City of Long Beach

Climate Resiliency

Assessment Report

Appendices

Prepared by

Aquarium of the Pacific

December 2015

City of Long Beach Climate Resiliency Assessment Report Appendices

Prepared by:

The **Aquarium of the Pacific**

December 2015

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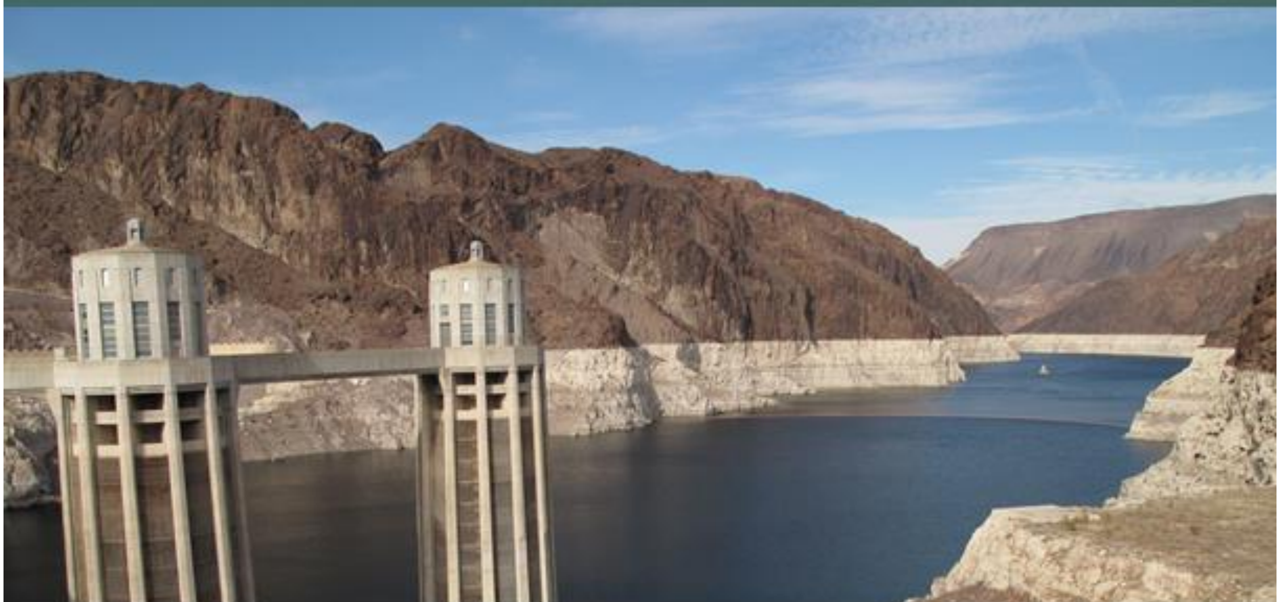
Appendix A

Pagan et al.'s (2015) Drought Report

Pagan et al.'s (2015) report entitled "Long Beach Climate Resiliency Study: Impacts on Water Supply and Demand." This 52 page report was commissioned as part of this resiliency study. Sections from the report's "Executive Summary" and conclusions section were used in the Drought section of this study, for this reason the authors of Pagan et al.'s report are included as co-authors in this study.



Long Beach Climate Resiliency Study: Impacts on Water Supply and Demand

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City of Long Beach Climate Resiliency Assessment Report Appendices

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Acronyms

AF	Acre-Feet
CMD	Center of Mass Date
CRB	Colorado River Basin
DWR	California Department of Water Resources
ESRI ArcGIS	Environmental Systems Research Institute's Geographic Information System
GCM	Global Climate Model
GEV	Generalized Extreme Value Distribution
GPCD	Gallons per Capita per Day
GHG	Greenhouse Gasses
HM	Hydrological Model
IPCC	Intergovernmental Panel on Climate Change
IRWP	Integrated Water Resources Plan
LA	City of Los Angeles
LAA	Los Angeles Aqueduct
LADWP	Los Angeles Department of Water and Power
LBWD	Long Beach Water Department
MAF	Million Acre-Feet
MK test	Mann Kendall Statistical Test
ML-OVB	Mono Lake and Owens Valley Basin
MLC	Mono Lake Committee
MWDSC	Metropolitan Water District of Southern California
ppmv	Parts per million by volume
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RUWMP	Regional Urban Water Management Plan
SJR-TLB	San Joaquin River and Tulare Lake Basin
SRB	Sacramento River Basin
SWC	Storm Water Capture
SWE	Snow Water Equivalent
SWP	State Water Project
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
UWMP	Urban Water Management Plan
WSAP	Metropolitan Water District's Water Supply Allocation Plan
WUS	Western United States

Figures and Tables

Executive Summary

The City of Long Beach is located in a semi-arid region with limited natural water supplies. Much like the rest of Southern California, Long Beach depends on imported water supplies to meet demand. Climate change will likely decrease the imported water supply availability, potentially leaving the city in shortage conditions. Therefore, it is necessary to study water supply in the regional context. Here we take a comprehensive multi-model approach to examine near term climate change impacts on all sources of water supply to Southern California and specific impacts to Long Beach. At the request of the City of Long Beach Mayor Robert Garcia, the authors and contributors to this report have:

- Evaluated how climate change will impact water supply to the City of Long Beach by the years 2030 and 2050; and
- Considered how Long Beach might become more climate resilient with respect to water supply.

Currently Long Beach obtains 39% of water supply from imported sources. Additionally, the 54% originating from groundwater is partially dependent upon imported sources for recharge. Recycled water makes up just 7% of the water supply portfolio. Plans to expand the recycled water system have not yet been realized. Currently, purchasing imported water is more cost effective for Long Beach than expanding the recycled water system or constructing a desalination facility. However, stress on imported water supplies from climate change could drive up prices and make expansions of local supplies more economically attractive. Long Beach has established itself as a leader in conservation, achieving a 31% reduction in gallons per capita per day (GPCD) from the 1980's to today. In the absence of that conservation, the City's reliance on its least reliable supply of water, the imported supplies, would be roughly double what it is today.

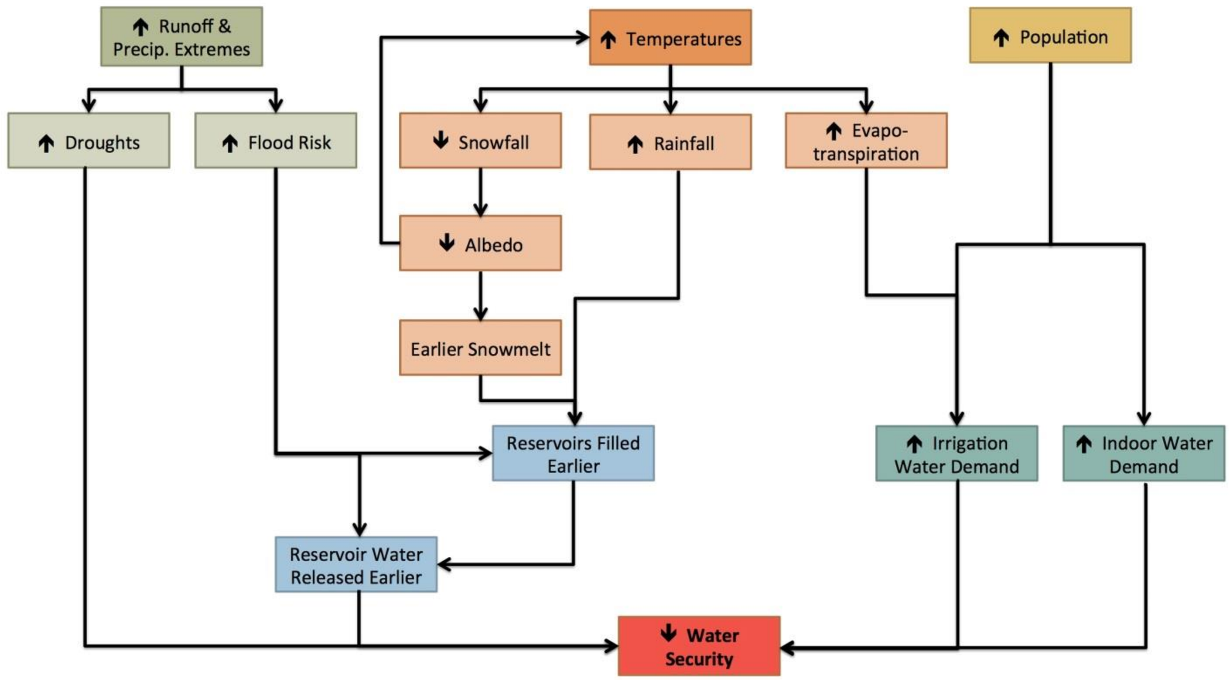
Impacts of Climate Change on Key Watersheds Outside of Long Beach:

Climate models project an increase from today's average surface temperatures of the Western U.S/ by 1 degree to 3 °F (0.5 to 1.7 °C) by the year 2030, and rise 2 degree to 4.5 degrees °F (1.2 to 2.5 °C) by the year 2050. The reliability of Southern California's imported supplies is highly dependent on the amount of precipitation in the watersheds of the Colorado River and the Sierra Nevada, specifically the form of precipitation as rain or snow. Imported supplies becomes less reliable as more precipitation comes in the form of rainfall and as the snowpack melts earlier in the year. Warmer temperatures will exacerbate both of these factors: more precipitation will come in the form of rain and what snowpack is formed, will melt earlier in the year. Projections of climate change suggest the Western United States (WUS) and the Southwest are particularly vulnerable due to this heavy reliance of temperature sensitive snowpack. The various climate models predicted a range of possible changes in annual average precipitation and runoff by the year 2050. However, there is broad consensus that the intensity and frequency of daily maximum runoff and precipitation events will increase. For example the current 100-year runoff event becomes approximately nine times more likely in the Colorado River watershed (9 "100-year events" per 100 years) and two times as likely in other basins that contribute to the Long Beach imported water supply. Total annual runoff also shifts to more extreme magnitudes. The increased frequency of abnormally low annual runoff increases the regions susceptibility to droughts. Regardless of positive or negative changes in annual runoff or precipitation, the region's imported water supply is projected to diminish by mid-century resulting from a lack of reservoir storage capacity to capture the increased proportion of rainfall derived runoff, more extreme winter runoff events and earlier snowmelt timing as projected by climate change.

Projected Climate Change Impacts in Long Beach:

Long Beach populations are expected to increase at a fairly slow rate. This together with extensive conservation efforts over the past 30 years will make it increasingly difficult for Long Beach to further reduce its gallons per capita per day (GPCD) water usage. Even if the target 100 GPCD is met, increases in population by 2050 will result in a net increase of water demand. Locally, temperatures are projected to rise 2.3-2.7°F (1.3-1.5°C) by 2050; however, annual precipitation is also projected to increase by 2050 however precipitation events are expected to be less frequent, greater in magnitude, and concentrated during the winter months when outdoor demand is low. Without citywide storm water capture efforts, any additional precipitation projected with climate change will not significantly offset demand. Substantially warmer summer temperatures will increase evapotranspiration and outdoor irrigation demand. Drought tolerant conversion efforts could reduce outdoor irrigation requirements by 10-24% and reduce the impacts of increased temperatures. While Long Beach has established itself as a leader in water conservation, further efforts to increase capture and utilization of local storm runoff and expansion of recycled water use must be made in order for the city to withstand future water supply reduction caused by climate change.

Summary of Projected Climate Change Impacts by 2050:



- **Western U.S.**
  - Temperature in the are expected to increase roughly 2 to 4.5°F
  - The increase in temperature is expected to shift peak runoff one to two weeks earlier in the year and reduced the overall snowpack.
  - The intensity and frequency of daily maximum runoff and precipitation events will increase (i.e., more flood-type events).
  - The frequency of abnormally low annual runoff will increase (i.e., more drought events).
  - For these reasons, imported water supplies are expected to be less reliable by the year 2050.
- **City of Long Beach**
  - Temperatures in Long Beach are expected to increase 2.3 to 2.7°F by the year 2050
  - Annual average precipitation in Long Beach is projected to increase by 0.3 to 1.2 inches by the year 2050.
    - But rain events are expected to be less frequent but greater in magnitude (i.e., fewer, but more severe storms)

Making Long Beach More Climate-Resilient:

Without citywide storm water capture efforts, any additional precipitation projected with climate change will not significantly offset demand. However, a portion of the additional precipitation coming off of the San Gabriel Mountains can be captured and used to replenish the groundwater basin in lieu of imported supplies. Warmer summer temperatures will increase plant needs for water and increase evaporation (evapotranspiration), thereby increasing outdoor irrigation demand. Drought tolerant conversion efforts will become more important in order to offset this trend, potentially reducing outdoor irrigation requirements by 10-24%. All else being equal, demand for water in Long Beach is not expected to increase significantly by the year 2050, given its very low rate of population increase; yet as noted above, the imported water supplies to the region are anticipated to become less reliable by the year 2050.

The City of Long Beach has already made efforts to reduce reliance on imported water supplies including but are not limited to the following:

- Certain projects are either underway or under investigation that could potentially eliminate the impact of climate change on the reliability of groundwater supplies.
- The use of recycled water is increasing.
- Per capita water use in Long Beach is very close to 100 gallons per capita per day; the regional wholesale water supplier has a commitment to ensure its customers, including the City of Long Beach, are guaranteed 100 gallons per capita per day during water shortages, contingent on enough water supply being available to meet these minimum demands.
- By virtue of its having made annual contributions towards the capital investments in the wholesale water agency sense the 1930's, Long Beach has acquired a "preferential right" to limited water supplies from the wholesale agency in excess of reasonable demands Long Beach may place on the agency during shortages; and
- The State of California is mandating more water conservation through statewide regulation, such as mandating that new construction be extremely water-wise and requiring that only very water-conserving devices, such as toilets, can be sold in California. These types of State mandates tend to have very little impact when they first become law, but their impact grows over time and will have enormous impacts on water demand by the year 2050.

Additional actions Long Beach may consider to increase the climate-resiliency of its water supply include:

- Given the projection of higher temperatures, Long Beach should continue its commitment to replacing landscapes that are not native to this region and require tremendous amounts of landscape irrigation (i.e., grass used on lawns, grass areas of parks and other large landscapes that provide no functional use, street medians, etc.). These landscapes should be replaced with gardens that thrive in the Long Beach semi-arid climate with little to no supplemental irrigation.
- Long Beach is not well situated to take advantage of the less frequent yet more powerful storms that are expected by 2050 because (1) Long Beach is a built-out community with little to no open land in which to entrain vast quantities of captured stormwater, and (2) the geology underlying the City prevents water pooled on the surface to percolate into the groundwater basin. Therefore to the extent stormwater is captured, most of it will be captured and used *on site* at homes, street medians, commercial sites, parks and other areas. The City may consider studying the cost-effectiveness of different stormwater capture strategies.
- Combining these two strategies. When landscapes are being converted to drought-friendly it typically requires little to no additional cost to build into the new landscape features that also retain stormwater on site. The City should not only encourage turf replacement but also encourage these projects to capture stormwater on site to the extent feasible (and thereby minimizing urban runoff).

Climate change will impact near every city throughout the world to a greater or lesser degree. Cities can become more climate change resilient through on-going awareness and monitoring of their environment, and planning for the expected impacts as the probability of those impacts increase. Thanks to the actions of Mayor Robert Garcia, the City of Long Beach is taking the first steps towards becoming a climate change resilience community. We hope this report will help the City achieve its goal of becoming a climate resilient community.

1.0 Introduction

The Long Beach Water Department (LBWD) is the retail agency that distributes water to the nearly 500,000 residents of Long Beach. LBWD is required by the California Department of Water Resources (DWR) to submit an Urban Water Management Plan (UWMP) every five years. Addressing climate change is currently an optional section to include in an agency's UWMP. LBWD's 2010 UWMP included a short section on the topic stating, "The effects of climate change will have on water supply and demand are unknown as this time, given the uncertainty with respect to local impacts, intensity, duration and timeliness…LBWD does not expect climate change to have a major impact on its local sources of water, such as groundwater and recycled water" (LBWD, 2010). The paragraph continues to state that climate change impacts on imported supplies were addressed in Metropolitan Water District of Southern California (MWDSC) 2010 Regional UWMP. Long Beach is one of 26 member agencies that purchase imported water from MWDSC which holds fourth and fifth priority rights to water from the Colorado River. Additionally, MWDSC is a contractor for the State Water Project, which is fed by the Sierra Nevada. Although MWDSC has addressed climate change to some extent, it is vital for retail agencies to understand and plan in conjunction with regional and wholesale agencies since climate change will not only affect imported supplied but local supplies as well. Both will impact local Southern California agencies. This report provides a comprehensive overview of potential impacts that climate change may have on Long Beach's water supply and demand. All imported sources of water to Southern California are evaluated along with local sources including groundwater, recycled water, stormwater capture, desalination, graywater use and conservation efforts (Figure 1).

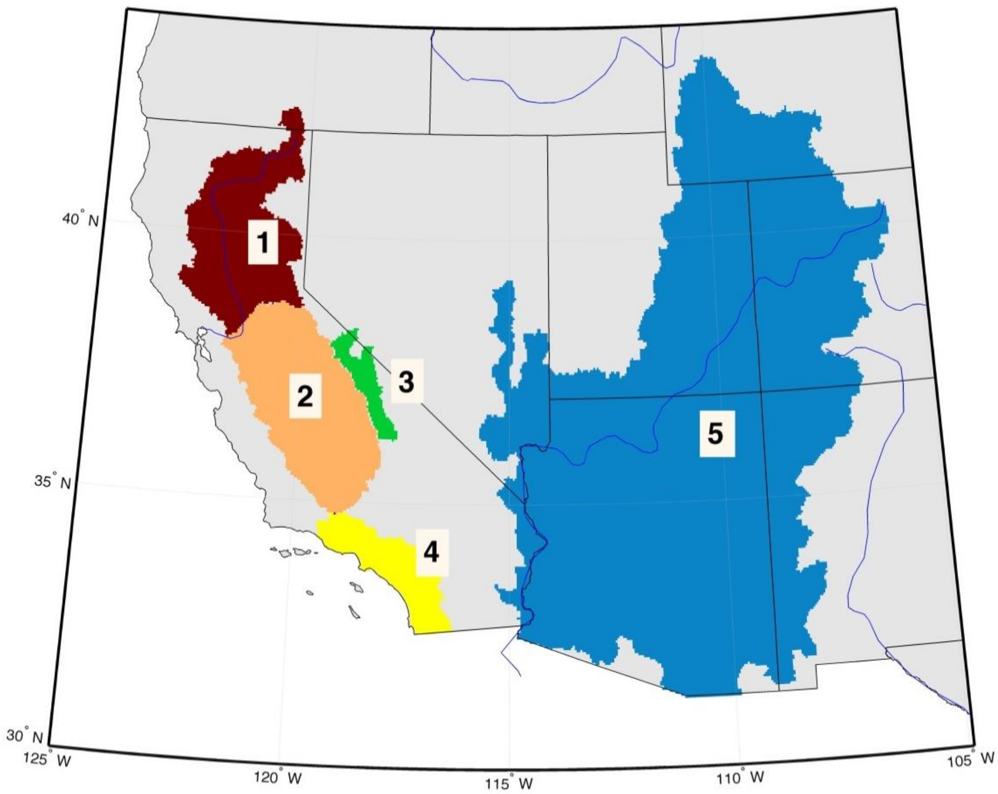


Figure 1: Map of all sources of water supply to Southern California and study basins including 1) Sacramento River (SRB), 2) San Joaquin-Tulare Lake (SJRB-TLB), 3) Mono Lake and Owens Valley (ML-OVB), 4) Southern Hydrologic Region and 5) Colorado River (CRB).

1.1 Current Imported Supply Limitations and Previous Study's Projections

Southern California's reliance on imported supplies revolves around snowpack and the timing of snowmelt from the Upper Colorado basin and Northern California regions. In the Western United States (WUS), approximately 75% of water discharge comes from spring snowmelt and is primarily controlled by precipitation and temperature (Cayan, 1996). Recent projections of climate change resulting from increases in anthropogenic greenhouse gases suggest the WUS and Southwest are particularly vulnerable considering this heavy reliance of temperature sensitive snowpack (Christensen & Lettenmaier, 2007; Diffenbaugh et al., 2005; IPCC, 2007; Rauscher et al., 2008). During the past century, 1°-2° C of warming has been observed over the Western United States (Barnett et al., 2004). Temperatures are projected to rise by 3° to 5° C by the end of the century, greater than the global average. These temperature increases are estimated to reduce snowpack, shift snowmelt timing and snowmelt-driven runoff timing up to two months earlier over much of the Western United States (Rauscher et al., 2008) and the San Joaquin-Sacramento River basin (He et al., 2013). Reservoirs are kept at low levels for flood control purposes in the winter months. As a result of warmer temperatures, reservoirs could fill earlier in the year with rainfall runoff and may not have additional capacity to hold snowmelt runoff, even though snowpack is reduced through climate change. Dam operating rules will likely require releasing this captured water to maintain their flood control capacity. This released water could be "lost" unless there are systems to move this water to other reservoirs or groundwater recharge facilities where it can be stored and used. Lack of timely local water resource expansion coupled with climate change may leave the area in extended periods of shortages. The following section provides a brief overview of current supply limitations from each imported supply source including 1) the Colorado River Aqueduct, 2) State Water Project and 3) Los Angeles Aqueduct.

1.1.1 Colorado River Aqueduct

The 630,000 km^2 Colorado River Basin provides water to over 30 million people across Wyoming, Utah, Colorado, New Mexico, Arizona, Nevada, California and Mexico (Christensen et al., 2004; Ficklin, Stewart, & Maurer, 2013). Approximately 70-80% of the water from the Colorado River is used for agricultural lands, both within the basin and exported to other regions of the WUS (USBR, 2011). The 1922 Colorado River Compact divided the basin into two sections: upper and lower. Each section was apportioned 7.5 million acre-feet (MAF). The Boulder Canyon Project Act of 1928 and the Upper Colorado River Basin Compact of 1948 divided the 7.5 million acre-feet from both the upper and lower regions to state specific allotments. It was not until 1944 with the installment of the Mexican Water Treaty that 1.5 million acre-feet of the Colorado River's water was promised to Mexico. The early 20th century was a particularly wet period in the basin. Average annual flows were approximately 16.1 million acre-feet in the 1920's when the compact was first signed. Therefore, calculations used to determine allocation amounts across the region in the aforementioned compacts and treaty were skewed (USGS, 2004). Since the mid 20th century, the basin has experienced much drier periods more typical for the semi-arid and arid WUS-Mexico region with annual flows reaching as low as 3.8 million acre-feet in 2002 (USGS, 2004).

In the Colorado River Basin, snowfall in the winter months accumulates until the spring when warmer temperatures melt the snow. The snowmelt is captured by the large reservoir systems of Lake Powell and Lake Mead until summer months when the Colorado River Aqueduct, altering the natural water cycle, redistributes the water. The state of California has an allotment of 4.4 million acre-feet surplus Colorado River water every year. Agricultural entities possess the first three priority rights totaling 3.85 million acre-feet. MWDSC, the primary wholesaler of water to the Southern California coastal hydrologic region, holds the fourth and fifth priority rights at 0.55 million acre-feet and 0.662 million acre-feet. MWDSC is also entitled to 0.18 million acre-feet of any surplus originating from the first three priority right holders (MWDSC, 2010). Arizona and Nevada's increasing populations have resulted in lower water availability for California. If population and demands continue to increase, MWDSC could be left with just the 0.55 million acre-feet fourth priority right water.

On the Colorado River, reservoir levels are projected to diminish up to 30% by 2050 (Barnett et al., 2004). Storage is expected to decline up to 40% by 2100 as a result of decreased runoff (Christensen et al., 2004), reducing water available for the Southwest. Minimal changes in precipitation are anticipated by 2040; however studies have shown the potential for both increases and decreases (Christensen & Lettenmaier, 2007). Any potential increase in precipitation can potentially be offset by greater rates of evaporation and evapotranspiration due to warmer temperatures, resulting in decreased streamflow. Total system demand in such a scenario would exceed reservoir inflows for the Colorado River (Christensen et al., 2004). Incorporating population growth estimates would further increase the system demand. These changes have the potential to adversely affect already scarce water supplies for Southern California.

1.1.2 State Water Project

The San Joaquin River Basin including the Tulare Lake Basin covers 82,000 km^2 of central California while the Sacramento River Basin extends from central to northern California at 71,000 km^2 (USGS, 2014). Combined, the basins provide over 80 percent of the runoff in California supporting 25 million people and the $36 billion dollar agricultural industry (Cloern et al., 2011; Gleick & Chalecki, 1999). In 1960, the California Water Resources Development Bond Act passed providing 1.75 billion dollars to construct the State Water Project (SWP). Runoff from both basins into the Sacramento-San Joaquin Delta where it is then pumped more than 700 miles to central and southern areas of the state through the California aqueduct (SWP) and the federal Central Valley Project (CVP). California and federal policy makers have grappled with numerous issues surrounding the Delta stemming from limited water resources and the challenge of dividing these limited sources between urban, agricultural and environmental users. The Delta is the largest estuary in the Western United States making it a critical ecosystem (Kibel, 2011). Endangered species such as the delta smelt can become entrained in the SWP and CVP pumps at the south side of the Delta. During drought periods water quality becomes an issue as seawater is drawn in from San Francisco Bay into the Delta, which impacts the aquatic species and adds minerals to the Delta water. In order to protect these species, water pumping at the Delta pumping facilities must be reduced or completely halted. The MWDSC is one of the largest SWP users at 1.9 million acre-feet; however this allocation is highly variable. During the 2014 drought, MWDSC received just 5% of their SWP allocation water due to pumping restrictions. Studies by DWR indicate that the probability of receiving 1.9 million acre-feet in any one year is only about 64% (DWR, 2012).

Between 30-40 km^3 of rain and snowfall flows to the Sacramento-San Joaquin watershed (Knowles & Cayan, 2002). Snowpack accumulated from December to March delays 40% of the water delivered past April 1st, resulting in a system heavily reliant on snowfall timing and reservoirs to store the melt water (Roos, 1989). The timing allows the reservoirs to maintain their flood storage capacity during the fall and early winter months, capture rainfall derived runoff later in the winter and early spring gradually filling the flood control “pool” and then capture the snowmelt when the flood danger is minimal. This reliance makes these systems high vulnerable to climate changes. Previous studies on the SJTLB and SRB have shown large uncertainties in precipitation changes over the basins. The potential impact on runoff ranges from reductions of annual flow to the Delta by 41% to increases by 16% (He et al., 2013). By 2060, April snowpack is projected to be just 66% of baseline normal conditions (Knowles & Cayan, 2002).

1.1.3 Los Angeles Aqueduct

The Los Angeles Aqueduct was constructed in 1913 with the purpose of providing water to the growing city of Los Angeles. Initially obtaining water from the Owens River, a second aqueduct was completed in 1970 that extended the aqueduct to the Mono Lake Basin (LADWP, 2013). The aqueduct conveys both surface water and groundwater as the city of Los Angeles purchased groundwater rights along the aqueduct route. Excessive pumping of the Owens River Valley and surface diversions has caused Owens Lake to now be considered a dry lakebed posing a health risk to locals as dust particles can cause respiratory problems. The USGS has stated that the Owens Valley is likely the largest source of PM-10 (particles smaller than 10 microns in diameter) in the U.S. (Reheis, 1997). Mitigation originating from human and environmental health concerns has resulted in LADWP being required to provide 40 TAF of water per year for dust control (LADWP, 2013). Environmental degradation from the Los Angeles Aqueduct was not limited to Owens Valley. Mono Lake’s unique tufa formations serve as nesting sites for migratory birds. Once LADWP began exporting water the lake’s elevation dropped from the historical average of 6,417 feet above sea level to 6,372 feet (MLC, 2015). Air and water quality issues ensued with increased exposure of the lakebed. Furthermore, predators were more easily able to access the nesting migratory birds as water levels declined. As a result the Mono Lake Committee was formed (MLC) which fought alongside organizations like the Sierra Club and the Audubon Society to halt LADWP diversions. After 20 years of challenges, the State Water Resources Control Board of California released decision 1631 (D1631) which restricted LADWP's ability to export based on the water level of Mono Lake further reducing water supply to Los Angeles (LA). From 2006-2010, the city of Los Angeles obtained 36% of its water supply from the Los Angeles Aqueduct, equivalent to 0.22 million acre-feet (LADWP, 2010).

Previous studies have examined the impacts of climate change on the Mono and Owens Valley basins on a global climate model resolution (Costa-Cabral et al., 2013; Ficklin, Stewart, & Maurer, 2013). By the end of the 21st century, temperatures are predicted to increase from 2-5°C while changes in annual precipitation are highly variable, ranging from -24 to 56% (Costa-Cabral et al., 2013). Although the Los Angeles Aqueduct strictly serves the city of Los Angeles (LA), LA is the largest user of MWDSC water and possesses the most preferential rights to MWDSC water. Therefore, if the Los Angeles Aqueduct water supply greatly decreases, LA would have to increase purchases from MWDSC, which could leave other member agencies of MWDSC more prone to shortage conditions.

