker, light contactor, type B, 60 amp, NEMA 12	1.00 ea	4.2	491	3,847	-	-	4,337.85 /ea	4,338
Circuit breaker, light contactor, type B, 100 amp, NEMA 12	3.00 ea	25.3	2,946	17,642	-	-	6,862.83 /ea	20,588
Motor control centers, incoming line, circuit breaker, alum, 225 amp, NEMA 12	2.00 ea	29.1	3,393	7,782	-	-	5,587.38 /ea	11,175
Motor control centers, incoming line, for 65000 amp bus bracing, add	2.00 ea		-	626	-	-	313.05 /ea	626
Motor control centers, incoming line, for NEMA 12 enclosure, add	2.00 ea		-	541	-	-	270.61 /ea	541
Motor control centers, incoming line, for 1/4" x 1" ground bus, add	2.00 ea	1.0	117	348	-	-	232.52 /ea	465
Motor control centers, main rating basic section, NEMA 1, for 65000 amp bus bracing, add	3.00 ea		-	1,698	-	-	565.96 /ea	1,698
Motor control centers, main rating basic section, NEMA 1, for NEMA 12 enclosure, add	3.00 ea		-	812	-	-	270.60 /ea	812
Motor control centers, main rating basic section, NEMA 1, for 1/4" x 1" ground bus, add	3.00 ea	1.5	175	523	-	-	232.52 /ea	698
Motor control centers, pilot light, standard, & push button	9.00 ea	6.0	700	3,247	-	-	438.55 /ea	3,947
Motor control center, structures, 22,000 rms, takes any combination of starters, 600 amp, up to 72" high	6.00 ea	60.0	6,998	20,162	-	-	4,526.67 /ea	27,160
E-2 001 MCC A - MCC B		**580.1**	**67,043**	**154,725**			**/LS**	**221,768**
E-3 001 Electrical Room								
PLC Cabinet	1.00 ea	15.0	1,728		-	-	1,727.53 /ea	1,728
Variable frequency drives, custom-engineered, 460 volt, 5 HP motor size	2.00 ea	28.6	3,332	9,551	-	-	6,441.41 /ea	12,883
Non-automatic transfer switch, enclosed, manual operated, 3 pole, 480 volt, 200 amp	1.00 ea	8.0	933	5,615	-	-	6,548.44 /ea	6,548
E-3 001 Electrical Room		**51.6**	**5,993**	**15,166**			**/LS**	**21,159**
E-6 001 Facility Electrical								
Receptacle allowance	1.00 LS		17,686	17,686	-	-	35,372.76 /LS	35,373
Lighting allowance	1.00 LS		26,530	53,059	-	-	79,588.72 /LS	79,589
E-6 001 Facility Electrical			**44,216**	**70,746**			**/LS**	**114,961**
E-7 001 Panels and loads								
Panel loads	1.00 E	76.8	8,843	17,686	-	-	26,529.61 /E	26,530
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 100 amp	1.00 ea	4.0	466	1,441	-	-	1,907.93 /ea	1,908
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 225 amp	1.00 ea	8.0	933	2,918	-	-	3,851.26 /ea	3,851
Panelboards, 3 pole 4 wire, main circuit breaker, 277/480 V, 100 amp	2.00 ea	8.0	933	3,891	-	-	2,412.01 /ea	4,824
E-7 001 Panels and loads		**96.8**	**11,176**	**25,937**			**/LS**	**37,113**
FS-1 001 Slide Gates								
84" Wide Rectangular Sluice Gate Wall Thimble - FURNISH	4.00 ea		-	50,583	-	-	12,645.76 /ea	50,583
84" Wide Rectangular Sluice Gate Wall Thimble - Installation	4.00 ea	336.0	34,394	-	-	-	8,598.39 /ea	34,394
84" Wide Rectangular Sluice Gate - FURNISH	4.00 ea		-	229,923	-	-	57,480.74 /ea	229,923
84" Wide Rectangular Sluice Gate - Installation	4.00 ea	224.0	22,929	-	-	-	5,732.26 /ea	22,929
FS-1 001 Slide Gates		**560.0**	**57,323**	**280,506**			**/EA**	**337,829**
FS-1 002 Bar Screens								
Stop Log Frame, 8' Wide Channel - FURNISH	2.00 ea		-	21,224	-	-	10,611.83 /ea	21,224
Stop Log Frame, 8' Wide Channel - Installation	2.00 ea	72.0	7,370	-	-	-	3,685.02 /ea	7,370
FS-1 002 Bar Screens		**72.0**	**7,370**	**21,224**			**/EA**	**28,594**
FS-1 003 Wash Press								
FURNISH Dewatering Screw Conveyor, 8" - 12" Dia.	20.00 lf		-	31,373	-	-	1,568.64 /lf	31,373
FURNISH Hydraulic Compactor	2.00 ea		-	47,059	-	-	23,529.58 /ea	47,059
Install Dewatering Screw Conveyor, 8" - 12" Dia.	20.00 lf	20.0	2,047	-	-	-	102.36 /lf	2,047
Install Hydraulic Compactor	2.00 ea	32.0	3,276	-	-	-	1,637.79 /ea	3,276

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
FS-1 003 Wash Press		**52.0**	**5,323**	**78,432**			**/EA**	**83,755**
FS-1 004 Grit Classifiers								
FURNISH Grit Classifier, 12" - 14" Inlet Dia.	2.00 ea		-	58,040	-	-	29,019.81 /ea	58,040
Install Grit Classifier, 12" - 14" Inlet Dia.	2.00 ea	64.0	6,551	-	-	-	3,275.57 /ea	6,551
FS-1 004 Grit Classifiers		**64.0**	**6,551**	**58,040**			**/EA**	**64,591**
FS-1 005 Grit Pumps								
3 hp PD Blower w/ all accessories for Grit Airlift Pump	2.00 ea	48.0	4,913	15,686	-	-	10,299.88 /ea	20,600
FS-1 005 Grit Pumps		**48.0**	**4,913**	**15,686**			**/EA**	**20,600**
HV-1 001 H2S Filter on HV-1								
Allerair 5000 DX	1.00 ea		177	2,299	-	-	2,476.09 /ea	2,476
HV-1 001 H2S Filter on HV-1			**177**	**2,299**			**/EA**	**2,476**
HV-1 002 Roof Fan on HV-1								
Fans,roof exhauster,centrifugal,aluminum housing,bird screen,back draft damper,v belt drive,1/4"sp, 2750 cfm,12"galvanized curb,21"sq damper	1.00 ea	4.0	463	2,653	-	-	3,116.40 /ea	3,116
HV-1 002 Roof Fan on HV-1		**4.0**	**463**	**2,653**			**/EA**	**3,116**
HV-1 003 Split unit on HV-1								
Split ductless system, cooling / heating, wall mount, 1 ton cooling	1.00 ea	16.0	1,957	2,653	-	-	4,609.88 /ea	4,610
HV-1 003 Split unit on HV-1		**16.0**	**1,957**	**2,653**			**/EA**	**4,610**
I-4 001 Life Safety Systems								
Gas detection system	1.00 E	160.0	18,427	70,746	-	-	89,172.48 /E	89,172
I-4 001 Life Safety Systems		**160.0**	**18,427**	**70,746**				**89,172**
PI-1 001 Instruments on PI-1								
LCP	2.00 ea	16.0	1,843	17,686	-	-	9,764.54 /ea	19,529
LE - Level Element / Sonic	2.00 ea	0.5	58	3,537	-	-	1,797.43 /ea	3,595
LS - Level Switch	4.00 ea	12.0	1,382	3,537	-	-	1,229.82 /ea	4,919
PI-1 001 Instruments on PI-1		**28.5**	**3,282**	**24,761**			**/LS**	**28,043**
PI-2 001 Instruments on PI-2								
PI - Pressure Indicator	2.00 ea	1.0	115	1,061	-	-	588.18 /ea	1,176
PI-2 001 Instruments on PI-2		**1.0**	**115**	**1,061**			**/LS**	**1,176**
PI-3 001 Instruments on PI-3								
LCP	3.00 ea	24.0	2,764	26,530	-	-	9,764.54 /ea	29,294
PI-3 001 Instruments on PI-3		**24.0**	**2,764**	**26,530**			**/LS**	**29,294**
PI-4 001 Instruments on PI-4								
LCP	3.00 ea	24.0	2,764	26,530	-	-	9,764.54 /ea	29,294
PI-4 001 Instruments on PI-4		**24.0**	**2,764**	**26,530**			**/LS**	**29,294**
PI-5 001 Instruments on PI-5								
LCP	3.00 ea	24.0	2,764	26,530	-	-	9,764.54 /ea	29,294
FT / FIT - Flow Transmitter	2.00 ea	3.0	346	53,059	-	-	26,702.33 /ea	53,405
PI - Pressure Indicator	2.00 ea	1.0	115	1,061	-	-	588.18 /ea	1,176
PI-5 001 Instruments on PI-5		**28.0**	**3,225**	**80,650**			**/LS**	**83,875**
PI-6 001 Instruments on PI-6								
LCP	2.00 ea	16.0	1,843	17,686	-	-	9,764.54 /ea	19,529
PI - Pressure Indicator	2.00 ea	1.0	115	1,061	-	-	588.18 /ea	1,176
30' 1/2" Galv Pipe Air Drop	2.00 ea	16.0	1,843	12	-	-	927.54 /ea	1,855
PI-6 001 Instruments on PI-6		**33.0**	**3,801**	**18,760**			**/LS**	**22,561**
PI-7 001 Instruments on PI-7								
LS - Level Switch	4.00 ea	12.0	1,382	3,537	-	-	1,229.82 /ea	4,919

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
PI-7 001 Instruments on PI-7		**12.0**	**1,382**	**3,537**			**/LS**	**4,919**
PI-8 001 Instruments on PI-8								
FT / FIT - Flow Transmitter	2.00 ea	3.0	346	53,059	-	-	26,702.33 /ea	53,405
PI-8 001 Instruments on PI-8		**3.0**	**346**	**53,059**			**/LS**	**53,405**
RFW090 GROUNDING								
Grounding repair or replacement	1.00 LS	40.0	4,665	7,075	-	-	11,739.59 /LS	11,740
RFW090 GROUNDING		**40.0**	**4,665**	**7,075**			**/LS**	**11,740**
RFW170 OTHER ELECTRICAL - COMM-LS-SEC								
Security allowance	1.00 ls	120.0	14,001	14,149	3,537	-	31,687.07 /ls	31,687
Life Safety allowance	1.00 ls	80.0	9,330	-	8,843	-	18,173.28 /ls	18,173
Comm allowance	1.00 ls	40.0	4,665	-	8,843	-	13,508.20 /ls	13,508
RFW170 OTHER ELECTRICAL - COMM-LS-SEC		**240.0**	**27,996**	**14,149**	**21,224**		**/LS**	**63,369**
RFW200 PLC-HMI, PROG, START, CX								
Programming, per hour, subcontract, all expenses	200.00 hr		-	-	61,902	-	309.51 /hr	61,902
DCS, Operator Workstation	1.00 ea	40.0	4,607	35,373	-	-	39,979.49 /ea	39,979
PLC Cabinet	1.00 ea	80.0	9,213	70,746	-	-	79,959.01 /ea	79,959
ICP Cabinet	1.00 ea	80.0	9,213	70,746	-	-	79,959.00 /ea	79,959
RFW200 PLC-HMI, PROG, START, CX		**200.0**	**23,034**	**176,864**	**61,902**		**/LS**	**261,800**
RFW900 MISC FACILITY								
Temp power	1.00 ls		-	-	78,432	-	78,431.92 /ls	78,432
Cleaning up	1.00 ls			-	31,373	-	31,372.76 /ls	31,373
Demo based on percentage of install MH, includes disposal	1.00 LS	1,000.0	106,118	35,373	-	4,422	145,912.66 /LS	145,913
Hazardous W cln/pu/dspl, liq pickup, vac trk,min charge,4hr,2compt,500	600.00 hr		-	-	180,401	-	300.67 /hr	180,401
Hazardous W cln/pu/dspl, liq pickup, vac trk, transp in 6900gal bulk t	120.00 mile		-	-	1,486	-	12.38 /mile	1,486
Clean up site detritus	1.00 acre	66.7	6,249	-	-		6,249.21 /acre	6,249
Misc. Mechanical allowance	1.00 ls		-	-	8,843	-	8,843.20 /ls	8,843
Misc Electrical allowance	1.00 ls		-	-	17,686	-	17,686.38 /ls	17,686
I&C misc allowance	1.00 ls		-	-	15,686	-	15,686.38 /ls	15,686
RFW900 MISC FACILITY		**1,066.7**	**112,368**	**35,373**	**333,907**	**4,422**	**/LS**	**486,069**
S-1 001 Expansion joint resealing on S-1								
Caulking and sealants, backer rod, polyethylene, 1/2" dia	1.00 clf	1.7	183	6	-	-	189.36 /clf	189
Caulking and sealants, polyurethane, bulk, in place, 1 or 2 component, 68 LF per gallon, 3/4" x 3/8"	100.00 lf	2.9	309	133	-	-	4.42 /lf	442
S-1 001 Expansion joint resealing on S-1		**4.7**	**492**	**139**			**/LS**	**631**
S-2 001 Aluminum Checkered Plate on S-2								
Alum checker plate	500.00 sf	40.0	5,636	14,697	-	566	41.80 /sf	20,900
S-2 001 Aluminum Checkered Plate on S-2		**40.0**	**5,636**	**14,697**		**566**	**/LS**	**20,900**
S-2 002 Aluminum Plank on S-2								
Floor grating plank, aluminum, 14 gauge x 9-1/2" wide, 2" rib, field fabricated from planks	3,410.00 lf	114.8	16,183	153,792	-	686	50.05 /lf	170,661
S-2 002 Aluminum Plank on S-2		**114.8**	**16,183**	**153,792**		**686**	**/LS**	**170,661**
S-4 001 Stair and Railing on S-4								
Stair, shop fabricated, steel, 3'-6" W, incl pipe railing, stringers, grating treads w/ safety nosing, per riser	29.00 risr	26.5	3,736	16,926	-	158	717.94 /risr	20,820
Stair, landing, steel pan, conventional	40.00 sf	8.0	1,127	4,669	-	48	146.11 /sf	5,844
Railing, pipe, steel, galvanized, 3 rails, 3'-6" high, posts @ 5' O.C., 1-1/2" dia, shop fabricated	10.00 lf	2.3	329	1,070	-	14	141.31 /lf	1,413
S-4 001 Stair and Railing on S-4		**36.9**	**5,193**	**22,665**		**220**	**/LS**	**28,078**

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
03 TI WRP 01 HEADWORKS	**1.00 LS**	**4,832.2**	**837,909**	**2,094,143**	**417,033**	**8,340**	**3,357,426.58 /LS**	**3,357,427**
04 TI WRP 04 EFFLUENT PUMP PLANT								
A2/A3 Doors								
Fire door, st, fl, "A" lbl, 3 hr, full pnl, 18 Ga., 3'-0" x 7'-0"	10.00 ea	10.0	1,079	8,932	-	-	1,001.01 /ea	10,010
Doors, rolling service, steel, manual, fire, class A, 20 gauge, 10' x 10' high, incl. hardware	2.00 ea	29.1	4,059	7,340	-	-	5,699.65 /ea	11,399
A2/A3 Doors		**39.1**	**5,138**	**16,271**			**/LS**	**21,409**
A4 Window								
Windows, steel sash, custom units, picture window, excl. glazing and trim	32.00 sf	2.6	357	1,698	-	-	64.22 /sf	2,055
A4 Window		**2.6**	**357**	**1,698**			**/LS**	**2,055**
E-1 401 E-1 Site Electrical								
Site Lighting Allowance	1.00 LS		8,843	13,265	-	-	22,107.98 /LS	22,108
E-1 401 E-1 Site Electrical			**8,843**	**13,265**			**/LS**	**22,108**
E-13 001 Conduit/Cable Sched (E13/E14)								
3/4" P/C sched	34.00 ea		48,107	60,134	-	-	3,183.55 /ea	108,241
1" P/C sched	12.00 ea		21,224	31,835	-	-	4,421.60 /ea	53,059
1.5" P/C sched	2.00 ea		5,306	7,075	-	-	6,190.24 /ea	12,380
2" P/C sched	3.00 ea		10,612	15,918	-	-	8,843.19 /ea	26,530
2.5" P/C sched	1.00 ea		4,422	7,075	-	-	11,496.14 /ea	11,496
3" P/C sched	4.00 ea		24,761	35,373	-	-	15,033.43 /ea	60,134
E-13 001 Conduit/Cable Sched (E13/E14)			**114,431**	**157,409**			**/LS**	**271,840**
E-2 401 E-2 Panels, Ltg								
Lighting allowance	1.00 LS		26,530	53,059	-	-	79,588.72 /LS	79,589
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 225 amp	1.00 ea	8.0	933	2,918	-	-	3,851.27 /ea	3,851
Panelboards, 3 pole 4 wire, main circuit breaker, 277/480 V, 100 amp	1.00 ea	4.0	467	1,945	-	-	2,411.99 /ea	2,412
E-2 401 E-2 Panels, Ltg		**12.0**	**27,929**	**57,923**			**/LS**	**85,852**
E-3 001 Electrical Room								
PLC Cabinet	1.00 ea	15.0	1,728	0	-	-	1,727.54 /ea	1,728
E-3 001 Electrical Room		**15.0**	**1,728**				**/LS**	**1,728**
E-3 401 MCC distribution								
Load interrupter switch, 2 position, 400 kVA & above, 13.8 kV, 600 amp w/CLF fuses, NEMA 1	1.00 ea	55.6	6,463	47,223	-	505	54,190.53 /ea	54,191
Transformers, 13,800 volts to 480/277 volts, 1050 kVA	1.00 ea	76.9	8,948	114,961	-	699	124,609.28 /ea	124,609
Circuit breaker, 3 pole, 125 to 600 amp, type MA	1.00 ea	5.0	583	7,207	-	-	7,790.34 /ea	7,790
Circuit breaker, 3 pole, 700 & 800 amp, type MA	2.00 ea	12.3	1,435	18,748	-	-	10,091.48 /ea	20,183
Switchboards, main circuit breaker, 3 pole, 4 wire, 277/480 volt, 2000 amp	1.00 ea	20.0	2,333	25,468	-	-	27,800.92 /ea	27,801
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	17.00 ea	52.3	6,100	57,127	-	-	3,719.26 /ea	63,227
Motor starter, size 2, FVNR, type B, circuit breaker, NEMA 12	1.00 ea	4.2	491	3,803	-	-	4,294.64 /ea	4,294
Motor starter, size 3, FVNR, type B, circuit breaker, NEMA 12	1.00 ea	8.4	982	5,925	-	-	6,907.04 /ea	6,907
Motor starter, size 4, FVNR, type B, circuit breaker, NEMA 12	3.00 ea	32.0	3,732	23,611	-	-	9,114.45 /ea	27,343
MCCPPH control cube and control	1.00 ea	16.0	1,866	44,216	-	-	46,081.96 /ea	46,082
Generator Switchgear	1.00 ea	100.0	11,663	265,296	-	-	276,958.33 /ea	276,958
Circuit breaker, light contactor, type B, 100 amp, NEMA 12	7.00 ea	58.9	6,875	41,165	-	-	6,862.83 /ea	48,040
Motor control centers, incoming line, circuit breaker, copper, 800 amp, NEMA 1	2.00 ea	35.6	4,147	27,944	-	-	16,045.59 /ea	32,091
Motor control centers, incoming line, for 65000 amp bus bracing, add	2.00 ea		-	626	-	-	313.05 /ea	626
Motor control centers, incoming line, for NEMA 12 enclosure, add	2.00 ea		-	541	-	-	270.61 /ea	541
Motor control centers, incoming line, for 1/4" x 1" ground bus, add	2.00 ea	1.0	117	348	-	-	232.52 /ea	465
Motor control centers, main rating basic section, NEMA 1, for 65000 amp bus bracing, add	5.00 ea		-	2,830	-	-	565.97 /ea	2,830
Motor control centers, main rating basic section, NEMA 1, for NEMA 12 enclosure, add	5.00 ea		-	1,353	-	-	270.60 /ea	1,353
Motor control centers, main rating basic section, NEMA 1, for 1/4" x 1" ground bus, add	5.00 ea	2.5	292	871	-	-	232.53 /ea	1,163

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
E-3 401 MCC distribution								
Motor control centers, pilot light, standard, & push button	22.00 ea	14.7	1,711	7,938	-	-	438.55 /ea	9,648
Motor control center, structures, 22,000 rms, takes any combination of starters, 600 amp, up to 72" high	5.00 ea	50.0	5,831	16,802	-	-	4,526.67 /ea	22,633
Variable frequency drives, custom-engineered, 460 volt, 125 HP motor size	1.00 ea	57.1	6,647	27,591	-	520	34,757.72 /ea	34,758
Variable frequency drives, custom-engineered, 460 volt, 650 HP motor size	2.00 ea	137.9	16,045	442,160	-	1,254	229,729.55 /ea	459,459
Generator set,diesel,3 phase 4 wire,277/480 v,2000 kw,incl battery,charger,muffler,automatic transfer switch&day tank,excl conduit,wiring,& concrete	1.00 ea	280.0	31,666	742,828	-	15,033	789,527.25 /ea	789,527
E-3 401 MCC distribution		**1,020.5**	**117,926**	**1,926,582**		**18,012**	**/LS**	**2,062,520**
PI-1 001 Instruments on PI-1								
Instruments	50.00 ea	200.0	23,034	176,864	-	-	3,997.95 /ea	199,898
PI-1 001 Instruments on PI-1		**200.0**	**23,034**	**176,864**			**/LS**	**199,898**
RFW-401 Metals								
Stair, shop fabricated, steel, 3'-6" W, incl pipe railing, stringers, grating treads w/ safety nosing, per riser	60.00 risr	54.9	7,730	35,019	-	327	717.94 /risr	43,076
Stair, landing, steel pan, conventional	40.00 sf	8.0	1,127	4,669	-	48	146.11 /sf	5,844
Railing, pipe, steel, galvanized, 3 rails, 3'-6" high, posts @ 5' O.C., 1-1/2" dia, shop fabricated	50.00 lf	11.7	1,646	5,350	-	70	141.31 /lf	7,066
Allowance for platforms and metals	1.00 ls		17,686	44,216	-	1,769	63,670.99 /ls	63,671
RFW-401 Metals		**74.5**	**28,189**	**89,254**		**2,214**	**/LS**	**119,657**
RFW-403 Allowances for undefined electrical								
Receptacle allowance	1.00 LS		17,686	17,686	-	-	35,372.76 /LS	35,373
Panel loads	2.00 E	153.6	17,686	35,373	-	-	26,529.59 /E	53,059
RFW-403 Allowances for undefined electrical		**153.6**	**35,373**	**53,059**			**/LS**	**88,432**
RFW090 GROUNDING								
Grounding repair or replacement	1.00 LS	40.0	4,665	7,075	-	-	11,739.61 /LS	11,740
RFW090 GROUNDING		**40.0**	**4,665**	**7,075**			**/LS**	**11,740**
RFW170 OTHER ELECTRICAL - COMM-LS-SEC								
Security allowance	1.00 ls	120.0	14,001	26,530	3,537	-	44,067.53 /ls	44,068
Life Safety allowance	1.00 ls	80.0	9,330	-	8,843	-	18,173.25 /ls	18,173
Comm allowance	1.00 ls	40.0	4,665	-	8,843	-	13,508.23 /ls	13,508
RFW170 OTHER ELECTRICAL - COMM-LS-SEC		**240.0**	**27,996**	**26,530**	**21,224**		**/LS**	**75,749**
RFW200 PLC-HMI, PROG, START, CX								
Programming, per hour, subcontract, all expenses	200.00 hr		-	-	61,902	-	309.51 /hr	61,902
DCS, Operator Workstation	1.00 ea	40.0	4,607	35,373	-	-	39,979.50 /ea	39,980
PLC Cabinet	1.00 ea	80.0	9,213	70,746	-	-	79,959.00 /ea	79,959
ICP Cabinet	1.00 ea	80.0	9,213	70,746	-	-	79,959.02 /ea	79,959
RFW200 PLC-HMI, PROG, START, CX		**200.0**	**23,034**	**176,864**	**61,902**		**/LS**	**261,800**
RFW405 Pumps								
FURNISH Horizontal Split-Case Pump, 101 - 500 hp	1.00 EA		-	78,432	-	-	78,431.91 /EA	78,432
FURNISH Horizontal Split-Case Pump, >1000 hp	2.00 EA		-	313,728	-	-	156,863.82 /EA	313,728
Set pump assembly, 101 - 500 hp	1.00 ea	60.0	6,142	78	-	-	6,220.13 /ea	6,220
Set pump assembly, >1000 hp	2.00 ea	240.0	24,567	314	-	-	12,440.28 /ea	24,881
10 hp pump	2.00 ea	91.4	10,894	53,767	-	-	32,330.22 /ea	64,660
25 hp pump	1.00 ea	47.1	5,607	27,414	-	-	33,021.03 /ea	33,021
60 hp pump	2.00 ea	110.3	13,148	66,147	-	-	39,647.40 /ea	79,295
50 hp pump	1.00 ea	53.3	6,355	30,244	-	-	36,598.46 /ea	36,598
75 hp pump	1.00 ea	59.3	7,061	41,563	-	-	48,623.82 /ea	48,624
RFW405 Pumps		**661.4**	**73,773**	**611,686**			**/LS**	**685,459**
RFW503 Filters								