2.0 Methodology and Data

Ten coupled atmosphere-ocean global climate models (GCMs) are used as the driving force for the Regional Climate Model system (RegCM4) at 18-km^2 to form an ensemble of simulations (Giorgi et al., 2012) (Table 1).The output from the GCM simulations is part of the Coupled Model Intercomparison Project Phase 5 (CMIP5), which was used for the latest Intergovernmental Panel on Climate Change (IPCC) report (IPCC, 2013). GHG concentrations for the present day period (1966-2005) are specified by observations. Minimum temperature, maximum temperature and precipitation are bias corrected following a modified version of the Wood et al. (2002,2004) approach outlined in Ashfaq et al (2010) (Ashfaq et al., 2010; Wood et al., 2004; Wood et al., 2002). Observed monthly mean 1-km PRISM data is regridded at 4-km and compared with modeled monthly means for temperature and precipitation. Each grid point is adjusted to the PRISM dataset and monthly mean values are redistributed on a daily timescale. Future period (2011-2050) GHGs are specified by the IPCC's Representative Concentration Pathway (RCP) 8.5. While RCP 8.5 GHG concentrations are considered to be relatively high, there is little difference between other RCP scenario concentrations in the early and mid 21st century. The output from each ensemble member is dynamically downscaled and used to drive the Variable Infiltration Capacity (VIC) hydrologic model at 4 km^2 over the entire U.S (Liang et al., 1994). All model processing was completed at Oak Ridge National Laboratory (ORNL). For the purposes of this study, two 20-year timeframes are considered, one which represents impacts to 2030 and the other to 2050.

Extensive efforts are being made to improve modeling techniques in order to obtain higher resolution datasets. The Climate Sensitivity Group at UCLA has created a hybrid dynamical and statistical downscaling approach to create a 2-km dataset over the Los Angeles Basin (Sun, Walton, & Hall, 2015; Walton et al., 2015). Recently the group broadened their research area and applied this technique to the Sierra Nevada at a 3-km resolution and 9-km solution over the rest of California. This study looks at all sources of imported water supply to California, including the Colorado River Basin, which has not been analyzed using the hybrid downscaling approach. To have comparable results across all basins, this study solely uses the ORNL 4-km dataset.

Table 1: Global climate models utilized in this study.

Model	Modeling Group, Country	Resolution (lat x lon)
ACCESS1-0	Center for Australian Weather and Climate Research, Australia	1.24° x 1.88°
BCC-CSM1-1	Beijing Climate Center and China Meteorological Administration, China	2.81° x 2.81°
CCSM4	National Center for Atmospheric Research (NCAR), United States of America	0.94° x 1.25°
CMCC-CM	Euro-Mediterranean Center for Climate Change, Italy	2.0° x 2.0°
FGOALS-g2	State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, China	2.8° x 2.8°
IPSL-CM5A-LR	Institute Pierre Simon Laplace, France	1.89° x 3.75°
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan	1.41° x 1.41°
MPI-ESM-MR	Max Planck Institute for Meteorology, Germany	1.88° x 1.88°
MRI-CGCM3	Meteorological Research Institute, Japan	1.13° x 1.13°
NorESM1-M	UNI Bjerknes Center for Climate Research, University of Bergen, Center for Intern Climate and Environmental Research, The Norwegian Meteorological Institute, University of Oslo, Norwegian Computing Center, Norwegian Institute for Air Research and the Norwegian Polar Institute, Norway	1.88° x 2.5°

Parameters evaluated to determine any potential hydrological changes include precipitation, evaporation, baseflow, runoff, snow water equivalent (SWE), soil moisture, temperature and albedo. The Mann-Kendall statistical test (MK test) is used to identify any trends in the data specifically runoff timing (Kendall, 1948; Mann, 1945). Commonly used for hydrologic applications, the MK test is non-parametric and evaluates data sets for upward or downward trends. Two-sample unpaired two-tailed Student t-tests are used to determine statistical significance across all parameters (Gosset, 1908). The Generalized Extreme Value (GEV) distribution is fitted to maximum annual one-day precipitation and runoff events as well as cumulative annual runoff to evaluate return period changes (Jenkinson, 1955, 1969). Population and historical demand information for Long Beach was obtained from LBWD's 2010 UWMP. A detailed summary of methodology for estimating irrigation demand and potential storm water capture can be found in Appendix A.

3.0 Results: Imported Supplies

Results are broken down into two categories: imported and local sources of water supply. Primary hydrological variables that influence imported supplies are evaluated comparing Period 1, baseline (1966-1985) to projected RCP 8.5 (2011-2030) and Period 2, baseline (1986-2005) to RCP 8.5 (2031-2050) potential changes. The impacts on Long Beach water supply resulting from possible alterations to each variable are discussed. Alterations to aforementioned hydrologic parameters are evaluated over the entire WUS study region and each imported supply basin on an annual and monthly basis. Frequencies of extreme runoff and precipitation events are evaluated. Shifts in annual and monthly snowmelt driven runoff amounts are also assessed.

3.1 Temperature Impacts on Snowpack

A comparison of potential changes in temperatures is achieved by subtracting RCP 8.5's averaged ensemble daily surface temperatures from the baseline. Surface temperatures are projected to rise by 0.5-1.5°C (0.9-2.7°F) under RCP 8.5 by 2030 and 1.2-2.5°C (2.2-4.5°F) by 2050 (Figure 2a). Changes in temperatures are statistically significant at a 95% confidence level for each grid point across the WUS using the two-sample two-tail Student's t-test. Albedo is the measurements of the reflectivity of Earth's surface, given as a value of 0 to 1.0. Greater albedo values indicate a more reflective surface, like snow, which will essentially reflect back incoming solar radiation. Lower albedo values closer to zero indicate a less reflective surface, like bare ground. Average January through April (JFMA) daily albedo greatly decreases up to 20% by 2030 and 25% by 2050 for the majority of the WUS (Figure 2b). Notably the major mountain ranges including the Sierra Nevada and Colorado Rocky Mountains experienced greater increases in temperatures than lower elevations. With rising temperatures, a smaller proportion of precipitation will fall as snow resulting in decreasing snowpack. Less snowpack can lower the region's albedo, a measurement of the reflectivity of incoming solar radiation. Lower albedo causes solar insolation to become trapped in Earth's atmosphere further warming the WUS, exacerbating the rate of snow melting. Albedo decreases most significantly during winter and spring months as a result of a declining snowpack. Temperatures increase closer to 1°C along the Pacific coastline in contrast to the arid inland regions of Southeast California and Southwest Arizona which project slightly higher temperature changes of 1.5°C. Coastal cities like Long Beach typically experience a lower range of temperature variations as a result of their proximity to the ocean. Under RCP 8.5 the ocean continues to act as a buffer for the WUS coastline resulting in a lower magnitude of temperature increases. Across all basins, RCP 8.5 summer months from June through September exhibits the greatest change in temperature. With the exception of very high elevations, snow depth decreases through the WUS. For Period 1, ensemble average JFMA snow depth diminishes by -17% for CRB, -14% for ML-OVB, -42% for SRB and -21% for SJRB-TLB. For Period 2, snow depth decreases by -22% for CRB, -27% for ML-OVB, -46% for SRB and -28% for SJRB-TLB (Figure 2c). While models MIROC5, MPI-ESM-MR and MRI-CGCM3 show snow depth increases for a few basins, the overwhelming model agreement is towards decreasing snow cover over the WUS (Figure 3). Greatest snowpack changes occur in the State Water Project basins of SRB and SJRB-TLB.

Projected Changes in Temperature, Albedo and Snow Depth

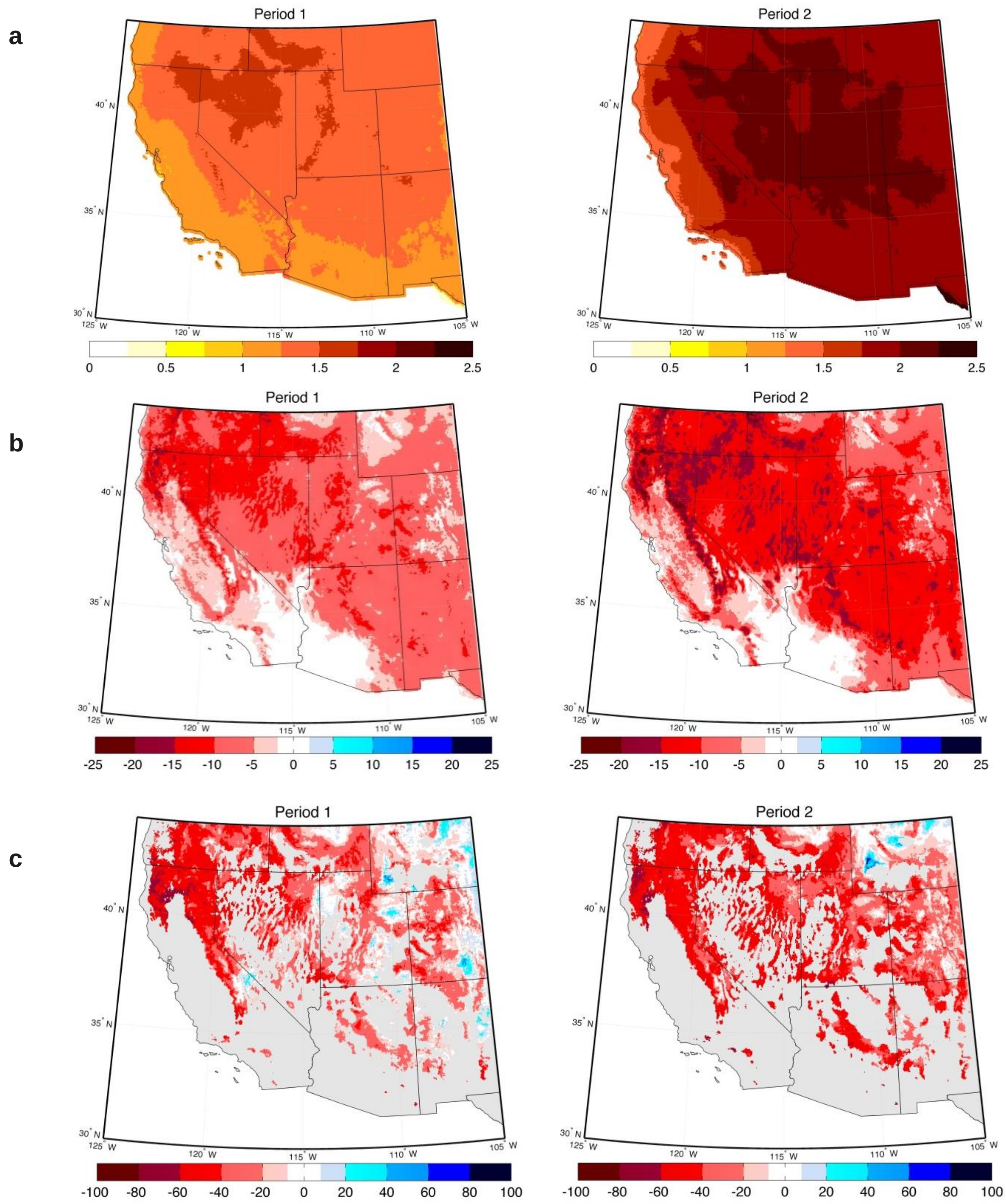


Figure 2: Ensemble average daily a) temperature change (°C), b) JFMA albedo percent change and c) snow depth JFMA percent change by Period 1 (2030) and Period 2 (2050) from baseline to RCP 8.5. Greatest changes are projected to occur in mid to high elevations as a result of the snow-albedo positive feedback.

Individual Model Changes in Snow Depth

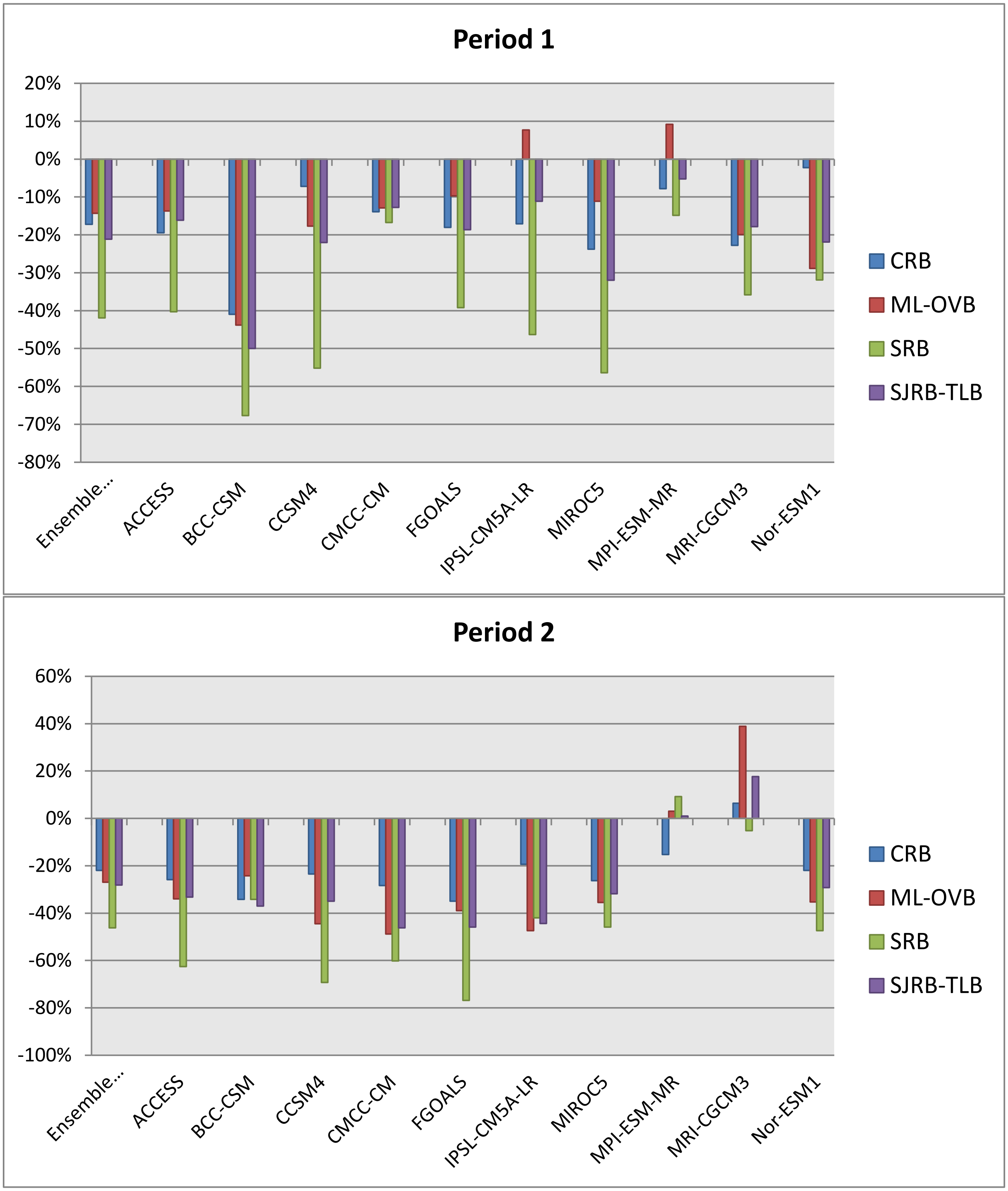


Figure 3: Ensemble and individual model average daily JFMA snow depth percent changes for each basin from baseline to 2030 and 2050.

3.2 Precipitation

Projections for changes in total annual precipitation greatly varied by model, basin and Period. Among the ten models responses to precipitation on a basin level for Period 1 ranges from -7 to 25% for CRB, -12 to 26% for ML-OVB, -14 to 17% for SRB and -14 to 21% for SJR-TLB. For Period 2, precipitation ranges from -7 to 17% for CRB, -16 to 24% for ML-OVB, -21 to 14% for SRB and -20 to 21% for SJR-TLB (Figure 4). This supports previous studies that have found varying precipitation changes for the first half of the 21st century (Christensen & Lettenmaier, 2007; Costa-Cabral et al., 2013). Rising GHG concentrations force increasing temperatures, driving higher evaporation rates which cause more water available for precipitation. Latest GCM projections predict increases in precipitation in mid and high latitudes towards the end of the century (IPCC, 2013). With the exception of the SRB in Period 1 and ML-OVB in Period 2, ensemble average annual precipitation slightly increases over the region.

Baseline vs. RCP 8.5 Precipitation Changes

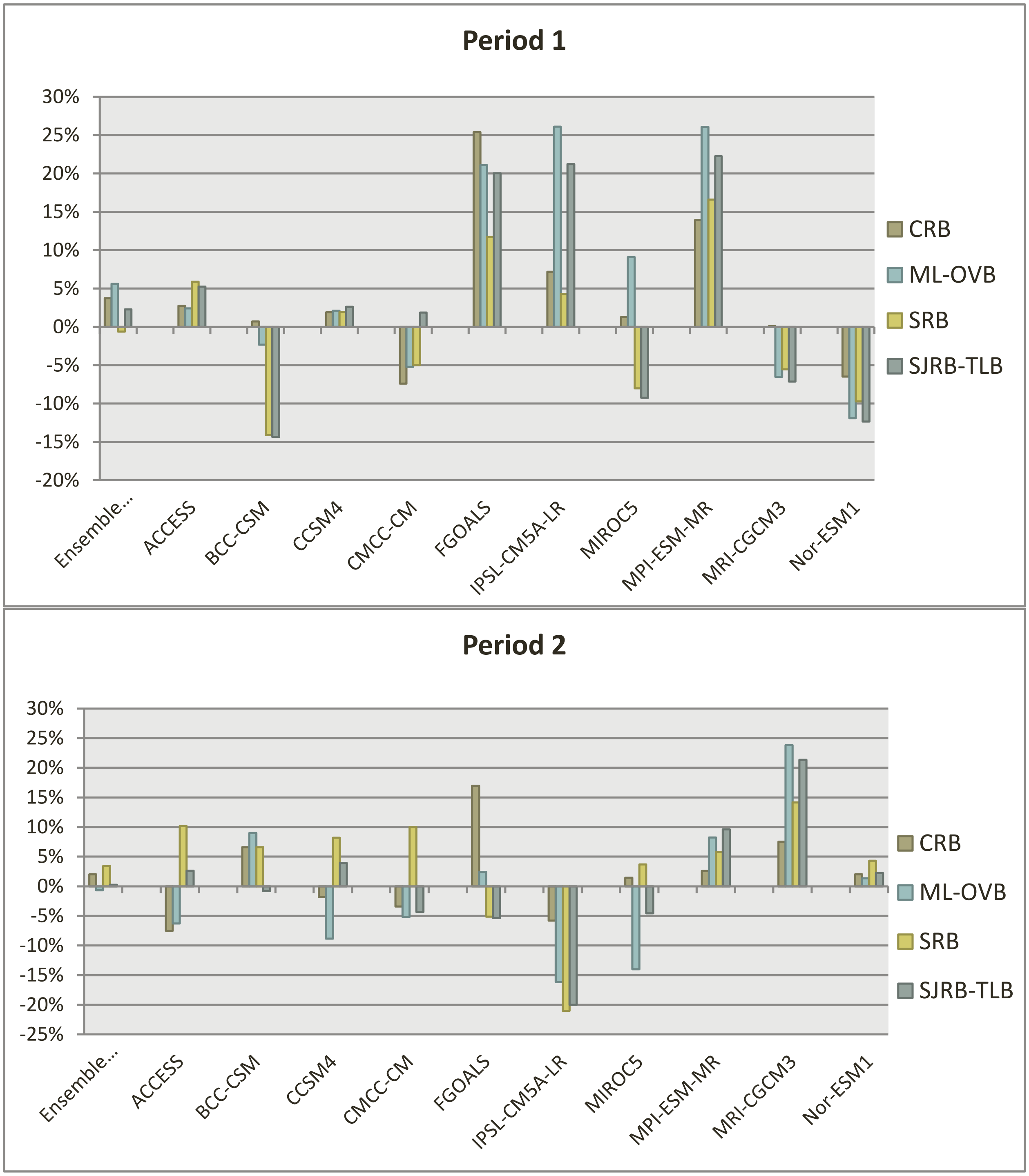


Figure 4: Ensemble and individual model average annual precipitation percent changes for each basin from baseline to 2030 and 2050.

3.2.1 Extreme Events

Annual one day maximum precipitation events are calculated for each year and model. The GEV distribution is fit on a basin and gridpoint level to determine the 10, 25, 50 and 100-year return periods for baseline and RCP 8.5 using a 30-year time series of the data set (1976-2005 versus RCP 8.5 2021-2050). Basin-wide peak one-day precipitation amounts increase for each return period by 19-68% for CRB, 8-16% for ML-OVB, 7% for SRB, and 13-16% for SJRB-TLB. The probability of experiencing the extreme 50 and 100-year events approximately doubles throughout the basins, except for the Colorado River where the 50-year event is six times more likely to occur and 100-year event nine times.

3.3 Evaporation

Evaporation changes between each model for Period 1 range from -7 to 21% for the CRB, -10 to 11% for ML-OVB, -4 to 9% for SRB and -7 to 13% for SJR-TLB. Period 2 evaporation changes range from -8 to 15% for the CRB, -12 to 8% for ML-OVB, -5 to 8% for SRB and -9 to 11% for SJR-TLB (Figure 5). With the exception of Mono Lake – Owens Valley basin for Period 2, all basins project slight increases in evaporation. Increasing evaporation is the result of increasing temperatures and potential increases in annual precipitation.

Baseline vs. RCP 8.5 Evaporation Changes

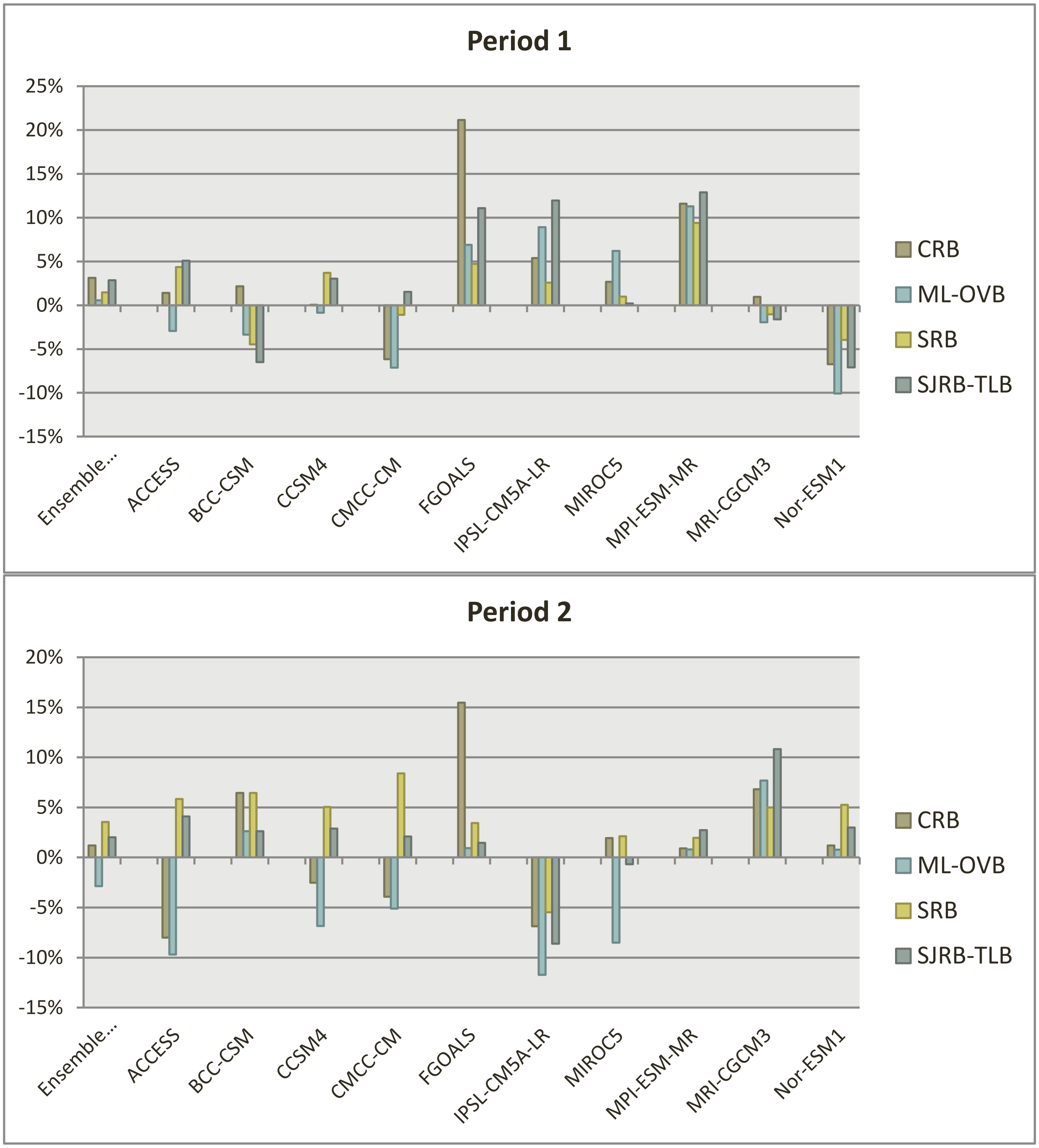
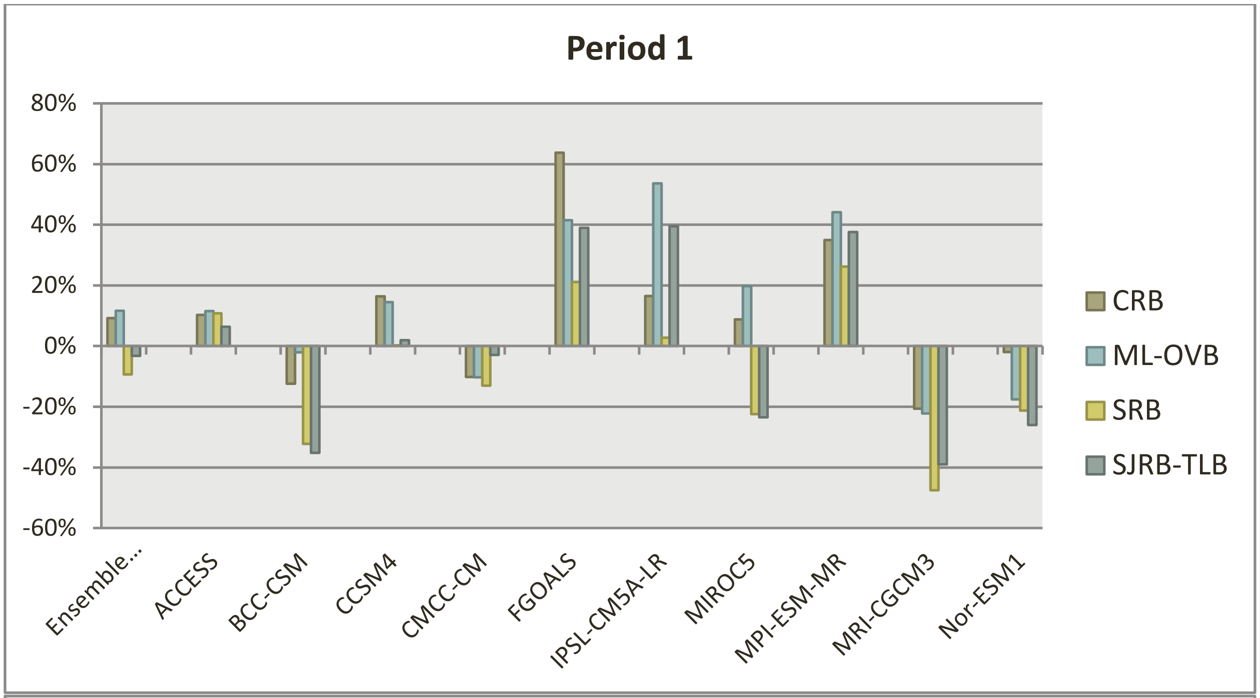


Figure 5: Ensemble and individual model average annual evaporation percent changes for each basin from baseline to 2030 and 2050.

3.4 Runoff

Alterations of average annual runoff vary by basin and are dependent upon changes in precipitation and evaporation in corresponding periods. Total 20-year average annual runoff changes between each model for Period 1 range from -21 to 64% for the CRB, -22 to 54% for ML-OVB, -48 to 26% for SRB and -39 to 39% for SJR-TLB. Period 2 runoff changes range from -7 to 21% for the CRB, -10 to 11% for ML-OVB, -4 to 9% for SRB and -7 to 13% for SJR-TLB. For Period 1, ensemble average runoff increases for Colorado River and Mono Lake-Owens Valley basins and decreases for Sacramento, San Joaquin and Tulare Lake basins. For Period 2, all basins except SJRB-TLB project greater runoff amounts (Figure 6).

Baseline vs. RCP 8.5 Runoff Changes



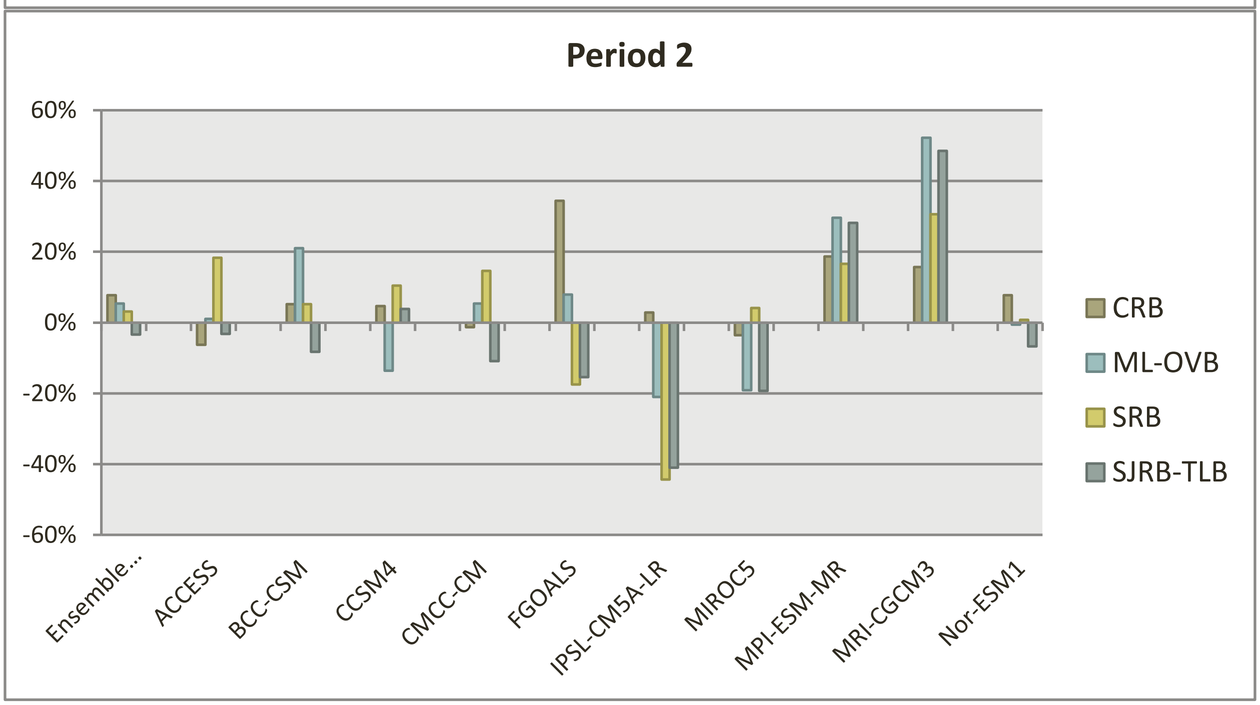


Figure 6: Ensemble and individual model average annual runoff percent changes for each basin from baseline to 2030 and 2050.

3.4.1 Shifts in Runoff Timing

The center of mass date (CMD), defined as the Julian day of the water year when 50% of annual runoff occurs, is crucial in regions like the WUS, which heavily rely on snowmelt for water supply and designed reservoirs on the basis of that timing (McCabe & Clark, 2005; Rauscher et al., 2008). The center of mass date is calculated for both scenarios at each grid point and basin for a subset of 30-years (1976-2005 compared with 2021-2050). Over most of the WUS (except Arizona), the ensemble average center of mass date under RCP 8.5 occurs earlier in the season with changes up to 20 days. At the basin scale, the CMD develops 6 to 11 days earlier (11 days for CRB, 7 days for ML-OVB, 6 day for SR, and 8 days for SJR-TLB) (Figure 7). Individual models and years show changes ranging from 50 to 80 days depending on the basin (Figure 8).

The MK test is run for each basin to identify any trends in the ensemble average runoff monthly data at a 95% confidence level. Months that exhibit changing trends have a calculated z-value greater than 1.96 or less than -1.96. Runoff increases during the winter and early spring months across all basins. Only the Colorado River and Mono Lake – Owens Valley basins exhibit statistically significant increases from December to May. Runoff decreases across all basins during the summer months, but only statistically significant for the SRB and SJR-TLB (Figure 9). Although there were minimal changes in average annual runoff over the forty-year scenarios, the distribution of runoff among months drastically changes. The shift in runoff occurring earlier in the year may represent shifts in snowmelt timing as a result of increasing temperatures. A separate analysis of monthly Colorado River flows at Lee's Ferry, Arizona in the Colorado River from 1906 to 2010 using the MK test revealed statistically significant decreases in flow from July to September and an increase in January. The flow measured at Lee's Ferry is fed by runoff originating from the upper Colorado River. Data from the United States Bureau of Reclamation (USBR) is used and considered to be unimpaired, accounting for the construction of the Glen Canyon Dam from 1956 to 1966. The observed trend of decreasing summer flows support a shift in snowmelt timing to earlier in the year.

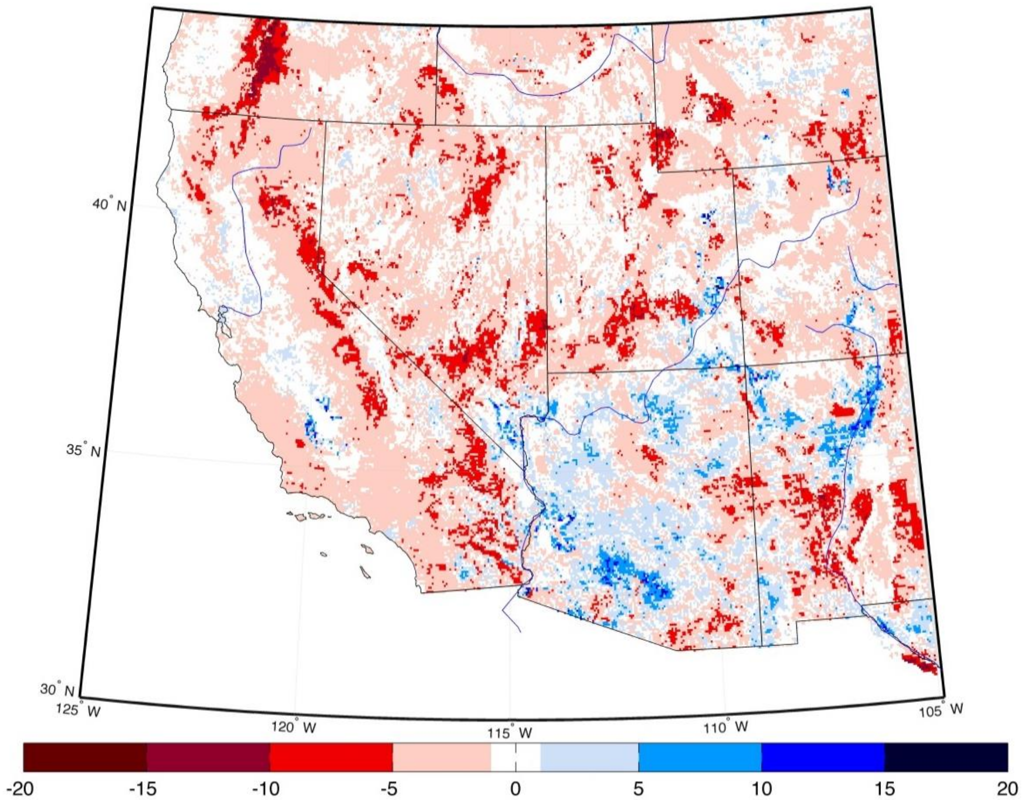


Figure 7: Change in CMD calculated for water years on a grid point basis. Negative values indicate peak runoff occurring earlier in the year as seen throughout the higher mountain ranges and the Sierra Nevada

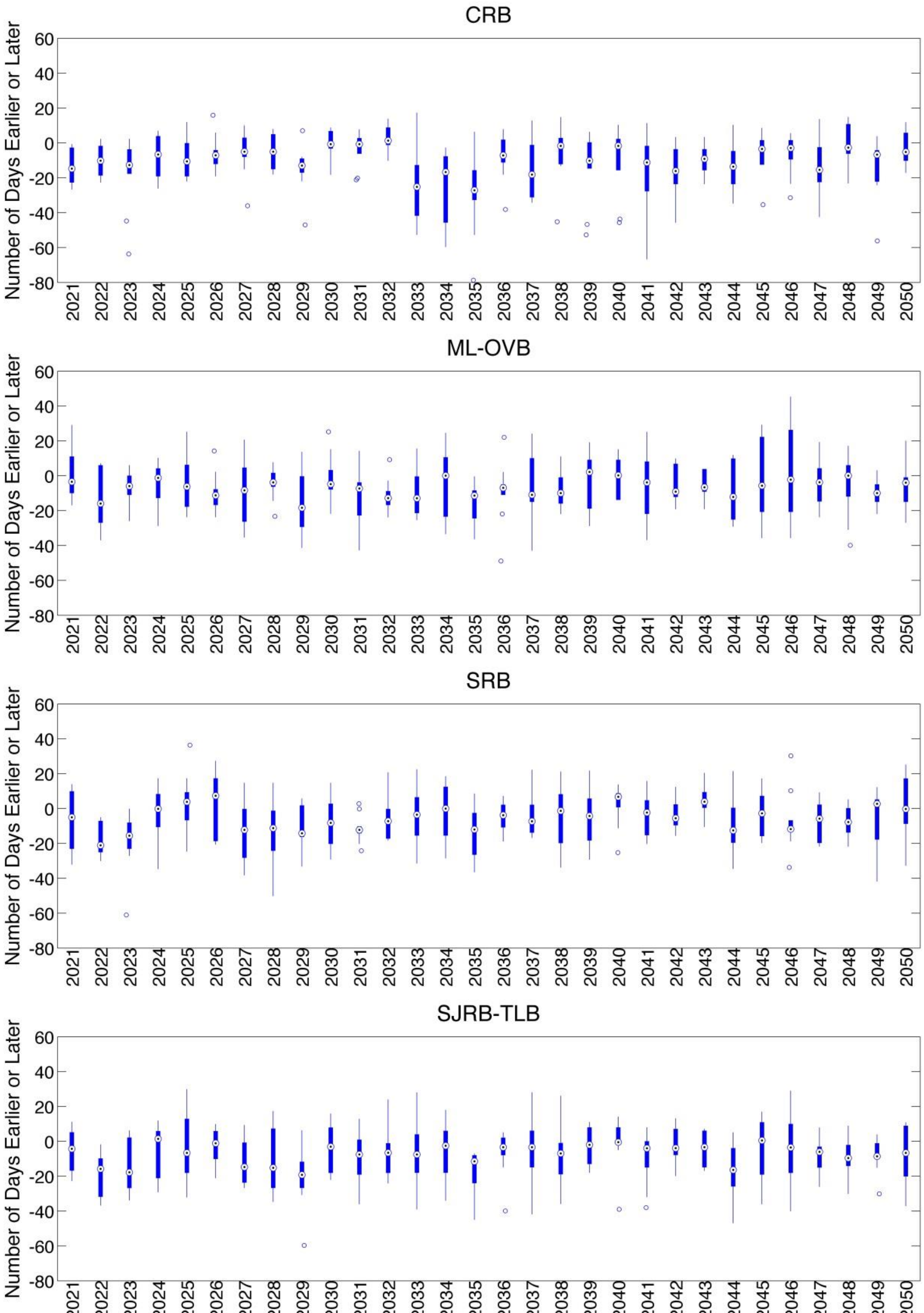


Figure 8: Change in CMD on a basin level for a) CRB, b) ML-OVB, c) SRB and d) SJRB-TLB. Boxplots represent the change of each model (n=10) under RCP 8.5 from baseline average CMDs. Black dots depict ensemble median and outliers are defined as being +/- 2.7 standard deviations from the median.

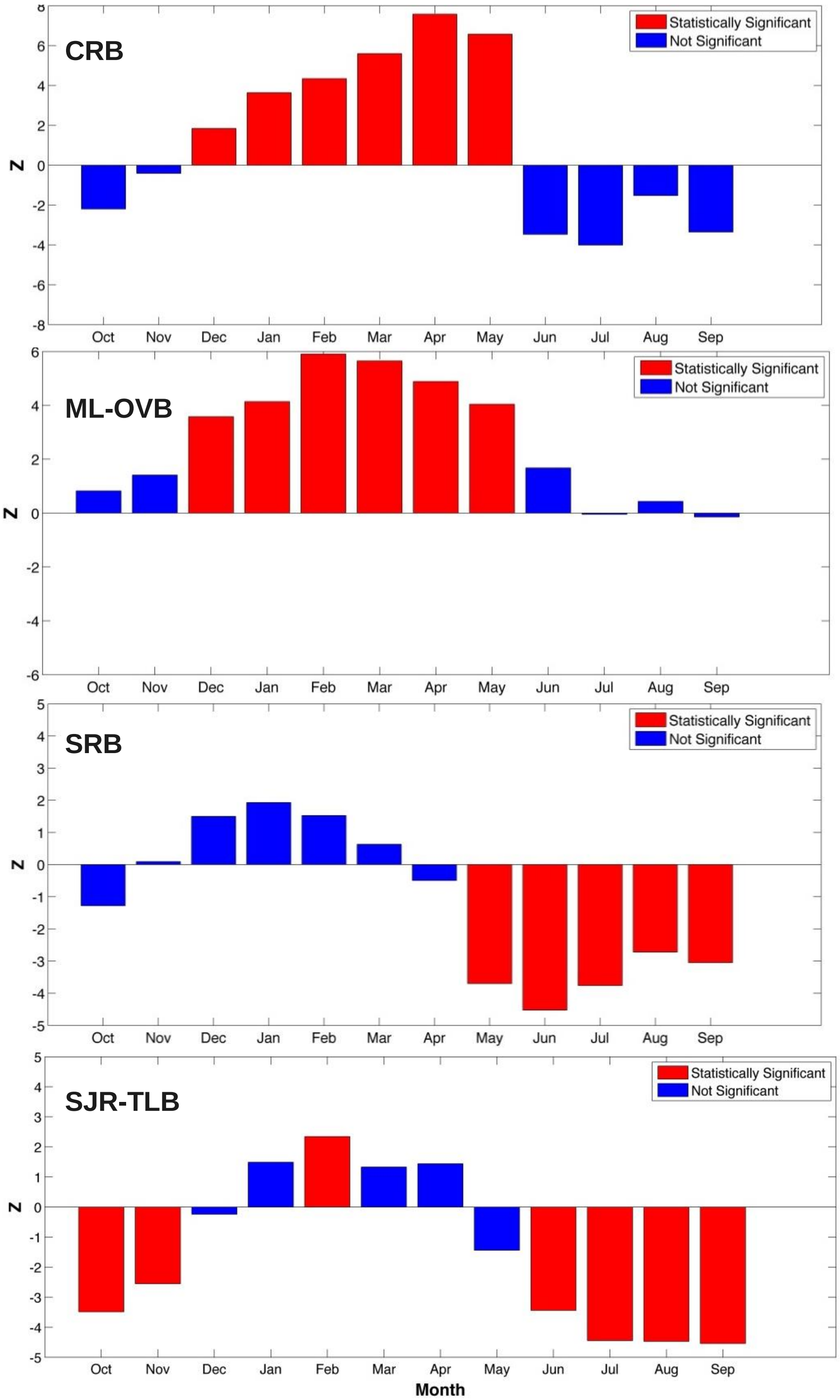


Figure 9: MK test results for monthly runoff trends. Z-values greater than +/- 1.96 are statistically significant. CRB and ML-OVB exhibit positive trends during the winter and spring months. Negative trends in the summer and fall are not statistically significant, resulting in a net increase in runoff for the basins. SRB and SJR-TLB exhibit significant decreases in the summer and early fall months also indicating a shift in snowmelt timing. An annual net decline in total annual runoff can be observed the SRB and SJR-TLB.

3.4.1 Extreme Events

Annual one day maximum runoff events were calculated for each year and model. The GEV distribution is fit on a basin and gridpoint level to determine the 10, 25, 50 and 100-year return periods for baseline and RCP 8.5 using a 30-year time series of the data set (baseline 1976-2005 versus RCP 8.5 2021-2050). Basin-wide peak one-day runoff amounts increase for each return period by 60-151% for CRB, 42-51% for ML-OVB, 12-15% for SRB, and 18-24% for SJRB-TLB. Mirroring extreme precipitation chaneges, the probability of experiencing the extreme 50 and 100-year events approximately doubles throughout the basins, except for the Colorado River Basin where the 50-year event is six times more likely to occur and 100-year event nine times.

In order to further examine annual shifts, GEV distribution was fit to water year cumulative maximum and mininum runoff amounts for a 30-year comparison (baseline 1976-2005 versus RCP 8.5 2021-2050) for 10, 25, 50 and 100-year return periods. On a basin level, amounts for extremely high annual runoff increases by 14-20% for CRB, 9-11% for ML-OVB, 2-4% for SRB, and 2-8% for SJRB-TLB. However, along the Sierra Nevada mountain range, the probability of greater than average cumulative runoff decreases. Abnormally dry annual runoff totals changes by 0 to -4% for CRB, 4 to 5% for ML-OVB, -4 to -17% for SRB, and -7 to -11% for SJRB-TLB. The probability of experiencing both extremely high and low cumulative runoff events increases with the exception of Mono Lake-Owens Valley basin for low annual runoff. Therefore, the Northern Sierra Nevada and the Colorado mountain ranges are more susceptible to drought and flooding in the mid-century.

3.5 Potential Impacts from MWDSC Water Shortage Allocation Plan

Long Beach's imported supply is limited when MWDSC enacts the Water Supply Allocation Plan (WSAP). MWDSC has entered into shortage conditions from a lack of precipitation and snowpack as recently as the 2011-2015 drought. In response to a lack of precipitation, minimal snowpack, and diminishing reservoir storage, MWDSC enacted a Regional Shortage Level 2 in 2015. As stated in the previous results section, State Water Project and Colorado River Aqueduct supplies are likely to decrease as a result of warmer temperatures driving less snowfall, more extreme events and shifts in snowmelt timing. Reservoirs, especially in Northern California, will fill earlier in the year and without additional storage water will need to be released for flood control purposes to comply with reservoir operating rules. Therefore, the probability of MWDSC enacting the WSAP will increase out to 2050. Historical MWDSC purchases are compared with potential imported supply caps from the 2015 WSAP under shortage levels 1, 5 and 10 using MWDSC's information regarding baseline water usage for 2013-2014 (Table 2). All calculations are derived from the 2015 WSAP. The Wholesale Minimum Allocation is based on Long Beach's 2013-14 baseline imported demand of 30,975 AF from MWDSC. The Retail Impact Adjustment Allocation is calculated by multiplying the baseline water demand by the Retail Impact Adjustment Factor for the specified Shortage Level and by Long Beach's dependence on MWDSC expressed as a percentage of purchased MWDSC supplies (30,975 AF) to total water demand (60,060 AF) or 51.6%. Conserving additional water is difficult when an agency has already significantly reduced GPCD over the baseline time period. MWDSC allots a certain amount of water to account for demand hardening which is a function of GPCD savings, Regional Shortage level, and dependence on MWDSC. The Minimum Per-Capita Adjustment ensured that all agencies receive 100 GPCD regardless of shortage level. If Long Beach's Minimum Wholesale Allocation amounts to anything below 100 GPCD, Long Beach would still receive 100 GPCD.

Table 2: Various stages of MWDSC's WSAP and subsequent supply reductions for each member agency including Long Beach.

Regional Shortage Level	Regional Shortage Percentage	Wholesale Minimum Allocation Factor	Retail Impact Adjustment Factor
1	5%	92.5%	2.5%
2	10%	85.0%	5.0%
3	15%	77.5%	7.5%
4	20%	70.0%	10.0%
5	25%	62.5%	12.5%
6	30%	55.0%	15.0%
7	35%	47.5%	17.5%
8	40%	40.0%	20.0%
9	45%	32.5%	22.5%
10	50%	25.0%	25.0%

A Regional Shortage Level 1 has almost no impact on Long Beach's overall imported supply, requiring the city to conserve only an additional 1.4% of supplies in order to meet demand. However, at Level's 5 and 10, Long Beach would fall 6,116 AF short of meeting baseline demand, requiring an additional 9% demand reduction (Table 3).

Table 3: Change in MWDSC imported water supply availability to Long Beach under Levels 1, 5 and 10 of the WSAP compared to baseline purchased supplies.

	Baseline (2013-2014)	Level 1	Level 5	Level 10
Wholesale Minimum Allocation		28,652	19,359	7,744
Retail Impact Adjustment Allocation		399	1,997	3,994
Conservation Demand Hardening Adjustment		1,137	2,654	4,550
Minimum Per-Capita Adjustment		0	849	8,572
TOTAL MWD ALLOCATION	30,975	30,188	24,859	24,859
Percent Reduction from Overall Demand		1.4%	9.0%	9.0%

Attributable to Long Beach's conservation successes, LBWD's retail level reliability is at nearly 90% (fraction of MWDSC Allocation and local supplies to allocation year demand) even under a Regional Shortage Level 10, one of the highest among MWD member agencies. The impacts from MWDSC's WSAP assume that Long Beach's demand and GPCD remains the same. As the City of Long Beach continues to conserve, reliability will increase and LBWD will have less imported restrictions if and when the WSAP in enacted. If supplies exist, LBWD has the option to purchase more water above their allocated amount at a much higher cost. MWDSC's WSAP guarantees total allocation for agencies that have reached 100 GPCD or less. It is highly likely that Long Beach will reach that goal in the next few years. However, even at a Regional Shortage Level of 10, MWDSC assumes that a least 1 million acre-feet will be available from imported and stored water, which may not be the case under climate change scenarios.

4.0 Local Supply and Demand Changes

4.1 Population Growth and Demand Changes

Long Beach is a built out city, with few new developments. LBWD's 2010 UWMP estimated annual population growth of 0.38% was obtained by taking the average growth projections from the California Department of Finance and Southern California Association of Governments. As of January 2015, the DOF estimates Long Beach's population to be 472,779, slightly above the UWMP's projection of 471,107. From census data, Long Beach population increased just 0.01% from 2000 to 2010. However from 2010 to January 2015, annual population increased by 0.46%. The average change from 2000-2010 of 0.16% is used to project population for this study (Table 4).

Table 4: Projected population changes to the City of Long Beach.

Year	Population
2015	472,779
2020	476,545
2025	480,341
2030	484,167
2035	488,024
2040	491,911
2045	495,829
2050	499,779

Long Beach's GPCD is 112 as of August 2014. Considering the city's history of significant water conservation and aftermath of the 2011-2015 drought, it is highly likely that Long Beach will reach 100 GPCD by 2025. However, the rate of GPCD reduction would be curtailed as a result of demand hardening. Of MWDSC member agencies, the city of Compton currently has the lowest GPCD from the 2013-2014 baseline of 85. With water intensive commercial businesses in Long Beach like the Port of Long Beach, it is unlikely that the city will get to 85 GPCD by 2050. Even with minimal population growth, without conservation beyond 100 GPCD, net water demand will rise for the city (Figure 10).

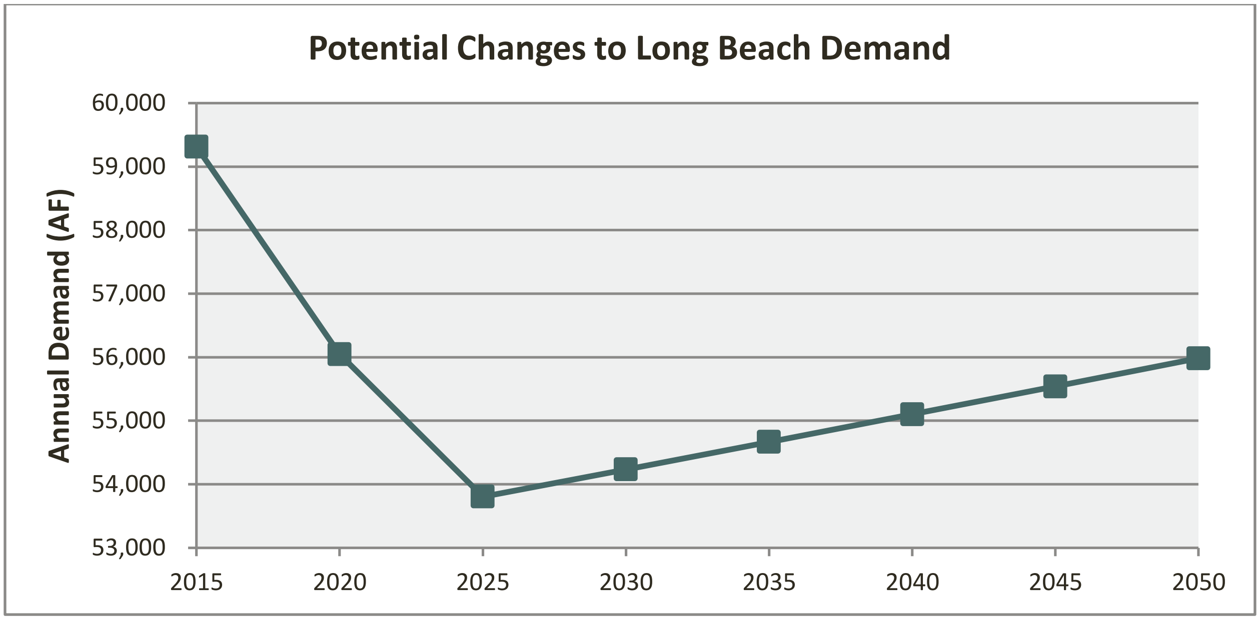


Figure 10: Change in annual demand assuming extensive conservation efforts resulting in 2025 demand dropping to 100 GPCD. Demand hardening may result in 2030-2050 demands to remain at 100 GPCD. Population growth, although minimal, counteracts conservation efforts.

Average daily temperatures for the greater Los Angeles area including Long Beach are projected to increase by 1-1.3°C (1.8-2.3°F) by 2030 and 1.3-1.5°C (2.3-2.7°F) by 2050 (Figure 11a). Annual total precipitation is also projected to increase by 2050 however, as explained in the section regarding extreme precipitation events, precipitation will occur in more extreme patterns during the winter months when demand is low (Figure 11b). Therefore, warmer temperatures will increase evaporation and water demand, specifically for outdoor irrigation during the summer months. Bias corrected annual evapotranspiration (ETo) in Long Beach increases by 4-8% for both Periods (Figure 11c).

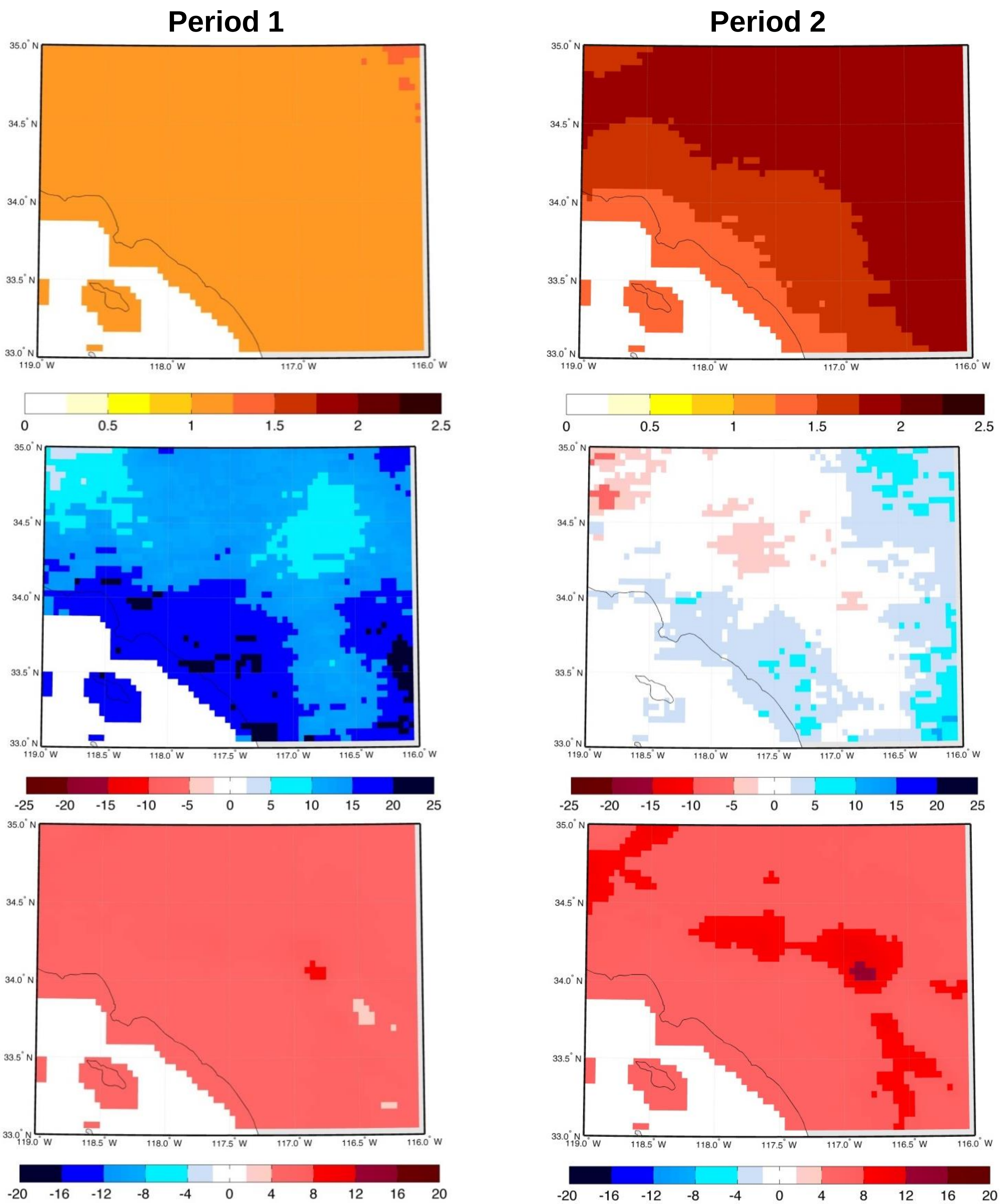


Figure 11: Ensemble average a) daily temperature changes (°C), b) daily cumulative annual precipitation percent change and c) bias corrected annual ETo percent change by Period 1 (2030) and Period 2 (2050) from baseline to RCP 8.5 for the greater Los Angeles region.