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
RFW503 Filters								
PLC Cabinet	1.00 ea	80.0	9,213	70,746	-	-	79,959.01 /ea	79,959
RFW503 Filters		**80.0**	**9,213**	**70,746**			**/LS**	**79,959**
RFW900 MISC FACILITY								
Temp power	1.00 ls		-	-	78,432	-	78,431.91 /ls	78,432
Cleaning up	1.00 ls		0	-	31,373	-	31,372.76 /ls	31,373
Demo based on percentage of install MH, includes disposal	1.00 LS	700.0	74,283	35,373	0	4,422	114,077.17 /LS	114,077
Hazardous W cln/pu/dspl, liq pickup, vac trk,min charge,4hr,2compt,500	100.00 hr		-	-	30,067	-	300.67 /hr	30,067
Hazardous W cln/pu/dspl, liq pickup, vac trk, transp in 6900gal bulk t	50.00 mile		-	-	619	-	12.38 /mile	619
Clean up site detritus	1.00 acre	66.7	6,249	-	-	0	6,249.21 /acre	6,249
Misc. Mechanical allowance	1.00 ls		-	-	35,373	-	35,372.78 /ls	35,373
Misc. Plumbing allowance	1.00 ls		-	-	8,843	-	8,843.19 /ls	8,843
Misc Electrical allowance	1.00 ls		-	-	17,686	-	17,686.38 /ls	17,686
I&C misc allowance	1.00 ls		-	-	31,373	-	31,372.77 /ls	31,373
Fans,roof exhauster,centrifugal,aluminum housing,bird screen,back draft damper,direct drive,1/4"sp, 815 cfm,12"galvanized curb,13"sq damper	2.00 ea	8.0	927	3,060	-	-	1,993.31 /ea	3,987
Fans,roof exhauster,centrifugal,aluminum housing,bird screen,back draft damper,v belt drive,1/4"sp, 8525 cfm,12"galvanized curb,28"sq damper	3.00 ea	20.0	2,317	14,459	-	-	5,591.94 /ea	16,776
RFW900 MISC FACILITY		**794.7**	**83,776**	**52,891**	**233,766**	**4,422**	**/LS**	**374,854**
04 TI WRP 04 EFFLUENT PUMP PLANT	**1.00 LS**	**3,533.4**	**585,405**	**3,438,116**	**316,892**	**24,647**	**4,365,059.20 /LS**	**4,365,059**

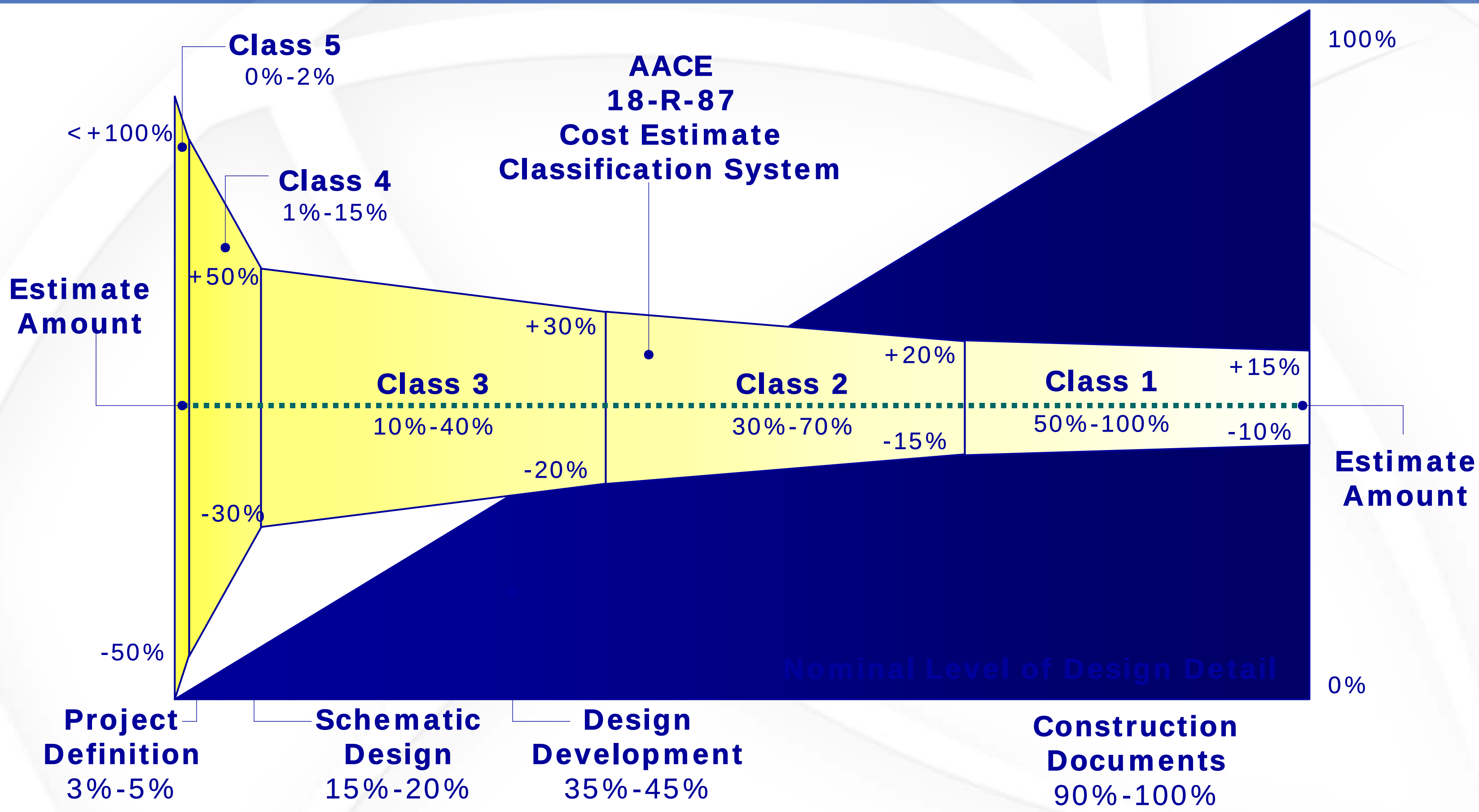
Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
05 TI WRP MCCs - ELECTRICAL EQUIPMENT								
RFW170 OTHER ELECTRICAL - COMM-LS-SEC								
Security allowance	1.00 ls	500.0	58,313	88,432	3,537	-	150,282.08 /ls	150,282
Life Safety allowance	1.00 ls	200.0	23,325	44,216	8,843	-	76,384.29 /ls	76,384
Comm allowance	1.00 ls	142.9	16,661	44,216	8,843	-	69,719.97 /ls	69,720
RFW170 OTHER ELECTRICAL - COMM-LS-SEC		**842.9**	**98,299**	**176,864**	**21,224**		**/LS**	**296,386**
RFW501 Biosolids								
Allowance for MCC feed and load recircuiting, based on MCC AMPS	1,200.00 AMP	300.0	34,551	63,671	-	-	81.85 /AMP	98,222
Allowance for MCC feed and load recircuiting, based on MCC AMPS	800.00 AMP	200.0	23,034	42,447	-	-	81.85 /AMP	65,481
Allowance for MCC feed and load recircuiting, based on MCC AMPS	1,200.00 AMP	300.0	34,551	63,671	-	-	81.85 /AMP	98,221
Allowance for MCC feed and load recircuiting, based on MCC AMPS	800.00 AMP	200.0	23,034	42,447	-	-	81.85 /AMP	65,481
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	81.00 ea	249.2	29,067	272,193	-	-	3,719.26 /ea	301,260
Circuit breaker, type A, 100 amp, NEMA 12	52.00 ea	106.7	12,440	90,130	-	-	1,972.50 /ea	102,570
Motor control centers, incoming line, main lug only, copper, 800 amp, NEMA 1	2.00 ea	21.3	2,488	11,142	-	-	6,815.22 /ea	13,630
Motor control centers, incoming line, main lug only, copper, 1200 amp, NEMA 1	2.00 ea	22.9	2,666	11,496	-	-	7,080.94 /ea	14,162
Motor control centers, incoming line, for copper bus, add	4.00 ea		-	842	-	-	210.47 /ea	842
Motor control centers, incoming line, for 65000 amp bus bracing, add	4.00 ea		-	1,252	-	-	313.05 /ea	1,252
Motor control centers, incoming line, for NEMA 12 enclosure, add	4.00 ea		-	1,082	-	-	270.60 /ea	1,082
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	4.00 ea	2.7	311	697	-	-	251.97 /ea	1,008
Motor control centers, pilot light, push to test, & select switch	81.00 ea	54.0	6,298	34,096	-	-	498.69 /ea	40,394
RFW501 Biosolids		**1,456.8**	**168,438**	**635,168**			**/LS**	**803,605**
RFW502 Digesters								
Allowance for MCC feed and load recircuiting, based on MCC AMPS	1,000.00 AMP	250.0	28,792	53,059	-	-	81.85 /AMP	81,851
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	37.5	4,319	7,959	-	-	54.57 /AMP	12,278
Allowance for Panel feed and load recircuiting, based on Panel AMPS	100.00 AMP	16.7	1,919	3,537	-	-	54.57 /AMP	5,457
Allowance for Panel feed and load recircuiting, based on Panel AMPS	100.00 AMP	16.7	1,919	3,537	-	-	54.57 /AMP	5,457
Allowance for Panel feed and load recircuiting, based on Panel AMPS	30.00 AMP	5.0	576	1,061	-	-	54.57 /AMP	1,637
Allowance for Panel feed and load recircuiting, based on Panel AMPS	30.00 AMP	5.0	576	1,061	-	-	54.57 /AMP	1,637
Panelboards, 3 pole 3 wire, main lugs, 480 V, 100 amp, no main breaker	1.00 ea	3.5	406	1,326	-	-	1,732.14 /ea	1,732
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 100 amp	3.00 ea	12.0	1,400	4,324	-	-	1,907.94 /ea	5,724
Motor starter, size 5, autotransformer, type B, circuit breaker, NEMA 1	5.00 ea	114.3	13,329	121,152	-	-	26,896.08 /ea	134,480
Circuit breaker, type A, 100 amp, NEMA 12	4.00 ea	8.2	957	6,933	-	-	1,972.50 /ea	7,890
Motor control centers, incoming line, main lug only, copper, 800 amp, NEMA 1	1.00 ea	10.7	1,244	5,571	-	-	6,815.21 /ea	6,815
Motor control centers, incoming line, main lug only, copper, 1200 amp, NEMA 1	1.00 ea	11.4	1,333	5,748	-	-	7,080.93 /ea	7,081
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	210	-	-	210.47 /ea	210
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.07 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.59 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	251.96 /ea	252
Motor control centers, pilot light, push to test, & select switch	5.00 ea	3.3	389	2,105	-	-	498.68 /ea	2,493
RFW502 Digesters		**494.9**	**57,236**	**218,343**			**/LS**	**275,578**
RFW503 Filters								
Red Voltage Primary Resistor Starter NEMA 12 600V 3P Size 6 250 HP	2.00 E	40.0	4,607	99,044	-	-	51,825.25 /E	103,650
Pump existing MH - wash and pump	6.00 ea	60.0	6,998		8,489	-	2,581.17 /ea	15,487
Allowance for MCC feed and load recircuiting, based on MCC AMPS	2,500.00 AMP	625.0	71,980	132,648	-	-	81.85 /AMP	204,628
Allowance for MV feed and load based on count	23.00 ea	547.6	63,068	81,357	-	-	6,279.38 /ea	144,426
MV CB in lineup	18.00 ea	432.0	50,254	754,501	-	8,614	45,187.19 /ea	813,369
MV Starter	5.00 ea	200.0	23,266	309,512	-	2,273	67,010.13 /ea	335,051
Transformers, 13,800 volts to 480/277 volts, 1500 kVA	2.00 ea	128.0	14,890	174,034	-	1,399	95,161.49 /ea	190,323
Filter Power/LCP panel configurations	16.00 ea	384.0	44,784	212,237	-	-	16,063.80 /ea	257,021
Motor starter, size 5, autotransformer, type B, circuit breaker, NEMA 1	7.00 ea	160.0	18,660	169,612	-	-	26,896.08 /ea	188,273
Circuit breaker, type A, 1200 amp, NEMA 12	2.00 ea	24.0	2,799	20,516	-	-	11,657.60 /ea	23,315

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
RFW503 Filters								
Circuit breaker, type A, 2500 amp, NEMA 12	3.00 ea	66.0	7,697	119,383	-	-	42,360.13 /ea	127,080
Circuit breaker, type A, 400 amp, NEMA 12	11.00 ea	40.0	4,665	63,715	-	-	6,216.38 /ea	68,380
Motor control centers, incoming line, main lug only, copper, 800 amp, NEMA 1	1.00 ea	10.7	1,244	5,571	-	-	6,815.22 /ea	6,815
Motor control centers, incoming line, main lug only, copper, 1200 amp, NEMA 1	1.00 ea	11.4	1,333	5,748	-	-	7,080.94 /ea	7,081
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	210	-	-	210.46 /ea	210
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.07 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.59 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	251.96 /ea	252
Motor control centers, pilot light, push to test, & select switch	5.00 ea	3.3	389	2,105	-	-	498.69 /ea	2,493
Variable frequency drives, custom-engineered, 460 volt, 150 HP motor size	7.00 ea	400.0	46,531	220,372	-	3,637	38,648.71 /ea	270,541
RFW503 Filters		**3,132.7**	**363,243**	**2,371,324**	**8,489**	**15,924**	**/LS**	**2,758,980**
RFW504 Aeration Tanks								
Allowance for MCC feed and load recircuiting, based on MCC AMPS	600.00 AMP	150.0	17,275	31,835	-	-	81.85 /AMP	49,111
Allowance for Panel feed and load recircuiting, based on Panel AMPS	1,200.00 AMP	200.0	23,034	42,447	-	-	54.57 /AMP	65,481
Allowance for Panel feed and load recircuiting, based on Panel AMPS	400.00 AMP	66.7	7,678	14,149	-	-	54.57 /AMP	21,827
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 400 amp	1.00 ea	14.0	1,637	5,394	-	-	7,031.21 /ea	7,031
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 1200 amp	1.00 ea	18.2	2,120	14,901	-	-	17,021.25 /ea	17,021
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	3.00 ea	9.2	1,077	10,081	-	-	3,719.26 /ea	11,158
Circuit breaker, type A, 100 amp, NEMA 12	4.00 ea	8.2	957	6,933	-	-	1,972.50 /ea	7,890
Motor control centers, incoming line, main lug only, copper, 600 amp, NEMA 1	1.00 ea	10.0	1,166	2,255	-	-	3,421.27 /ea	3,421
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	210	-	-	210.47 /ea	210
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.04 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.60 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	251.96 /ea	252
Motor control centers, pilot light, push to test, & select switch	3.00 ea	2.0	233	1,263	-	-	498.69 /ea	1,496
RFW504 Aeration Tanks		**479.0**	**55,255**	**130,227**			**/LS**	**185,482**
RFW505 Compressor								
Allowance for MCC feed and load recircuiting, based on MCC AMPS	600.00 AMP	150.0	17,275	31,835	-	-	81.85 /AMP	49,111
Allowance for Panel feed and load recircuiting, based on Panel AMPS	800.00 AMP	133.3	15,356	28,298	-	-	54.57 /AMP	43,654
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	37.5	4,319	7,959	-	-	54.57 /AMP	12,278
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	37.5	4,319	7,959	-	-	54.57 /AMP	12,278
Allowance for Panel feed and load recircuiting, based on Panel AMPS	100.00 AMP	16.7	1,919	3,537	-	-	54.57 /AMP	5,457
Allowance for Panel feed and load recircuiting, based on Panel AMPS	100.00 AMP	16.7	1,919	3,537	-	-	54.57 /AMP	5,457
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 800 amp	1.00 ea	15.4	1,794	11,408	-	-	13,201.96 /ea	13,202
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 100 amp	2.00 ea	8.0	933	2,883	-	-	1,907.95 /ea	3,816
Panelboards, 3 pole 4 wire, main circuit breaker, 277/480 V, 225 amp	2.00 ea	16.0	1,866	6,721	-	-	4,293.43 /ea	8,587
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	9.00 ea	27.7	3,230	30,244	-	-	3,719.26 /ea	33,473
Circuit breaker, type A, 100 amp, NEMA 12	3.00 ea	6.2	718	5,200	-	-	1,972.49 /ea	5,917
Motor control centers, incoming line, main lug only, copper, 600 amp, NEMA 1	1.00 ea	10.0	1,166	2,255	-	-	3,421.27 /ea	3,421
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	210	-	-	210.48 /ea	210
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.05 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.59 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	251.97 /ea	252
Motor control centers, pilot light, push to test, & select switch	9.00 ea	6.0	700	3,788	-	-	498.69 /ea	4,488
RFW505 Compressor		**481.6**	**55,592**	**146,593**			**/LS**	**202,185**
RFW506 Final Tanks								
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	37.5	4,319	7,959	-	-	54.57 /AMP	12,278
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	37.5	4,319	7,959	-	-	54.57 /AMP	12,278
Allowance for Panel feed and load recircuiting, based on Panel AMPS	100.00 AMP	16.7	1,919	3,537	-	-	54.57 /AMP	5,457
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 100 amp	1.00 ea	4.0	466	1,441	-	-	1,907.94 /ea	1,908

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
RFW506 Final Tanks								
Panelboards, 3 pole 4 wire, main circuit breaker, 277/480 V, 225 amp	2.00 ea	16.0	1,866	6,721	-	-	4,293.42 /ea	8,587
RFW506 Final Tanks		**111.7**	**12,890**	**27,617**			**/LS**	**40,507**
RFW507 Primary Tanks								
Allowance for Panel feed and load recircuiting, based on Panel AMPS	400.00 AMP	66.7	7,678	14,149	-	-	54.57 /AMP	21,827
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 400 amp	2.00 ea	28.1	3,274	10,789	-	-	7,031.20 /ea	14,062
RFW507 Primary Tanks		**94.7**	**10,952**	**24,938**			**/LS**	**35,889**
RFW508 Chlorination								
Allowance for MV feed and load based on count	1.00 ea	23.8	2,742	3,537	-	-	6,279.37 /ea	6,279
Allowance for MCC feed and load recircuiting, based on MCC AMPS	2,400.00 AMP	600.0	69,101	127,342	-	-	81.85 /AMP	196,443
MV CB in lineup	1.00 ea	24.0	2,792	41,917	-	479	45,187.20 /ea	45,187
Transformers, 13,800 volts to 480/277 volts, 1500 kVA	1.00 ea	64.0	7,445	87,017	-	699	95,161.48 /ea	95,161
Circuit breaker, type A, 1200 amp, NEMA 12	2.00 ea	24.0	2,799	20,516	-	-	11,657.62 /ea	23,315
Circuit breaker, type A, 2500 amp, NEMA 12	1.00 ea	22.0	2,566	39,794	-	-	42,360.13 /ea	42,360
Circuit breaker, type A, 400 amp, NEMA 12	6.00 ea	21.8	2,545	34,754	-	-	6,216.38 /ea	37,298
RFW508 Chlorination		**779.6**	**89,989**	**354,877**		**1,178**	**/LS**	**446,045**
RFW509 Sludge Treat								
Allowance for MCC feed and load recircuiting, based on MCC AMPS	600.00 AMP	150.0	17,275	31,836	-	-	81.85 /AMP	49,111
Allowance for Panel feed and load recircuiting, based on Panel AMPS	400.00 AMP	66.7	7,678	14,149	-	-	54.57 /AMP	21,827
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 400 amp	1.00 ea	14.0	1,637	5,394	-	-	7,031.19 /ea	7,031
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	9.00 ea	27.7	3,230	30,244	-	-	3,719.26 /ea	33,473
Circuit breaker, type A, 100 amp, NEMA 12	2.00 ea	4.1	478	3,467	-	-	1,972.51 /ea	3,945
Motor control centers, incoming line, main lug only, copper, 600 amp, NEMA 1	1.00 ea	10.0	1,166	2,255	-	-	3,421.25 /ea	3,421
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	210	-	-	210.47 /ea	210
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.06 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.60 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	251.96 /ea	252
Motor control centers, pilot light, push to test, & select switch	9.00 ea	6.0	700	3,788	-	-	498.69 /ea	4,488
RFW509 Sludge Treat		**279.2**	**32,242**	**92,101**			**/LS**	**124,343**
RFW510 Administration								
Allowance for MCC feed and load recircuiting, based on MCC AMPS	600.00 AMP	150.0	17,275	31,835	-	-	81.85 /AMP	49,111
Allowance for Panel feed and load recircuiting, based on Panel AMPS	400.00 AMP	66.7	7,678	14,149	-	-	54.57 /AMP	21,827
Allowance for Panel feed and load recircuiting, based on Panel AMPS	800.00 AMP	133.3	15,356	28,298	-	-	54.57 /AMP	43,654
Allowance for Panel feed and load recircuiting, based on Panel AMPS	1,200.00 AMP	200.0	23,034	42,447	-	-	54.57 /AMP	65,481
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	37.5	4,319	7,959	-	-	54.57 /AMP	12,278
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	37.5	4,319	7,959	-	-	54.57 /AMP	12,278
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	37.5	4,319	7,959	-	-	54.57 /AMP	12,278
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	37.5	4,319	7,959	-	-	54.57 /AMP	12,278
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	37.5	4,319	7,959	-	-	54.57 /AMP	12,278
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	37.5	4,319	7,959	-	-	54.57 /AMP	12,278
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 800 amp	1.00 ea	15.4	1,794	11,408	-	-	13,201.96 /ea	13,202
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 1200 amp	1.00 ea	18.2	2,120	14,901	-	-	17,021.25 /ea	17,021
Panelboards, 3 pole 4 wire, main lugs, 277/480 V, 225 amp, no main breaker	6.00 ea	40.0	4,665	9,445	-	-	2,351.60 /ea	14,110
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	4.00 ea	12.3	1,435	13,442	-	-	3,719.26 /ea	14,877
Circuit breaker, type A, 100 amp, NEMA 12	5.00 ea	10.3	1,196	8,666	-	-	1,972.50 /ea	9,862
Motor control centers, incoming line, main lug only, copper, 600 amp, NEMA 1	1.00 ea	10.0	1,166	2,255	-	-	3,421.27 /ea	3,421
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	210	-	-	210.48 /ea	210
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.05 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.60 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	251.95 /ea	252
Motor control centers, pilot light, push to test, & select switch	4.00 ea	2.7	311	1,684	-	-	498.69 /ea	1,995