In order to quantify outdoor irrigation demand changes, the Blaney Criddle method is used to calculate the average monthly change in ETo for both Periods. ETo is bias corrected using CIMIS data from 1990-2005. Monthly and annual outdoor demand is calculated for three residential customer classes: single family (SF), duplex (DPLX) and multi-family (MF). Crop coefficients determine the watering need of various plants. Grass lawns have a higher water demand and therefore a higher crop coefficient (Kc) compared to drought tolerant plants. Different values of Kc are used to estimate future demand and determine the potential water savings of programs like Lawn to Garden, which incentivize Long Beach customers to replace grass lawns with drought tolerant plants. Two Kc's are compared assuming 30% or 50% of residential landscape area is converted to drought tolerant plants by 2050. We assume that all irrigation management and equipment efficiency remain constant, although efficiency is expected to improve as new technologies develop.

Using the zoning data dictionary provided with the Zoning GIS information from the City of Long Beach, Specific Zoning District Classifications were used to calculate parcel, landscape and rooftop areas for the three customer classes. A summary of data derived from GIS and used to calculate outdoor irrigation demand can be found in Table 5.

Table 5: Data obtained from GIS in order to estimate total irrigated area for SF, MF and DPLX customers. Rooftop area information is used to determine potential stormwater capture offsets to outdoor irrigation demand.

	SF	DPLX	MF
Total Parcel Area (ft^2)	406,047,806	64,652,885	82,604,503
Number of Parcels	55,898	10,376	6,261
Average Parcel Area (ft^2)	7,264	6,231	13,193
Average Landscape Size (ft^2)*	2,060	1,975	1,561
Fraction of Landscape Area to Average Parcel Area	28.4%	31.7%	8.5%
Total Rooftop Area (ft^2)	120,258,487	26,071,963	27,893,738
Number of Rooftops	71,767	14,643	10,321

** Average landscape size for each customer class estimated from a random sample by the Long Beach Water Department for SF and Loyola Marymount University for DPLX and MF properties.*

LBWD expects no new single-family developments for Long Beach. Instead, currently commercial or single family zoned areas would be converted to higher density multi-family properties. Since this portion of the study focuses on outdoor irrigation needs, the total area of irrigated landscapes for 2050 in Long Beach is assumed to remain equal to current estimates. Residential accounts make up roughly 66% of LBWD's demand of about 40,000 AF. LBWD estimates that 50% of total single family demand goes to outdoor irrigation. That proportion drops for multi-family properties, as they tend to have much smaller landscaped areas in proportion to parcel. Average annual modeled historical outdoor water consumption from 1966-2005 using the bias corrected Blaney Criddle method and a Kc of 0.66 yielded 9,100-13,200 AF, equivalent to stating that outdoor irrigation accounts for 23-33% of all demand for the combined customer classes.

If baseline Kc remained the same and residents of Long Beach halted drought tolerant conversions but installed two rain barrels for storm water capture (SWC) per residential property (an extremely optimistic scenario), average annual outdoor irrigation demand would increase by 5% or approximately 530 AF of water per year due to warming temperatures. If 30% of irrigation landscapes were converted to California friendly gardens along with SWC, the City of Long Beach would on average save 1,060 AF of water per year or 10% of water used for outdoor irrigation. If 50% of lawns are converted with SWC, savings potential increases to 2,630 AF per year, 24% lower than baseline outdoor irrigation water demand and 4% of overall demand for the city (Figure 12). This analysis was completed with and without potential storm water capture optimistically assuming that each residential property has two 55-gallon rain barrels which, if filled, could be used to offset a portion of irrigation demands twice per month. Additional savings from rain barrels were minimal, saving an annual average of 110-130 AF per year or 0.18-0.22% of total citywide water consumption. While demand drops off quickly for both drought tolerant conversion scenarios, water demands continue to rise out to 2050 as a result of warming temperatures driving summer evapotranspiration.

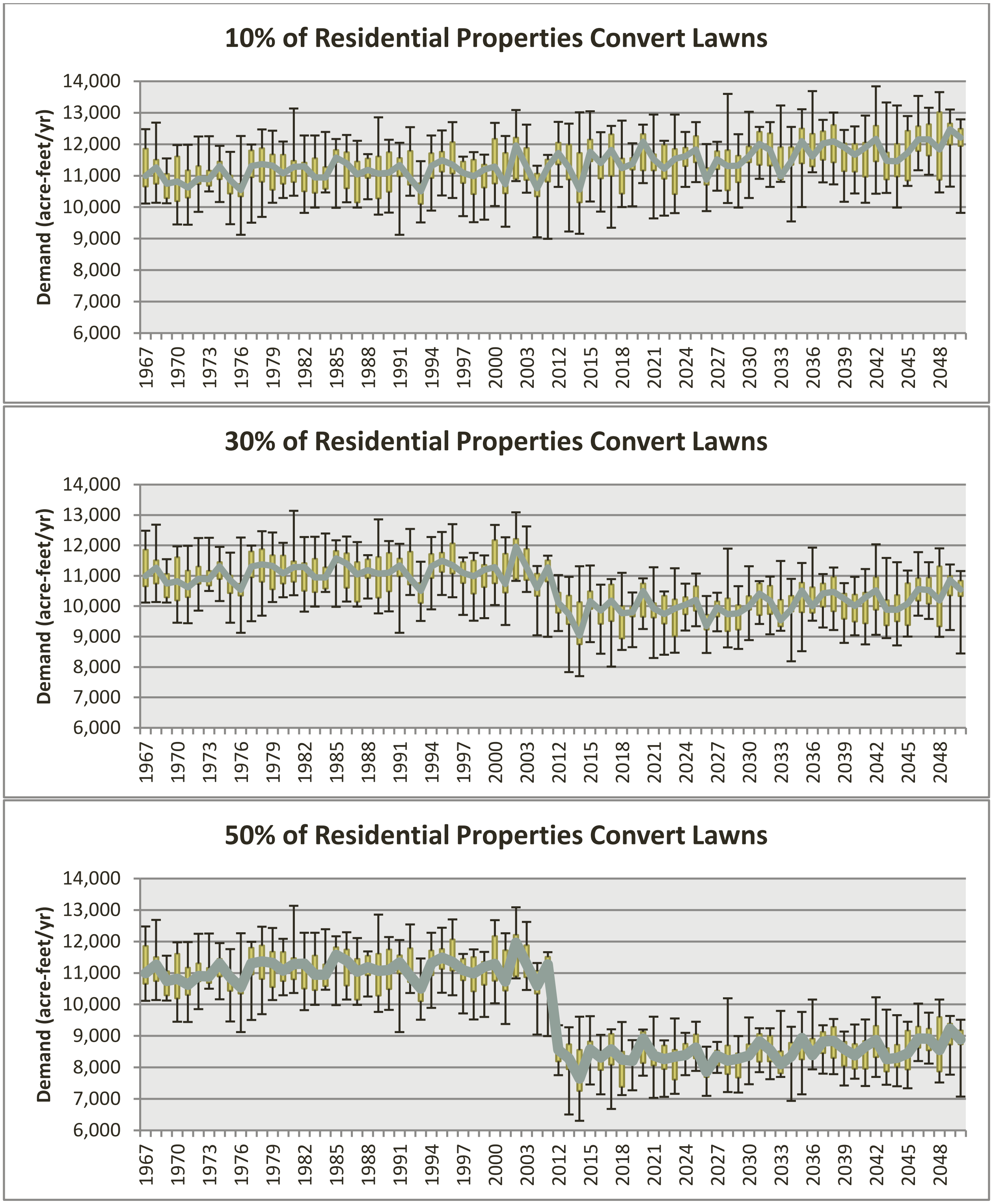


Figure 12: Projected outdoor irrigation demand changes for combined single family, multi-family and duplex accounts. Each boxplot represents the 10-model spread of annual demand comparing baseline Kc of 0.66 without SWC to Kc of 0.66 with SWC, Kc of 0.57 with SWC and Kc of 0.48 with SWC.

4.2 Recycled Water

LBWD's Recycled Water System Expansion Program was intended to increase recycled water usage to 9,000 AF per year, or about 15% of total water demand. As a result of system load issues and a limited amount of recycled water available from the Long Beach Water Reclamation Plant (operated by the Los Angeles County Sanitation Districts), LBWD has not pursued recycled water expansion to the degree intended for the program. Currently recycled water usage is approximately 4,200 AF per year and prospective recycled water users warned about the potential water interruptions due to lack of supply.

Most recycled water consumed in Long Beach goes towards outdoor irrigation. As shown in the analysis of residential users, ETo is expected to increase driven by warmer temperatures. As a result demand for recycled water will increase, causing even more system load problems. Installing isolated reclaimed water pipelines in an extensively urbanized city like Long Beach drives construction expenses upwards to a point where expanding recycled water efforts is not a cost effective option for an agency. As is the case across the majority of Southern California, LBWD choose to continue to purchase cheaper imported supplies of water.

4.3 Groundwater

Long Beach currently has the rights to pump 32,692 AF per year from the Central Basin and 0.7 acre-feet per year from the West Coast Basin. The 32,692 AF is a set amount that cannot be exceeded unless additional water rights are obtained and due to lack of wells groundwater from the West Coast Basin is not utilized (UWMP, 2010). Groundwater is largely viewed as a local source, however recharge is necessary to prevent over pumping. While recharge can consist of recycled and captured storm water, a large portion originates from imported sources. From MWDSC's 2015 WSAP the 10-year historical average groundwater replenishment from MWDSC to its member agencies was 150,000 AF. Many Southern California water agencies have argued whether or not purchases of imported water for groundwater recharge should be given equal priority during drought conditions. Under extreme drought conditions it is plausible that utilizing imported supplies for groundwater recharge could completely halt. Until recharge requirements can be fulfilled entirely by recycled or captured stormwater runoff, groundwater should not be viewed as an entirely local reliable source of supply under climate change scenarios.

4.4 Desalination

Long Beach's 2010 UWMP projected approximately 10% of water demand would be met by desalination in the future. LBWD operated its own desalination research facility starting in 2001, even obtaining a patent for the "Long Beach Method", a process that reduced the amount of energy needed and environmental impacts associated with desalination. However, even with energy savings using the Long Beach Method, desalination was determined to be too costly and the research facility was closed. Currently, imported water supplies are still less expensive than investing in desalination. However, LBWD has not entirely ruled out the possibility of building a large-scale plant if imported water costs rise, which is plausible under climate change scenarios.

4.5 Graywater

LBWD sponsored a Graywater Pilot Program administered by Long Beach's Office of Sustainability. In 2011, 33 homes were selected to participate in "Laundry to Landscape" where washing machine discharge water was diverted to outdoor irrigation. Surprisingly, water usage increased among the homes that participated in the program. There are a number of factors that could have influenced participant's water consumption (i.e. the economy, current water use restrictions, additional or less family members in the household). However, one critical flaw and limitation to graywater systems is California's health code, which prevents graywater from being used in typical pop-up spray heads to avoid exposure to people. Grass lawns, which consume large amounts of water, are typically irrigated by these spray heads therefore graywater could not offset these demands. Citywide expansions of graywater systems are not likely to occur at this point.

5.0 Conclusions

Climate change will result in warmer temperatures over the WUS and more extreme precipitation and runoff events impacting imported water supply availability to Long Beach by three main ways:

1) The frequency of extreme precipitation and runoff events increases.

2) A higher fraction of precipitation will fall as rain rather than snow, diminishing snowpack and filling storage reservoirs quickly.

3) Remaining snowpack will melt earlier in the year.

As a result of limitations of current surface water storage and to maintain flood control standards, reservoirs in the WUS, especially Northern California, will not be capable of capturing more frequent, concentrated amounts of rainfall and earlier snowmelt. Consequently, water will have to be released during winter months when demand is low throughout the state. A signficaint amount of water will be lost to the ocean without additional facilities to store or convey surface water for purposes like groundwater recharge, thus leaving the area prone to shortages. Cumulative annual runoff also has an increased probability of being significantly less than historical amounts. The increased frequency of abnormally low annual runoff increases the regions susceptibility to droughts.

LBWD is much less reliant on imported sources compared to other MWDSC member agencies. However, Long Beach could still be negatively impacted if ever MWDSC cannot fulfill delivery requirements resulting from a decreased amount of imported supply availability which is plausible under climate change scenarios. Further reductions beyond LBWD's 100 GPCD goal will be difficult to achieve when considering demand hardening. Although minimal, population growth has the potential to exceed further GPCD reductions, resulting in a net increase in water usage. Average annual precipitation may increase for the Long Beach area however precipitation events are more likely to occur in less frequent but larger magntitude events limited to winter months. Irrigation requirements are low in the winter and with lack of city scale storm water capture, additional rainfall would not significantly offset demand. Simply equipping residents with rain barrels would also have little effect on demand. Warmer summer temperatures increase ETo and plant watering requirements. Large scale drought tolerant conversions could save Long Beach an additional 2,630 AF per year despite a warmer climate. Groundwater makes up over half of LBWD's water supply, but should not be considered a truly local supply resilient to climate change as a portion of recharge water originiates from the same imported supplies. Plans for recycled water expansion have not been realized. Currently, purchasing imported water is more financially sound for LBWD than expansion of recycled water lines. Investing in recycled water treatment and expansion despite being more expensive than imported water would greatly increase Long Beach's self reliance. Although significant demand reductions have been achieved, there are still a number of ways for Long Beach to further reduce reliance on imported supplies which will be necessary in order to become a truly sustainable and climate resilient city.

Supplemental Information

In order to analyze potential residential outdoor irrigation demand changes, historical evapotranspiration (ETo) data is obtained from DWR's California Irrigation Management Information System (CIMIS) from weather station 174 located at El Dorado Park in Long Beach for 1990-2005. Average residential single-family (RSF) lot size was provided by LBWD using a sample of 200 homes throughout Long Beach. A duplicate approach is taken utilizing Geographic Information System (GIS) map estimates for 110 residential duplex (R-DUPLX) and multi-family (RMF) buildings. The proportion of irrigated landscape area to total lot size for each customer class is calculated and applied to all customers for that category. All GIS mapping datasets originate from the City of Long Beach's online GIS data catalog. VIC provides data regarding evaporation changes, but not ETo, which is critical in understanding plant water needs. ETo is calculated using the Blaney-Criddle method (FAO, 1998):

$$ET_O = p\left(0.46T_{mean} + 8\right)$$

Where T_{mean} is the mean daily temperature in degrees Celsius and p is mean daily percentage of annual daytime hours for a given latitude and time of a year. The change in ETo using the Blaney-Criddle method is calculated on a monthly basis for each Period and model. Model bias is calculated by subtracting monthly simulated ETo from observed CIMIS ETo. The bias is then subtracted from baseline and RCP 8.5 ETo. Only a fraction of precipitation which falls will be available for plants to utilize, also known as effective rainfall (P_e) where:

$$P_e = \textit{Total rainfall - runoff –evaporation - minus deep percolation}$$

Following the Food and Agriculture Organization (FAO) method for calculating P_e when slope maximum is 4-5%:

$$Pe = (0.8 * P) – 25 \quad \text{if } P > 75 \text{ mm}$$

$$Pe = (0.6 * P) – 10 \quad \text{if } P < 75 \text{ mm}$$

Where P is monthly average precipitation in mm. VIC precipitation is already bias corrected therefore additional correcting was not necessary. Plant watering needs will differ based on the plant type and stage of growth by a factor called the crop coefficient (Kc). For the purposes of this study, it was assumed 90% of properties did not already have drought friendly landscapes, i.e. turf grass lawns. Cool season grasses have a Kc of 0.8 while warm seasons have a Kc of 0.6. An averaged Kc of 0.7 is used to represent grass lawns. Drought tolerant plants can have a Kc as low as 0.2-0.3. Assuming that 90% of existing landscapes were grass and 10% drought tolerant, an average Kc is applied to all landscapes of 0.66. ETo must be corrected by incorporating varying Kc values with irrigation equipment and management efficiency:

$$ETAF=Kc/IE$$

$$IE=DU*IME$$

Where ETAF is the evapotranspiration adjustment factor IE is the efficiency of irrigation equipment, DU is the distribution uniformity of irrigation equipment and IME is the irrigation management efficiency. DU and IME values are obtained from DWR's white paper on Evapotranspiration Adjustment Factor. Average DU for a landscape is 0.79, representing a mix of irrigation equipment (i.e. spray/rotor heads and drip irrigation). IME can vary between type of customer. Homeowners are less likely to be as efficient as large commercial customers with full time landscape staff. However, to be conservative on watering need estimates and to follow DWR's protocol, an IME of 0.90 is used. IE is therefore 0.7.

Water demands are calculated using:

$$ID=ETAF-Pe$$

Where ID is irrigation demand in mm. Given average irrigated area sizes by customer class, ID is converted into acre-feet.

Using assessor parcel information and GIS, total rooftop area by each customer class is derived in order to determine potential storm water capture. Historical ID assumes residents do not have rain capture devices. To evaluate the potential offset in demand of rain barrels, we optimistically assume every single family, multi-family and duplex customer in the future will have two standard 55-gallon (7.35 ft^3) rain barrels that can be filled up and used twice a month. Rainfall typical occurs in concentrated events in Long Beach and because of soil saturation, the water in a rain barrel may not be needed for outdoor irrigation for weeks. Therefore, rain barrels used twice a month when enough rainfall is available is again an optimistic assumption. Potential storm water capture on a monthly basis is calculated by:

$$SWC=Pe \times RTA$$

$$PSWC= \text{number of rooftops} * 29.4\ ft^3$$

Where SWC is storm water capture, RTA is rooftop area by customer class, PSWC is potential storm water capture and 7.35 ft^3 is rain barrel storage capacity assuming two rain barrels at each property are filled up twice a month.

Therefore, adjusted ID with storm water capture is determined by:

$$ID\_SWC = \begin{cases} ID-PSWC & \text{if } SWC > PWC \\ ID & \text{if } SWC < PWC \end{cases}$$

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Appendix B

Additional *CoSMoS 3.0* Information

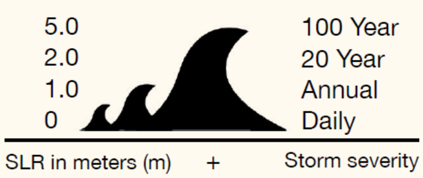
Coastal Storm Modeling System for Southern California

Over the next century, sea level rise in the Los Angeles region is expected to match global projections with an increase of 0.1-0.6 meters (5-24 inches) from 2000 to 2050 and 0.4-1.7 meters (17-66 inches) from 2000 to 2100. Rising seas, combined with the threat of other coastal impacts such as coastal erosion, high tides and severe storms, are driving coastal communities to begin planning for these challenges and identifying strategies to adapt. CoSMoS results support numerous local municipalities who may use the findings to plan for climate change impacts, including adaptation planning, updating Local Coastal Plans per guidance from the State of California, and conducting risk assessments for local hazard mitigation plans.

- CoSMoS is a modeling system that projects coastal flooding and erosion due to both sea level rise and storms driven by climate change
- CoSMoS features the full spectrum of sea level rise and coastal storm scenarios to meet management and planning horizons
- CoSMoS provides the science needed to understand and evaluate how sea level rise could impact your community
- CoSMoS allows municipalities to identify critical assets and populations vulnerable to coastal flooding

40 Scenarios:

Sea Level Rise + Coastal Storms



Results include SLR from 0-2 m in 0.25 cm increments, plus 5 m

Results project:

Coastal Flooding
Waves
Currents
Beach Change
Cliff Retreat
River Discharge

CoSMoS was developed by the U.S. Geological Survey and Deltares. The full suite of CoSMoS results and data covering 40 scenarios for Southern California will be officially released in summer 2016. Results will be free of charge and publicly accessible through the mapping tool at Our Coast, Our Future (www.prbo.org/ocof). Users may select combinations of sea level rise and storm scenarios to visualize the flooding depth extent and uncertainty associated with each scenario. Results can be overlain with GIS information on ecology, land use, and infrastructure attributes.

ADAPTLA

Sea Level Rise & Coastal Impacts Planning: CoSMoS Fact Sheet

Benefits of CoSMoS 3.0

The Coastal Storm Modeling System (CoSMoS) provides region-specific flood hazard projections at a detailed parcel scale from Point Conception to the Mexican border. It is based on an active scientific development approach that utilizes cutting-edge science to provide the optimum model outputs possible at this time. CoSMoS uses a combination of historic conditions and global climate models to project future conditions. It also provides flood projections specific for the bathymetry and topography of Southern California. This information will allow communities to identify both current and projected vulnerabilities to a suite of coastal storms, in combination with sea level rise.

- Flood hazard projections include flooding extent, depth, duration, and uncertainty
- Long-term coastal evolution projections for sandy beaches and cliffs
- Discharge from rivers provides information for event response

A Community of Practice

Regional AdaptLA strives to provide the best available science, technical assistance and capacity-building to assist Los Angeles coastal communities in planning for sea level rise and other climate change-related coastal impacts. As we are building a community of practice in the Los Angeles region, several communities are already engaged in using CoSMoS results, including Santa Monica, Hermosa Beach, Venice, and the Los Angeles Emergency Management Department.

Technical Assistance

Through AdaptLA and the Southern California Coastal Impacts Project, USC Sea Grant is working with Southern California's coastal communities to ensure that CoSMoS meets their needs and effectively supports planning and policy decisions. A series of regional training workshops and webinars on climate change adaptation planning is underway at this time. The USC Sea Grant team is also available for technical assistance and consultations. Please contact Dr. Juliette Finzi Hart for more information: jahart@usc.edu / 213.740.1937

Results

CoSMoS model results are available by contacting Dr. Patrick Barnard at USGS: pbarnard@usgs.gov

USGS science for a changing world

Funding for CoSMoS

Funding for CoSMoS 3.0 comes from a combination of internal USGS resources, funding from the CA Coastal Conservancy, CA Department of Fish & Wildlife, City of Imperial Beach, and the Tijuana River National Estuarine Research Reserve.

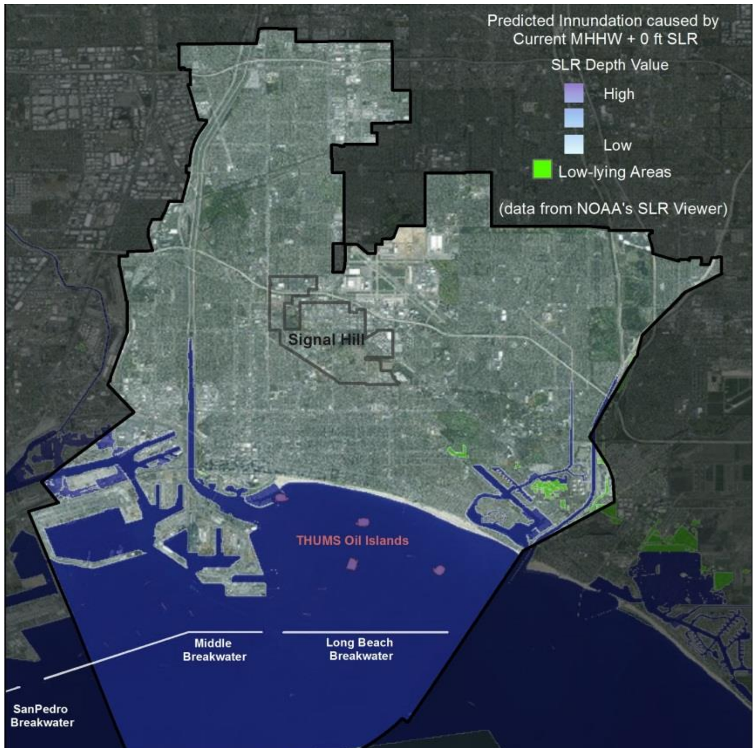
USC Sea Grant leads the outreach for CoSMoS with funding support from California Coastal Conservancy.

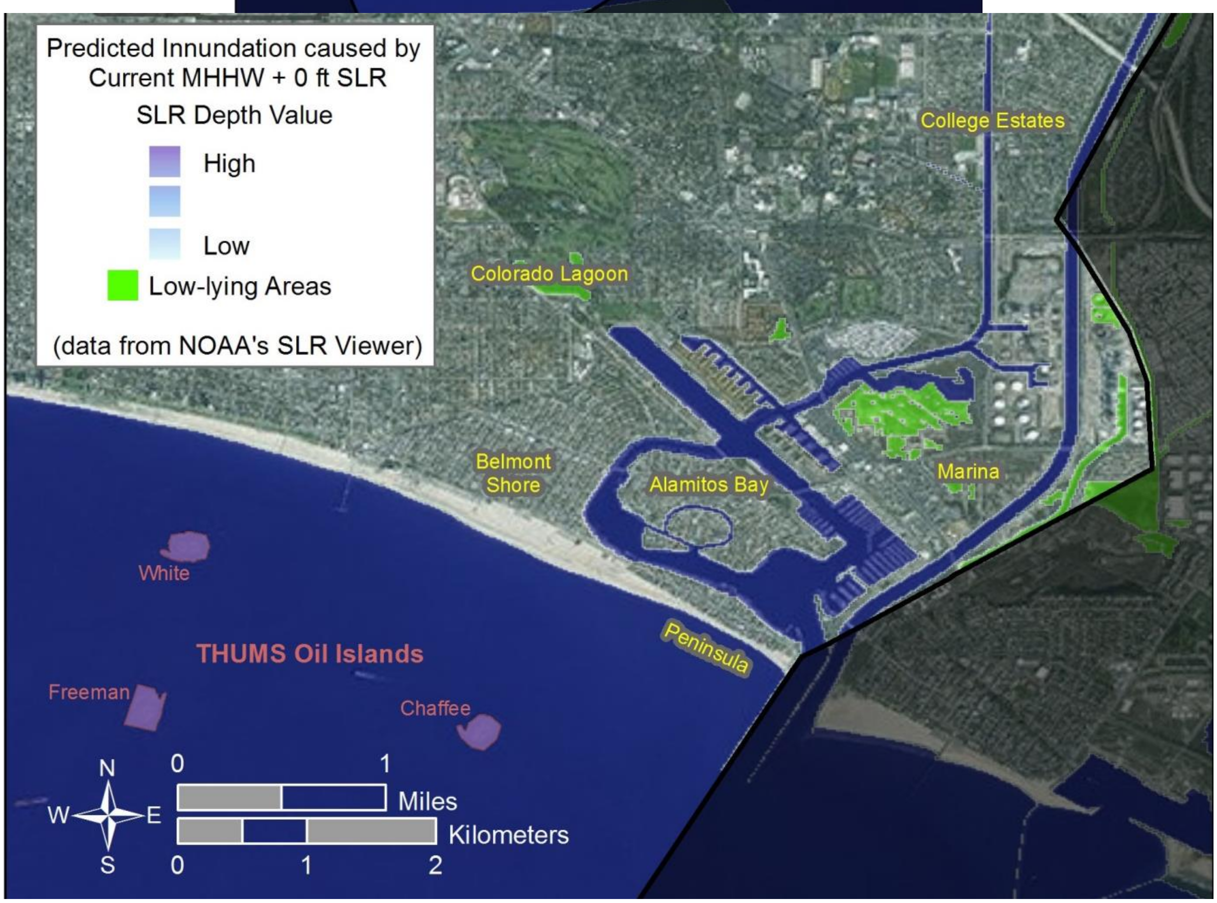
Sea Grant University of Southern California
City of Santa Monica A Sustainable Community sustainablesm.org
LARC Los Angeles Regional Collaborative for Climate Action and Sustainability
Heal the Bay
bay restoration commission STEWARDS OF SANTA MONICA BAY
Coastal Conservancy
CALIFORNIA COASTAL COMMISSION
CALIFORNIA OCEAN PROTECTION COUNCIL

Appendix C

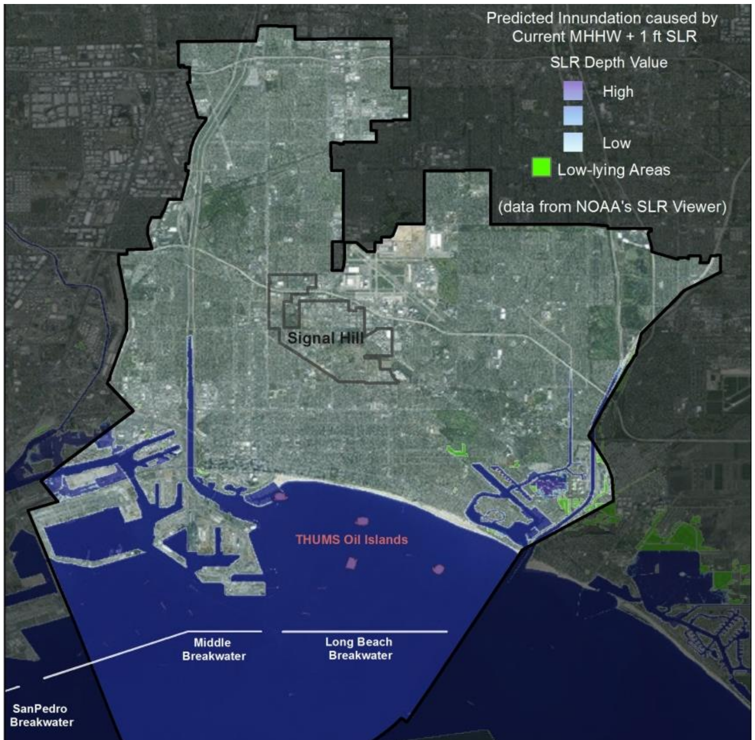
NOAA's *Sea Level Rise Viewer* Results for Long Beach

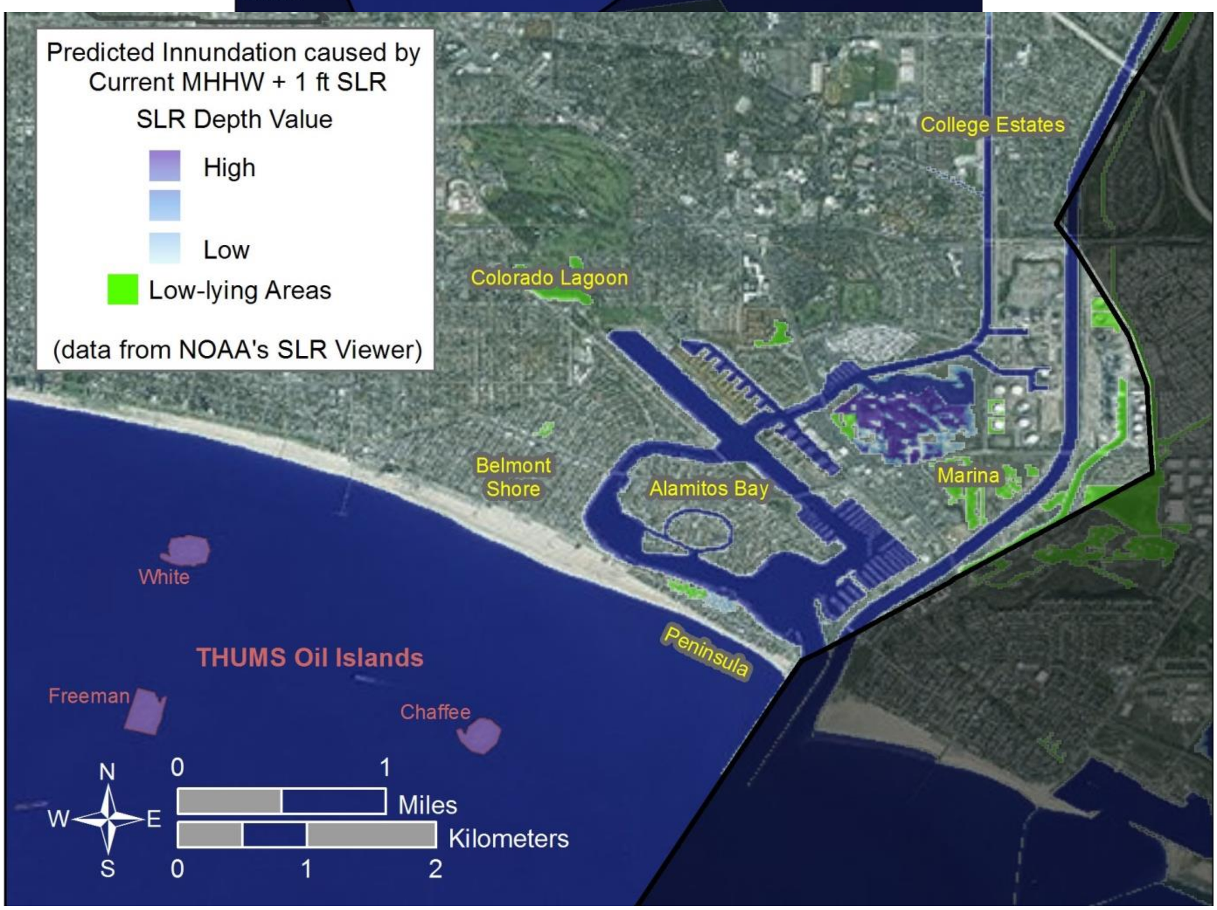
Predicted Inundation Caused by Current Mean Higher High Water (MHHW) plus **0** *ft* Sea Level Rise (SLR)



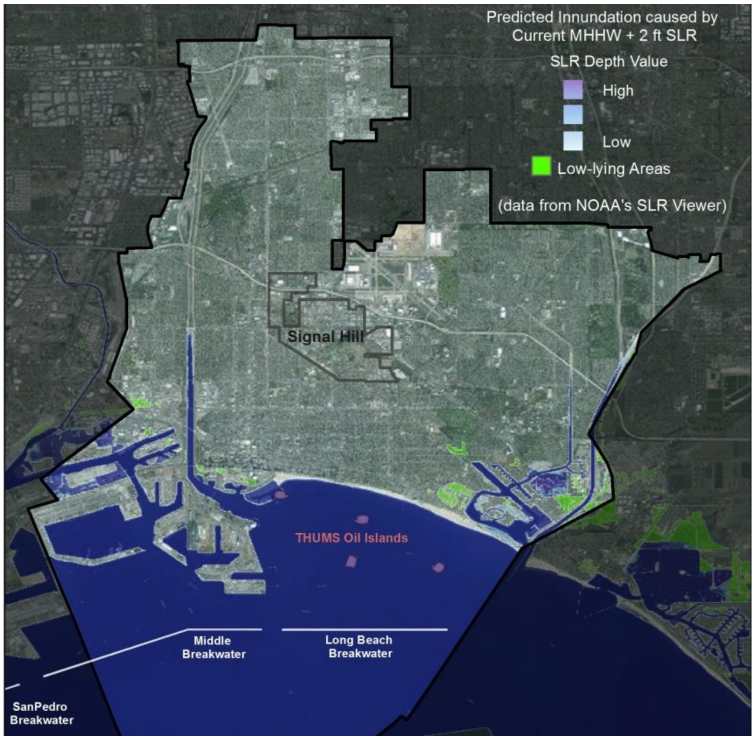


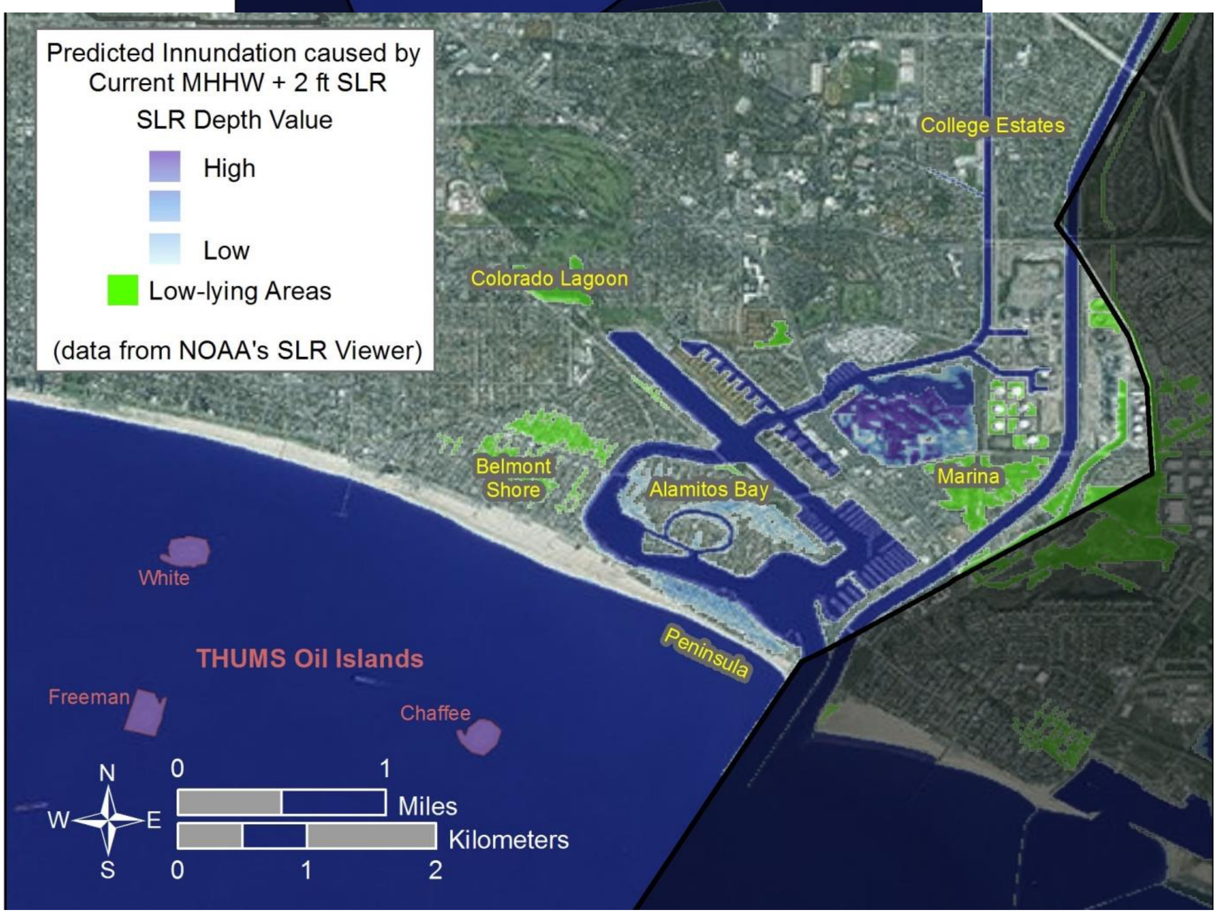
Predicted Inundation Caused by Current Mean Higher High Water (MHHW) plus **1** *ft* Sea Level Rise (SLR)



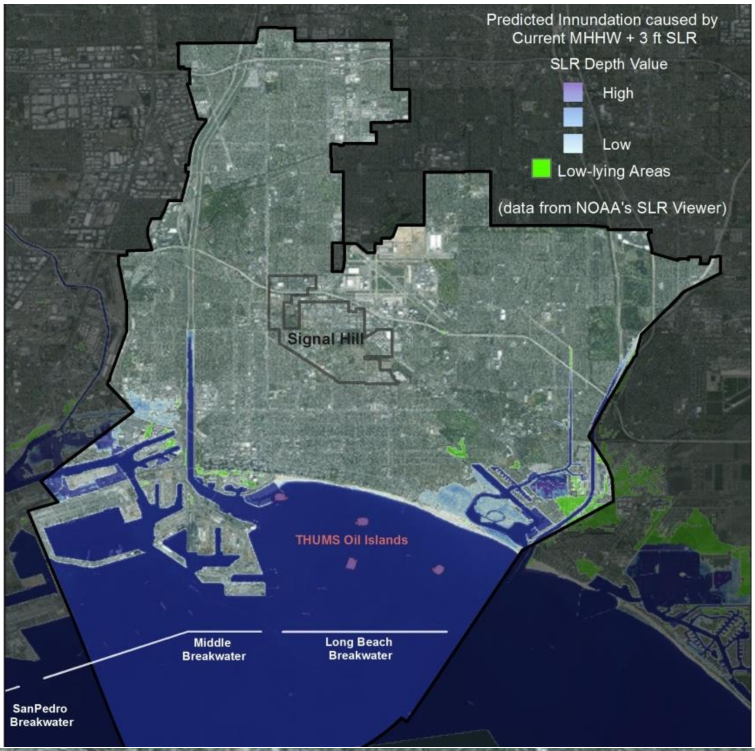


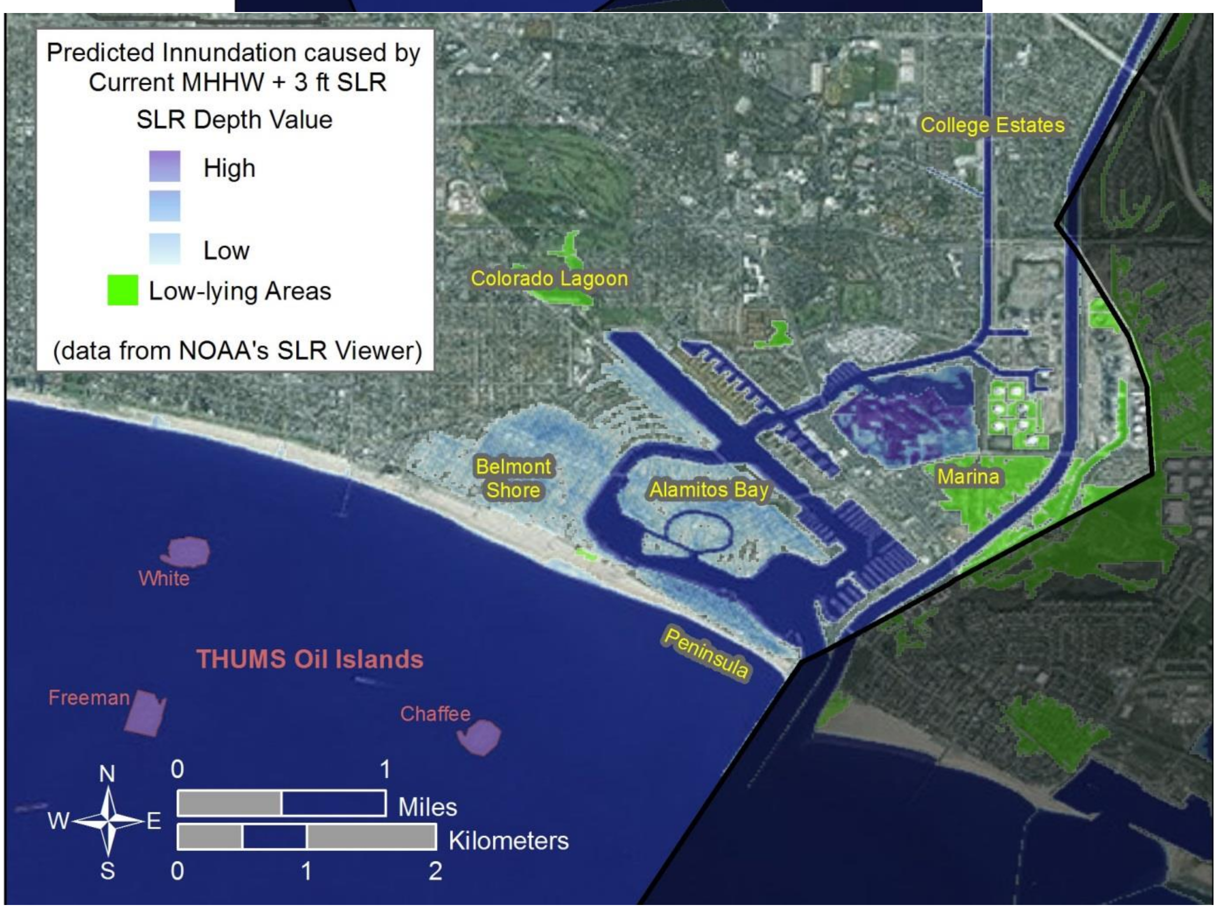
Predicted Inundation Caused by Current Mean Higher High Water (MHHW) plus **2** *ft* Sea Level Rise (SLR)



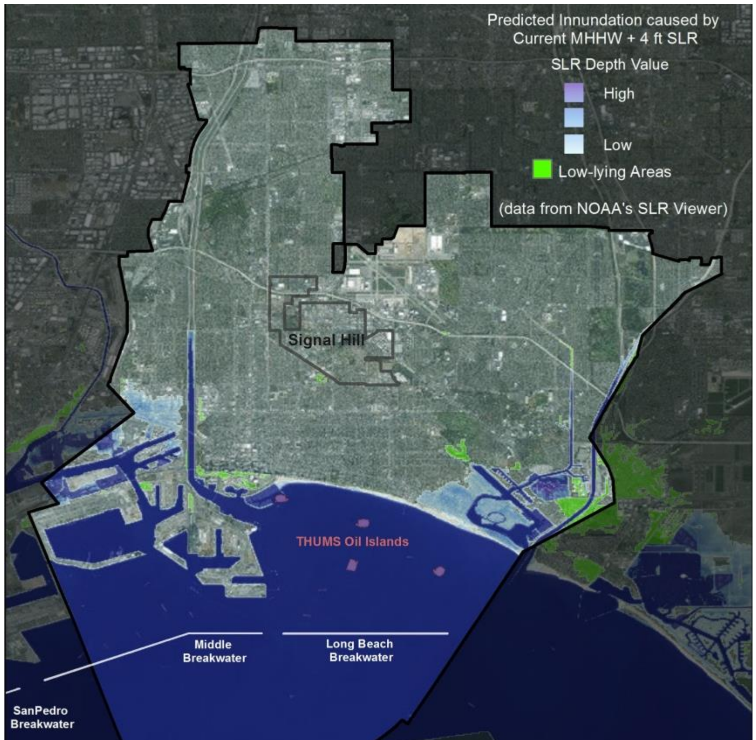


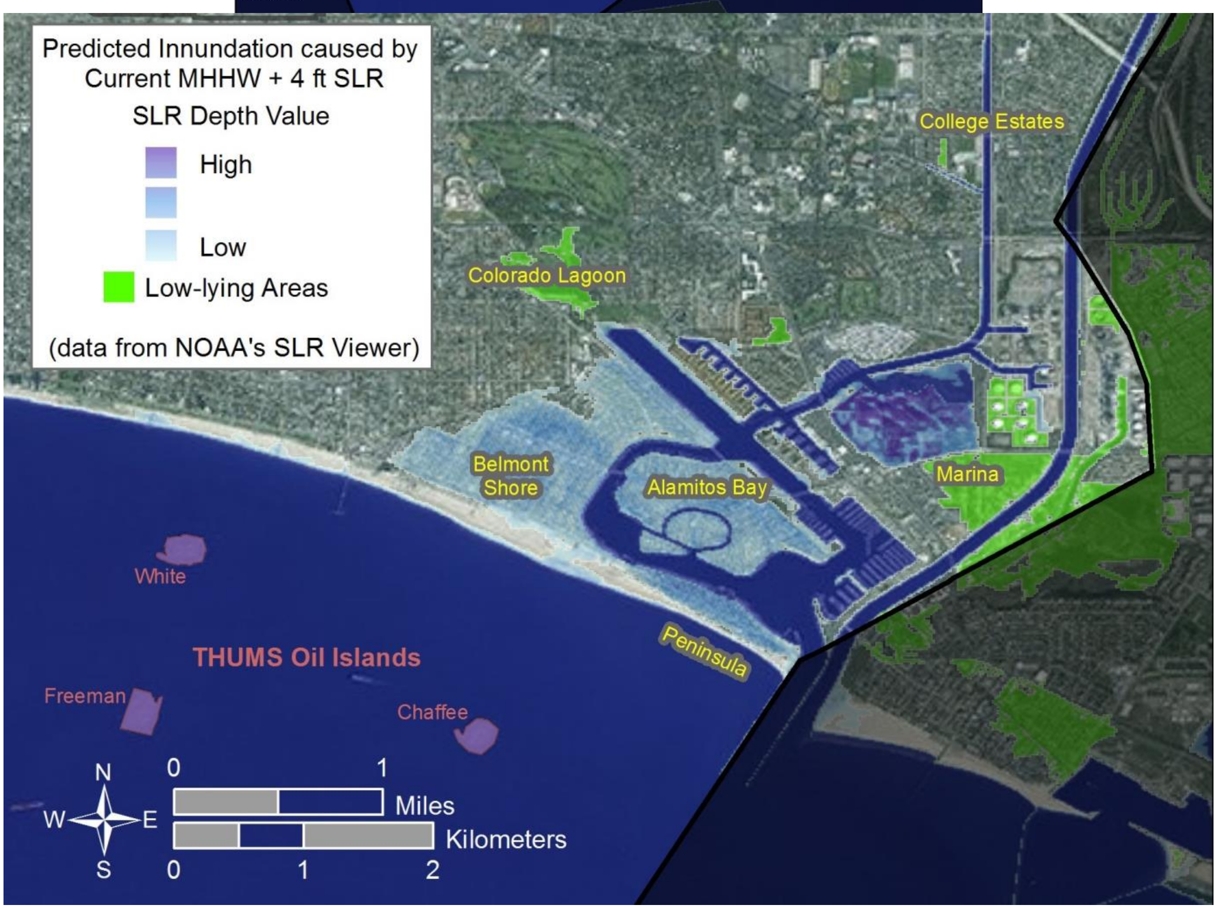
Predicted Inundation Caused by Current Mean Higher High Water (MHHW) plus **3** *ft* Sea Level Rise (SLR)



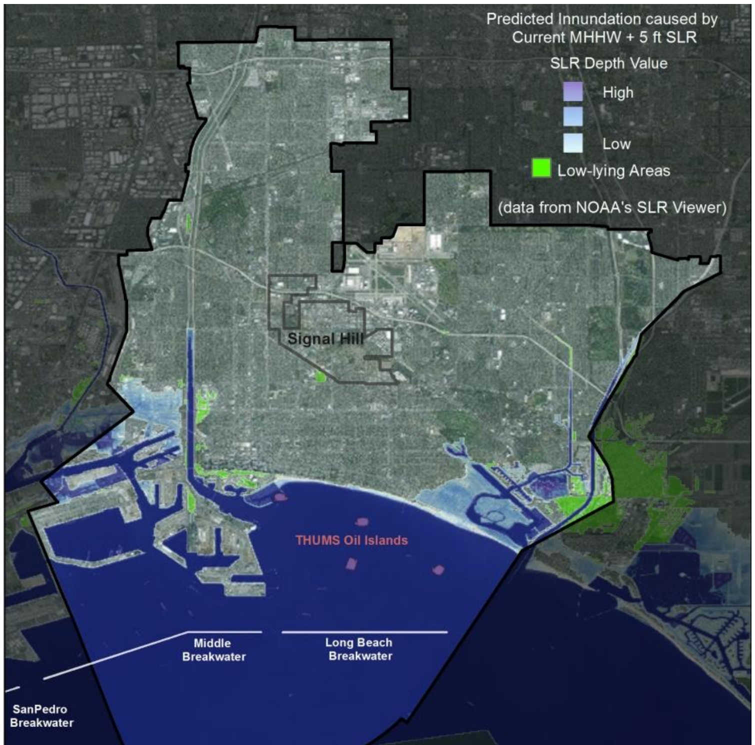


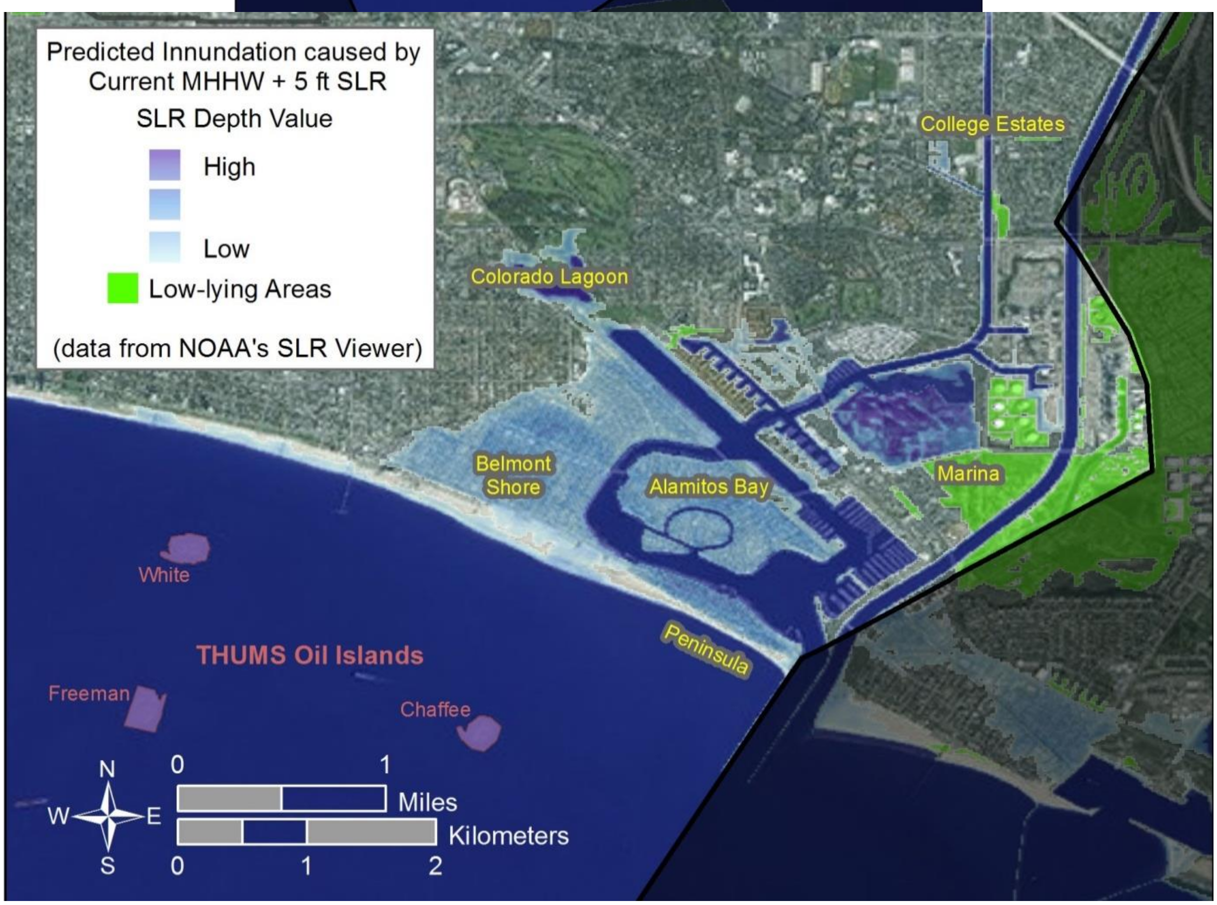
Predicted Inundation Caused by Current Mean Higher High Water (MHHW) plus **4** *ft* Sea Level Rise (SLR)



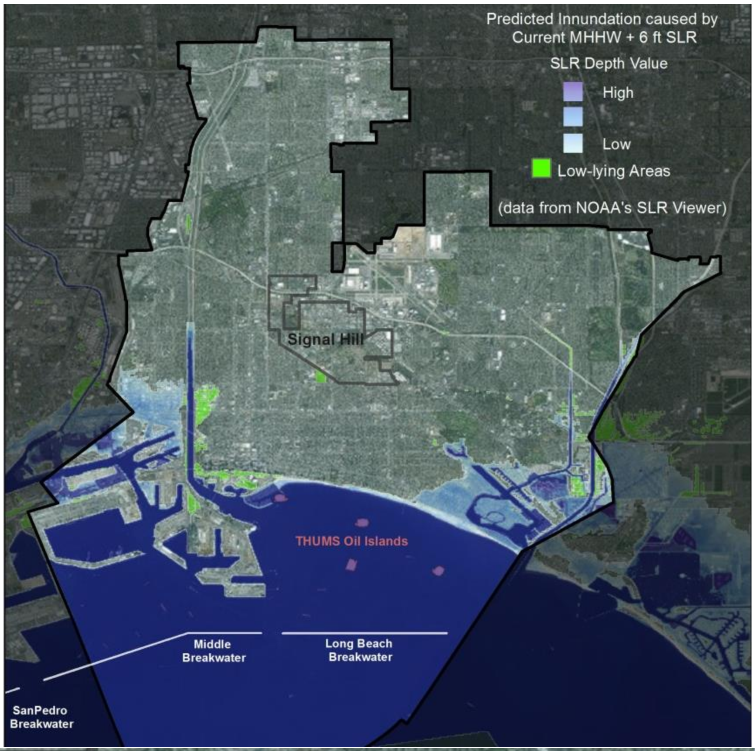


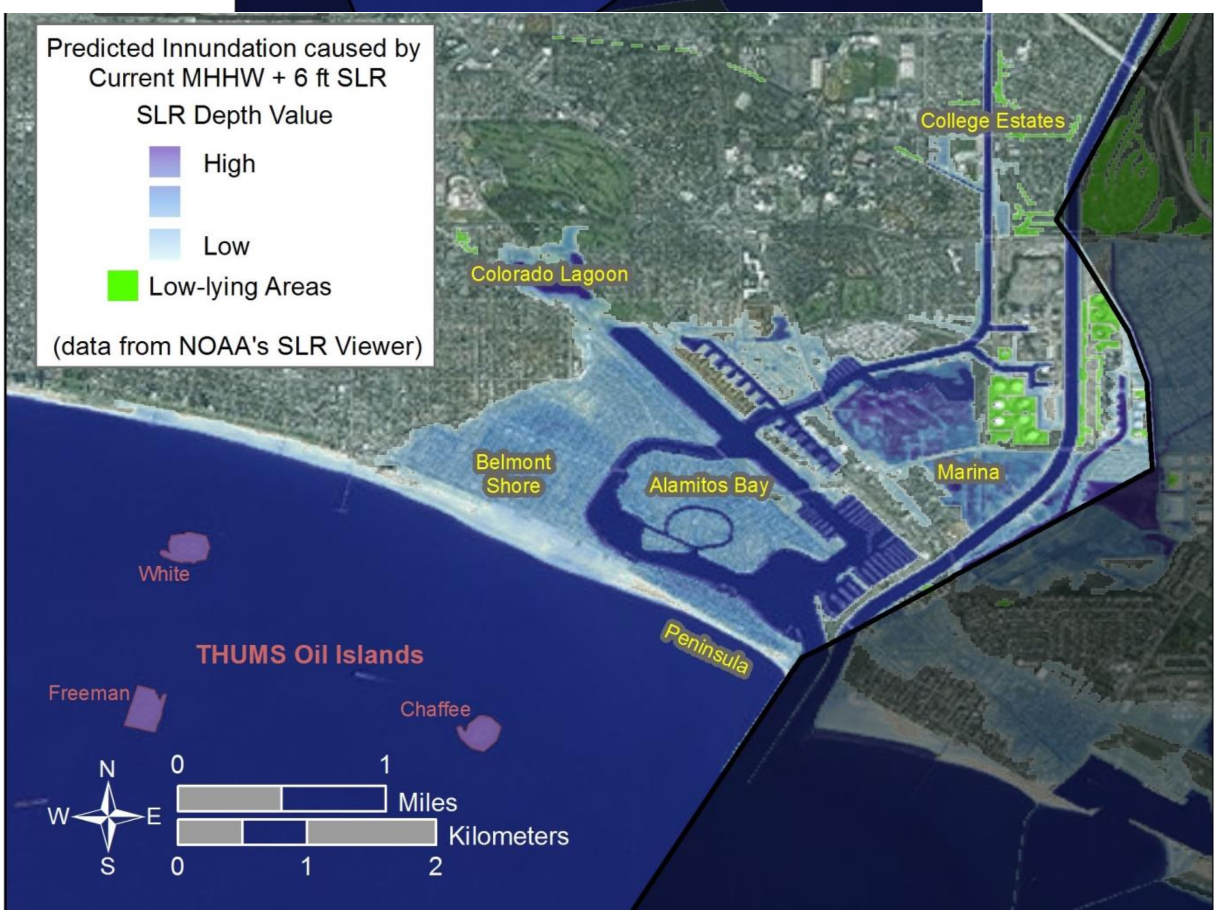
Predicted Inundation Caused by Current Mean Higher High Water (MHHW) plus **5** *ft* Sea Level Rise (SLR)