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
RFW510 Administration		884.5	102,022	227,251			/LS	329,273
RFW900 MISC FACILITY								
Temp power	1.00 ls		-	-	156,864	-	156,863.84 /ls	156,864
Cleaning up	1.00 ls			-	78,432	-	78,431.90 /ls	78,432
Demo based on percentage of install MH, includes disposal	1.00 LS	1,200.0	127,342	35,373		4,422	167,136.31 /LS	167,136
Hazardous W cln/pu/dspl, liq pickup, vac trk,min charge,4hr,2compt,500	100.00 hr		-	-	70,746	-	707.46 /hr	70,746
Hazardous W cln/pu/dspl, liq pickup, vac trk, transp in 6900gal bulk t	50.00 mile		-	-	2,653	-	53.06 /mile	2,653
Misc Electrical allowance	1.00 ls		-	-	17,686	-	17,686.37 /ls	17,686
RFW900 MISC FACILITY		1,200.0	127,342	35,373	326,381	4,422	/LS	493,517
05 TI WRP MCCs - ELECTRICAL EQUIPMENT	**1.00 LS**	**10,237.4**	**1,173,499**	**4,440,676**	**356,094**	**21,523**	**5,991,791.53 /LS**	**5,991,792**

AACE – Classification System



Construction Cost Estimate Accuracy Ranges

CH2MHILL

Estimate Class	Class 5	Class 4	Class 3	Class 2	Class 1
LEVEL OF PROJECT DEFINITION Expressed as a % of complete definition	**0% to 2%**	**1% to 15%**	**10% to 40%**	**30% to 70%**	**50% to 100%**
END USAGE Typical Purpose of Estimate	**Concept Screening**	**Study or Feasibility**	**Budget Authorization, or Control**	**Control or Bid / Tender**	**Check Estimate or Bid / Tender**
METHODOLOGY Typical estimating method	**Capacity Factored, Parametric Models, Judgment, or Analogy**	**Equipment Factored or Parametric Models**	**Semi-Detailed Unit Costs with Assembly Level Line Items**	**Detailed Unit Cost with Forced Detailed Take-Off**	**Detailed Unit Cost with Detailed Take-Off**
EXPECTED ACCURACY RANGE Typical variation in low and high ranges [a]	**L: -20% to -50%** **H: +30% to +100%**	**L: -15% to -30%** **H: +20% to +50%**	**L: -10% to -20%** **H: +10% to +30%**	**L: -5% to -15%** **H: +5% to +20%**	**L: -3% to -10%** **H: +3% to +15%**
PREPARATION EFFORT Typical degree of effort relative to least cost index of 1 [b]	**1**	**2 to 4**	**3 to 10**	**4 to 20**	**5 to 100**
REFINED CLASS DEFINITION	Class 5 estimates are generally prepared based on very limited information, and subsequently have very wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systematic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with very little effort expended - sometimes requiring less than 1 hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation.	Class 4 estimates are generally prepared based on very limited information, and subsequently have very wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 5% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems and preliminary engineered process and utility equipment lists. Level of Project Definition Required: 1% to 15% of full project definition.	Class 3 estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. As such, they typically form the initial control estimate against which all actual costs and resources will be monitored. Typically, engineering is from 10% to 40% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, preliminary piping and instrument diagrams, utility flow diagrams, preliminary piping and instrument diagrams, plot plan, developed layout drawings, and essentially complete engineering process and utility equipment lists. Level Of Project Definition Required: 10% to 40% of full project definition.	Class 2 estimates are generally prepared to form a detailed control baseline against which all project work is monitored in terms of cost and progress control. For contractors, this class of estimate is often used as the "bid" estimate to establish contract value. Typically, engineering is from 30% to 70% complete, and would comprise at a minimum the following: Process flow diagrams, utility flow diagrams, piping and instrument flow diagrams, heat and material balances, final plot plan, final layout drawings, complete engineered process and utility equipment lists, single line diagrams for electrical, electrical equipment and motor schedules, vendor quotations, detailed project execution plans, resourcing and work force plans, etc.	Class 1 estimates are generally prepared for discrete parts or sections of the total project rather than generating this level of detail for the entire project. The parts of the project estimated at this level of detail will typically be used by subcontractors for bids, or by owners for check estimates. The updated estimate is often referred to as the current control estimate and becomes the new baseline for cost/schedule control of the project. Class 1 estimates may be prepared for parts of the project to comprise a fair price estimate or bid check estimate to compare against a contractor's bid estimate, or to evaluate/dispute claims. Typically, engineering is from 50% to 100% complete, and would comprise virtually all engineering and design documentation of the project, and complete project execution and commissioning plans. Level for Project Definition Required: 50% to 100% of full project definition.
END USAGE DEFINED	Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.	Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.	Class 3 estimates are typically prepared to support full project funding requests, and become the first of the project phase "control estimate" against which all actual costs and resources will be monitored for variations to the budget. They are used as the project budget until replaced by more detailed estimates. In many owner organizations, a Class 3 estimate may be the last estimate required and could well form the only basis for cost/schedule control.	Class 2 estimates are typically prepared as the detailed control baseline against which all actual costs an resources will now be monitored for variation to the budget, and form a part of the change/variation control program.	Class 1 estimates are typically prepared to form a current control estimate to be used as the final control baseline against which all actual coasts and resources will now be monitored for variations to the budget, and form a part of the change/variation control program. They may be used to evaluate bid checking, to support vendor/contractor negotiations, or for claim evaluations and dispute resolution.
ESTIMATING METHODS USED	Class 5 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques.	Class 4 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques.	Class 3 estimates usually involve more deterministic estimating methods that stochastic methods. They usually involve a high degree of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring and other stochastic methods may be used to estimate less-significant areas of the project.	Class 2 estimates always involve a high degree of deterministic estimating methods. Class 2 estimates are prepared in great detail, and often involve tens of thousands of unit cost line items. For those areas of the project still undefined, an assumed level of detailed takeoff (forced detail) may be developed to use as line items in the estimate instead of relying on factoring methods.	Class 1 estimates involve the highest degree of deterministic estimating methods, and require a great amount of effort. Class 1 estimates are prepared in great detail, and thus are usually performed on only the most important or critical areas of the project. All items in the estimate are usually unit cost line items based on actual design quantities.
EXPECTED ACCURACY RANGE	Typical accuracy ranges for Class 5 estimates are -20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 3 estimates are -10% to -20% on the low side, and +10% to +30% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 2 estimates are -5% to -15% on the low side, and +5% to +20% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 1 estimates are -3% to -10% on the low side, and +3% to +15% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.
EFFORT TO PREPARE (for US$20MM project):	As little as 1 hour or less to prepare to perhaps more than 200 hours, depending on the project and the estimating methodology used.	Typically, as little as 20 hours or less to perhaps more than 300 hours, depending on the project and the estimating methodology used.	Typically, as little as 150 hours or less to perhaps more than 1500 hours, depending on the project and the estimating methodology used.	Typically, as little as 300 hours or less to perhaps more than 3000 hours, depending on the project and the estimating methodology used. Bid Estimates typically require more effort than estimates used for funding or control purposes	Class 1 estimates require the most effort to create, and as such are generally developed for only selected areas of the project, or for bidding purposes. A complete Class 1 estimate may involve as little as 600 hours or less, to perhaps more than 6,000 hours, depending on the project and the estimating methodology used. Bid estimate typically require more effort than estimates used for funding or control purposes.
ANSI Standard Reference Z94.2-1989 name; Alternate Estimate Names, Terms, Expressions, Synonyms:	Order of Magnitude Estimate; Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of thumb.	Budget Estimate; Screening, top-down, feasibility, authorization, factored, pre-design, pre-study.	Budget Estimate; Budget, scope, sanction, semi-detailed, authorization, preliminary control, concept study, development, basic engineering phase estimate, target estimate.	Definitive Estimate; Detailed Control, forced detail, execution phase, master control, engineering, bid, tender, change order estimate.	Definitive Estimate; Full detail, release, fall-out, tender, firm price, bottoms-up, final, detailed control, forced detail, execution phase, master control, fair price, definitive, change order estimate.

Estimate Class	Class 5	Class 4	Class 3	Class 2	Class 1
Estimate Input Checklist and Maturity Index	**Class 5**	**Class 4**	**Class 3**	**Class 2**	**Class 1**
GENERAL PROJECT DATA					
Project Scope Description	General	Preliminary	Defined	Defined	Defined
Plant Production / Facility Capacity	Assumed	Preliminary	Defined	Defined	Defined
Plant Location	General	Approximate	Specific	Specific	Specific
Soils & Hydrology	None	Preliminary	Defined	Defined	Defined
Integrated Project Plan	None	Preliminary	Defined	Defined	Defined
Project Master Schedule	None	Preliminary	Defined	Defined	Defined
Escalation Strategy	None	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	None	Preliminary	Defined	Defined	Defined
Project Code of Accounts	None	Preliminary	Defined	Defined	Defined
Contracting Strategy	Assumed	Assumed	Preliminary	Defined	Defined
ENGINEERING DELIVERABLES:	**Class 5**	**Class 4**	**Class 3**	**Class 2**	**Class 1**
Block Flow Diagrams	Started / Preliminary	Preliminary / Complete	Complete	Complete	Complete
Plot Plans		Started	Preliminary / Complete	Complete	Complete
Process Flow Diagrams (PFDs)		Started / Preliminary	Preliminary / Complete	Complete	Complete
Utility Flow Diagrams (UFDs)		Started / Preliminary	Preliminary / Complete	Complete	Complete
Piping & Instrument Diagrams (P&IDS)		Started	Preliminary / Complete	Complete	Complete
Heat and Material Balances		Started	Preliminary / Complete	Complete	Complete
Process Equipment List		Started / Preliminary	Preliminary / Complete	Complete	Complete
Utility Equipment List		Started / Preliminary	Preliminary / Complete	Complete	Complete
Electrical One Line Drawings		Started / Preliminary	Preliminary / Complete	Complete	Complete
Specifications and Datasheets		Started	Preliminary / Complete	Complete	Complete
General Equipment Arrangement Drawings		Started	Preliminary / Complete	Complete	Complete
Spare Parts Lists			Started / Preliminary	Preliminary	Complete
Architectural Details / Schedules		Started	Preliminary / Complete	Complete	Complete
Structural Details		Started	Preliminary / Complete	Complete	Complete
Mechanical Discipline Drawings			Started	Preliminary	Preliminary / Complete
Electrical Discipline Drawings			Started	Preliminary	Preliminary / Complete
System Discipline Drawings			Started	Preliminary	Preliminary / Complete
Civil/Site Discipline Drawings			Started	Preliminary	Preliminary / Complete
Demolition Details		Started	Preliminary / Complete	Complete	Complete

APPENDIX F: IDENTIFICATION & EVALUATION OF MITIGATION MEASURES TO ENHANCE FLOOD RESILIENCE

LASAN - Pumping Plants

TABLE 5 - IDENTIFY & EVALUATE MITIGATION MEASURES TO ENHANCE FLOOD RESILIENCE

Mitigation Measures			Evaluation Criteria			Recommendation			
1	2		3	4	5	6	7		
Assets/ Operations	Possible Mitigation Measures	Cost Range	Effectiveness (Low, Med, High)	Practicality (Low, Med, High)	Estimated Cost ($)	Evaluation of Mitigation Measure	Recommend Mitigation Measure (Yes/No)?	Short or Long Term	Notes
Buildings									
1. Prevent buildings from flooding.									
	a. Caulk and/or seal wall and floor penetrations.	$	Med	High		Will protect electrical room	Yes	Long	
	c. Install waterproof protection (e.g., removable/semi-permanent structures, sealed doors, shields) for building entry points (e.g., windows, doors, garages).	$$	High	High		Will protect electrical room	Yes	Long	
	d. Install floodwalls, levees or berms around buildings.	$$$	High	High		Will protect facility from mud slides too	Yes	Long	Only for Temescal
2. Protect critical components if buildings do flood.									
3. Maintain operations when the electrical grid is down.									
4. Maintain continuity of operations during flooding.									
Instrumentation and Electrical Controls									
1. Protect instrumentation and electrical controls from flood damage.									
	e. Replace instrumentation and control enclosures with waterproof models.	$–$$$	High	High		Will protect electrical systems if control rooms are flooded	Yes	Long	
2. Maintain continuity of operations (e.g., redundant controls at another location) if instrumentation and controls are damaged by a flood.									
Power Supply									
1. Long before a flood, take measures to reduce the duration of power outages.									
2. Secure backup generators.									
	b. Have pump stations wired to accept a portable generator. Ensure that "quick connect" capability is installed and ready, and that on-site personnel are trained.	$	High	High		Backup for onsite generator in case it is damaged	Yes	Long	
	d. Procure and install your own portable or permanent generators. Consider multi-fuel generators.	$$$	High	High		Generator is on site at facility	Yes	Long	
3. Secure a source of fuel for backup generators.									
4. Install an alternative energy system									
5. Prepare/protect electrical connections/equipment									
	d. Evaluate existing electrical panels to determine the best method of connecting external portable generators to the facility or to individual pieces of equipment.	$	High	High		Backup for onsite generator in case it is damaged	Yes	Long	
	e. Replace/upgrade electrical connections/motor controls/junction boxes with watertight panels.	$$	High	High		Will protect electrical systems if control rooms are flooded	Yes	Long	Above ground panels associated with the backup generator?
Lift Stations - Wastewater									
1. Prevent lift stations from flooding									
	b. Extend vent lines above anticipated flood stage to prevent floodwater from entering the lift station.	$–$$	High	High			Yes	Long	
2. Protect critical components if lift stations do flood									
	a. Install unions in the conduit system to reduce the time required to repair damaged sections.	$	Med	High		Will also help inform CIP on what to replace at next asset evaluation	Yes	Long	
	e. Replace vulnerable components with a submersible option (e.g., pumps, flow meters, gate/valve operators, etc.).	$$$	High	High		Will protect electrical systems if control rooms are flooded	Yes	Long	Replace sump pump to pump out flooded dry well, etc.
3. Maintain lift station operations when the electrical grid is down									
4. Have a means of bypassing normal lift station operations when necessary									

APPENDIX G: MITIGATION COST ESTIMATES

MEMORANDUM CH2MHILL®

Preliminary Estimates: LASAN – Pumpstations - Mitigation

PREPARED FOR: WILLIAM MCMILLIN/NJO
PREPARED BY: Robert Wells/PDX
DATE: SEPTEMBER 22, 2015

Background

The purpose of the estimates is to determine the value of work to protect components likely destroyed by water ingress due to a tsunami event. The estimates for facilities at Class V level of definition (per request) have been prepared based on several assumptions. The drawings from previous projects were utilized to provide a characterization of the work. The value of the work is determined in 2015 dollars with no escalation for future dates. The assumption is that labor resources, whether local or imported, will be costed at 2015 union rates.

The estimate scope is based on Table 5 of the Flood Resiliency Guide, completed 09/21/2015. Each mitigation strategy is summarized and cost reported as described in each section of Table 5, as identified as construction costs related to mitigation. Omitted costs for strategies identified Table 5 are assumed to be non-construction costs.

Costs

The estimates for Sunset PP and Temescal PP were based on line item takeoffs from the drawings. The estimate includes cost allocations of indirect costs, general requirements, markups, bond and taxes. The costs in the attached estimate reports do not include an allowance for market conditions.

The markups included in the reported cost are as follows: Subcontractor and Prime Contractor general requirements, overhead and profit (total), 44%; Bonds and Insurance, 2%, Estimating Contingency, 15%.

Table 1: Estimated Project Costs (Class V Range)

Project	-50% accuracy limit	As reported cost	+100% accuracy limit
Sunset PP	$0.36M	**$0.73M**	$1.46M
Temescal PP	$0.36M	**$0.72M**	$1.44M

In order to standardize a value by which to compare alternatives, it is advisable and an industry standard for municipalities to use the 80th percentile of the range of costs. For these projects, the following values represent the 80th percentile:

Sunset: $1.24M

Temescal: $1.22M

Attachments

The attached reports are organized by Facility and Work Activity, which generally represents a portion or component of the facility or process.

- Detail Reports, 4pp
- Summary Reports, 2pp
- AACE Classification System, 3pp

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
01M SUNSET MITIGATION								
Buildings 1.a. Caulk and seal penetrations								
Caulking and sealants, acoustical sealants, elastomeric, cartridges	40.00 ea		-	603	-	-	15.08 /ea	603
Caulking and sealants, backer rod, polyethylene, 1/2" dia	5.00 clf	8.7	699	32	-	-	146.28 /clf	731
Caulking and sealants, silicone rubber, bulk	5.00 gal		-	404	-	-	80.71 /gal	404
Caulking and sealants, silicone rubber, cartridges	5.00 gal		-	399	-	-	79.82 /gal	399
Caulking and sealants, neoprene gaskets, closed cell, adhesive, 1/2" x 1"	100.00 lf	4.0	322	231	-	-	5.52 /lf	552
Caulking and sealants, resin epoxy coating, heavy duty, 2 component	5.00 gal		-	271	-	-	54.10 /gal	271
Masonry joint sealants, oil base, 1/2" x 1/2" joint, includes cut-out and re-caulk, excludes scaffolding	500.00 lf	27.6	2,217	479	-	-	5.39 /lf	2,696
Buildings 1.a. Caulk and seal penetrations		**40.3**	**3,238**	**2,418**			**/LS**	**5,656**
Buildings 1.c. Install Waterproof protection								
Watertight flood door	8.00 ea	128.0	12,264	36,895	-	-	6,144.80 /ea	49,158
Buildings 1.c. Install Waterproof protection		**128.0**	**12,264**	**36,895**			**/LS**	**49,158**
Inst & El Ctrls 1.e. Replace instr and ctrl enclosures with waterproof								
PLC Cabinet	1.00 ea	80.0	10,164	26,607	-	-	36,771.15 /ea	36,771
ICP Cabinet	1.00 ea	80.0	10,164	26,607	-	-	36,771.13 /ea	36,771
FT / FIT - Flow Transmitter - Magnetic, 12"	1.00 ea	9.5	1,207	7,095	-	-	8,302.16 /ea	8,302
LT / LIT - Level Transmitter	2.00 ea	4.5	572	5,321	-	-	2,946.56 /ea	5,893
LS - Level Switch Ultrasonic	2.00 ea	6.0	762	4,257	-	-	2,509.71 /ea	5,019
Inst & El Ctrls 1.e. Replace instr and ctrl enclosures with waterproof		**180.0**	**22,870**	**69,887**			**/LS**	**92,757**
LS-WW 1.b Extend vent lines above anticipated flood stage								
Ductwork, installation cost, stainless steel, round, 20 ga.	200.00 lb	6.7	852	-		-	4.26 /lb	852
Fans, prop exh, wl shtr, 1/4" S.P., v-belt dr, 3 ph, 10,100 CFM, 1 HP	2.00 ea	8.9	1,136	3,725	-	-	2,430.49 /ea	4,861
LS-WW 1.b Extend vent lines above anticipated flood stage		**15.6**	**1,988**	**3,725**			**/LS**	**5,713**
LS-WW 2.a. Install unions in the conduit system								
Pullout and reterminate	40.00 ea	160.0	18,481		-	-	462.02 /ea	18,481
UNY Conduit Union	40.00 E	16.0	1,848	4,870	-	-	167.95 /E	6,718
Cut & Thread RGS Conduit	80.00 E	44.0	5,082	-	-	-	63.53 /E	5,082
LS-WW 2.a. Install unions in the conduit system		**220.0**	**25,411**	**4,870**			**/LS**	**30,281**
LS-WW 2.e. Replace vulnerable components with a submersible option								
Pump, submersible sump, automatic, plastic, 1/2 H.P., 1-1/2" discharge	1.00 ea	6.0	763	2,129	-	-	2,891.69 /ea	2,892
LS-WW 2.e. Replace vulnerable components with a submersible option		**6.0**	**763**	**2,129**			**/LS**	**2,892**
Power Sply 2.b. Have pump stations wired to accept a portable generator								
Wire, copper, stranded, 600 volt, 500 kcmil, type XHHW, in raceway	4.00 clf	20.0	2,339	7,805	-	-	2,535.99 /clf	10,144
Rigid galvanized steel conduit, 4" diameter, to 15' H, incl 2 terminations, 2 elbows & 11 beam clamps per 100 LF	100.00 lf	40.0	4,679	4,080	-	-	87.58 /lf	8,758
Non-automatic transfer switch, enclosed, manual operated, 3 pole, 480 volt, 400 amp N3R with pin conn	1.00 ea	10.0	1,170	15,299	-	-	16,468.55 /ea	16,469
Power Sply 2.b. Have pump stations wired to accept a portable generator		**70.0**	**8,188**	**27,183**			**/LS**	**35,371**
Power Sply 2.d. Procure portable generators								
Generator set,diesel,3 phase 4 wire,277/480 v,300 kw,incl battery,charger,muffler,automatic transfer switch&day tank,excl conduit,wiring,& concrete	1.00 ea	8.0	933	86,206	-	829	87,968.43 /ea	87,968
Trailer mount feature	1.00 ea			8,869	-	829	9,697.98 /ea	9,698
Power Sply 2.d. Procure portable generators		**8.0**	**933**	**95,075**		**1,658**	**/LS**	**97,666**
Power Sply 5.d. Prepare Protect Electrical - evaluation								
Consultant - designer	1.00 wk	40.0	10,643	-	-	-	10,642.72 /wk	10,643
Power Sply 5.d. Prepare Protect Electrical - evaluation		**40.0**	**10,643**				**/LS**	**10,643**
Power Sply 5.e. Watertight electrical components (assume 1.3 material, 1.3 lab fct)								

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
Power Sply 5.e. Watertight electrical components (assume 1.3 material, 1.3 lab fct)								
Security allowance	1.00 ls	120.0	15,446	14,190	3,548	-	33,183.48 /ls	33,183
Life Safety allowance	1.00 ls	80.0	10,293	-	8,869	-	19,161.87 /ls	19,162
Comm allowance	1.00 ls	40.0	5,146	-	8,869	-	14,015.41 /ls	14,015
Transformer, dry-type, nonventilated, single phase 480 V primary 120/240 V secondary, 25 kVA	1.00 ea	23.1	2,974	5,073	-	-	8,046.55 /ea	8,047
Switchboards, main circuit breaker, 3 pole, 4 wire, 277/480 volt, 600 amp	1.00 ea	18.9	2,433	9,281	-	-	11,714.21 /ea	11,714
Switchboards, metering section 24", add	1.00 ea	11.6	1,487	2,537	-	-	4,023.34 /ea	4,023
Switchboards, Nema 3R, add	1.00 ea	10.4	1,338	1,038	-	-	2,375.76 /ea	2,376
Switchboards, TVSS, add	1.00 ea	1.3	167	2,075	-	-	2,242.60 /ea	2,243
Panelboards, 3 phase 4 wire, main circuit breaker, 277/480 V, 100 amp, 30 circuits, NEHB, incl 20 A 1 pole plug-in breakers	1.00 ea	27.4	3,521	6,341	-	-	9,862.50 /ea	9,863
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 1	4.00 ea	15.4	1,982	17,294	-	-	4,819.19 /ea	19,277
RVSS 75HP	4.00 ea	64.0	8,234	88,547	-	-	24,195.46 /ea	96,782
Circuit breaker, light contactor, type B, 30 Amp, NEMA 1	1.00 ea	3.9	496	4,324	-	-	4,819.21 /ea	4,819
Circuit breaker, light contactor, type B, 100 amp, NEMA 1	1.00 ea	10.4	1,338	7,552	-	-	8,890.00 /ea	8,890
Fusible switch, type A, 30 Amp, NEMA 1	9.00 ea	17.7	2,272	21,272	-	-	2,616.03 /ea	23,544
Motor control center, structures, 22,000 rms, takes any combination of starters, 600 amp, up to 72" high	10.00 ea	130.0	16,726	43,813	-	-	6,053.86 /ea	60,539
Motor control center, for copper bus add per structure	10.00 ea		-	6,111	-	-	611.07 /ea	6,111
Motor control center, for 42,000 rms, add per structure	10.00 ea		-	4,589	-	-	458.88 /ea	4,589
Motor control center, for pilot lights, add per starter	8.00 ea	5.2	669	2,195	-	-	358.04 /ea	2,864
Motor control center, for push button, add per starter	8.00 ea	5.2	669	2,195	-	-	358.03 /ea	2,864
Motor control center, for auxiliary contacts, add per starter	8.00 ea	5.2	669	3,265	-	-	491.78 /ea	3,934
Metering, surge arrestor, TVSS	1.00 ea	0.7	84	14,989	-	-	15,072.15 /ea	15,072
Motor starter, magnetic, FVNR, size 00, 480 volt, 2 HP, NEMA 1, incl enclosure & heaterS, n12	8.00 ea	23.8	3,058	22,045	-	-	3,137.88 /ea	25,103
Automatic transfer switches, enclosed, 3 pole, 480 volt, 600 amp	1.00 ea	20.8	2,676	19,831	-	-	22,507.11 /ea	22,507
Power Sply 5.e. Watertight electrical components (assume 1.3 material, 1.3 lab fct)		**634.8**	**81,679**	**298,557**	**21,285**		**/LS**	**401,521**
01M SUNSET MITIGATION	**1.00 LS**	**1,342.7**	**167,976**	**540,739**	**21,285**	**1,658**	**731,657.85 /LS**	**731,658**

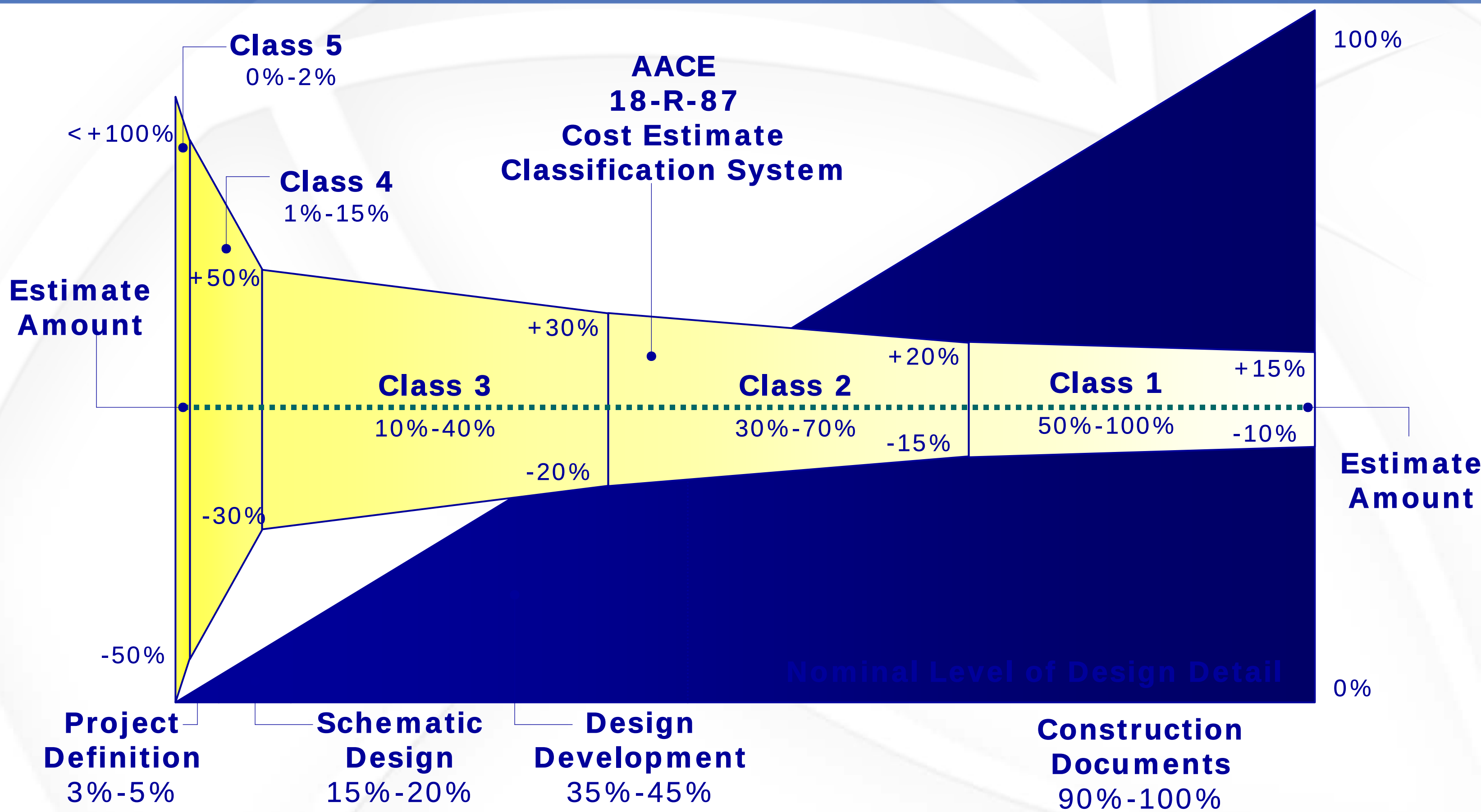
Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
02M TEMESCAL MITIGATION								
Buildings 1.a. Caulk and seal penetrations								
Caulking and sealants, acoustical sealants, elastomeric, cartridges	80.00 ea		-	1,206	-	-	15.08 /ea	1,206
Caulking and sealants, backer rod, polyethylene, 1/2" dia	10.00 clf	17.4	1,398	65	-	-	146.28 /clf	1,463
Caulking and sealants, silicone rubber, bulk	10.00 gal		-	807	-	-	80.71 /gal	807
Caulking and sealants, silicone rubber, cartridges	10.00 gal		-	798	-	-	79.82 /gal	798
Caulking and sealants, neoprene gaskets, closed cell, adhesive, 1/2" x 1"	200.00 lf	8.0	643	461	-	-	5.52 /lf	1,104
Caulking and sealants, resin epoxy coating, heavy duty, 2 component	10.00 gal		-	541	-	-	54.10 /gal	541
Masonry joint sealants, oil base, 1/2" x 1/2" joint, includes cut-out and re-caulk, excludes scaffolding	1,000.00 lf	55.2	4,434	958	-	-	5.39 /lf	5,392
Buildings 1.a. Caulk and seal penetrations		**80.6**	**6,475**	**4,836**			**/LS**	**11,312**
Buildings 1.c. Install Waterproof protection								
Watertight flood door	5.00 ea	80.0	7,665	23,059	-	-	6,144.79 /ea	30,724
Buildings 1.c. Install Waterproof protection		**80.0**	**7,665**	**23,059**			**/LS**	**30,724**
Buildings 1.d. Install floodwalls, levees or berms around buildings								
Concrete pumping, subcontract, all inclusive price	29.63 cy		-	-	631	-	21.29 /cy	631
Forms in place, structural walls, to 8' high, hand set	1,600.00 sf	240.0	19,174	2,838	-	-	13.76 /sf	22,012
Reinforcing in place, A615 Gr 60, priced per lbs.	5,925.93 lb		-	5,256	2,102	-	1.24 /lb	7,358
Concrete, ready mix, 5000 psi	29.63 CY		-	5,729	-	-	193.34 /CY	5,729
Add for concrete waste, 5000 psi	1.48 cy		-	286	-	-	193.34 /cy	286
Placing concrete, concrete pump, for structural wall to 12" thick	29.63 cy	25.2	1,561	-	-	-	52.70 /cy	1,561
Patch & plug tieholes	1,600.00 sf	24.0	1,488	57	-	-	0.97 /sf	1,545
Curing, water	1,600.00 sf	5.3	331	142	-	-	0.30 /sf	473
Buildings 1.d. Install floodwalls, levees or berms around buildings		**294.5**	**22,553**	**14,307**	**2,733**		**/LS**	**39,594**
Inst & El Ctrls 1.e. Replace instr and ctrl enclosures with waterproof								
PLC Cabinet	1.00 ea	80.0	10,164	26,607	-	-	36,771.14 /ea	36,771
ICP Cabinet	1.00 ea	80.0	10,164	26,607	-	-	36,771.15 /ea	36,771
FT / FIT - Flow Transmitter - Magnetic, 12"	1.00 ea	9.5	1,207	7,095	-	-	8,302.15 /ea	8,302
LT / LIT - Level Transmitter	2.00 ea	4.5	572	5,321	-	-	2,946.56 /ea	5,893
LS - Level Switch Ultrasonic	2.00 ea	6.0	762	4,257	-	-	2,509.71 /ea	5,019
Inst & El Ctrls 1.e. Replace instr and ctrl enclosures with waterproof		**180.0**	**22,870**	**69,887**			**/LS**	**92,757**
LS-WW 1.b Extend vent lines above anticipated flood stage								
Ductwork, installation cost, stainless steel, round, 20 ga.	300.00 lb	10.0	1,278	-		-	4.26 /lb	1,278
Fans, prop exh, wl shtr, 1/4" S.P., v-belt dr, 3 ph, 10,100 CFM, 1 HP	30.00 ea	133.3	17,041	55,874	-	-	2,430.50 /ea	72,915
LS-WW 1.b Extend vent lines above anticipated flood stage		**143.3**	**18,319**	**55,874**			**/LS**	**74,193**
LS-WW 2.a. Install unions in the conduit system								
Pullout and reterminate	80.00 ea	320.0	36,961		-	-	462.02 /ea	36,961
UNY Conduit Union	80.00 E	32.0	3,696	9,740	-	-	167.95 /E	13,436
Cut & Thread RGS Conduit	160.00 E	88.0	10,164	-	-	-	63.53 /E	10,164
LS-WW 2.a. Install unions in the conduit system		**440.0**	**50,822**	**9,740**			**/LS**	**60,562**
LS-WW 2.e. Replace vulnerable components with a submersible option								
Pump, submersible sump, automatic, plastic, 1/2 H.P., 1-1/2" discharge	1.00 ea	6.0	763	2,129	-	-	2,891.69 /ea	2,892
LS-WW 2.e. Replace vulnerable components with a submersible option		**6.0**	**763**	**2,129**			**/LS**	**2,892**
Power Sply 2.b. Have pump stations wired to accept a portable generator								
Wire, copper, stranded, 600 volt, 500 kcmil, type XHHW, in raceway	4.00 clf	20.0	2,339	7,805	-	-	2,535.99 /clf	10,144
Rigid galvanized steel conduit, 4" diameter, to 15' H, incl 2 terminations, 2 elbows & 11 beam clamps per 100 LF	100.00 lf	40.0	4,679	4,080	-	-	87.58 /lf	8,758
Non-automatic transfer switch, enclosed, manual operated, 3 pole, 480 volt, 400 amp N3R with pin conn	1.00 ea	10.0	1,170	15,299	-	-	16,468.56 /ea	16,469

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
Power Sply 2.b. Have pump stations wired to accept a portable generator		**70.0**	**8,188**	**27,183**			**/LS**	**35,371**
Power Sply 2.d. Procure portable generators								
Generator set,diesel,3 phase 4 wire,277/480 v,300 kw,incl battery,charger,muffler,automatic transfer switch&day tank,excl conduit,wiring,& concrete	1.00 ea	8.0	933	86,206	-	829	87,968.43 /ea	87,968
Trailer mount feature	1.00 ea			8,869	-	829	9,697.97 /ea	9,698
Power Sply 2.d. Procure portable generators		**8.0**	**933**	**95,075**		**1,658**	**/LS**	**97,666**
Power Sply 5.d. Prepare Protect Electrical - evaluation								
Consultant - designer	1.00 wk	40.0	10,643	-	-	-	10,642.72 /wk	10,643
Power Sply 5.d. Prepare Protect Electrical - evaluation		**40.0**	**10,643**				**/LS**	**10,643**
Power Sply 5.e. Watertight electrical components (assume 1.3 material, 1.3 lab fct)								
Security allowance	1.00 ls	120.0	15,446	14,190	3,548	-	33,183.48 /ls	33,183
Life Safety allowance	1.00 ls	80.0	10,293	-	8,869	-	19,161.88 /ls	19,162
Comm allowance	1.00 ls	40.0	5,146	-	4,434	-	9,580.93 /ls	9,581
Transformer, dry-type, ventilated, 3 phase 480 V primary 120/208 V secondary, 15 kVA	1.00 ea	18.9	2,433	2,479	-	-	4,911.76 /ea	4,912
Switchboards, main circuit breaker, 3 pole, 4 wire, 277/480 volt, 400 amp	1.00 ea	18.2	2,348	7,379	-	-	9,726.51 /ea	9,727
Switchboards, metering section 24", add	1.00 ea	11.6	1,487	2,537	-	-	4,023.35 /ea	4,023
Switchboards, Nema 3R, add	1.00 ea	10.4	1,338	1,038	-	-	2,375.75 /ea	2,376
Panelboards, 3 phase 4 wire, main circuit breaker, 277/480 V, 100 amp, 30 circuits, NEHB, incl 20 A 1 pole plug-in breakers	1.00 ea	27.4	3,521	6,341	-	-	9,862.51 /ea	9,863
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 1	3.00 ea	11.6	1,487	12,971	-	-	4,819.22 /ea	14,458
RVSS 75HP	3.00 ea	48.0	6,176	66,411	-	-	24,195.44 /ea	72,586
Circuit breaker, light contactor, type B, 30 Amp, NEMA 1	1.00 ea	3.9	496	4,324	-	-	4,819.23 /ea	4,819
Circuit breaker, light contactor, type B, 60 amp, NEMA 1	1.00 ea	5.2	669	4,958	-	-	5,626.78 /ea	5,627
Motor control center, structures, 22,000 rms, takes any combination of starters, 600 amp, up to 72" high	7.00 ea	91.0	11,708	30,669	-	-	6,053.86 /ea	42,377
Motor control center, for copper bus add per structure	7.00 ea		-	4,277	-	-	611.07 /ea	4,277
Motor control center, for 42,000 rms, add per structure	7.00 ea		-	3,212	-	-	458.88 /ea	3,212
Motor control center, for pilot lights, add per starter	6.00 ea	3.9	502	1,646	-	-	358.04 /ea	2,148
Motor control center, for push button, add per starter	6.00 ea	3.9	502	1,646	-	-	358.03 /ea	2,148
Motor control center, for auxiliary contacts, add per starter	6.00 ea	3.9	502	2,449	-	-	491.78 /ea	2,951
Metering, surge arrestor, TVSS	1.00 ea	0.7	84	14,989	-	-	15,072.15 /ea	15,072
Power Sply 5.e. Watertight electrical components (assume 1.3 material, 1.3 lab fct)		**498.5**	**64,136**	**181,515**	**16,851**		**/LS**	**262,502**
02M TEMESCAL MITIGATION	**1.00 LS**	**1,840.9**	**213,366**	**483,607**	**19,584**	**1,658**	**718,215.00 /LS**	**718,215**

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
01M SUNSET MITIGATION								
Buildings 1.a. Caulk and seal penetrations		40.3	3,238	2,418			/LS	5,656
Buildings 1.c. Install Waterproof protection		128.0	12,264	36,895			/LS	49,158
Inst & El Ctrls 1.e. Replace instr and ctrl enclosures with waterproof		180.0	22,870	69,887			/LS	92,757
LS-WW 1.b Extend vent lines above anticipated flood stage		15.6	1,988	3,725			/LS	5,713
LS-WW 2.a. Install unions in the conduit system		220.0	25,411	4,870			/LS	30,281
LS-WW 2.e. Replace vulnerable components with a submersible option		6.0	763	2,129			/LS	2,892
Power Sply 2.b. Have pump stations wired to accept a portable generator		70.0	8,188	27,183			/LS	35,371
Power Sply 2.d. Procure portable generators		8.0	933	95,075		1,658	/LS	97,666
Power Sply 5.d. Prepare Protect Electrical - evaluation		40.0	10,643				/LS	10,643
Power Sply 5.e. Watertight electrical components (assume 1.3 material, 1.3 lab fct)		634.8	81,679	298,557	21,285		/LS	401,521
01M SUNSET MITIGATION	**1.00 LS**	**1,342.7**	**167,976**	**540,739**	**21,285**	**1,658**	**731,657.85 /LS**	**731,658**

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
02M TEMESCAL MITIGATION								
Buildings 1.a. Caulk and seal penetrations		80.6	6,475	4,836			/LS	11,312
Buildings 1.c. Install Waterproof protection		80.0	7,665	23,059			/LS	30,724
Buildings 1.d. Install floodwalls, levees or berms around buildings		294.5	22,553	14,307	2,733		/LS	39,594
Inst & El Ctrls 1.e. Replace instr and ctrl enclosures with waterproof		180.0	22,870	69,887			/LS	92,757
LS-WW 1.b Extend vent lines above anticipated flood stage		143.3	18,319	55,874			/LS	74,193
LS-WW 2.a. Install unions in the conduit system		440.0	50,822	9,740			/LS	60,562
LS-WW 2.e. Replace vulnerable components with a submersible option		6.0	763	2,129			/LS	2,892
Power Sply 2.b. Have pump stations wired to accept a portable generator		70.0	8,188	27,183			/LS	35,371
Power Sply 2.d. Procure portable generators		8.0	933	95,075		1,658	/LS	97,666
Power Sply 5.d. Prepare Protect Electrical - evaluation		40.0	10,643				/LS	10,643
Power Sply 5.e. Watertight electrical components (assume 1.3 material, 1.3 lab fct)		498.5	64,136	181,515	16,851		/LS	262,502
02M TEMESCAL MITIGATION	**1.00 LS**	**1,840.9**	**213,366**	**483,607**	**19,584**	**1,658**	**718,215.00 /LS**	**718,215**