Predicted Inundation Caused by Current Mean Higher High Water (MHHW) plus **6** *ft* Sea Level Rise (SLR)

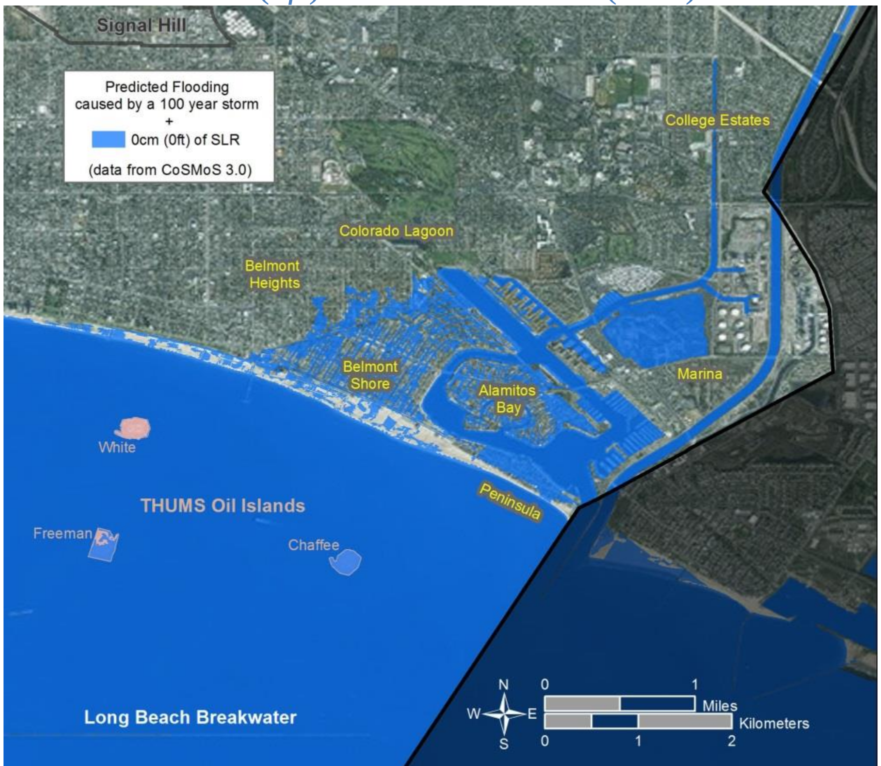




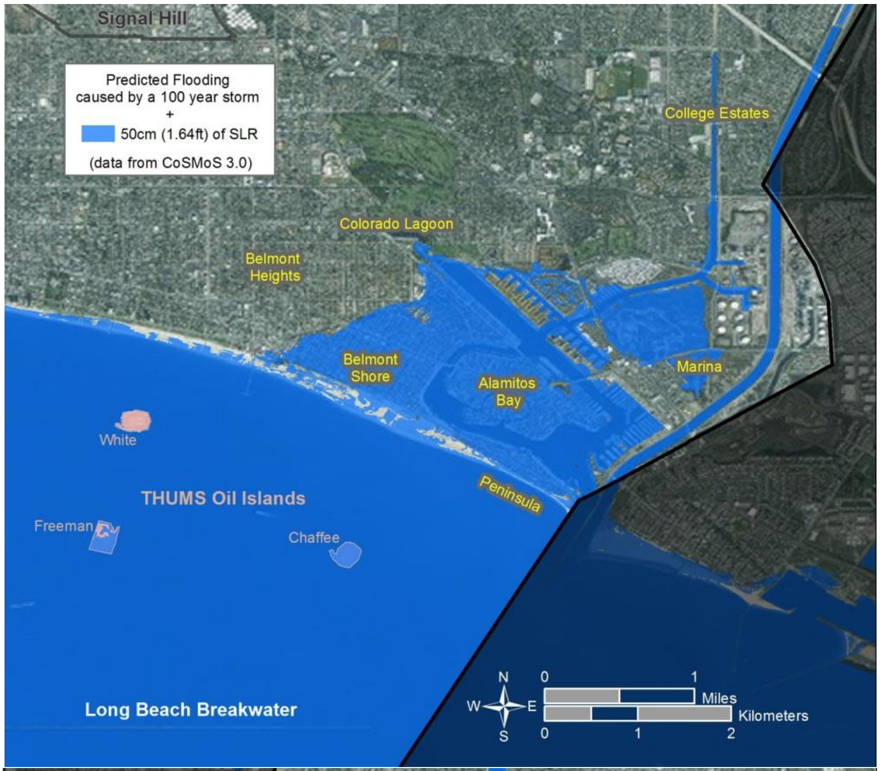
Appendix D

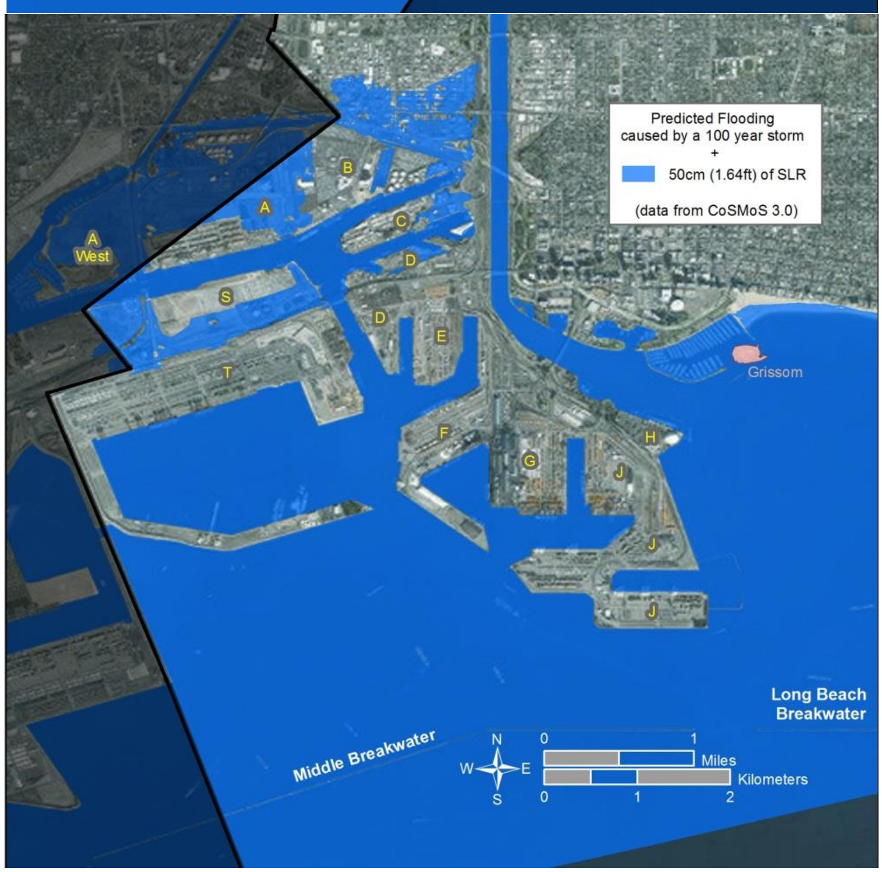
Additional *CoSMoS 3* Results for Long Beach

Predicted Inundation Caused by a 100 year storm plus **0***cm* (**0***ft*) of Sea Level Rise (SLR)

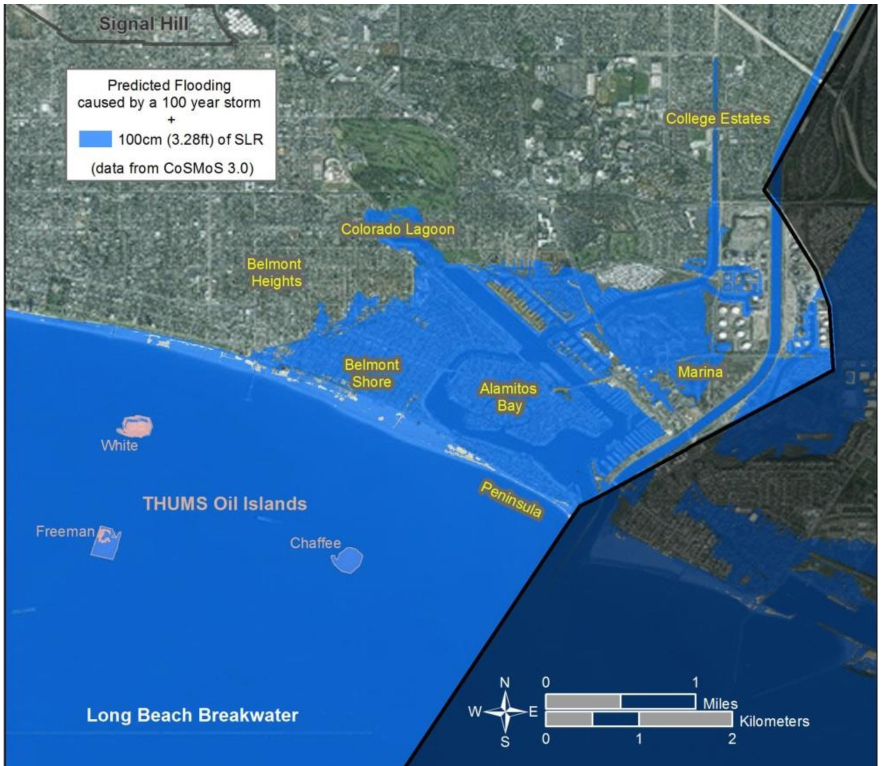


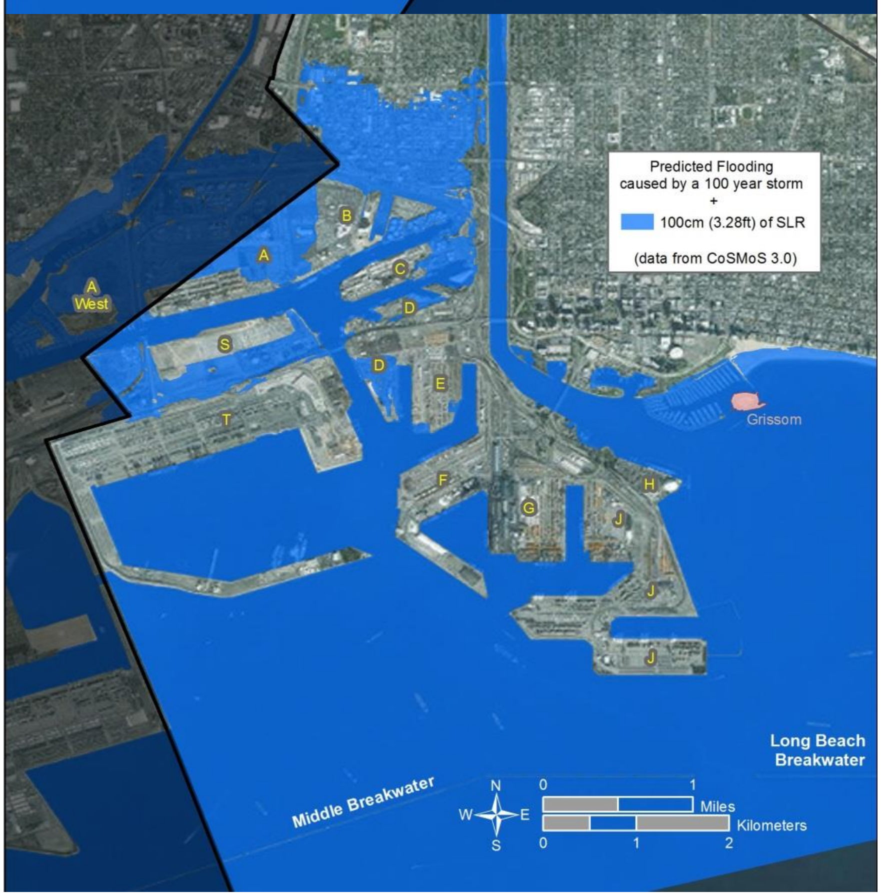
Predicted Inundation Caused by a 100 year storm plus **50***cm* (**1.64***ft*) of Sea Level Rise (SLR)



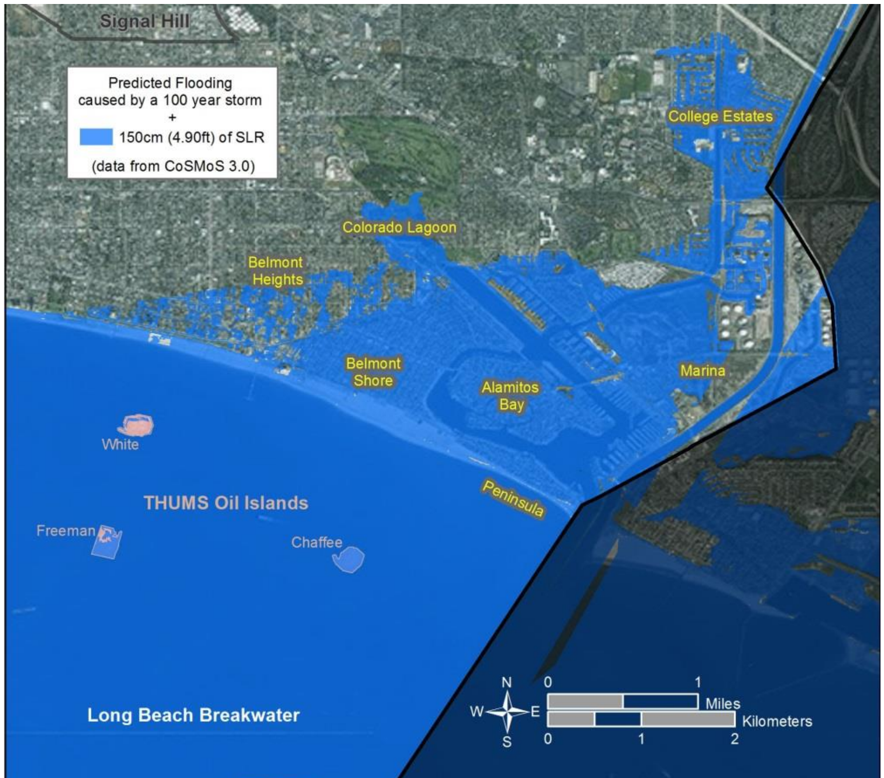


Predicted Inundation Caused by a 100 year storm plus **100***cm* (**3.28***ft*) of Sea Level Rise (SLR)





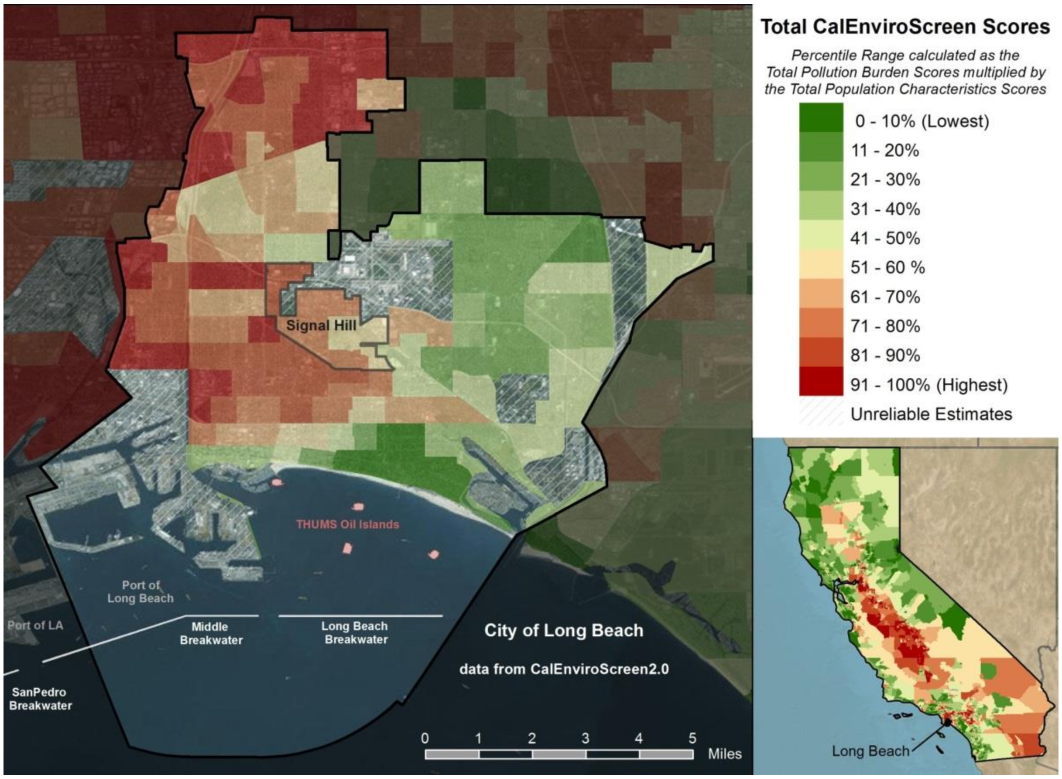
Predicted Inundation Caused by a 100 year storm plus **150***cm* (**4.90***ft*) of Sea Level Rise (SLR)



Appendix E

Additional *CalEnviroScreen 2.0* Results for Long Beach

Total CalEnviroScreen Scores



City of Long Beach		
Mean	Min	Max
33.449	5.645	61.150

State of California		
Mean	Min	Max
26.606	1.1612	89.216

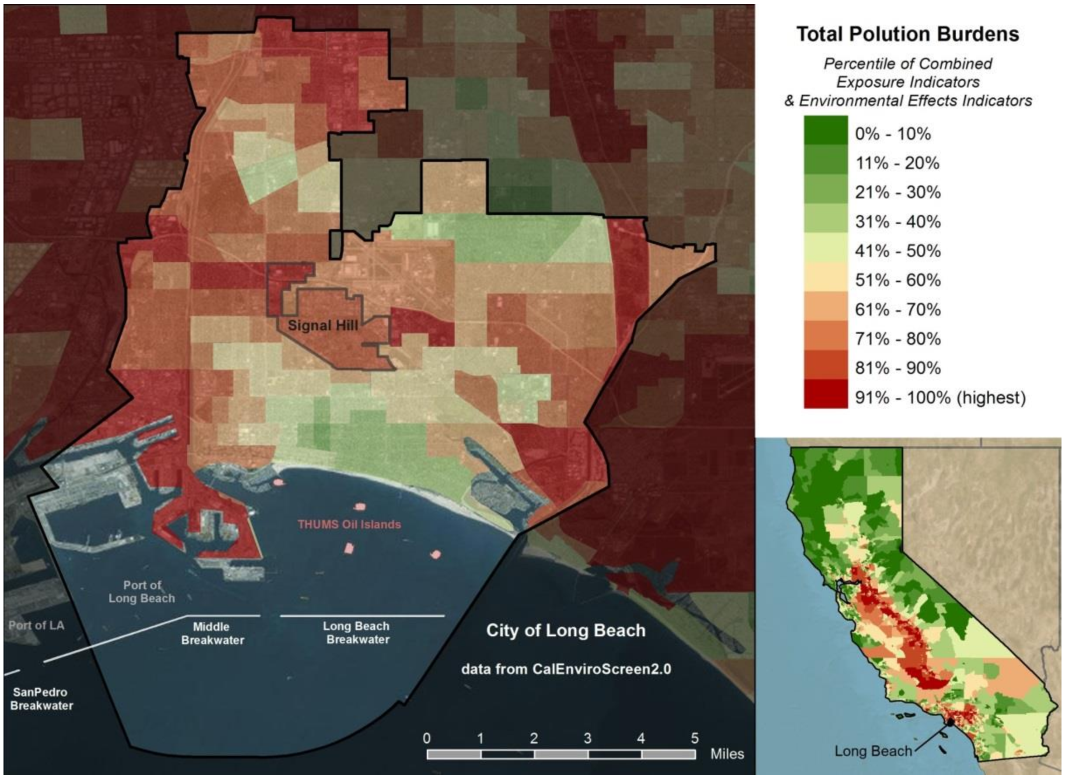
Red indicates High Values for the Long Beach area compared to the overall state values

Note: the above statistics are based on the Total Scores.
The mapped values on the left are these scores depicted as deciles (10 equal groups).

Total *CalEnviroScreen 2.0* Scores are calculated from the Total Scores for the following two groups of indicators: **Pollution Burdens** and **Population Characteristics**. Census tracts with darker red colors have the higher *CalEnviroScreen* scores and therefore have relatively high pollution burdens and population sensitivities. Census tracts with lighter green colors have lower scores, and correspondingly lower pollution burdens and sensitivities. Numerical scores for each census tract, as well as the individual indicator scores for each census tract, may be found online at OEHHA's web site at (*http://www.oehha.ca.gov/ej/ces2*).

The Long Beach map is a "close-up" of the statewide map and is intended to provide greater clarity on the relative scoring of census tracts in those regions. Colors on this map reflect the relative statewide scoring of individual census tracts.

Total Pollution Burdens



City of Long Beach		
Mean	Min	Max
67.330	27.044	98.208

State of California		
Mean	Min	Max
50.006	0.0124	100

Red indicates High Values for the Long Beach area compared to the overall state values

This map shows the combined **Pollution Burden** scores, in which "pollution burden" represents the potential degree of exposures to pollutants and the adverse environmental conditions caused by pollution.

Total Pollution Burden Scores for each census tract are derived from the average percentiles of the seven **Exposures Indicators** and five **Environmental Effects Indicators**, shown below (with their corresponding Appendix page numbers):

Exposure Indicators:

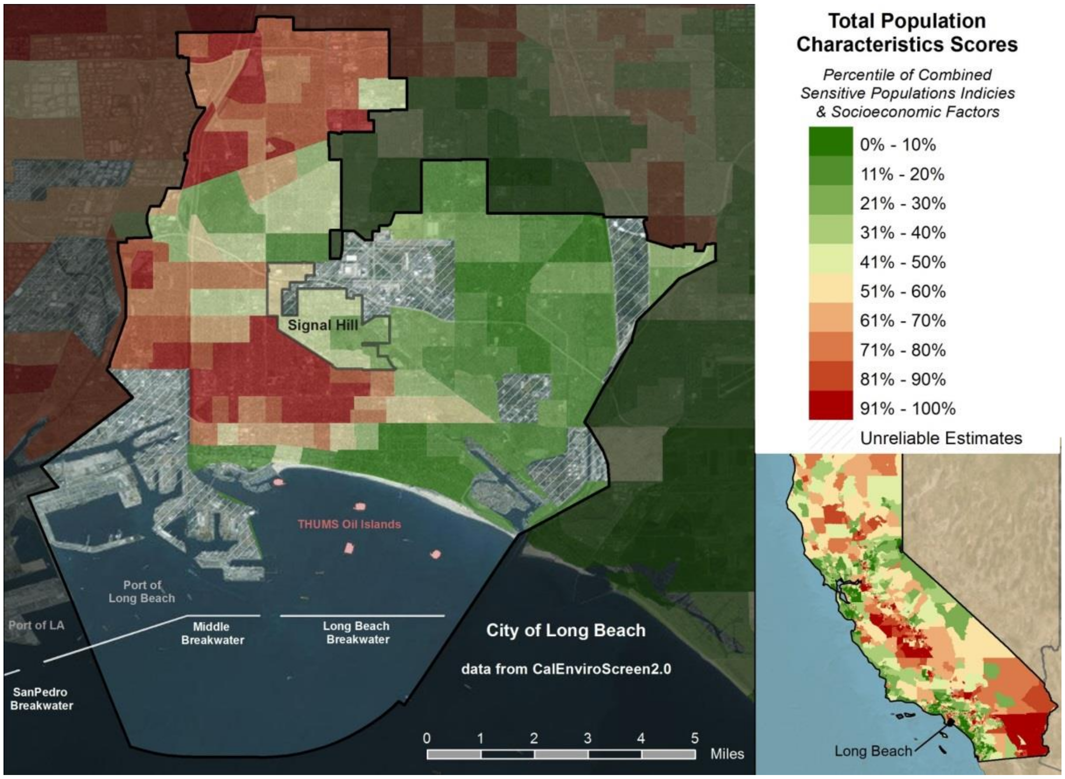
1. **Ozone** Concentrations (E6)
2. **PM2.5** Concentrations (E7)
3. **Diesel PM** Emissions (E8)
4. **Pesticide Use** (E9)
5. **Toxic Releases** from Facilities (E10)
6. **Traffic Density** (E11)
7. **Drinking Water Contaminants** (E12)

Environmental Effects Indicators:

1. **Cleanup Sites** (E13)
2. **Groundwater Threats** (E14)
3. **Hazardous Waste** Facilities & Generators (E15)
4. **Impaired Water Bodies** (E16)
5. **Solid Waste** Sites & Facilities (E17)

"Indicators from the Environmental Effects component were given half the weight of the indicators from the Exposures component. The calculated average pollution burden score (average of the indicators) was divided by 10 and rounded to one decimal place for a Pollution Burden score ranging from 0.1 -10." (OEHHA 2014, page 90)

Total Population Characteristic Scores



City of Long Beach		
Mean	Min	Max
58.019	0.564	99.448

State of California		
Mean	Min	Max
50.006	0.0125	100

Red indicates High Values for the Long Beach area compared to the overall state values

This map shows the combined **Population Characteristic** scores, in which "population characteristics" represent the potential biological traits, health status, or community characteristics that can cause increased vulnerability to **Pollution Burdens**.