AACE – Classification System



Construction Cost Estimate Accuracy Ranges

Estimate Class	Class 5	Class 4	Class 3	Class 2	Class 1
LEVEL OF PROJECT DEFINITION Expressed as a % of complete definition	0% to 2%	1% to 15%	10% to 40%	30% to 70%	50% to 100%
END USAGE Typical Purpose of Estimate	Concept Screening	Study or Feasibility	Budget Authorization, or Control	Control or Bid / Tender	Check Estimate or Bid / Tender
METHODOLOGY Typical estimating method	Capacity Factored, Parametric Models, Judgment, or Analogy	Equipment Factored or Parametric Models	Semi-Detailed Unit Costs with Assembly Level Line Items	Detailed Unit Cost with Forced Detailed Take-Off	Detailed Unit Cost with Detailed Take-Off
EXPECTED ACCURACY RANGE Typical variation in low and high ranges [a]	L: -20% to -50% H: +30% to +100%	L: -15% to -30% H: +20% to +50%	L: -10% to -20% H: +10% to +30%	L: -5% to -15% H: +5% to +20%	L: -3% to -10% H: +3% to +15%
PREPARATION EFFORT Typical degree of effort relative to least cost index of 1 [b]	1	2 to 4	3 to 10	4 to 20	5 to 100
REFINED CLASS DEFINITION	Class 5 estimates are generally prepared based on very limited information, and subsequently have very wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systematic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with very little effort expended - sometimes requiring less than 1 hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation.	Class 4 estimates are generally prepared based on very limited information, and subsequently have very wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 5% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems and preliminary engineered process and utility equipment lists. Level of Project Definition Required: 1% to 15% of full project definition.	Class 3 estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. As such, they typically form the initial control estimate against which all actual costs and resources will be monitored. Typically, engineering is from 10% to 40% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, preliminary piping and instrument diagrams, utility flow diagrams, preliminary piping and instrument diagrams, plot plan, developed layout drawings, and essentially complete engineering process and utility equipment lists. Level Of Project Definition Required: 10% to 40% of full project definition.	Class 2 estimates are generally prepared to form a detailed control baseline against which all project work is monitored in terms of cost and progress control. For contractors, this class of estimate is often used as the "bid" estimate to establish contract value. Typically, engineering is from 30% to 70% complete, and would comprise at a minimum the following: Process flow diagrams, utility flow diagrams, piping and instrument flow diagrams, heat and material balances, final plot plan, final layout drawings, complete engineered process and utility equipment lists, single line diagrams for electrical, electrical equipment and motor schedules, vendor quotations, detailed project execution plans, resourcing and work force plans, etc.	Class 1 estimates are generally prepared for discrete parts or sections of the total project rather than generating this level of detail for the entire project. The parts of the project estimated at this level of detail will typically be used by subcontractors for bids, or by owners for check estimates. The updated estimate is often referred to as the current control estimate and becomes the new baseline for cost/schedule control of the project. Class 1 estimates may be prepared for parts of the project to comprise a fair price estimate or bid check estimate to compare against a contractor's bid estimate, or to evaluate/dispute claims. Typically, engineering is from 50% to 100% complete, and would comprise virtually all engineering and design documentation of the project, and complete project execution and commissioning plans. Level for Project Definition Required: 50% to 100% of full project definition.
END USAGE DEFINED	Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.	Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.	Class 3 estimates are typically prepared to support full project funding requests, and become the first of the project phase "control estimate" against which all actual costs and resources will be monitored for variations to the budget. They are used as the project budget until replaced by more detailed estimates. In many owner organizations, a Class 3 estimate may be the last estimate required and could well form the only basis for cost/schedule control.	Class 2 estimates are typically prepared as the detailed control baseline against which all actual costs an resources will now be monitored for variation to the budget, and form a part of the change/variation control program.	Class 1 estimates are typically prepared to form a current control estimate to be used as the final control baseline against which all actual coasts and resources will now be monitored for variations to the budget, and form a part of the change/variation control program. They may be used to evaluate bid checking, to support vendor/contractor negotiations, or for claim evaluations and dispute resolution.
ESTIMATING METHODS USED	Class 5 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques.	Class 4 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques.	Class 3 estimates usually involve more deterministic estimating methods that stochastic methods. They usually involve a high degree of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring and other stochastic methods may be used to estimate less-significant areas of the project.	Class 2 estimates always involve a high degree of deterministic estimating methods. Class 2 estimates are prepared in great detail, and often involve tens of thousands of unit cost line items. For those areas of the project still undefined, an assumed level of detailed takeoff (forced detail) may be developed to use as line items in the estimate instead of relying on factoring methods.	Class 1 estimates involve the highest degree of deterministic estimating methods, and require a great amount of effort. Class 1 estimates are prepared in great detail, and thus are usually performed on only the most important or critical areas of the project. All items in the estimate are usually unit cost line items based on actual design quantities.
EXPECTED ACCURACY RANGE	Typical accuracy ranges for Class 5 estimates are -20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 3 estimates are -10% to -20% on the low side, and +10% to +30% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 2 estimates are -5% to -15% on the low side, and +5% to +20% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 1 estimates are -3% to -10% on the low side, and +3% to +15% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.
EFFORT TO PREPARE (for US$20MM project):	As little as 1 hour or less to prepare to perhaps more than 200 hours, depending on the project and the estimating methodology used.	Typically, as little as 20 hours or less to perhaps more than 300 hours, depending on the project and the estimating methodology used.	Typically, as little as 150 hours or less to perhaps more than 1500 hours, depending on the project and the estimating methodology used.	Typically, as little as 300 hours or less to perhaps more than 3000 hours, depending on the project and the estimating methodology used. Bid Estimates typically require more effort than estimates used for funding or control purposes	Class 1 estimates require the most effort to create, and as such are generally developed for only selected areas of the project, or for bidding purposes. A complete Class 1 estimate may involve as little as 600 hours or less, to perhaps more than 6,000 hours, depending on the project and the estimating methodology used. Bid estimate typically require more effort than estimates used for funding or control purposes.
ANSI Standard Reference Z94.2-1989 name; Alternate Estimate Names, Terms, Expressions, Synonyms:	Order of Magnitude Estimate; Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of thumb.	Budget Estimate; Screening, top-down, feasibility, authorization, factored, pre-design, pre-study.	Budget Estimate; Budget, scope, sanction, semi-detailed, authorization, preliminary control, concept study, development, basic engineering phase estimate, target estimate.	Definitive Estimate; Detailed Control, forced detail, execution phase, master control, engineering, bid, tender, change order estimate.	Definitive Estimate; Full detail, release, fall-out, tender, firm price, bottoms-up, final, detailed control, forced detail, execution phase, master control, fair price, definitive, change order estimate.

Estimate Class	Class 5	Class 4	Class 3	Class 2	Class 1
Estimate Input Checklist and Maturity Index	**Class 5**	**Class 4**	**Class 3**	**Class 2**	**Class 1**
GENERAL PROJECT DATA					
Project Scope Description	General	Preliminary	Defined	Defined	Defined
Plant Production / Facility Capacity	Assumed	Preliminary	Defined	Defined	Defined
Plant Location	General	Approximate	Specific	Specific	Specific
Soils & Hydrology	None	Preliminary	Defined	Defined	Defined
Integrated Project Plan	None	Preliminary	Defined	Defined	Defined
Project Master Schedule	None	Preliminary	Defined	Defined	Defined
Escalation Strategy	None	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	None	Preliminary	Defined	Defined	Defined
Project Code of Accounts	None	Preliminary	Defined	Defined	Defined
Contracting Strategy	Assumed	Assumed	Preliminary	Defined	Defined
ENGINEERING DELIVERABLES:	**Class 5**	**Class 4**	**Class 3**	**Class 2**	**Class 1**
Block Flow Diagrams	Started / Preliminary	Preliminary / Complete	Complete	Complete	Complete
Plot Plans		Started	Preliminary / Complete	Complete	Complete
Process Flow Diagrams (PFDs)		Started / Preliminary	Preliminary / Complete	Complete	Complete
Utility Flow Diagrams (UFDs)		Started / Preliminary	Preliminary / Complete	Complete	Complete
Piping & Instrument Diagrams (P&IDS)		Started	Preliminary / Complete	Complete	Complete
Heat and Material Balances		Started	Preliminary / Complete	Complete	Complete
Process Equipment List		Started / Preliminary	Preliminary / Complete	Complete	Complete
Utility Equipment List		Started / Preliminary	Preliminary / Complete	Complete	Complete
Electrical One Line Drawings		Started / Preliminary	Preliminary / Complete	Complete	Complete
Specifications and Datasheets		Started	Preliminary / Complete	Complete	Complete
General Equipment Arrangement Drawings		Started	Preliminary / Complete	Complete	Complete
Spare Parts Lists			Started / Preliminary	Preliminary	Complete
Architectural Details / Schedules		Started	Preliminary / Complete	Complete	Complete
Structural Details		Started	Preliminary / Complete	Complete	Complete
Mechanical Discipline Drawings			Started	Preliminary	Preliminary / Complete
Electrical Discipline Drawings			Started	Preliminary	Preliminary / Complete
System Discipline Drawings			Started	Preliminary	Preliminary / Complete
Civil/Site Discipline Drawings			Started	Preliminary	Preliminary / Complete
Demolition Details		Started	Preliminary / Complete	Complete	Complete

Preliminary Estimates: LASAN – Terminal Island Water Reclamation Plant – Mitigation

PREPARED FOR: WILLIAM MCMILLIN/NJO

PREPARED BY: Robert Wells/PDX

DATE: NOVEMBER 17, 2015

Background

The purpose of the estimates is to determine the value of work to modify facility and process components to avoid destruction by water ingress due to a tsunami event. The estimates for facilities at Class V level of definition (per request) have been prepared based on several assumptions. The value of the work is determined in 2015 dollars with no escalation for future dates. The assumption is that labor resources, whether local or imported, will be costed at 2015 union rates.
The estimate scope is based on Table 5 of the Flood Resiliency Guide, completed 09/21/2015. Each mitigation strategy is summarized and cost reported as described in each section of Table 5, as identified as construction costs related to mitigation. Omitted costs for strategies identified Table 5 are assumed to be non-construction costs.

Cost Basis

The drawings from previous projects were utilized to provide a characterization of the work. These drawings and the scope included are as follows:

- **Headworks**
    - Microfilm scans in MS Word document: Headworks D-34202-120612 as-bids. Scope from these drawings includes sealing of openings, doors, and window for expected ingress level.
    - Microfilm scans in MS Word document: Lift Station D-29274 PIE as-builts. Scope from these drawings includes sealing of openings, doors, and window for expected ingress level.
- **MCCs – Electrical**
    - Microfilm scans in MS Word documents: Biosolids D-32313 PIE as-builts, Digesters D-25078-80-750428 PIE as-builts, Filters D-30738-40-940331 PIE as-bid, LASAN-TI-Admin_Building, LASAN-TI-AerationTanks, LASAN-TI-Biosolids, LASAN-TI-CompressorBldg, LASAN-TI-FinalTanks, TI power & MCCs-1972 plant. Scope includes: temp power, relocation or replacement in new location of electrical distribution panels and MCC to elevations designed to avoid expected ingress level.
- **Effluent Pumping Plant**
    - Microfilm scans in MS Word document: EPP & Em Gen D-23942-720420 as-bids. Scope from these drawings includes sealing of openings, doors, and window for expected ingress level.
- **Advanced Water Treatment Facility (AWTF)**
    - PDF as-bids: AWTF Ph1 elevations-150925-kf, D31528, D31529, D31530, D31532, D31533. sealing of openings, doors, windows and conduits, replacement of electrical enclosures with watertight assemblies, securing of tanks in Chemical Storage Facility, to address expected ingress level.

Costs

The estimates were based on line item takeoffs from the drawings. The estimate includes cost allocations of indirect costs, general requirements, markups, bond and taxes. The costs in the attached estimate reports do not include an allowance for market conditions.

The markups included in the reported cost are as follows: Subcontractor and Prime Contractor general requirements, overhead and profit (total), 44%; Bonds and Insurance, 2%, Estimating Contingency, 15%.

Table 1: Estimated Project Costs (Class V Range)

Project	-50% accuracy limit	As reported cost	+100% accuracy limit
Terminal Island Water Reclamation Plant Headworks/Lift Station	$0.13M	**$0.23M**	$0.46M
Terminal Island Water Reclamation Plant Effluent Pump Plant	$0.09M	**$0.17M**	$0.37M
Terminal Island Water Reclamation Plant MCCs in Facilities	$3.24M	**$6.47M**	$12.94M
Terminal Island Water Reclamation Plant AWTF	$0.53M	**$1.06M**	$2.12M

In order to standardize a value by which to compare alternatives, it is advisable and an industry standard for municipalities to use the 80th percentile of the range of costs. For these projects, the following values represent the 80th percentile:

HEADWORKS/LS:	$0.39M
EFFLUENT PUMP PLANT:	$0.31M
MCCs IN FACILITIES:	$11.00M
AWTF:	$1.80M
Total for TI WRP	$13.51M

Attachments

The attached reports are organized by Facility and Work Activity, which generally represents a portion or component of the facility or process.

- Detail Reports, 7pp
- AACE Classification System, 3pp

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
03M TI WRP 01 HEADWORKS MITIGATION								
D-E-3 001 Hazardous Area								
Nema 7 enclosed motor/switch/control	31.00 ea	225.5	26,319	78,204	-	-	3,371.69 /ea	104,522
D-E-3 001 Hazardous Area		**225.5**	**26,319**	**78,204**			**/LS**	**104,522**
E-1 LS01 MCC NEW, misc dist								
Structure allowance	1.00 E	40.0	4,611	8,852	-	-	13,462.68 /E	13,463
Allowance for MCC feed and load recircuiting, based on MCC AMPS	600.00 AMP	85.7	9,881	42,488	-	-	87.28 /AMP	52,368
Allowance for Panel feed and load recircuiting, based on Panel AMPS	1,200.00 AMP	240.0	27,667	63,731	-	-	76.17 /AMP	91,398
Allowance for Panel feed and load recircuiting, based on Panel AMPS	100.00 AMP	20.0	2,306	5,311	-	-	76.17 /AMP	7,616
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 1200 amp	1.00 ea	18.2	2,122	14,915	-	-	17,037.39 /ea	17,037
Panelboards, 3 phase 4 wire, main circuit breaker, 277/480 V, 100 amp, 30 circuits, NEHB, incl 20 A 1 pole plug-in breakers	1.00 ea	21.1	2,458	4,868	-	-	7,325.98 /ea	7,326
Motor starter, size 3, FVNR, type B, circuit breaker, NEMA 12	4.00 ea	33.7	3,932	23,722	-	-	6,913.59 /ea	27,654
Circuit breaker, light contactor, type B, 30 Amp, NEMA 12	1.00 ea	3.1	359	3,585	-	-	3,944.09 /ea	3,944
Circuit breaker, light contactor, type B, 60 amp, NEMA 12	2.00 ea	8.4	983	7,701	-	-	4,341.95 /ea	8,684
Circuit breaker, light contactor, type B, 100 amp, NEMA 12	6.00 ea	50.5	5,898	35,318	-	-	6,869.34 /ea	41,216
Motor control centers, incoming line, circuit breaker, copper, 400 amp, NEMA 1	1.00 ea	13.3	1,556	5,842	-	-	7,398.51 /ea	7,399
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.34 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.88 /ea	271
Motor control centers, incoming line, for 1/4" x 1" ground bus, add	1.00 ea	0.5	58	174	-	-	232.72 /ea	233
Motor control centers, main rating basic section, NEMA 1, for 65000 amp bus bracing, add	1.00 ea		-	567	-	-	566.52 /ea	567
Motor control centers, main rating basic section, NEMA 1, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.85 /ea	271
Motor control centers, main rating basic section, NEMA 1, for 1/4" x 1" ground bus, add	1.00 ea	0.5	58	174	-	-	232.76 /ea	233
Motor control centers, pilot light, standard, & push button	4.00 ea	2.7	311	1,445	-	-	438.97 /ea	1,756
Motor control center, structures, 22,000 rms, takes any combination of starters, 600 amp, up to 72" high	6.00 ea	60.0	7,004	20,182	-	-	4,530.96 /ea	27,186
Variable frequency drives, custom-engineered, 460 volt, 50 HP motor size	2.00 ea	86.5	10,096	29,387	-	-	19,741.67 /ea	39,483
Automatic transfer switches, enclosed, 3 pole, 480 volt, 100 amp	1.00 ea	6.2	718	4,647	-	-	5,365.45 /ea	5,365
E-1 LS01 MCC NEW, misc dist		**690.3**	**80,020**	**273,763**			**/LS**	**353,783**
E-2 001 MCC A - MCC B								
PVC RGS XP load circuit	17.00 E	340.0	39,194	45,143	-	-	4,961.02 /E	84,337
PVC RGS MCC feed	2.00 E	80.0	9,222	17,703	-	-	13,462.67 /E	26,925
Structure allowance	2.00 E	80.0	9,222	17,703	-	-	13,462.69 /E	26,925
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	7.00 ea	21.5	2,514	23,545	-	-	3,722.79 /ea	26,060
Motor starter, size 2, FVNR, type B, circuit breaker, NEMA 12	2.00 ea	8.4	983	7,612	-	-	4,297.70 /ea	8,595
Circuit breaker, light contactor, type B, 30 Amp, NEMA 12	1.00 ea	3.1	359	3,585	-	-	3,944.08 /ea	3,944
Circuit breaker, light contactor, type B, 60 amp, NEMA 12	1.00 ea	4.2	492	3,850	-	-	4,341.97 /ea	4,342
Circuit breaker, light contactor, type B, 100 amp, NEMA 12	3.00 ea	25.3	2,949	17,659	-	-	6,869.33 /ea	20,608
Motor control centers, incoming line, circuit breaker, alum, 225 amp, NEMA 12	2.00 ea	29.1	3,396	7,789	-	-	5,592.68 /ea	11,185
Motor control centers, incoming line, for 65000 amp bus bracing, add	2.00 ea		-	627	-	-	313.35 /ea	627
Motor control centers, incoming line, for NEMA 12 enclosure, add	2.00 ea		-	542	-	-	270.86 /ea	542
Motor control centers, incoming line, for 1/4" x 1" ground bus, add	2.00 ea	1.0	117	349	-	-	232.75 /ea	465
Motor control centers, main rating basic section, NEMA 1, for 65000 amp bus bracing, add	3.00 ea		-	1,699	-	-	566.50 /ea	1,699
Motor control centers, main rating basic section, NEMA 1, for NEMA 12 enclosure, add	3.00 ea		-	813	-	-	270.86 /ea	813
Motor control centers, main rating basic section, NEMA 1, for 1/4" x 1" ground bus, add	3.00 ea	1.5	175	523	-	-	232.74 /ea	698
Motor control centers, pilot light, standard, & push button	9.00 ea	6.0	700	3,250	-	-	438.97 /ea	3,951
Motor control center, structures, 22,000 rms, takes any combination of starters, 600 amp, up to 72" high	6.00 ea	60.0	7,004	20,182	-	-	4,530.96 /ea	27,186
E-2 001 MCC A - MCC B		**660.1**	**76,328**	**172,575**			**/LS**	**248,903**
E-3 001 Electrical Room (incl LS)								
Variable frequency drives, custom-engineered, 460 volt, 5 HP motor size	2.00 ea	28.6	3,335	9,560	-	-	6,447.52 /ea	12,895

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
E-3 001 Electrical Room (incl LS)								
Non-automatic transfer switch, enclosed, manual operated, 3 pole, 480 volt, 200 amp	1.00 ea	8.0	934	5,621	-	-	6,554.64 /ea	6,555
E-3 001 Electrical Room (incl LS)		**36.6**	**4,269**	**15,180**			**/LS**	**19,450**
E-7 001 Panels and loads								
Panel loads	1.00 E	76.8	8,852	17,703	-	-	26,554.73 /E	26,555
Structure allowance	1.00 E	40.0	4,611	8,852	-	-	13,462.68 /E	13,463
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 100 amp	1.00 ea	4.0	467	1,443	-	-	1,909.73 /ea	1,910
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 225 amp	1.00 ea	8.0	934	2,921	-	-	3,854.93 /ea	3,855
Panelboards, 3 pole 4 wire, main circuit breaker, 277/480 V, 100 amp	2.00 ea	8.0	934	3,895	-	-	2,414.30 /ea	4,829
E-7 001 Panels and loads		**136.8**	**15,797**	**34,813**			**/LS**	**50,611**
RFW171 Conduit entrance grouting/sealing								
Grouting/sealing allowance	1.00 ls	20.0	2,335	3,541	0	-	5,875.35 /ls	5,875
RFW171 Conduit entrance grouting/sealing		**20.0**	**2,335**	**3,541**			**/LS**	**5,875**
RFW600 Consulting								
Consultant - designer	1.00 wk	40.0	10,622	-	-	-	10,621.89 /wk	10,622
RFW600 Consulting		**40.0**	**10,622**				**/LS**	**10,622**
RFW610 Sealing								
Caulking and sealants, backer rod, polyethylene, 1/2" dia	3.00 clf	5.2	549	19	-	-	189.55 /clf	569
Caulking and sealants, polyurethane, bulk, in place, 1 or 2 component, 68 LF per gallon, 3/4" x 3/8"	3,000.00 lf	88.2	9,288	3,983	-	-	4.42 /lf	13,271
RFW610 Sealing		**93.4**	**9,837**	**4,003**			**/LS**	**13,840**
RFW615 Watertight Openings								
Allowance for rolling door flood barrier	5.00 ea	200.0	27,935	132,774	-	-	32,141.76 /ea	160,709
Watertight window	3.00 sf	3.0	419	1,328	-	-	582.26 /sf	1,747
Watertight flood door	7.00 ea	112.0	13,074	32,220	-	-	6,470.60 /ea	45,294
RFW615 Watertight Openings		**315.0**	**41,429**	**166,321**			**/LS**	**207,750**
RFW900 MISC FACILITY								
Temp power	1.00 ls		-	-	31,406	-	31,406.29 /ls	31,406
Demo based on percentage of install MH, includes disposal	1.00 LS	400.0	42,488	3,541		4,426	50,453.98 /LS	50,454
Misc. Mechanical allowance	1.00 ls		-	-	8,852	-	8,851.56 /ls	8,852
Misc Electrical allowance	1.00 ls		-	-	17,703	-	17,703.15 /ls	17,703
I&C misc allowance	1.00 ls		-	-	15,703	-	15,703.14 /ls	15,703
RFW900 MISC FACILITY		**400.0**	**42,488**	**3,541**	**73,664**	**4,426**	**/LS**	**124,118**
03M TI WRP 01 HEADWORKS MITIGATION	**1.00 LS**	**2,617.7**	**309,444**	**751,940**	**73,664**	**4,426**	**1,139,473.84 /LS**	**1,139,474**