Total Population Characteristic Scores for each census tract are derived from the average percentiles of the three **Sensitive Populations Indicators** and four **Socioeconomic Factor Indicators**, shown below (along with their corresponding Appendix page numbers):

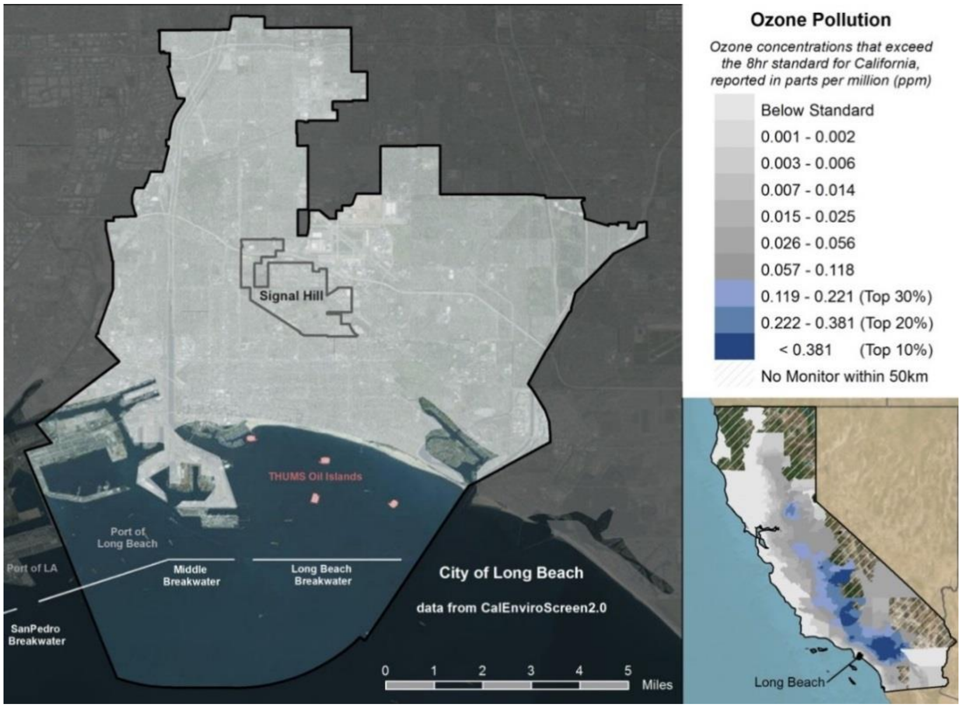
Sensitive Population Indicators:

1. **High Risk Age Groups** (E18)
2. **Asthma** (E19)
3. **Low Birth Weights** (E20)

Socioeconomic Factor Indicators

1. **High School Education** (E21)
2. **Linguistic Isolation** (E22)
3. **Poverty** (E23)
4. **Unemployment** (E24)

Ozone Pollution



City of Long Beach		
Mean	**Min**	**Max**
0.0003 *ppm* over CA limit = 0.07 *ppm* *Total*	0 *ppm* over CA limit ≤ 0.07 *ppm* *Total*	0.0029 *ppm* over CA limit = 0.07 *ppm* *Total*

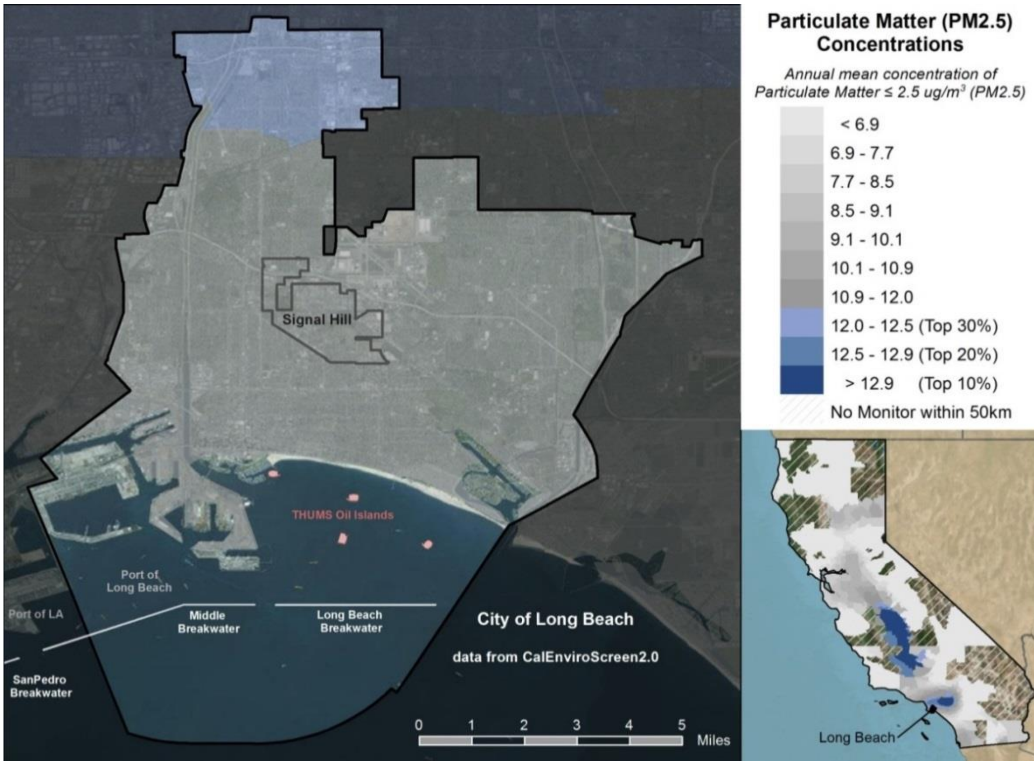
State of California		
Mean	**Min**	**Max**
0.104 *ppm* over CA limit = 0.17 *ppm* *Total*	0 *ppm* over CA limit ≤ 0.07 *ppm* *Total*	1.277 *ppm* over CA limit = 1.35 *ppm* *Total*

CalEnviroScreen 2.0 **Ozone Pollution** values are used to evaluate **air quality** in census tracts due to the **impacts of Ozone**. The above map shows the portion of the daily maximum 8-hour ozone concentration over the California 8-hour standard (0.070 ppm), averaged over three years (2009 to 2011).

“Ozone pollution causes numerous adverse health effects, including respiratory irritation and lung disease. The health impacts of ozone and other criteria air pollutants (particulate matter (PM), nitrogen dioxide, carbon monoxide, sulfur dioxide, and lead) have been considered in the development of health-based standards. Of the six criteria air pollutants, ozone and particle pollution pose the most widespread and significant health threats. The California Air Resources Board maintains a wide network of air monitoring stations that provides information that may be used to better understand exposures to ozone and other pollutants across the state.” (OEHHA 2014, page 19)

“Ozone is an extremely reactive form of oxygen. In the upper atmosphere ozone provides protection against the sun’s ultraviolet rays. Ozone at ground level is the primary component of smog. Ground-level ozone is formed from the reaction of oxygen-containing compounds with other air pollutants in the presence of sunlight. Ozone levels are typically at their highest in the afternoon and on hot days (NRC, 2008). Adverse effects of ozone, including lung irritation, inflammation and exacerbation of existing chronic conditions, can be seen at even low exposures (Alexis et al.2010, Fann et al. 2012, Zanobetti and Schwartz 2011). A long-term study in southern California found that rates of asthma hospitalization for children increased during warm season episodes of high ozone concentration (Moore et al.2008).” (OEHHA 2014, p19-20)

Particulate Matter (PM2.5) Concentrations



City of Long Beach		
Mean	Min	Max
11.475 µg/m³	10.690 µg/m³	12.209 µg/m³

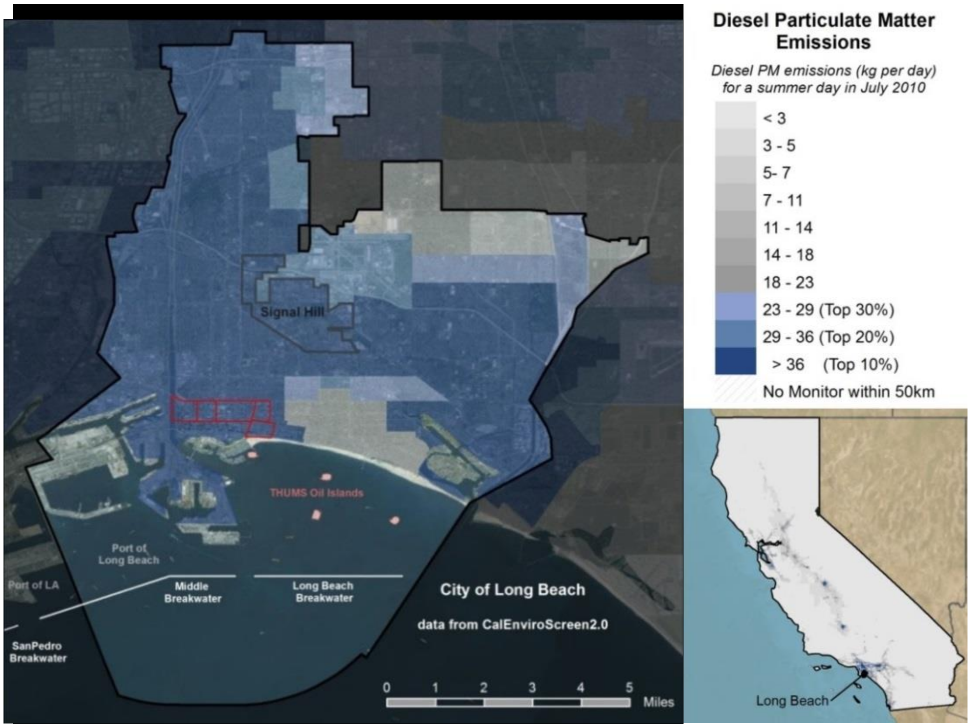
State of California		
Mean	Min	Max
10.014 µg/m³	2.303 µg/m³	17.044 µg/m³

Red indicates High Values for the Long Beach area compared to the overall state values

CalEnviroScreen 2.0 **PM2.5** values are used to evaluate **air quality** in census tracts due to the **impacts of Particulate Matter less than or equal to 2.5 ug/m³** (PM2.5).

"Particulate matter (PM) is a complex mixture of aerosolized solid and liquid particles including such substances as organic chemicals, dust, allergens and metals. These particles can come from many sources, including cars and trucks, industrial processes, wood burning, or other activities involving combustion. The composition of PM depends on the local and regional sources, time of year, location and weather. The behavior of particles and the potential for PM to cause adverse health effects is directly related to particle size. The smaller the particle size, the more deeply the particles can penetrate into the lungs. Some fine particles have also been shown to enter the bloodstream. Those most susceptible to the effects of PM exposure include children, the elderly, and persons suffering from cardiopulmonary disease, asthma, and chronic illness (US EPAUS EPA, 2012a). PM2.5 refers to particles that have a diameter of 2.5 micrometers or less. Particles in this size range can have adverse effects on the heart and lungs, including lung irritation, exacerbation of existing respiratory disease, and cardiovascular effects. The US EPA has set a new standard for ambient PM2.5 concentration of 12 µg/m3, down from 15 µg/m3. According to EPA's projections, by the year 2020 only seven counties nationwide will have PM2.5 concentrations that exceed this standard. All are in California (US EPA, 2012b)." (OEHHA 2014, pages 23-24)

Diesel Particulate Matter (DieselPM) Emissions



City of Long Beach		
Mean	**Min**	**Max**
51.630 *kg/day*	**6.51** *kg/day*	**164.4** *kg/day* *= State Max*

State of California		
Mean	**Min**	**Max**
18.240 *kg/day*	0 *kg/day*	**164.4** ***kg/day***

Red indicates High Values for the Long Beach area compared to the overall state values

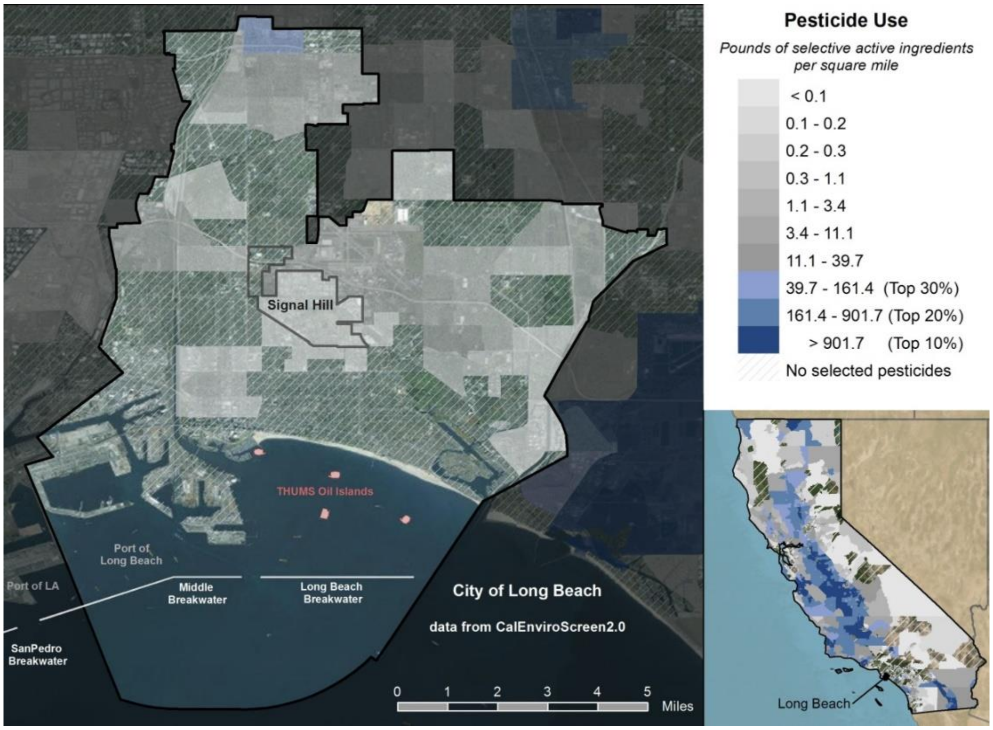
Note: the majority of Long Beach (86 out of 116 total census tracts which is >75%) has diesel PM emissions >36 kg/day which is higher than 90% of California.

The Census Tracks outlined in red have Diesel PM values equal to the state maximum (164.4 kg/day).

CalEnviroScreen 2.0 **Diesel PM** Emissions Values are used to evaluate **air quality** in census tracts due to the impacts **of diesel particulate matter (PM)**.

"Diesel particulate matter (diesel PM) occurs throughout the environment from both on-road and off-road sources. Major sources of diesel PM include trucks, buses, cars, ships and locomotive engines. Diesel PM is concentrated near ports, rail yards and freeways where many such sources exist. Exposure to diesel PM has been shown to have numerous adverse health effects including irritation to the eyes, throat and nose, cardiovascular and pulmonary disease, and lung cancer." (OEHHA 2014)

Pesticide Use



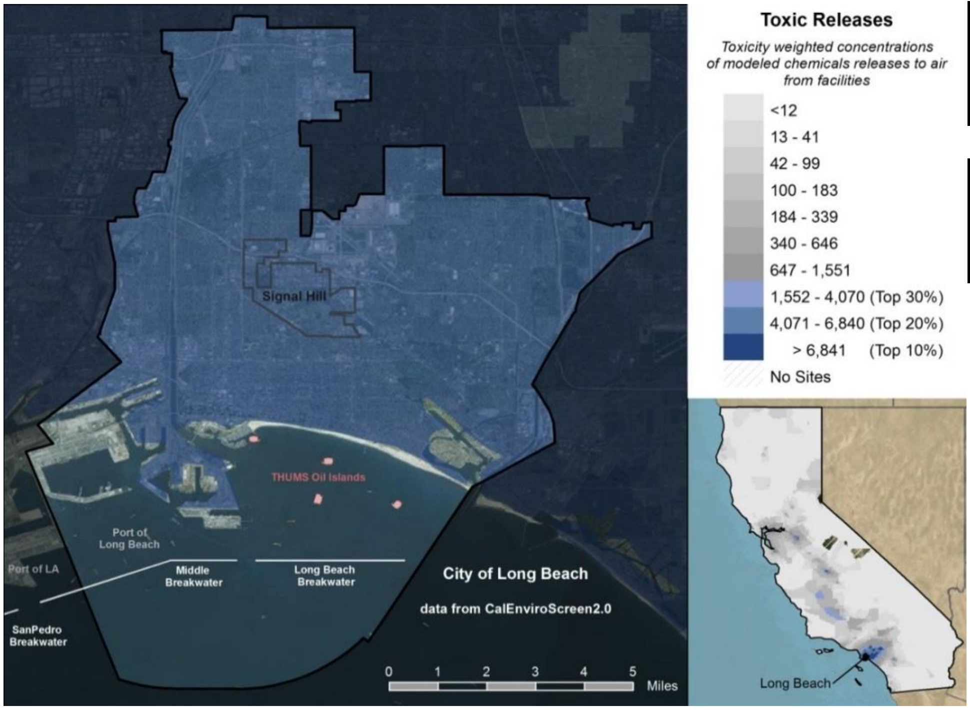
City of Long Beach		
Mean	**Min**	**Max**
1.142 *lbs/mi²*	0 *lbs/mi²*	50.149 *lbs/mi²*

State of California		
Mean	**Min**	**Max**
287.109 *lbs/mi²*	0 *lbs/mi²*	86,025.5 *lbs/mi²*

CalEnviroScreen 2.0 **Pesticide Use** Values are used to evaluate the amount of **Environmental Contamination** in census tracts due to the **impacts of Pesticides**.

"Communities near agricultural fields, primarily farm worker communities, may be at risk for exposure to pesticides. Drift or volatilization of pesticides from agricultural fields can be a significant source of pesticide exposure. Complete statewide data on human exposures to pesticides do not exist. The most robust pesticide information available statewide are data maintained by the California Department of Pesticide Regulation showing where and when pesticides are used across the state. Pesticide use, especially use of volatile chemicals that can easily become airborne, can serve as an indicator of potential exposure. Similarly, unintended environmental damage from the use of pesticides may increase in areas with greater use." (OEHHA 2014, page 41)

Toxic Releases



City of Long Beach		
Mean	Min	Max
11,843.0918 *TRI Score*	8,085.847 *TRI Score*	36,475.982 *TRI Score*

State of California		
Mean	Min	Max
2,963.695 *TRI Score*	0.000002 *TRI Score*	758,910.7 *TRI Score*

Red indicates High Values for the Long Beach area compared to the overall state values

Note: ALL of Long Beach has Toxic Release values >6,841 which is higher than 90% of California.

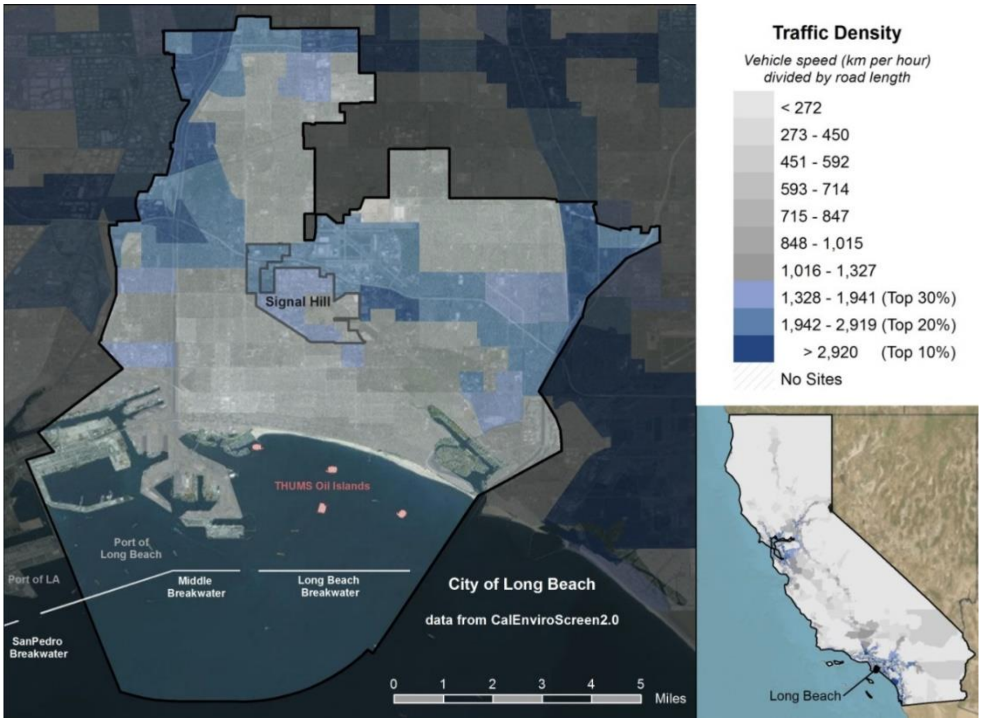
CalEnviroScreen 2.0 **Toxic Release** Values are used to evaluate the amount of **Environmental Contamination** in census tracts due to the **impacts of Toxic chemicals** discharged to the environment as reported in Toxic Release Inventories.

"The U.S. Environmental Protection Agency (US EPA) maintains a toxic substance inventory of on-site releases to air, water, and land and underground injection of any classified chemical, as well as quantities transferred off-site. The data are reported by each facility."

"The Toxics Release Inventory (TRI) provides public information on emissions and releases into the environment from a variety of facilities across the state. TRI data do not, however, provide information on the extent of public exposure to these chemicals. That said, US EPA has stated that "[d]isposal or other releases of chemicals into the environment occur through a range of practices that could ultimately affect human exposure to the toxic chemicals." (US EPA, 2010). A study of pollution in the printed wiring board industry found that among states with high TRI emissions in 2006, RSEI risk scores for California were by far the highest. According to the study, California combines high toxic emissions with a high risk score, based on location, composition of emissions and population exposure modeling (Lam et al., 2011).

Air monitoring data at hundreds of locations across the United States have identified over a dozen hazardous air pollutants at concentrations that exceed California cancer or non-cancer benchmarks (McCarthy et al., 2009)." (OEHHA 2014, pages 47-48)

Traffic Density



City of Long Beach		
Mean	Min	Max
1,386.7 km/hr/km	445.3 km/hr/km	5,641.4 km/hr/km

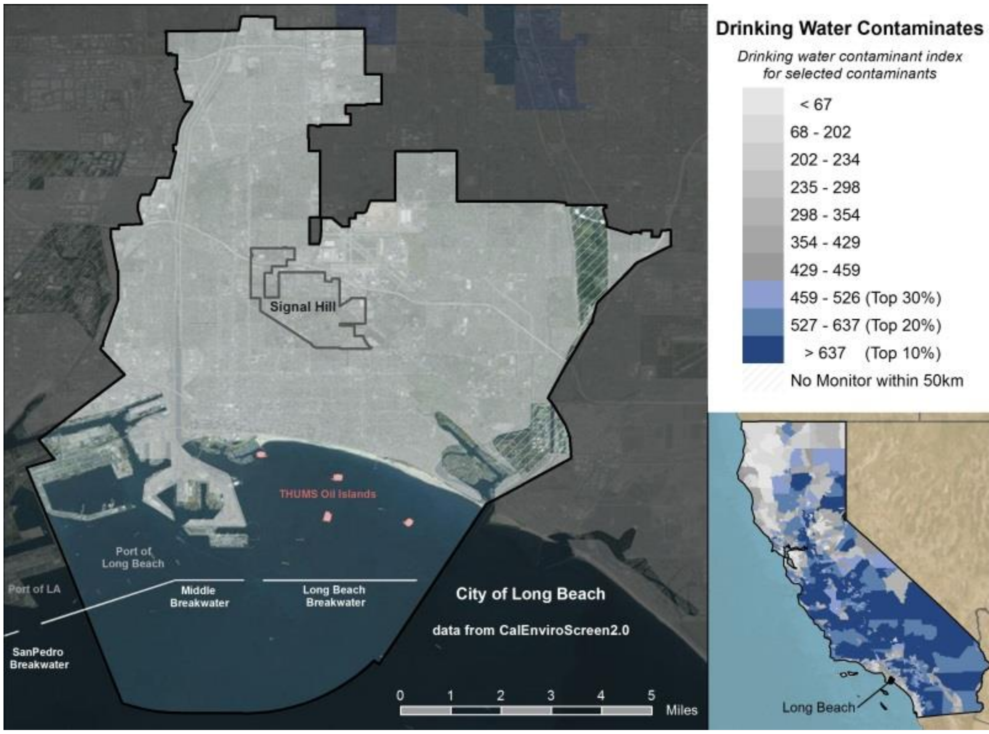
State of California		
Mean	Min	Max
1,252.2 km/hr/km	0 km/hr/km	43,561.8 km/hr/km

Red indicates High Values for the Long Beach area compared to the overall state values

CalEnviroScreen 2.0 **Traffic Density** Values are used to evaluate the **Air Quality** in census tracts due to the **impacts of Automobiles**. Traffic density values are estimated as vehicle km per hour divided by total road length (km) within 150m of the census boundary. The most recent year for which data are available for use by this tool is 2004

"While California has the strictest auto emissions standards in the U.S., the state is also known for its freeways and heavy traffic. Traffic is a significant source of air pollution, particularly in urban areas, where more than 50% of particulate emissions come from traffic. Exhaust from vehicles contains a large number of toxic chemicals, including nitrogen oxides, carbon monoxide, and benzene. Traffic exhaust also plays a role in the formation of photochemical smog. Health effects of concern from these pollutants include heart and lung disease, cancer, and increased mortality. " (OEHHA 2014, page 52)

Drinking Water Contaminants



City of Long Beach		
Mean	Min	Max
221.785	175.271	314.904

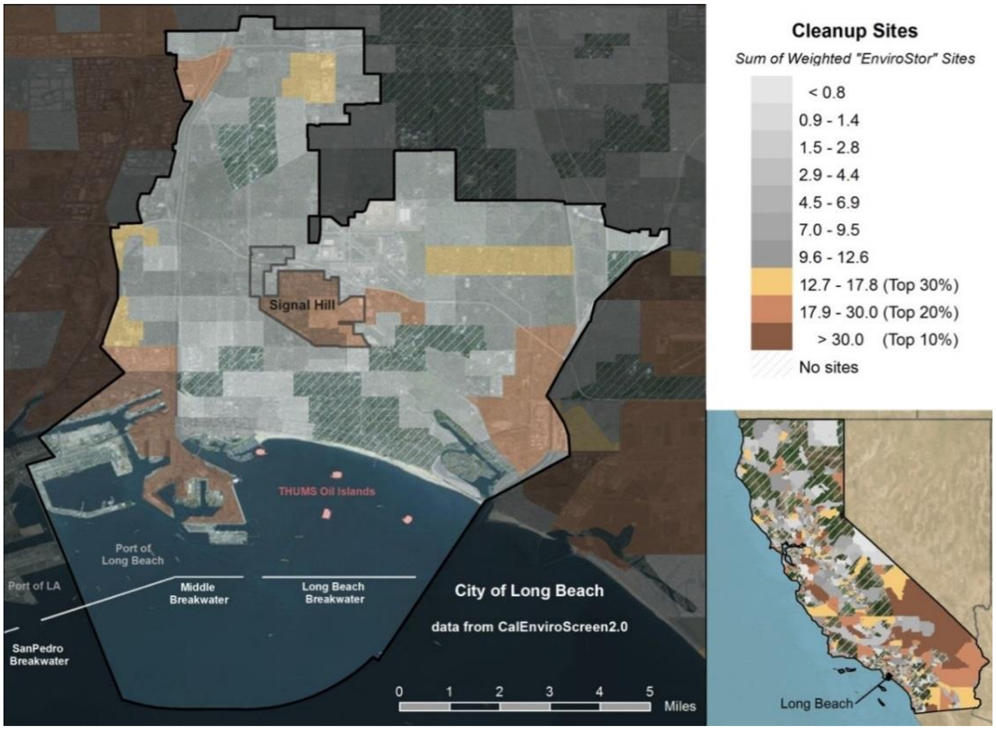
State of California		
Mean	Min	Max
351.936	0	1,012.585

Red indicates High Values for the Long Beach area compared to the overall state values

CalEnviroScreen 2.0 **Drinking Water Contaminate** Values are used to evaluate the amount of **Environmental Contamination** in census tracts due to the **impacts of contaminated drinking water**. "The drinking water contaminant index is a combination of contaminant data that takes into account the relative concentrations of different contaminants and whether multiple contaminants are present. The indicator does not indicate whether water is safe to drink."

"Californians receive their drinking water from a wide variety of sources and distribution systems. In 2005, approximately 93% of Californians received their water from public water systems (USGS, 2009). According to the California Department of Public Health, approximately 98% of public water systems meet all federal and state drinking water standards (CDPH, 2011). However, drinking water quality varies with location, water source, treatment method, and the ability of the water purveyor to remove contaminants before distribution. Because water is universally consumed, drinking water contamination has the potential to result in widespread exposures. Contaminants may be introduced into drinking water sources in many ways, such as by natural occurrence, accidents, industrial releases, and agricultural runoff. California water systems have a high rate of compliance with drinking water standards. In 2011, systems serving only between 1.4 and 2.7 percent of the state's population were in violation of one or more drinking water standards (CDPH, 2011 Annual Compliance Report). The drinking water contaminant index used in CalEnviroScreen 2.0 is not a measure of Compliance with these standards." (OEHHA 2014)

Cleanup Sites



City of Long Beach		
Mean	Min	Max
6.558	0	78.8

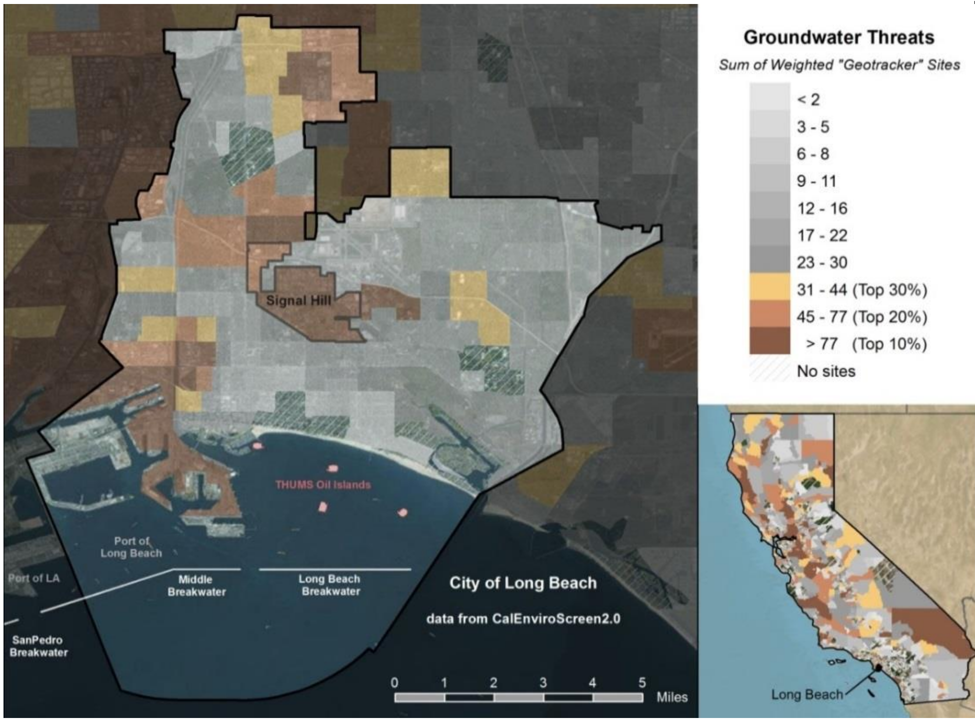
State of California		
Mean	Min	Max
8.393	0	322.50

CalEnviroScreen 2.0 **Cleanup Site** Values are used to evaluate the **Environmental Effects** in census tracts due to the **presence of Cleanup Sites** (calculated as the sum weighted "EnviroStor" sites).

"Sites undergoing cleanup actions by governmental authorities or by property owners have suffered environmental degradation due to the presence of hazardous substances. Of primary concern is the potential for people to come into contact with these substances. Some of these "brownfield" sites are also underutilized due to cleanup costs or concerns about liability. The most complete set of information available related to cleanup sites and brownfields in California is maintained by the Department of Toxic Substances Control. Since the nature and the magnitude of the threat and burden posed by hazardous substances vary among the different types of sites as well as the site status, the indicator takes both into account. Weights were also adjusted based on proximity to populated census blocks. EnviroStor is a public database that provides access to information maintained by DTSC on site cleanup." "The database contains information related to the status of the site such as required cleanup actions, involvement/land use restriction, or 'no involvement.'" "US EPA maintains and distributes the dataset for National Priorities List (NPL) Superfund sites nationwide."

Contaminated sites can pose a variety of risks to nearby residents. Hazardous substances can move off-site and impact surrounding communities through volatilization, groundwater plume migration, or windblown dust. Studies have found levels of organochlorine pesticides in blood (Gaffney et al. 2005) and toxic metals in house dust (Zota et al. 2011) that were correlated with residents' proximity to contaminated sites." (OEHHA 2014, page 57)

Ground Water Threats



City of Long Beach		
Mean	**Min**	**Max**
28.350	0	221.45

State of California		
Mean	**Min**	**Max**
27.059	0	2,061.5

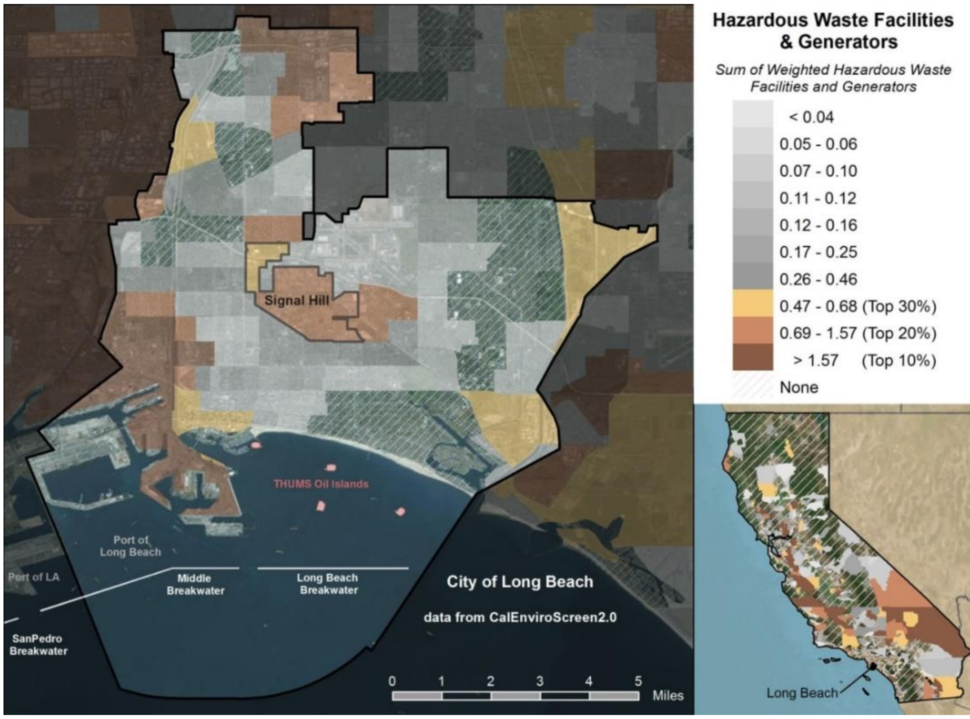
Red indicates High Values for the Long Beach area compared to the overall state values

CalEnviroScreen 2.0 **Groundwater Threat** Values are used to evaluate the **Environmental Effects** in census tracts due to the **presence of groundwater threats** (calculated as the sum weighted "GeoTracker" sites).

"Many activities can pose threats to groundwater quality. These include the storage and disposal of hazardous materials on land and in underground storage tanks at various types of commercial, industrial, and military sites. Thousands of storage tanks in California have leaked petroleum or other hazardous substances, degrading soil and groundwater. Storage tanks are of particular concern when they can affect drinking water supplies. Storage tank sites can expose people to contaminated soil and volatile contaminants in air. In addition, the land surrounding these sites may be taken out of service due to perceived cleanup costs or concerns about liability. The most complete set of information related to sites that may impact groundwater and require cleanup is maintained by the State Water Resources Control Board.

The nature and the magnitude of the threat and burden posed by sites maintained in GeoTracker vary significantly by site type (e.g., leaking underground storage tank or cleanup site) and status (e.g., Completed Case Closed or Active Clean up). The indicator takes into account information about the type of site, its status, and its proximity to populated census blocks." (OEHHA 2014, page 64)

Hazardous Waste Facilities & Generators



City of Long Beach		
Mean	Min	Max
0.712	0	16.585

State of California		
Mean	Min	Max
0.458	0	26.02

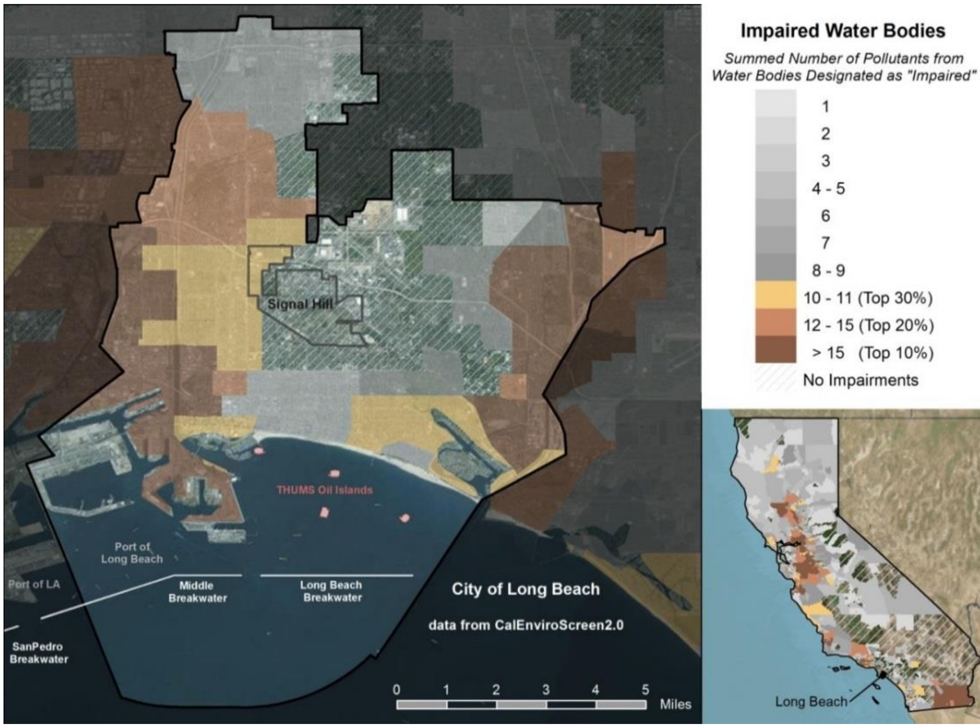
Red indicates High Values for the Long Beach area compared to the overall state values

CalEnviroScreen 2.0 **Hazardous Waste** Facilities & Generator Values are used to evaluate the **Environmental Effects** in census tracts due to the **presence of Hazardous Waste** (calculated as the sum weighted hazardous waste facilities & generator sites).

"Most hazardous waste must be transported from hazardous waste generators to permitted recycling, treatment, storage, or disposal facilities (TSDF) by registered hazardous waste transporters. Most shipments must be accompanied by a hazardous waste manifest. There are widespread concerns for both human health and the environment from sites that serve for the processing or disposal of hazardous waste. Many newer facilities are designed to prevent the contamination of air, water, and soil with hazardous materials, but even newer facilities may negatively affect perceptions of surrounding areas in ways that have economic, social and health impacts. The Department of Toxic Substances Control maintains data on permitted facilities that are involved in the treatment, storage, or disposal of hazardous waste as well as information on hazardous waste generators."

"Hazardous waste by definition that is potentially dangerous or harmful to human health or the environment. US EPA and DTSC both have standards for determining when waste materials must be managed as hazardous waste. Hazardous waste can be liquids, solids, or contained gases. It can include manufacturing by-products, and discarded used or unused materials such as cleaning fluids (solvents) or pesticides. Used oil and contaminated soil generated from a site clean-up can be hazardous wastes (DTSC, Defining Hazardous Waste). In 1995, 97% of toxic chemicals released nationwide came from small generators and facilities (McGlinn, 2000). Generators of hazardous waste may treat waste onsite or send it elsewhere for disposal." (OEHHA 2014, page 72)

Impaired Water Bodies



City of Long Beach		
Mean	Min	Max
9.052	0	29

State of California		
Mean	Min	Max
3.251	0	34

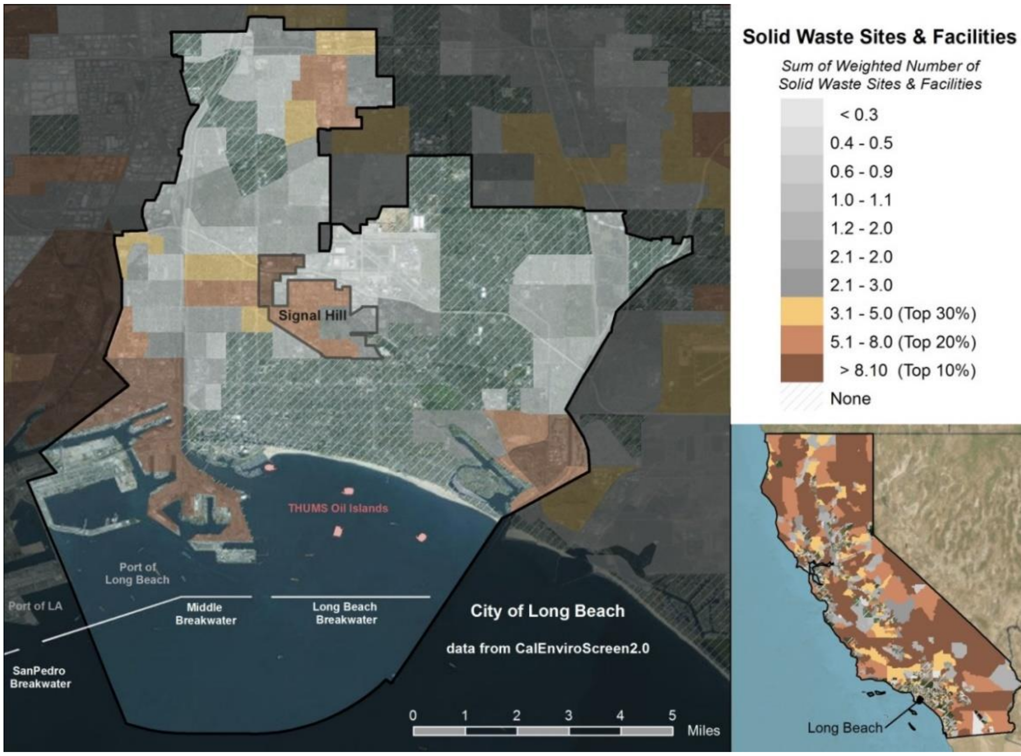
Red indicates High Values for the Long Beach area compared to the overall state values

CalEnviroScreen 2.0 **Impaired Water Bodies** Values are used to evaluate the **Environmental Effects** in census tracts due to the **presence of Impaired Water** (calculated as the summed number of pollutants from water bodies designated as "Impaired").

"Contamination of California streams, rivers, and lakes by pollutants can compromise the use of the water body for drinking, swimming, fishing, aquatic life protection, and other beneficial uses. When this occurs, such bodies are considered "impaired." Information on impairments to these water bodies can help determine the extent of environmental degradation within an area. The SWRCB provides information relevant to the condition of California surface waters. Such information is required by the Federal Clean Water Act. Every two years, State and Regional Water Boards assess the quality of California surface waters. Lakes, streams and rivers that do meet water quality standards, or are not expected to meet water quality standards, are listed as impaired under Section 303(d) of the Clean Water Act.

Rivers, lakes, estuaries and marine waters in California are important for many different uses. Water bodies used for recreation may also be important to the quality of life of nearby residents if subsistence fishing is critical to their livelihood (CalEPA, 2002). Water bodies also support abundant flora and fauna. Changes in aquatic environments can affect biological diversity and overall health of ecosystems. Aquatic species important to local economies may be impaired if the habitats where they seek food and reproduce are changed. Marine wildlife like fish and shellfish that are exposed to toxic substances may potentially expose local consumers to toxic substances as well (CalEPA, 2002). Excessive hardness, unpleasant odor or taste, turbidity, color, weeds, and trash in the waters are types of pollutants affecting water aesthetics (CalEPA, 2002), which in turn can affect nearby communities. " (OEHHA 2014, page 79)

Solid Waste Sites and Facilities



City of Long Beach		
Mean	Min	Max
1.401	0	16.6

State of California		
Mean	Min	Max
1.377	0	61.5

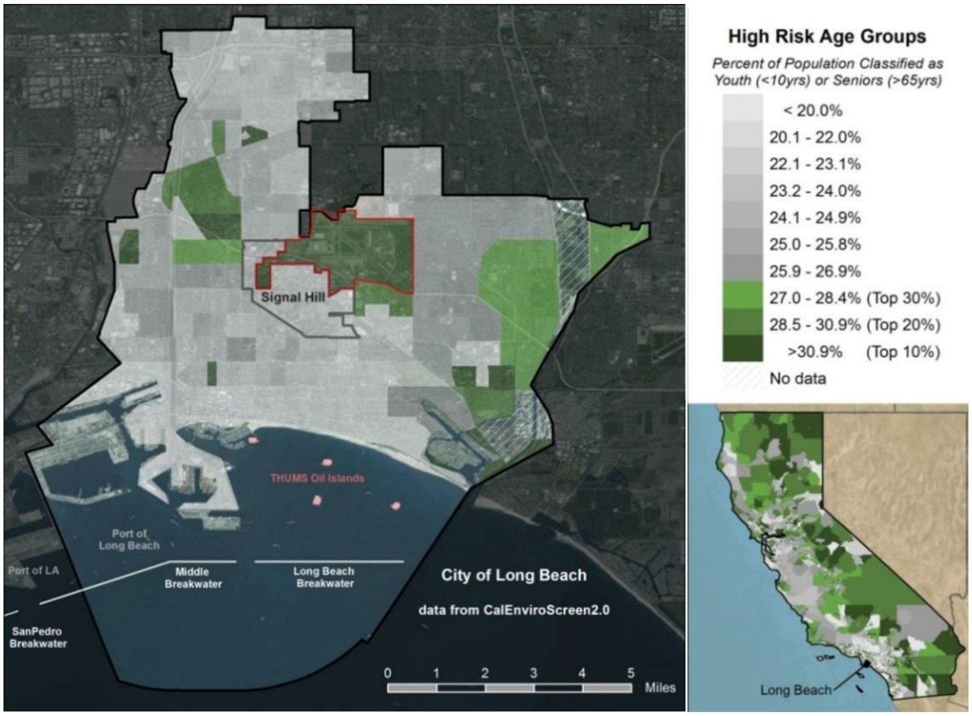
Red indicates High Values for the Long Beach area compared to the overall state values

CalEnviroScreen 2.0 **Solid Waste** Sites and Facilities Values are used to evaluate the **Environmental Effects** in census tracts due to the **presence of Solid Waste** (calculated as the sum weighted number of solid waste sites and facilities).

"Many newer solid waste landfills are designed to prevent the contamination of air, water, and soil with hazardous materials. However, older sites that are out of compliance with current standards or illegal solid waste sites may degrade environmental conditions in the surrounding area and pose a risk of exposure. Other types of facilities, such as composting, treatment and recycling facilities, may raise concerns about odors, vermin, and increased truck traffic. While data that describe environmental effects from the siting and operation of all types of solid waste facilities are not currently available, the California Department of Resources Recycling and Recovery (CalRecycle) maintains data on facilities that operate within the state, as well as sites that are abandoned, no longer in operation, or illegal.

Solid waste sites can have multiple impacts on a community. Waste gases like methane and carbon dioxide can be released into the air from disposal sites for decades, even after site closure (US EPA, 2011; Ofungwu and Eget, 2005). Fires, although rare, can pose a health risk from exposure to smoke and ash (CalRecycle, 2010a; US Fire Administration, 2002). Odors and the known presence of solid waste may impair a community's perceived desirability and affect the health and quality of life of nearby residents (Heaney et al., 2011). " (OEHHA 2014, page 83)

High Risk Age Groups



City of Long Beach		
Mean	Min	Max
24.030 %	0.7 %	100 %

State of California		
Mean	Min	Max
25.083 %	0 %	100 %

Red indicates High Values for the Long Beach area compared to the overall state values

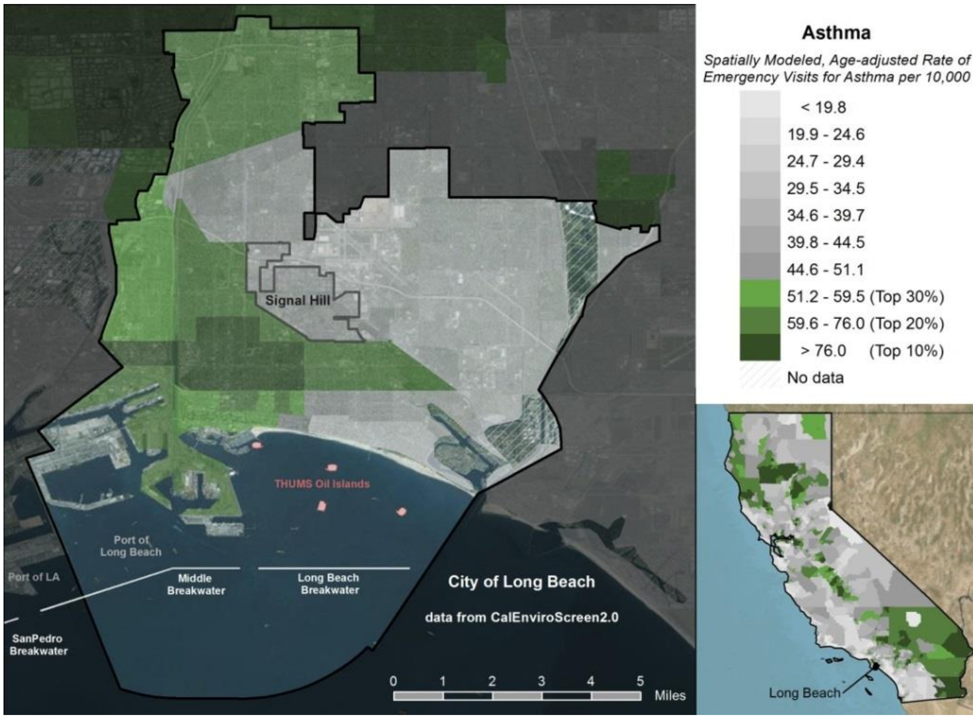
The Census Track outlined in red is made up of exclusively high risk age groups and equal to the state maximum (100%) for this category.

CalEnviroScreen 2.0 **Youth and Senior Age** Values are used as a **Sensitive Population Indicator** in census tracts, calculated as Percent of the Population classified as either "youth" (under 10 years old) or "Seniors" (65 or older).

"Children can be especially sensitive to the adverse effects of pollutants for many reasons. Children are often more susceptible to the health effects of air pollution because their immune systems and organs are still immature. Irritation or inflammation caused by air pollution is more likely to obstruct their narrow airways. Children, especially toddlers and young children, may have higher background exposures to multiple contaminants from contact with the ground, from breathing through their mouths, and from spending a significant amount of time outdoors. Further, exposure to toxic contaminants in air or other sources during infancy or childhood could affect the development of the respiratory, nervous, endocrine and immune systems, and could increase the risk of cancer later in life. Elderly populations can also be more vulnerable to adverse health effects from exposures to pollutants than younger adults. This population is more likely to have health conditions that may worsen responses, such as weakened immune system and existing cardiovascular and respiratory disease. A history of exposure to pollutants, or interactions with medications, may influence responses.

As part of the 2010 decennial census, the U.S. Census Bureau questionnaire asked all census respondents for the age and date of birth of all members of the household."
(OEHHA 2014, page 93)

Asthma



City of Long Beach		
Mean	**Min**	**Max**
56.981	0	**103**

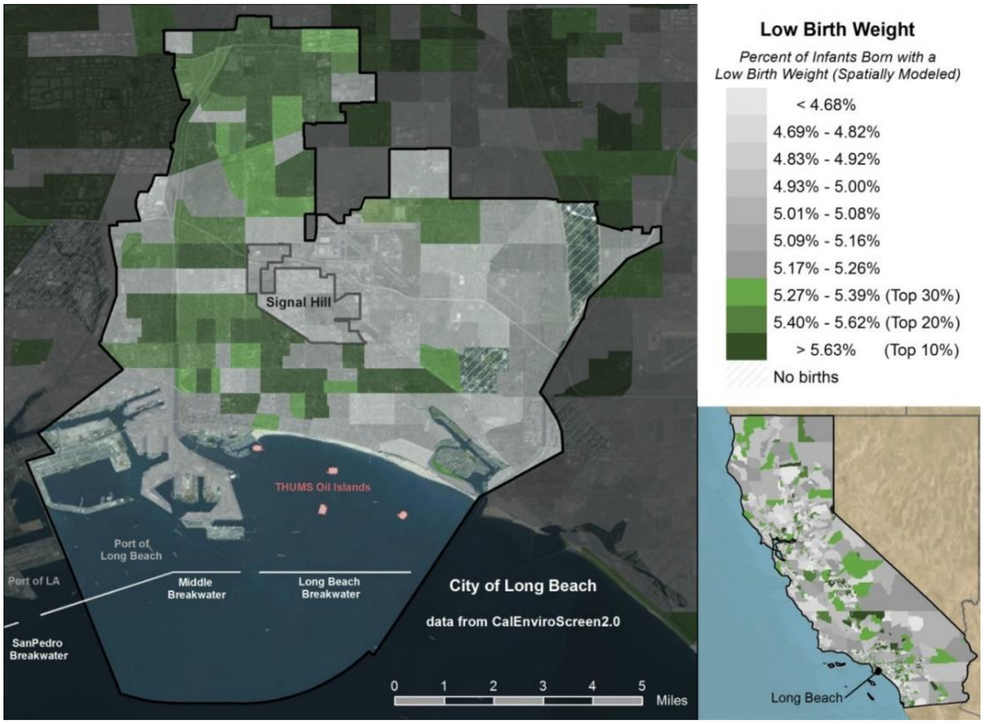
State of California		
Mean	**Min**	**Max**
44.487	0	236.164

Red indicates High Values for the Long Beach area compared to the overall state values

CalEnviroScreen 2.0 **Asthma** Values are used as a **Sensitive Population Indicator** in census tracts, calculated as the spatially modeled, age-adjusted rate of emergency room visits for Asthma, per 10,000 people.

“Asthma is a chronic lung disease characterized by episodic breathlessness, wheezing, coughing, and chest tightness. While the causes of asthma are poorly understood, it is well established that exposure to traffic and outdoor air pollutants, including particulate matter, ozone, and diesel exhaust, can trigger asthma attacks. Nearly three million Californians currently have asthma and about five million have had it at some point in their lives. Children, the elderly and low-income Californians suffer disproportionately from asthma (California Health Interview Survey, 2009).” “Since 2005, hospitals licensed by the state of California to provide emergency medical services are required to report all emergency department (ED) visits to OSHPD. Federally-owned facilities, including Veterans Administration and Public Health Services hospitals are not required to report. The ED dataset includes information on the principal diagnosis, which can be used to identify which patients visited the ED because of asthma.” (OEHHA 2014, pages 98)

Low Birth Weights



City of Long Beach		
Mean	Min	Max
0.0533 %	0.0443 %	0.0645 %

State of California		
Mean	Min	Max
0.0512 %	0.0390 %	0.0714 %

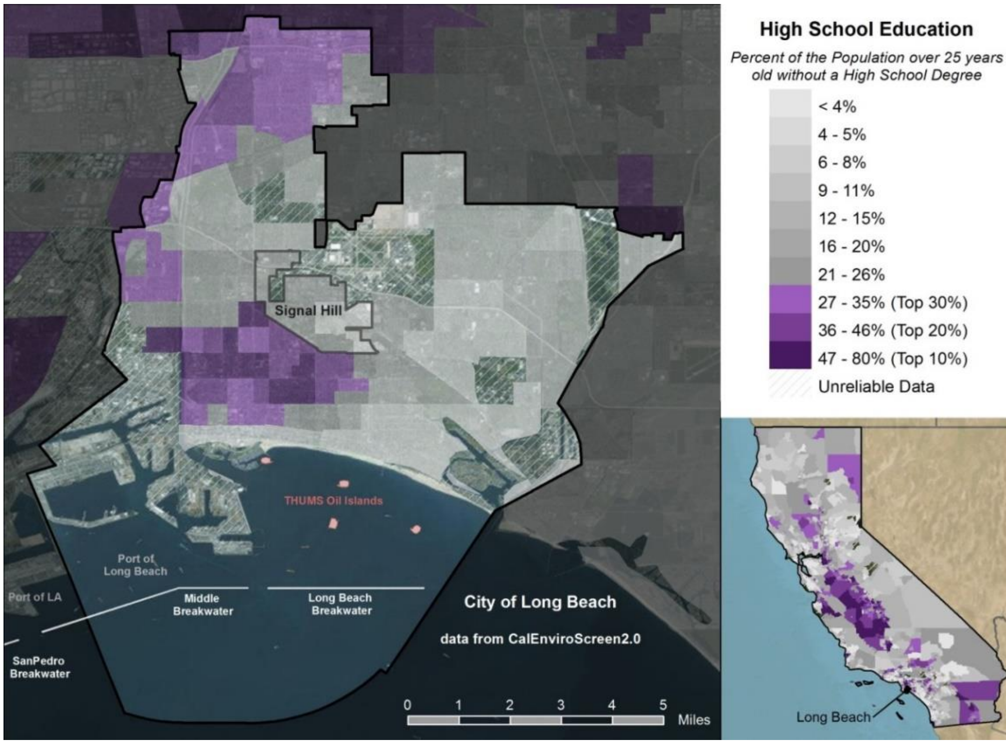
Red indicates High Values for the Long Beach area compared to the overall state values

CalEnviroScreen 2.0 **Low Birth Weight** (LBW) Values are used as a **Sensitive Population Indicator** in census tracts, calculated as the Percent of infants born with a low birth weight, spatially modeled.

"Infants born weighing less than 2,500 grams (about 5.5 pounds) are classified as low birth weight (LBW), a condition that is associated with increased risk of later health problems as well as infant mortality. Most LBW infants are small because they were born early. Infants born at full term (after 37 complete weeks of pregnancy) can also be LBW if their growth was restricted during pregnancy. Nutritional status, lack of prenatal care, stress, and maternal smoking are known risk factors for LBW. Studies also suggest links with environmental exposures to lead, air pollution, toxic air contaminants, traffic pollution, pesticides, and polychlorinated biphenyls (PCBs). These children are at risk for chronic health conditions that may make them more sensitive to environmental exposures after birth."

"LBW is considered a key marker of overall population health. Being born low weight puts individuals at higher risk of health conditions that can subsequently make them more sensitive to environmental exposures. For example, children born low weight are at increased risk of developing asthma (Nepomnyaschy and Reichman, 2006). Asthma symptoms, in turn, are worsened by exposure to air pollution. LBW can also put one at increased risk of coronary heart disease and type 2 diabetes (Barker et al., 2002). These conditions can predispose one to mortality associated with particulate air pollution or excessive heat (Bateson and Schwartz, 2004; Basu and Samet, 2002)." (OEHHA 2014, page 103)

High School Education



City of Long Beach		
Mean	Min	Max
22.515 %	0 %	55.9 %

State of California		
Mean	Min	Max
20.034 %	0 %	79.6 %

Red indicates High Values for the Long Beach area compared to the overall state values