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
04M TI WRP 04 EFFLUENT PP								
E-2 401 E-2 Panels, Ltg								
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 225 amp	1.00 ea	8.0	934	2,921	-	-	3,854.92 /ea	3,855
Panelboards, 3 pole 4 wire, main circuit breaker, 277/480 V, 100 amp	1.00 ea	4.0	467	1,947	-	-	2,414.29 /ea	2,414
E-2 401 E-2 Panels, Ltg		**12.0**	**1,401**	**4,868**			**/LS**	**6,269**
E-3 401 MCC distribution								
Structure allowance	1.00 E	40.0	4,611	8,852	-	-	13,462.67 /E	13,463
Allowance for MCC feed and load recircuiting, based on MCC AMPS	1,600.00 AMP	228.6	26,349	113,300	-	-	87.28 /AMP	139,649
Allowance for Generator feed and load recircuiting, based on MCC AMPS	1,600.00 AMP	228.6	26,349	113,300	-	-	87.28 /AMP	139,649
Load interrupter switch, 2 position, 400 kVA & above, 13.8 kV, 600 amp w/CLF fuses, NEMA 1	1.00 ea	55.6	6,469	47,267	-	506	54,241.88 /ea	54,242
Transformers, 13,800 volts to 480/277 volts, 1050 kVA	1.00 ea	76.9	8,957	115,070	-	700	124,727.40 /ea	124,727
Circuit breaker, 3 pole, 125 to 600 amp, type MA	1.00 ea	5.0	584	7,214	-	-	7,797.74 /ea	7,798
Circuit breaker, 3 pole, 700 & 800 amp, type MA	2.00 ea	12.3	1,437	18,765	-	-	10,101.04 /ea	20,202
Switchboards, main circuit breaker, 3 pole, 4 wire, 277/480 volt, 2000 amp	1.00 ea	20.0	2,335	25,493	-	-	27,827.28 /ea	27,827
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	17.00 ea	52.3	6,106	57,181	-	-	3,722.79 /ea	63,287
Motor starter, size 2, FVNR, type B, circuit breaker, NEMA 12	1.00 ea	4.2	492	3,806	-	-	4,297.70 /ea	4,298
Motor starter, size 3, FVNR, type B, circuit breaker, NEMA 12	1.00 ea	8.4	983	5,931	-	-	6,913.60 /ea	6,914
Motor starter, size 4, FVNR, type B, circuit breaker, NEMA 12	3.00 ea	32.0	3,736	23,634	-	-	9,123.08 /ea	27,369
MCCPPH control cube and control	1.00 ea	16.0	1,868	44,258	-	-	46,125.67 /ea	46,126
Generator Switchgear	1.00 ea	100.0	11,674	265,547	-	-	277,220.83 /ea	277,221
Circuit breaker, light contactor, type B, 100 amp, NEMA 12	7.00 ea	58.9	6,881	41,204	-	-	6,869.34 /ea	48,085
Motor control centers, incoming line, circuit breaker, copper, 800 amp, NEMA 1	2.00 ea	35.6	4,151	27,971	-	-	16,060.80 /ea	32,122
Motor control centers, incoming line, for 65000 amp bus bracing, add	2.00 ea		-	627	-	-	313.35 /ea	627
Motor control centers, incoming line, for NEMA 12 enclosure, add	2.00 ea		-	542	-	-	270.86 /ea	542
Motor control centers, incoming line, for 1/4" x 1" ground bus, add	2.00 ea	1.0	117	349	-	-	232.74 /ea	465
Motor control centers, main rating basic section, NEMA 1, for 65000 amp bus bracing, add	5.00 ea		-	2,833	-	-	566.50 /ea	2,833
Motor control centers, main rating basic section, NEMA 1, for NEMA 12 enclosure, add	5.00 ea		-	1,354	-	-	270.86 /ea	1,354
Motor control centers, main rating basic section, NEMA 1, for 1/4" x 1" ground bus, add	5.00 ea	2.5	292	872	-	-	232.74 /ea	1,164
Motor control centers, pilot light, standard, & push button	22.00 ea	14.7	1,712	7,945	-	-	438.97 /ea	9,657
Motor control center, structures, 22,000 rms, takes any combination of starters, 600 amp, up to 72" high	5.00 ea	50.0	5,837	16,818	-	-	4,530.96 /ea	22,655
Variable frequency drives, custom-engineered, 460 volt, 125 HP motor size	1.00 ea	57.1	6,654	27,617	-	520	34,790.65 /ea	34,791
Variable frequency drives, custom-engineered, 460 volt, 650 HP motor size	2.00 ea	137.9	16,061	442,579	-	1,255	229,947.29 /ea	459,895
Generator set,diesel,3 phase 4 wire,277/480 v,2000 kw,incl battery,charger,muffler,automatic transfer switch&day tank,excl conduit,wiring,& concrete	1.00 ea	280.0	31,696	743,532	-	15,048	790,275.64 /ea	790,276
E-3 401 MCC distribution		**1,517.6**	**175,347**	**2,163,860**		**18,029**	**/LS**	**2,357,236**
RFW-403 Allowances for undefined electrical								
Panel loads	2.00 E	153.6	17,703	35,406	-	-	26,554.74 /E	53,109
RFW-403 Allowances for undefined electrical		**153.6**	**17,703**	**35,406**			**/LS**	**53,109**
RFW171 Conduit entrance grouting/sealing								
Grouting/sealing allowance	1.00 ls	20.0	2,335	3,541		-	5,875.36 /ls	5,875
RFW171 Conduit entrance grouting/sealing		**20.0**	**2,335**	**3,541**			**/LS**	**5,875**
RFW610 Sealing								
Caulking and sealants, backer rod, polyethylene, 1/2" dia	6.00 clf	10.4	1,098	39	-	-	189.55 /clf	1,137
Caulking and sealants, polyurethane, bulk, in place, 1 or 2 component, 68 LF per gallon, 3/4" x 3/8"	6,000.00 lf	176.5	18,575	7,966	-	-	4.42 /lf	26,542
RFW610 Sealing		**186.9**	**19,674**	**8,005**			**/LS**	**27,679**
RFW615 Watertight Openings								
Allowance for rolling door flood barrier	2.00 ea	80.0	11,174	53,109	-	-	32,141.76 /ea	64,284

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
RFW615 Watertight Openings								
Watertight window	32.00 sf	32.0	4,470	2,266	-	-	210.49 /sf	6,736
Watertight flood door	10.00 ea	160.0	18,678	46,028	-	-	6,470.60 /ea	64,706
RFW615 Watertight Openings		**272.0**	**34,322**	**101,404**			**/LS**	**135,725**
RFW900 MISC FACILITY								
Temp power	1.00 ls		-	-	31,406	-	31,406.30 /ls	31,406
Demo based on percentage of install MH, includes disposal	1.00 LS			35,406		4,426	39,832.08 /LS	39,832
Misc. Mechanical allowance	1.00 ls		-	-	35,406	-	35,406.29 /ls	35,406
Misc. Plumbing allowance	1.00 ls		-	-	8,852	-	8,851.58 /ls	8,852
Misc Electrical allowance	1.00 ls		-	-	17,703	-	17,703.14 /ls	17,703
I&C misc allowance	1.00 ls		-	-	31,406	-	31,406.30 /ls	31,406
RFW900 MISC FACILITY				**35,406**	**124,774**	**4,426**	**/LS**	**164,606**
04M TI WRP 04 EFFLUENT PP	**1.00 LS**	**2,162.1**	**250,781**	**2,352,491**	**124,774**	**22,455**	**2,750,500.38 /LS**	**2,750,500**

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
05M TI WRP 02 MCCs - ELECTRICAL EQUIPMENT								
RFW171 Conduit entrance grouting/sealing								
Grouting/sealing allowance	8.00 EA	160.0	18,678	28,325		-	5,875.36 /EA	47,003
RFW171 Conduit entrance grouting/sealing		**160.0**	**18,678**	**28,325**			**/LS**	**47,003**
RFW501 Biosolids								
Structure allowance	4.00 E	160.0	18,444	35,406	-	-	13,462.68 /E	53,851
Allowance for MCC feed and load recircuiting, based on MCC AMPS	1,200.00 AMP	171.4	19,762	84,975	-	-	87.28 /AMP	104,737
Allowance for MCC feed and load recircuiting, based on MCC AMPS	800.00 AMP	114.3	13,175	56,650	-	-	87.28 /AMP	69,825
Allowance for MCC feed and load recircuiting, based on MCC AMPS	1,200.00 AMP	171.4	19,762	84,975	-	-	87.28 /AMP	104,737
Allowance for MCC feed and load recircuiting, based on MCC AMPS	800.00 AMP	114.3	13,175	56,650	-	-	87.28 /AMP	69,825
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	81.00 ea	249.2	29,094	272,451	-	-	3,722.79 /ea	301,546
Circuit breaker, type A, 100 amp, NEMA 12	52.00 ea	106.7	12,452	90,215	-	-	1,974.37 /ea	102,667
Motor control centers, incoming line, main lug only, copper, 800 amp, NEMA 1	2.00 ea	21.3	2,490	11,153	-	-	6,821.69 /ea	13,643
Motor control centers, incoming line, main lug only, copper, 1200 amp, NEMA 1	2.00 ea	22.9	2,668	11,507	-	-	7,087.65 /ea	14,175
Motor control centers, incoming line, for copper bus, add	4.00 ea		-	843	-	-	210.67 /ea	843
Motor control centers, incoming line, for 65000 amp bus bracing, add	4.00 ea		-	1,253	-	-	313.35 /ea	1,253
Motor control centers, incoming line, for NEMA 12 enclosure, add	4.00 ea		-	1,083	-	-	270.86 /ea	1,083
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	4.00 ea	2.7	311	698	-	-	252.20 /ea	1,009
Motor control centers, pilot light, push to test, & select switch	81.00 ea	54.0	6,304	34,128	-	-	499.16 /ea	40,432
RFW501 Biosolids		**1,188.2**	**137,637**	**741,988**			**/LS**	**879,626**
RFW502 Digesters								
Structure allowance	1.00 E	40.0	4,611	8,852	-	-	13,462.68 /E	13,463
Allowance for MCC feed and load recircuiting, based on MCC AMPS	1,000.00 AMP	142.9	16,468	70,813	-	-	87.28 /AMP	87,281
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	45.0	5,187	11,950	-	-	76.17 /AMP	17,137
Allowance for Panel feed and load recircuiting, based on Panel AMPS	100.00 AMP	20.0	2,306	5,311	-	-	76.17 /AMP	7,617
Allowance for Panel feed and load recircuiting, based on Panel AMPS	100.00 AMP	20.0	2,306	5,311	-	-	76.17 /AMP	7,617
Allowance for Panel feed and load recircuiting, based on Panel AMPS	30.00 AMP	6.0	692	1,593	-	-	76.16 /AMP	2,285
Allowance for Panel feed and load recircuiting, based on Panel AMPS	30.00 AMP	6.0	692	1,593	-	-	76.17 /AMP	2,285
Panelboards, 3 pole 3 wire, main lugs, 480 V, 100 amp, no main breaker	1.00 ea	3.5	406	1,328	-	-	1,733.79 /ea	1,734
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 100 amp	3.00 ea	12.0	1,401	4,328	-	-	1,909.75 /ea	5,729
Motor starter, size 5, autotransformer, type B, circuit breaker, NEMA 1	5.00 ea	114.3	13,341	121,267	-	-	26,921.57 /ea	134,608
Circuit breaker, type A, 100 amp, NEMA 12	4.00 ea	8.2	958	6,940	-	-	1,974.37 /ea	7,897
Motor control centers, incoming line, main lug only, copper, 800 amp, NEMA 1	1.00 ea	10.7	1,245	5,577	-	-	6,821.67 /ea	6,822
Motor control centers, incoming line, main lug only, copper, 1200 amp, NEMA 1	1.00 ea	11.4	1,334	5,754	-	-	7,087.65 /ea	7,088
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	211	-	-	210.67 /ea	211
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.35 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.86 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	252.19 /ea	252
Motor control centers, pilot light, push to test, & select switch	5.00 ea	3.3	389	2,107	-	-	499.16 /ea	2,496
RFW502 Digesters		**443.9**	**51,413**	**253,691**			**/LS**	**305,104**
RFW503 Filters								
Structure allowance	12.00 E	480.0	55,333	106,219	-	-	13,462.68 /E	161,552
Red Voltage Primary Resistor Starter NEMA 12 600V 3P Size 6 250 HP	2.00 E	40.0	4,611	99,138	-	-	51,874.36 /E	103,749
Allowance for MCC feed and load recircuiting, based on MCC AMPS	2,500.00 AMP	357.1	41,171	177,031	-	-	87.28 /AMP	218,202
Allowance for MV feed and load based on count	23.00 ea	1,150.0	132,569	142,510	-	-	11,959.98 /ea	275,080
MV CB in lineup	18.00 ea	432.0	50,302	755,216	-	8,623	45,230.02 /ea	814,140
MV Starter	5.00 ea	200.0	23,288	309,805	-	2,275	67,073.65 /ea	335,368
Transformers, 13,800 volts to 480/277 volts, 1500 kVA	2.00 ea	128.0	14,904	174,199	-	1,400	95,251.68 /ea	190,503
Filter Power/LCP panel configurations	16.00 ea	384.0	44,827	212,438	-	-	16,079.03 /ea	257,265
Motor starter, size 5, autotransformer, type B, circuit breaker, NEMA 1	7.00 ea	160.0	18,678	169,773	-	-	26,921.57 /ea	188,451
Circuit breaker, type A, 1200 amp, NEMA 12	2.00 ea	24.0	2,802	20,536	-	-	11,668.65 /ea	23,337

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
RFW503 Filters								
Circuit breaker, type A, 2500 amp, NEMA 12	3.00 ea	66.0	7,705	119,496	-	-	42,400.29 /ea	127,201
Circuit breaker, type A, 400 amp, NEMA 12	11.00 ea	40.0	4,669	63,776	-	-	6,222.28 /ea	68,445
Motor control centers, incoming line, main lug only, copper, 800 amp, NEMA 1	1.00 ea	10.7	1,245	5,577	-	-	6,821.69 /ea	6,822
Motor control centers, incoming line, main lug only, copper, 1200 amp, NEMA 1	1.00 ea	11.4	1,334	5,754	-	-	7,087.65 /ea	7,088
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	211	-	-	210.66 /ea	211
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.34 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.86 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	252.19 /ea	252
Motor control centers, pilot light, push to test, & select switch	5.00 ea	3.3	389	2,107	-	-	499.16 /ea	2,496
Variable frequency drives, custom-engineered, 460 volt, 150 HP motor size	7.00 ea	400.0	46,576	220,581	-	3,641	38,685.34 /ea	270,797
RFW503 Filters		**3,887.2**	**450,480**	**2,585,124**		**15,939**	**/LS**	**3,051,543**
RFW504 Aeration Tanks								
Structure allowance	2.00 E	80.0	9,222	17,703	-	-	13,462.68 /E	26,925
Allowance for MCC feed and load recirciuting, based on MCC AMPS	600.00 AMP	85.7	9,881	42,488	-	-	87.28 /AMP	52,369
Allowance for Panel feed and load recirciuting, based on Panel AMPS	1,200.00 AMP	240.0	27,667	63,731	-	-	76.17 /AMP	91,398
Allowance for Panel feed and load recirciuting, based on Panel AMPS	400.00 AMP	80.0	9,222	21,244	-	-	76.17 /AMP	30,466
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 400 amp	1.00 ea	14.0	1,638	5,399	-	-	7,037.87 /ea	7,038
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 1200 amp	1.00 ea	18.2	2,122	14,915	-	-	17,037.38 /ea	17,037
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	3.00 ea	9.2	1,078	10,091	-	-	3,722.79 /ea	11,168
Circuit breaker, type A, 100 amp, NEMA 12	4.00 ea	8.2	958	6,940	-	-	1,974.37 /ea	7,897
Motor control centers, incoming line, main lug only, copper, 600 amp, NEMA 1	1.00 ea	10.0	1,167	2,257	-	-	3,424.52 /ea	3,425
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	211	-	-	210.67 /ea	211
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.35 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.85 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	252.20 /ea	252
Motor control centers, pilot light, push to test, & select switch	3.00 ea	2.0	233	1,264	-	-	499.16 /ea	1,497
RFW504 Aeration Tanks		**548.0**	**63,267**	**187,001**			**/LS**	**250,268**
RFW505 Compressor								
Structure allowance	2.00 E	80.0	9,222	17,703	-	-	13,462.68 /E	26,925
Allowance for MCC feed and load recirciuting, based on MCC AMPS	600.00 AMP	85.7	9,881	42,488	-	-	87.28 /AMP	52,368
Allowance for Panel feed and load recirciuting, based on Panel AMPS	800.00 AMP	160.0	18,444	42,488	-	-	76.17 /AMP	60,932
Allowance for Panel feed and load recirciuting, based on Panel AMPS	225.00 AMP	45.0	5,187	11,950	-	-	76.17 /AMP	17,137
Allowance for Panel feed and load recirciuting, based on Panel AMPS	225.00 AMP	45.0	5,188	11,950	-	-	76.17 /AMP	17,137
Allowance for Panel feed and load recirciuting, based on Panel AMPS	100.00 AMP	20.0	2,306	5,311	-	-	76.17 /AMP	7,616
Allowance for Panel feed and load recirciuting, based on Panel AMPS	100.00 AMP	20.0	2,306	5,311	-	-	76.17 /AMP	7,616
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 800 amp	1.00 ea	15.4	1,796	11,419	-	-	13,214.48 /ea	13,214
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 100 amp	2.00 ea	8.0	934	2,886	-	-	1,909.76 /ea	3,820
Panelboards, 3 pole 4 wire, main circuit breaker, 277/480 V, 225 amp	2.00 ea	16.0	1,868	6,727	-	-	4,297.49 /ea	8,595
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	9.00 ea	27.7	3,233	30,272	-	-	3,722.79 /ea	33,505
Circuit breaker, type A, 100 amp, NEMA 12	3.00 ea	6.2	718	5,205	-	-	1,974.37 /ea	5,923
Motor control centers, incoming line, main lug only, copper, 600 amp, NEMA 1	1.00 ea	10.0	1,167	2,257	-	-	3,424.50 /ea	3,425
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	211	-	-	210.67 /ea	211
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.34 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.86 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	252.20 /ea	252
Motor control centers, pilot light, push to test, & select switch	9.00 ea	6.0	700	3,792	-	-	499.16 /ea	4,492
RFW505 Compressor		**545.6**	**63,028**	**200,726**			**/LS**	**263,754**
RFW506 Final Tanks								
Allowance for Panel feed and load recirciuting, based on Panel AMPS	225.00 AMP	45.0	5,187	11,950	-	-	76.17 /AMP	17,137
Allowance for Panel feed and load recirciuting, based on Panel AMPS	225.00 AMP	45.0	5,188	11,950	-	-	76.17 /AMP	17,137

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
RFW506 Final Tanks								
Allowance for Panel feed and load recircuiting, based on Panel AMPS	100.00 AMP	20.0	2,306	5,311	-	-	76.17 /AMP	7,616
Panelboards, 3 pole 4 wire, main circuit breaker, 120/208 V, 100 amp	1.00 ea	4.0	467	1,443	-	-	1,909.76 /ea	1,910
Panelboards, 3 pole 4 wire, main circuit breaker, 277/480 V, 225 amp	2.00 ea	16.0	1,868	6,727	-	-	4,297.49 /ea	8,595
RFW506 Final Tanks		**130.0**	**15,015**	**37,380**			**/LS**	**52,395**
RFW507 Primary Tanks								
Allowance for Panel feed and load recircuiting, based on Panel AMPS	400.00 AMP	80.0	9,222	21,244	-	-	76.17 /AMP	30,466
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 400 amp	2.00 ea	28.1	3,277	10,799	-	-	7,037.87 /ea	14,076
RFW507 Primary Tanks		**108.1**	**12,499**	**32,043**			**/LS**	**44,542**
RFW508 Chlorination								
Structure allowance	2.00 E	80.0	9,222	17,703	-	-	13,462.68 /E	26,925
Allowance for MCC feed and load recircuiting, based on MCC AMPS	2,400.00 AMP	342.9	39,524	169,950	-	-	87.28 /AMP	209,474
Allowance for MV feed and load based on count	1.00 ea	23.8	2,745	3,541	-	-	6,285.32 /ea	6,285
MV CB in lineup	1.00 ea	24.0	2,795	41,956	-	479	45,230.01 /ea	45,230
Transformers, 13,800 volts to 480/277 volts, 1500 kVA	1.00 ea	64.0	7,452	87,099	-	700	95,251.71 /ea	95,252
Circuit breaker, type A, 1200 amp, NEMA 12	2.00 ea	24.0	2,802	20,536	-	-	11,668.66 /ea	23,337
Circuit breaker, type A, 2500 amp, NEMA 12	1.00 ea	22.0	2,568	39,832	-	-	42,400.27 /ea	42,400
Circuit breaker, type A, 400 amp, NEMA 12	6.00 ea	21.8	2,547	34,787	-	-	6,222.27 /ea	37,334
RFW508 Chlorination		**602.5**	**69,654**	**415,404**		**1,179**	**/LS**	**486,238**
RFW509 Sludge Treat								
Structure allowance	1.00 E	40.0	4,611	8,852	-	-	13,462.69 /E	13,463
Allowance for MCC feed and load recircuiting, based on MCC AMPS	600.00 AMP	120.0	13,833	42,488	-	-	93.87 /AMP	56,321
Allowance for Panel feed and load recircuiting, based on Panel AMPS	400.00 AMP	57.1	6,587	21,244	-	-	69.58 /AMP	27,831
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 400 amp	1.00 ea	14.0	1,638	5,399	-	-	7,037.86 /ea	7,038
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	9.00 ea	27.7	3,233	30,272	-	-	3,722.79 /ea	33,505
Circuit breaker, type A, 100 amp, NEMA 12	2.00 ea	4.1	479	3,470	-	-	1,974.38 /ea	3,949
Motor control centers, incoming line, main lug only, copper, 600 amp, NEMA 1	1.00 ea	10.0	1,167	2,257	-	-	3,424.51 /ea	3,425
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	211	-	-	210.67 /ea	211
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.34 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.86 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	252.20 /ea	252
Motor control centers, pilot light, push to test, & select switch	9.00 ea	6.0	700	3,792	-	-	499.16 /ea	4,492
RFW509 Sludge Treat		**279.6**	**32,327**	**118,743**			**/LS**	**151,070**
RFW510 Administration								
Structure allowance	2.00 E	80.0	9,222	17,703	-	-	13,462.68 /E	26,925
Allowance for MCC feed and load recircuiting, based on MCC AMPS	600.00 AMP	85.7	9,881	42,488	-	-	87.28 /AMP	52,368
Allowance for Panel feed and load recircuiting, based on Panel AMPS	400.00 AMP	80.0	9,222	21,244	-	-	76.17 /AMP	30,466
Allowance for Panel feed and load recircuiting, based on Panel AMPS	800.00 AMP	160.0	18,444	42,488	-	-	76.17 /AMP	60,932
Allowance for Panel feed and load recircuiting, based on Panel AMPS	1,200.00 AMP	240.0	27,667	63,731	-	-	76.17 /AMP	91,398
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	45.0	5,188	11,950	-	-	76.17 /AMP	17,137
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	45.0	5,188	11,950	-	-	76.17 /AMP	17,137
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	45.0	5,188	11,950	-	-	76.17 /AMP	17,137
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	45.0	5,187	11,950	-	-	76.17 /AMP	17,137
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	45.0	5,188	11,950	-	-	76.17 /AMP	17,137
Allowance for Panel feed and load recircuiting, based on Panel AMPS	225.00 AMP	45.0	5,187	11,950	-	-	76.17 /AMP	17,137
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 800 amp	1.00 ea	15.4	1,796	11,419	-	-	13,214.47 /ea	13,214
Switchboards, main circuit breaker, 3 pole, 3 wire, to 600 volt, 1200 amp	1.00 ea	18.2	2,122	14,915	-	-	17,037.38 /ea	17,037
Panelboards, 3 pole 4 wire, main lugs, 277/480 V, 225 amp, no main breaker	6.00 ea	40.0	4,669	9,453	-	-	2,353.82 /ea	14,123
Motor starter, size 1, FVNR, type B, circuit breaker, NEMA 12	4.00 ea	12.3	1,437	13,454	-	-	3,722.79 /ea	14,891
Circuit breaker, type A, 100 amp, NEMA 12	5.00 ea	10.3	1,197	8,675	-	-	1,974.37 /ea	9,872
Motor control centers, incoming line, main lug only, copper, 600 amp, NEMA 1	1.00 ea	10.0	1,167	2,257	-	-	3,424.50 /ea	3,425

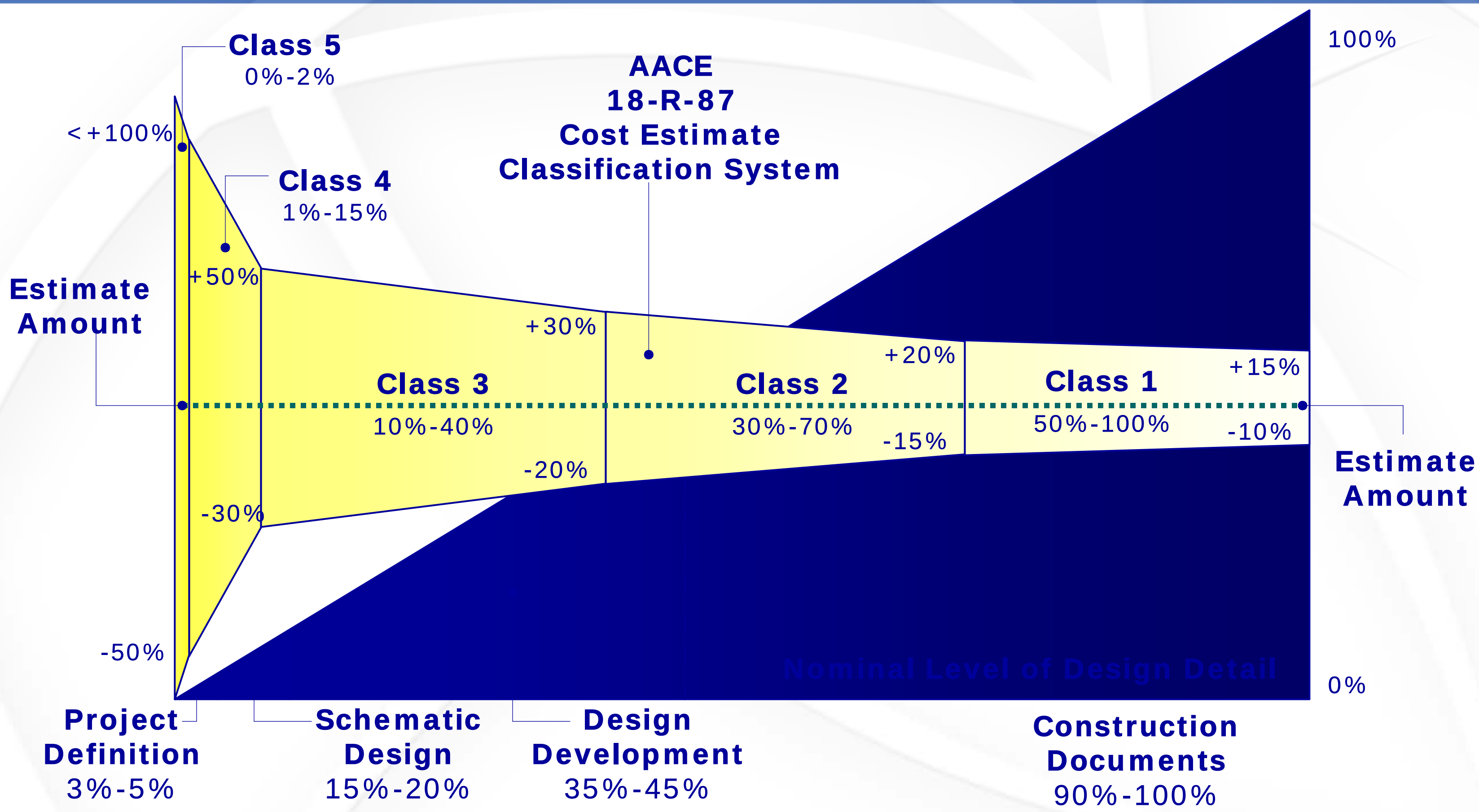
Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
RFW510 Administration								
Motor control centers, incoming line, for copper bus, add	1.00 ea		-	211	-	-	210.68 /ea	211
Motor control centers, incoming line, for 65000 amp bus bracing, add	1.00 ea		-	313	-	-	313.33 /ea	313
Motor control centers, incoming line, for NEMA 12 enclosure, add	1.00 ea		-	271	-	-	270.86 /ea	271
Motor control centers, incoming line, for 1/4" x 2" ground bus, add	1.00 ea	0.7	78	174	-	-	252.21 /ea	252
Motor control centers, pilot light, push to test, & select switch	4.00 ea	2.7	311	1,685	-	-	499.16 /ea	1,997
RFW510 Administration		**1,025.2**	**118,340**	**322,179**			**/LS**	**440,518**
RFW900 MISC FACILITY								
Temp power	1.00 ls		-	-	157,031	-	157,031.47 /ls	157,031
Demo based on percentage of install MH, includes disposal	1.00 LS	1,200.0	127,463	35,406		4,426	167,294.74 /LS	167,295
Misc Electrical allowance	1.00 ls		-	-	177,031	-	177,031.46 /ls	177,031
RFW900 MISC FACILITY		**1,200.0**	**127,463**	**35,406**	**334,063**	**4,426**	**/LS**	**501,358**
05M TI WRP 02 MCCs - ELECTRICAL EQUIPMENT	**1.00 LS**	**10,118.4**	**1,159,801**	**4,958,011**	**334,063**	**21,544**	**6,473,418.56 /LS**	**6,473,419**

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
03M TI WRP 01 HEADWORKS MITIGATION								
D-E-3 001 Hazardous Area		225.5	26,319	78,204			/LS	104,522
E-1 LS01 MCC NEW, misc dist		690.3	80,020	273,763			/LS	353,783
E-2 001 MCC A - MCC B		660.1	76,328	172,575			/LS	248,903
E-3 001 Electrical Room (incl LS)		36.6	4,269	15,180			/LS	19,450
E-7 001 Panels and loads		136.8	15,797	34,813			/LS	50,611
RFW171 Conduit entrance grouting/sealing		20.0	2,335	3,541			/LS	5,875
RFW600 Consulting		40.0	10,622				/LS	10,622
RFW610 Sealing		93.4	9,837	4,003			/LS	13,840
RFW615 Watertight Openings		315.0	41,429	166,321			/LS	207,750
RFW900 MISC FACILITY		400.0	42,488	3,541	73,664	4,426	/LS	124,118
03M TI WRP 01 HEADWORKS MITIGATION	**1.00 LS**	**2,617.7**	**309,444**	**751,940**	**73,664**	**4,426**	**1,139,473.82 /LS**	**1,139,474**

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
04M TI WRP 04 EFFLUENT PP								
E-2 401 E-2 Panels, Ltg		12.0	1,401	4,868			/LS	6,269
E-3 401 MCC distribution		1,517.6	175,347	2,163,860		18,029	/LS	2,357,236
RFW-403 Allowances for undefined electrical		153.6	17,703	35,406			/LS	53,109
RFW171 Conduit entrance grouting/sealing		20.0	2,335	3,541			/LS	5,875
RFW610 Sealing		186.9	19,674	8,005			/LS	27,679
RFW615 Watertight Openings		272.0	34,322	101,404			/LS	135,725
RFW900 MISC FACILITY				35,406	124,774	4,426	/LS	164,606
04M TI WRP 04 EFFLUENT PP	**1.00 LS**	**2,162.1**	**250,781**	**2,352,491**	**124,774**	**22,455**	**2,750,500.39 /LS**	**2,750,500**

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
05M TI WRP 02 MCCs - ELECTRICAL EQUIPMENT								
RFW171 Conduit entrance grouting/sealing		160.0	18,678	28,325			/LS	47,003
RFW501 Biosolids		1,188.2	137,637	741,988			/LS	879,626
RFW502 Digesters		443.9	51,414	253,690			/LS	305,104
RFW503 Filters		3,887.2	450,480	2,585,124		15,939	/LS	3,051,543
RFW504 Aeration Tanks		548.0	63,267	187,001			/LS	250,268
RFW505 Compressor		545.6	63,028	200,726			/LS	263,754
RFW506 Final Tanks		130.0	15,015	37,380			/LS	52,395
RFW507 Primary Tanks		108.1	12,499	32,043			/LS	44,542
RFW508 Chlorination		602.5	69,654	415,404		1,179	/LS	486,238
RFW509 Sludge Treat		279.6	32,327	118,743			/LS	151,070
RFW510 Administration		1,025.2	118,340	322,179			/LS	440,518
RFW900 MISC FACILITY		1,200.0	127,463	35,406	334,063	4,426	/LS	501,358
05M TI WRP 02 MCCs - ELECTRICAL EQUIPMENT	**1.00 LS**	**10,118.4**	**1,159,801**	**4,958,011**	**334,063**	**21,544**	**6,473,418.56 /LS**	**6,473,419**

AACE – Classification System



Construction Cost Estimate Accuracy Ranges

CH2MHILL

Estimate Class	Class 5	Class 4	Class 3	Class 2	Class 1
LEVEL OF PROJECT DEFINITION Expressed as a % of complete definition	**0% to 2%**	**1% to 15%**	**10% to 40%**	**30% to 70%**	**50% to 100%**
END USAGE Typical Purpose of Estimate	**Concept Screening**	**Study or Feasibility**	**Budget Authorization, or Control**	**Control or Bid / Tender**	**Check Estimate or Bid / Tender**
METHODOLOGY Typical estimating method	**Capacity Factored, Parametric Models, Judgment, or Analogy**	**Equipment Factored or Parametric Models**	**Semi-Detailed Unit Costs with Assembly Level Line Items**	**Detailed Unit Cost with Forced Detailed Take-Off**	**Detailed Unit Cost with Detailed Take-Off**
EXPECTED ACCURACY RANGE Typical variation in low and high ranges [a]	**L: -20% to -50%** **H: +30% to +100%**	**L: -15% to -30%** **H: +20% to +50%**	**L: -10% to -20%** **H: +10% to +30%**	**L: -5% to -15%** **H: +5% to +20%**	**L: -3% to -10%** **H: +3% to +15%**
PREPARATION EFFORT Typical degree of effort relative to least cost index of 1 [b]	**1**	**2 to 4**	**3 to 10**	**4 to 20**	**5 to 100**
REFINED CLASS DEFINITION	Class 5 estimates are generally prepared based on very limited information, and subsequently have very wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systematic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with very little effort expended - sometimes requiring less than 1 hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation.	Class 4 estimates are generally prepared based on very limited information, and subsequently have very wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 5% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems and preliminary engineered process and utility equipment lists. Level of Project Definition Required: 1% to 15% of full project definition.	Class 3 estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. As such, they typically form the initial control estimate against which all actual costs and resources will be monitored. Typically, engineering is from 10% to 40% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, preliminary piping and instrument diagrams, utility flow diagrams, preliminary piping and instrument diagrams, plot plan, developed layout drawings, and essentially complete engineering process and utility equipment lists. Level Of Project Definition Required: 10% to 40% of full project definition.	Class 2 estimates are generally prepared to form a detailed control baseline against which all project work is monitored in terms of cost and progress control. For contractors, this class of estimate is often used as the "bid" estimate to establish contract value. Typically, engineering is from 30% to 70% complete, and would comprise at a minimum the following: Process flow diagrams, utility flow diagrams, piping and instrument flow diagrams, heat and material balances, final plot plan, final layout drawings, complete engineered process and utility equipment lists, single line diagrams for electrical, electrical equipment and motor schedules, vendor quotations, detailed project execution plans, resourcing and work force plans, etc.	Class 1 estimates are generally prepared for discrete parts or sections of the total project rather than generating this level of detail for the entire project. The parts of the project estimated at this level of detail will typically be used by subcontractors for bids, or by owners for check estimates. The updated estimate is often referred to as the current control estimate and becomes the new baseline for cost/schedule control of the project. Class 1 estimates may be prepared for parts of the project to comprise a fair price estimate or bid check estimate to compare against a contractor's bid estimate, or to evaluate/dispute claims. Typically, engineering is from 50% to 100% complete, and would comprise virtually all engineering and design documentation of the project, and complete project execution and commissioning plans. Level for Project Definition Required: 50% to 100% of full project definition.
END USAGE DEFINED	Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.	Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.	Class 3 estimates are typically prepared to support full project funding requests, and become the first of the project phase "control estimate" against which all actual costs and resources will be monitored for variations to the budget. They are used as the project budget until replaced by more detailed estimates. In many owner organizations, a Class 3 estimate may be the last estimate required and could well form the only basis for cost/schedule control.	Class 2 estimates are typically prepared as the detailed control baseline against which all actual costs an resources will now be monitored for variation to the budget, and form a part of the change/variation control program.	Class 1 estimates are typically prepared to form a current control estimate to be used as the final control baseline against which all actual coasts and resources will now be monitored for variations to the budget, and form a part of the change/variation control program. They may be used to evaluate bid checking, to support vendor/contractor negotiations, or for claim evaluations and dispute resolution.
ESTIMATING METHODS USED	Class 5 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques.	Class 4 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques.	Class 3 estimates usually involve more deterministic estimating methods that stochastic methods. They usually involve a high degree of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring and other stochastic methods may be used to estimate less-significant areas of the project.	Class 2 estimates always involve a high degree of deterministic estimating methods. Class 2 estimates are prepared in great detail, and often involve tens of thousands of unit cost line items. For those areas of the project still undefined, an assumed level of detailed takeoff (forced detail) may be developed to use as line items in the estimate instead of relying on factoring methods.	Class 1 estimates involve the highest degree of deterministic estimating methods, and require a great amount of effort. Class 1 estimates are prepared in great detail, and thus are usually performed on only the most important or critical areas of the project. All items in the estimate are usually unit cost line items based on actual design quantities.
EXPECTED ACCURACY RANGE	Typical accuracy ranges for Class 5 estimates are -20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 3 estimates are -10% to -20% on the low side, and +10% to +30% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 2 estimates are -5% to -15% on the low side, and +5% to +20% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 1 estimates are -3% to -10% on the low side, and +3% to +15% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.
EFFORT TO PREPARE (for US$20MM project):	As little as 1 hour or less to prepare to perhaps more than 200 hours, depending on the project and the estimating methodology used.	Typically, as little as 20 hours or less to perhaps more than 300 hours, depending on the project and the estimating methodology used.	Typically, as little as 150 hours or less to perhaps more than 1500 hours, depending on the project and the estimating methodology used.	Typically, as little as 300 hours or less to perhaps more than 3000 hours, depending on the project and the estimating methodology used. Bid Estimates typically require more effort than estimates used for funding or control purposes	Class 1 estimates require the most effort to create, and as such are generally developed for only selected areas of the project, or for bidding purposes. A complete Class 1 estimate may involve as little as 600 hours or less, to perhaps more than 6,000 hours, depending on the project and the estimating methodology used. Bid estimate typically require more effort than estimates used for funding or control purposes.
ANSI Standard Reference Z94.2-1989 name; Alternate Estimate Names, Terms, Expressions, Synonyms:	Order of Magnitude Estimate; Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of thumb.	Budget Estimate; Screening, top-down, feasibility, authorization, factored, pre-design, pre-study.	Budget Estimate; Budget, scope, sanction, semi-detailed, authorization, preliminary control, concept study, development, basic engineering phase estimate, target estimate.	Definitive Estimate; Detailed Control, forced detail, execution phase, master control, engineering, bid, tender, change order estimate.	Definitive Estimate; Full detail, release, fall-out, tender, firm price, bottoms-up, final, detailed control, forced detail, execution phase, master control, fair price, definitive, change order estimate.

Estimate Class	Class 5	Class 4	Class 3	Class 2	Class 1
Estimate Input Checklist and Maturity Index	Class 5	Class 4	Class 3	Class 2	Class 1
GENERAL PROJECT DATA					
Project Scope Description	General	Preliminary	Defined	Defined	Defined
Plant Production / Facility Capacity	Assumed	Preliminary	Defined	Defined	Defined
Plant Location	General	Approximate	Specific	Specific	Specific
Soils & Hydrology	None	Preliminary	Defined	Defined	Defined
Integrated Project Plan	None	Preliminary	Defined	Defined	Defined
Project Master Schedule	None	Preliminary	Defined	Defined	Defined
Escalation Strategy	None	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	None	Preliminary	Defined	Defined	Defined
Project Code of Accounts	None	Preliminary	Defined	Defined	Defined
Contracting Strategy	Assumed	Assumed	Preliminary	Defined	Defined

ENGINEERING DELIVERABLES:	Class 5	Class 4	Class 3	Class 2	Class 1
Block Flow Diagrams	Started / Preliminary	Preliminary / Complete	Complete	Complete	Complete
Plot Plans		Started	Preliminary / Complete	Complete	Complete
Process Flow Diagrams (PFDs)		Started / Preliminary	Preliminary / Complete	Complete	Complete
Utility Flow Diagrams (UFDs)		Started / Preliminary	Preliminary / Complete	Complete	Complete
Piping & Instrument Diagrams (P&IDS)		Started	Preliminary / Complete	Complete	Complete
Heat and Material Balances		Started	Preliminary / Complete	Complete	Complete
Process Equipment List		Started / Preliminary	Preliminary / Complete	Complete	Complete
Utility Equipment List		Started / Preliminary	Preliminary / Complete	Complete	Complete
Electrical One Line Drawings		Started / Preliminary	Preliminary / Complete	Complete	Complete
Specifications and Datasheets		Started	Preliminary / Complete	Complete	Complete
General Equipment Arrangement Drawings		Started	Preliminary / Complete	Complete	Complete
Spare Parts Lists			Started / Preliminary	Preliminary	Complete
Architectural Details / Schedules		Started	Preliminary / Complete	Complete	Complete
Structural Details		Started	Preliminary / Complete	Complete	Complete
Mechanical Discipline Drawings			Started	Preliminary	Preliminary / Complete
Electrical Discipline Drawings			Started	Preliminary	Preliminary / Complete
System Discipline Drawings			Started	Preliminary	Preliminary / Complete
Civil/Site Discipline Drawings			Started	Preliminary	Preliminary / Complete
Demolition Details		Started	Preliminary / Complete	Complete	Complete

Preliminary Estimates: LASAN – Terminal Island Water Reclamation Plant – Mitigation

PREPARED FOR: WILLIAM MCMILLIN/NJO

PREPARED BY: Robert Wells/PDX

DATE: NOVEMBER 24, 2015

Background

The purpose of the estimate is to determine the value of work to modify facility and process components to avoid destruction by water ingress due to a tsunami event. The estimates for facilities at Class V level of definition (per request) have been prepared based on several assumptions. The value of the work is determined in 2015 dollars with no escalation for future dates. The assumption is that labor resources, whether local or imported, will be costed at 2015 union rates.
The strategy for this mitigation is to construct a 6' above grade 12" thick concrete wall, on a 6' wide by 2' deep footer, and utilize watertight swing doors to allow for passage.

Cost Basis

The drawings from previous projects were utilized to provide a characterization of the work. These drawings and the scope included information from which to determine the site footprint, which was estimated to have a perimeter of 5800 lineal feet, and to include 2 openings for ingress and egress to the site.

Costs

The estimates were based on line item takeoffs from the drawings. The estimate includes cost allocations of indirect costs, general requirements, markups, bond and taxes. The costs in the attached estimate reports do not include an allowance for market conditions.

The markups included in the reported cost are as follows: Subcontractor and Prime Contractor general requirements, overhead and profit (total), 44%; Bonds and Insurance, 2%, Estimating Contingency, 15%.

Table 1: Estimated Project Costs (Class V Range)

Project	-50% accuracy limit	As reported cost	+100% accuracy limit
Terminal Island Water Reclamation Plant	$1.87M	**$3.73M**	$7.46M

In order to standardize a value by which to compare alternatives, it is advisable and an industry standard for municipalities to use the 80th percentile of the range of costs. For these projects, the following values represent the 80th percentile:

Site Wall: $6.34M

Attachments

The attached reports are organized by Facility and Work Activity, which generally represents a portion or component of the facility or process.

- Detail Reports, 3pp
- AACE Classification System, 3pp

Facility Summary

Job Size: 1 LS
Duration:

Project: LASAN EPA CLIMATE RISK
Project No.: 664398.0D.05
Design Stage: 0

Estimator: Wells R
Revision / Date: 0 / SEPT 2015
Estimate Class: 6

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
07W Wall around TI WRP								
RFW800 Wall								
03-35-10-00 Concrete Miscellaneous Items								
Form oil, coverage varies greatly, maximum, includes material only	238.93 gal		-	8,368	-	-	35.02 /gal	8,368
Waterstop, rubber, center bulb, split, 3/8" thick x 6" wide	1,400.00 lf	77.238	8,310	34,827	-	-	30.81 /lf	43,136
Waterstop, rubber, field union, 3/8" x 6" wide, walls	117.00 ea	18.720	2,014	7,018	-	-	77.20 /ea	9,032
03-35-10-00 Concrete Miscellaneous Items		**95.958**	**10,324**	**50,212**			**/CY**	**60,536**
07-00-02-00 Thermal & Moisture Protection, Waterproofing								
Waterproofing, integral, walls, cols, beams, add to cost of reg. conc.	1,742.22 cy		-	37,192	-	-	21.35 /cy	37,192
07-00-02-00 Thermal & Moisture Protection, Waterproofing				**37,192**			**/SF**	**37,192**
*** unassigned ***								
C.I.P. concrete forms, wall, wood bulkhead with 2 piece keyway, 1 use, includes erecting, bracing, stripping and cleaning	1,400.00 lf	253.582	26,568	4,693	-	-	22.33 /lf	31,261
Cip concret forms,walls,steel framed plywd,over 8'16'hg,based 50 us purchsd forms,4 us bracing lumber,includes erecting,bracing,stripping and cleaning	89,600.00 sfca	5,600.000	586,707	107,493	-	-	7.75 /sfca	694,200
Reinforcing Steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	62.22 ton	663.702	79,473	109,776	-	-	3,041.52 /ton	189,249
Reinforcing in place, unloading & sorting, add - walls, cols, beams	62.22 ton	34.844	4,051	-	-	807	78.07 /ton	4,857
Reinforcing, crane cost for handling, add to above, walls, cols, beams	62.22 ton	37.875	4,403	-	-	877	84.85 /ton	5,280
Concrete, ready mix, regular weight, walls/cols/beams, 4000 psi	1,742.22 cy		-	319,669	-	-	183.48 /cy	319,669
Structural concrete, placing, walls, pumped, 15" thick, includes strike off & consolidation, excludes material	1,742.22 cy	929.179	84,500	-	-	15,019	57.12 /cy	99,519
Finishing: break ties & patch voids (walls, cols or beams)	44,800.00 sf	663.488	65,125	2,371	-	-	1.51 /sf	67,496
*** unassigned ***		**8,182.670**	**850,827**	**544,003**		**16,702**		**1,411,532**
RFW800 Wall		**8,278.628**	**861,151**	**631,407**		**16,702**		**1,509,260**
RFW810 Footer								
03-35-10-00 Concrete Miscellaneous Items								
Waterstop, PVC, dumbbell type, 3/8" thick x 6" wide	5,600.00 lf	308.952	33,239	35,963	-	-	12.36 /lf	69,201
Waterstop, fittings, rubber, flat, dumbbell or center bulb, field union, 3/8" thick x 6" wide	467.00 ea	74.720	8,039	28,013	-	-	77.20 /ea	36,052
03-35-10-00 Concrete Miscellaneous Items		**383.672**	**41,277**	**63,976**			**/CY**	**105,253**
31-20-07-15 Earthworks, Sitework, Borrow								
Aggregate for earthwork,crushed stone,1.40 tons per cy, 3/8",spread with 200 hp dozer,includes load pit and haul,2 miles rnd trip,excludes compaction	2,903.70 lcy	135.516	12,687	130,634	-	17,404	55.35 /lcy	160,725
31-20-07-15 Earthworks, Sitework, Borrow		**135.516**	**12,687**	**130,634**		**17,404**	**/CY**	**160,725**
31-20-15-00 Earthworks, Sitework, Hauling and Dump Fees								
Hauling, excavated or borrow material, loose cubic yards, 5 mile round trip, 1.1 loads/hour, 20 C.Y. dump trailer, highway haulers, excludes loading	5,807.41 lcy	324.866	28,430	-	-	40,508	11.87 /lcy	68,938
31-20-15-00 Earthworks, Sitework, Hauling and Dump Fees		**324.866**	**28,430**			**40,508**	**/CY**	**68,938**
31-25-01-00 Earthworks, Structural, Excavation								
Excavating, trench or continuous footing, common earth, 1/2 C.Y. excavator, 1' to 4' deep, excludes sheeting or dewatering	5,807.41 bcy	464.593	45,449	-	-	15,384	10.48 /bcy	60,833
Excavating, trench or continuous footing, common earth, for tamping backfilled trenches, 6" lift, air tamped, excludes sheeting or dewatering, add	2,903.70 ecy	232.296	19,977	-	-	2,059	7.59 /ecy	22,036
Excavating, trench or continuous footing, common earth, trim sides and bottom for concrete pours, excludes sheeting or dewatering	33,600.00 sf	537.600	46,902	-	-	1,315	1.44 /sf	48,217
Excavating, trench backfill, 1 C.Y. bucket, 100' haul, front end loader, wheel mounted, excludes dewatering	2,903.70 lcy	174.222	17,730	-	-	5,686	8.06 /lcy	23,417
31-25-01-00 Earthworks, Structural, Excavation		**1,408.711**	**130,058**			**24,445**	**/CY**	**154,503**
*** unassigned ***								
C.I.P. concrete forms, footing, continuous wall, dowel supports, 1 use, more than 20' below grade, includes erecting, bracing, stripping and cleaning	5,600.00 lf	358.400	36,624	8,299	-	-	8.02 /lf	44,923
C.I.P. concrete forms, footing, keyway, tapered wood, 2" x 4", 4 use, includes erecting, bracing, stripping and cleaning	5,600.00 lf	84.504	9,091	1,976	-	-	1.98 /lf	11,067
Reinforcing Steel, in place, footings, #4 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	149.33 ton	2,275.551	272,480	263,463	-	-	3,588.91 /ton	535,943
Reinforcing steel, unload and sort, add to base	149.33 ton	83.626	9,722	-	-	1,936	78.07 /ton	11,658
Reinforcing steel, crane cost for handling, average, add	149.33 ton	90.899	10,567	-	-	2,104	84.85 /ton	12,672
Struct concrete,ready mix,normal wt,4000 psi,includes local aggregate,sand,portland cement and water,delivered,excludes all additives and treatments	2,563.56 cy		-	470,371	-	-	183.48 /cy	470,371

ch2m

Facility Summary

Job Size: 1 LS
Duration:

Project: LASAN EPA CLIMATE RISK
Project No.: 664398.0D.05
Design Stage: 0

Estimator: Wells R
Revision / Date: 0 / SEPT 2015
Estimate Class: 6

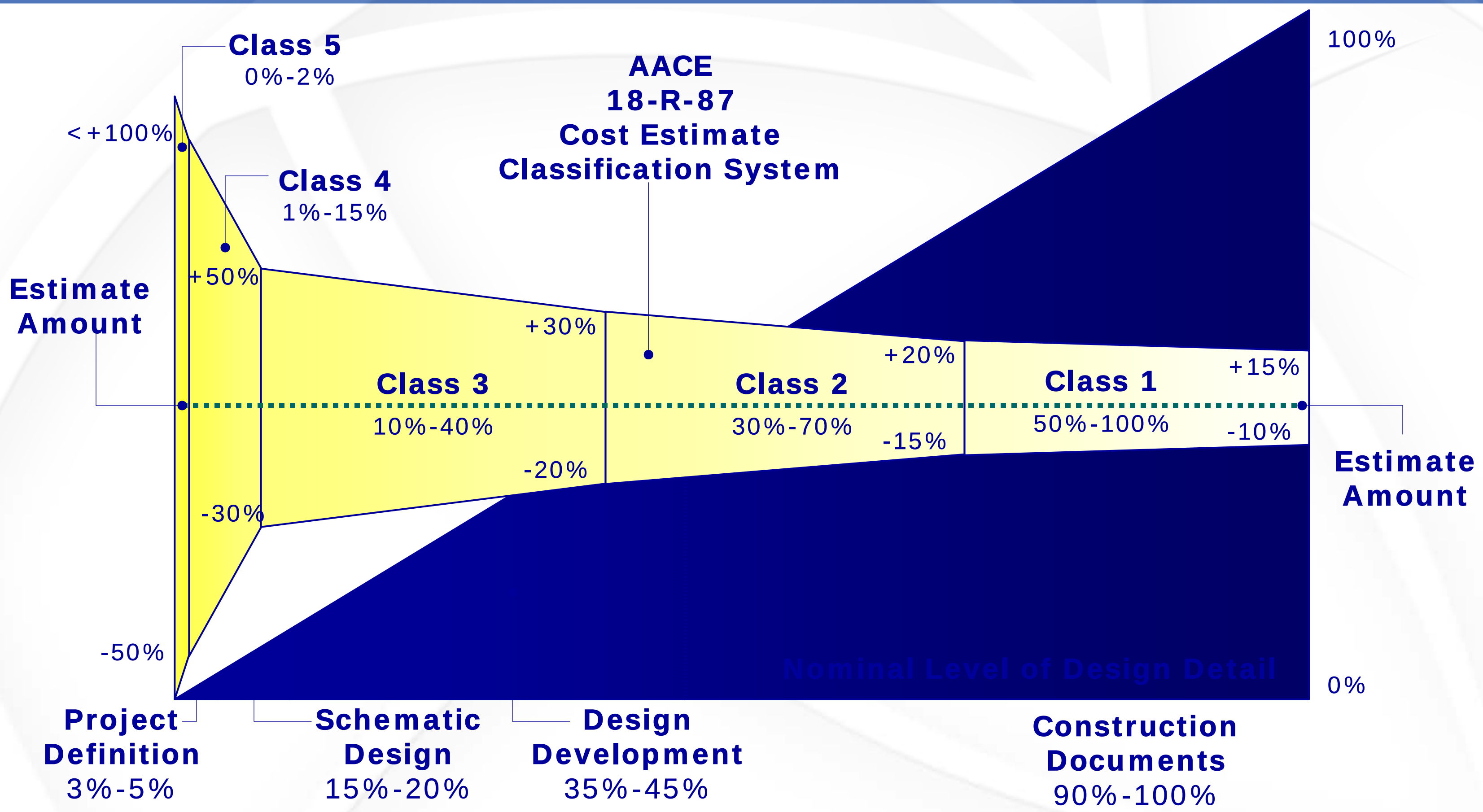
Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Total Cost/Unit	Total Amount
* unassigned *								
Structural concrete, placing, continuous footing, deep, direct chute, includes strike off & consolidation, excludes material	2,563.56 cy	878.941	77,916	-	-	1,599	31.02 /cy	79,515
* unassigned *		3,771.921	416,401	744,109		5,639		1,166,149
RFW810 Footer		6,024.687	628,853	938,719		87,997		1,655,569
RFW820 Demo fence								
02-01-09-01 Demolition, Other								
Selective demolition, chain link fences & gates, fence, 12' high	2,800.00 lf	168.000	15,540	-	-	3,403	6.77 /lf	18,943
02-01-09-01 Demolition, Other		168.000	15,540			3,403	/SF	18,943
RFW820 Demo fence		168.000	15,540			3,403		18,943
RFW830 Swing Doors								
* unassigned *								
Watertight swing door, custom build, turnkey, subcontract allowance	2.00 EA				391,066	-	195,533.23 /EA	391,066
* unassigned *					391,066			391,066
RFW830 Swing Doors					391,066			391,066
RFW840 Demo Wall								
02-01-01-00 General Site Demolition								
Selective demolition, rubbish handling, dumpster, 40 c.y., 13 ton capacity, weekly rental, includes one dump per week, cost added to demolition cost.	20.00 week		-	27,346	-	-	1,367.31 /week	27,346
Selective demolition, rubbish handling, loading & trucking, machine loading truck, includes 2 mile haul, cost to be added to demolition cost.	311.11 cy	82.964	7,571	-	-	2,689	32.98 /cy	10,260
02-01-01-00 General Site Demolition		82.964	7,571	27,346		2,689	/AC	37,606
02-01-02-99 Selective Demolition, Cut-out, Concrete, Other								
Selective concrete demolition, average reinforcing, break into small pieces, excludes shoring, bracing, saw torch cutting, loading, hauling, dumping	311.11 cy	777.775	67,468	-	-	5,840	235.64 /cy	73,309
02-01-02-99 Selective Demolition, Cut-out, Concrete, Other		777.775	67,468			5,840	/CF	73,309
RFW840 Demo Wall		860.739	75,039	27,346		8,530		110,915
RFW850 Contaminated Materials Allowance								
33-55-01-00 Utility Trenching, Excavate Trench								
Dump fees, trench spoils	1.00 LS		-	-	44,107	-	44,106.64 /LS	44,107
33-55-01-00 Utility Trenching, Excavate Trench					44,107		/CY	44,107
RFW850 Contaminated Materials Allowance					44,107			44,107
07W Wall around TI WRP	**1.00 LS**	**15,332.053**	**1,580,583**	**1,597,472**	**435,173**	**116,631**	**3,729,859.80 /LS**	**3,729,860**

Job Size: 1 LS	Project: LASAN EPA CLIMATE RISK	Estimator: Wells R
Duration:	Project No.: 664398.0D.05	Revision / Date: 0 / SEPT 2015
	Design Stage: 0	Estimate Class: 6

Partial Totals

Description	Amount	Totals	Hours	Rate	% of Total
Labor	1,580,583		15,332.053 hrs		42.38%
Material	1,597,472				42.83%
Subcontract	435,173				11.67%
Equipment	116,631		3,077.777 hrs		3.13%
Other					
Total	**3,729,859**	**3,729,859**			100.00
Preliminary Engineering					
Final Engineering and Precon					
SDC - Construction Management					
Total Design		**3,729,859**			
Partial Total		**3,729,859**			

AACE – Classification System



Construction Cost Estimate Accuracy Ranges

Estimate Class	Class 5	Class 4	Class 3	Class 2	Class 1
LEVEL OF PROJECT DEFINITION Expressed as a % of complete definition	**0% to 2%**	**1% to 15%**	**10% to 40%**	**30% to 70%**	**50% to 100%**
END USAGE Typical Purpose of Estimate	**Concept Screening**	**Study or Feasibility**	**Budget Authorization, or Control**	**Control or Bid / Tender**	**Check Estimate or Bid / Tender**
METHODOLOGY Typical estimating method	**Capacity Factored, Parametric Models, Judgment, or Analogy**	**Equipment Factored or Parametric Models**	**Semi-Detailed Unit Costs with Assembly Level Line Items**	**Detailed Unit Cost with Forced Detailed Take-Off**	**Detailed Unit Cost with Detailed Take-Off**
EXPECTED ACCURACY RANGE Typical variation in low and high ranges [a]	**L: -20% to -50%** **H: +30% to +100%**	**L: -15% to -30%** **H: +20% to +50%**	**L: -10% to -20%** **H: +10% to +30%**	**L: -5% to -15%** **H: +5% to +20%**	**L: -3% to -10%** **H: +3% to +15%**
PREPARATION EFFORT Typical degree of effort relative to least cost index of 1 [b]	**1**	**2 to 4**	**3 to 10**	**4 to 20**	**5 to 100**
REFINED CLASS DEFINITION	Class 5 estimates are generally prepared based on very limited information, and subsequently have very wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systematic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with very little effort expended - sometimes requiring less than 1 hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation.	Class 4 estimates are generally prepared based on very limited information, and subsequently have very wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 5% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems and preliminary engineered process and utility equipment lists. Level of Project Definition Required: 1% to 15% of full project definition.	Class 3 estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. As such, they typically form the initial control estimate against which all actual costs and resources will be monitored. Typically, engineering is from 10% to 40% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, preliminary piping and instrument diagrams, utility flow diagrams, preliminary piping and instrument diagrams, plot plan, developed layout drawings, and essentially complete engineering process and utility equipment lists. Level Of Project Definition Required: 10% to 40% of full project definition.	Class 2 estimates are generally prepared to form a detailed control baseline against which all project work is monitored in terms of cost and progress control. For contractors, this class of estimate is often used as the "bid" estimate to establish contract value. Typically, engineering is from 30% to 70% complete, and would comprise at a minimum the following: Process flow diagrams, utility flow diagrams, piping and instrument flow diagrams, heat and material balances, final plot plan, final layout drawings, complete engineered process and utility equipment lists, single line diagrams for electrical, electrical equipment and motor schedules, vendor quotations, detailed project execution plans, resourcing and work force plans, etc.	Class 1 estimates are generally prepared for discrete parts or sections of the total project rather than generating this level of detail for the entire project. The parts of the project estimated at this level of detail will typically be used by subcontractors for bids, or by owners for check estimates. The updated estimate is often referred to as the current control estimate and becomes the new baseline for cost/schedule control of the project. Class 1 estimates may be prepared for parts of the project to comprise a fair price estimate or bid check estimate to compare against a contractor's bid estimate, or to evaluate/dispute claims. Typically, engineering is from 50% to 100% complete, and would comprise virtually all engineering and design documentation of the project, and complete project execution and commissioning plans. Level for Project Definition Required: 50% to 100% of full project definition.
END USAGE DEFINED	Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.	Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.	Class 3 estimates are typically prepared to support full project funding requests, and become the first of the project phase "control estimate" against which all actual costs and resources will be monitored for variations to the budget. They are used as the project budget until replaced by more detailed estimates. In many owner organizations, a Class 3 estimate may be the last estimate required and could well form the only basis for cost/schedule control.	Class 2 estimates are typically prepared as the detailed control baseline against which all actual costs an resources will now be monitored for variation to the budget, and form a part of the change/variation control program.	Class 1 estimates are typically prepared to form a current control estimate to be used as the final control baseline against which all actual coasts and resources will now be monitored for variations to the budget, and form a part of the change/variation control program. They may be used to evaluate bid checking, to support vendor/contractor negotiations, or for claim evaluations and dispute resolution.
ESTIMATING METHODS USED	Class 5 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques.	Class 4 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques.	Class 3 estimates usually involve more deterministic estimating methods that stochastic methods. They usually involve a high degree of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring and other stochastic methods may be used to estimate less-significant areas of the project.	Class 2 estimates always involve a high degree of deterministic estimating methods. Class 2 estimates are prepared in great detail, and often involve tens of thousands of unit cost line items. For those areas of the project still undefined, an assumed level of detailed takeoff (forced detail) may be developed to use as line items in the estimate instead of relying on factoring methods.	Class 1 estimates involve the highest degree of deterministic estimating methods, and require a great amount of effort. Class 1 estimates are prepared in great detail, and thus are usually performed on only the most important or critical areas of the project. All items in the estimate are usually unit cost line items based on actual design quantities.
EXPECTED ACCURACY RANGE	Typical accuracy ranges for Class 5 estimates are -20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 3 estimates are -10% to -20% on the low side, and +10% to +30% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 2 estimates are -5% to -15% on the low side, and +5% to +20% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.	Typical accuracy ranges for Class 1 estimates are -3% to -10% on the low side, and +3% to +15% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.
EFFORT TO PREPARE (for US$20MM project):	As little as 1 hour or less to prepare to perhaps more than 200 hours, depending on the project and the estimating methodology used.	Typically, as little as 20 hours or less to perhaps more than 300 hours, depending on the project and the estimating methodology used.	Typically, as little as 150 hours or less to perhaps more than 1500 hours, depending on the project and the estimating methodology used.	Typically, as little as 300 hours or less to perhaps more than 3000 hours, depending on the project and the estimating methodology used. Bid Estimates typically require more effort than estimates used for funding or control purposes	Class 1 estimates require the most effort to create, and as such are generally developed for only selected areas of the project, or for bidding purposes. A complete Class 1 estimate may involve as little as 600 hours or less, to perhaps more than 6,000 hours, depending on the project and the estimating methodology used. Bid estimate typically require more effort than estimates used for funding or control purposes.
ANSI Standard Reference Z94.2-1989 name; Alternate Estimate Names, Terms, Expressions, Synonyms:	Order of Magnitude Estimate; Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of thumb.	Budget Estimate; Screening, top-down, feasibility, authorization, factored, pre-design, pre-study.	Budget Estimate; Budget, scope, sanction, semi-detailed, authorization, preliminary control, concept study, development, basic engineering phase estimate, target estimate.	Definitive Estimate; Detailed Control, forced detail, execution phase, master control, engineering, bid, tender, change order estimate.	Definitive Estimate; Full detail, release, fall-out, tender, firm price, bottoms-up, final, detailed control, forced detail, execution phase, master control, fair price, definitive, change order estimate.

Estimate Class	Class 5	Class 4	Class 3	Class 2	Class 1
Estimate Input Checklist and Maturity Index	Class 5	Class 4	Class 3	Class 2	Class 1
GENERAL PROJECT DATA					
Project Scope Description	General	Preliminary	Defined	Defined	Defined
Plant Production / Facility Capacity	Assumed	Preliminary	Defined	Defined	Defined
Plant Location	General	Approximate	Specific	Specific	Specific
Soils & Hydrology	None	Preliminary	Defined	Defined	Defined
Integrated Project Plan	None	Preliminary	Defined	Defined	Defined
Project Master Schedule	None	Preliminary	Defined	Defined	Defined
Escalation Strategy	None	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	None	Preliminary	Defined	Defined	Defined
Project Code of Accounts	None	Preliminary	Defined	Defined	Defined
Contracting Strategy	Assumed	Assumed	Preliminary	Defined	Defined
ENGINEERING DELIVERABLES:	**Class 5**	**Class 4**	**Class 3**	**Class 2**	**Class 1**
Block Flow Diagrams	Started / Preliminary	Preliminary / Complete	Complete	Complete	Complete
Plot Plans		Started	Preliminary / Complete	Complete	Complete
Process Flow Diagrams (PFDs)		Started / Preliminary	Preliminary / Complete	Complete	Complete
Utility Flow Diagrams (UFDs)		Started / Preliminary	Preliminary / Complete	Complete	Complete
Piping & Instrument Diagrams (P&IDS)		Started	Preliminary / Complete	Complete	Complete
Heat and Material Balances		Started	Preliminary / Complete	Complete	Complete
Process Equipment List		Started / Preliminary	Preliminary / Complete	Complete	Complete
Utility Equipment List		Started / Preliminary	Preliminary / Complete	Complete	Complete
Electrical One Line Drawings		Started / Preliminary	Preliminary / Complete	Complete	Complete
Specifications and Datasheets		Started	Preliminary / Complete	Complete	Complete
General Equipment Arrangement Drawings		Started	Preliminary / Complete	Complete	Complete
Spare Parts Lists			Started / Preliminary	Preliminary	Complete
Architectural Details / Schedules		Started	Preliminary / Complete	Complete	Complete
Structural Details		Started	Preliminary / Complete	Complete	Complete
Mechanical Discipline Drawings			Started	Preliminary	Preliminary / Complete
Electrical Discipline Drawings			Started	Preliminary	Preliminary / Complete
System Discipline Drawings			Started	Preliminary	Preliminary / Complete
Civil/Site Discipline Drawings			Started	Preliminary	Preliminary / Complete
Demolition Details		Started	Preliminary / Complete	Complete	Complete

APPENDIX H: REPLACE-IN-KIND AND ADAPTATION MEASURES COST METHODOLOGIES

Several methodologies were used to develop replace-in-kind costs and the costs of short- and long-term adaptation measures for LA Sanitation's assets. The following four costing methods were used during the assessment, and are described below:

- Association for the Advancement of Cost Engineering's (AACE) Class 5 cost estimates for replace-in-kind costs and adaptation measures
- Conceptual design report opinion of costs
- Conceptual-level cost curves for additional replace-in-kind costs
- Scaled costs for additional adaptation measures based on AACE Class 5 cost estimates for adaptation measures

Replace-in-kind Costs

Replace-in-kind costs were developed for the replacement of assets that may be damaged or destroyed during extreme events such as flooding from sea-level rise and coastal storm surge, tsunamis, mudslides. These intense events may occur more frequently due to climate change. Replace-in-kind costs were developed to clean and replace damaged or destroyed assets, such as:

- Clean facility and demolish/remove damaged assets
- Replace Electrical and Power – MCCs, backup generators, conduits, lights, etc.
- Replace HVAC – Fans and ducts
- Replace Instrumentation and Controls (I&C) – Control panels, etc.
- Replace Process Mechanical – pumps, motors, etc.
- Replace Structural/Architectural – doors, etc.

The replace-in-kind cost estimates were not developed to entirely replace a facility, and assumed site and civil structural elements of a facility such as the foundations, walls, equipment pads, and roofs remain intact. Two methods were used to estimate costs for the pumping plants and the Terminal Island Water Reclamation Plant (TIWRP). The AACE Class 5 cost estimates for replace-in-kind costs were performed for Pumping Plant No. 632 Sunset Boulevard, Pumping Plant No. 634 Temescal Canyon and TIWRP. Conceptual-level pumping plant cost curves were used for developing replace-in-kind costs for facilities added to the exercise including Pumping Plant No. 639 North Pulga Canyon, Pumping Plant No. 680 22nd and Signal, and Pumping Plant No. 686 Nissan Way. The preliminary opinion of costs of conceptual upgrades to stormwater Pumping Plant No. 647 were used for that facility.

The conceptual-level cost curves were in a CH2M costing tool applied to the exercise. The costs curves are a function of peak pump station capacity. The costs are localized using the Construction Cost Index (CCI) published by Engineering News Record (ENR). The base CCI in the tool was 7888 and the Los Angeles CCI used to scale the costs was 10981. The cost curve includes the following elements and percentages of the costs: mechanical (35-40%), electrical (10-15%), I&C (5%) and the remaining 30%-50% for structural, architectural, masonry and site civil. The percentages were adjusted to be consistent with the original costs developed using the AACE Class 5 method.

Adaptation Measures

The costs of short- and long-term adaptation measures for Pumping Plant No. 632 Sunset Boulevard, Pumping Plant No. 634 Temescal Canyon and TIWRP were estimated using the AACE Class 5 cost methodology. Those costs were scaled to estimate the costs for the additional facilities added to the exercise including Pumping Plant No. 639 North Pulga Canyon, Pumping Plant No. 680 22nd and Signal, Pumping Plant No. 686 Nissan Way, and stormwater Pumping Plant No. 647 Venice Beach. Costs were broken down into waterproofing and power adaptation measure categories from the two original pumping plants AACE Class 5 cost estimates. The costs for those adaptation measure categories were then scaled for the additional pumping plants based on their peak flow capacities. Additional costs were added for raising vents, adding bollards and replacing hatches based on engineering judgment.

carollo

Engineers...Working Wonders With Water®

in collaboration with

ch2m: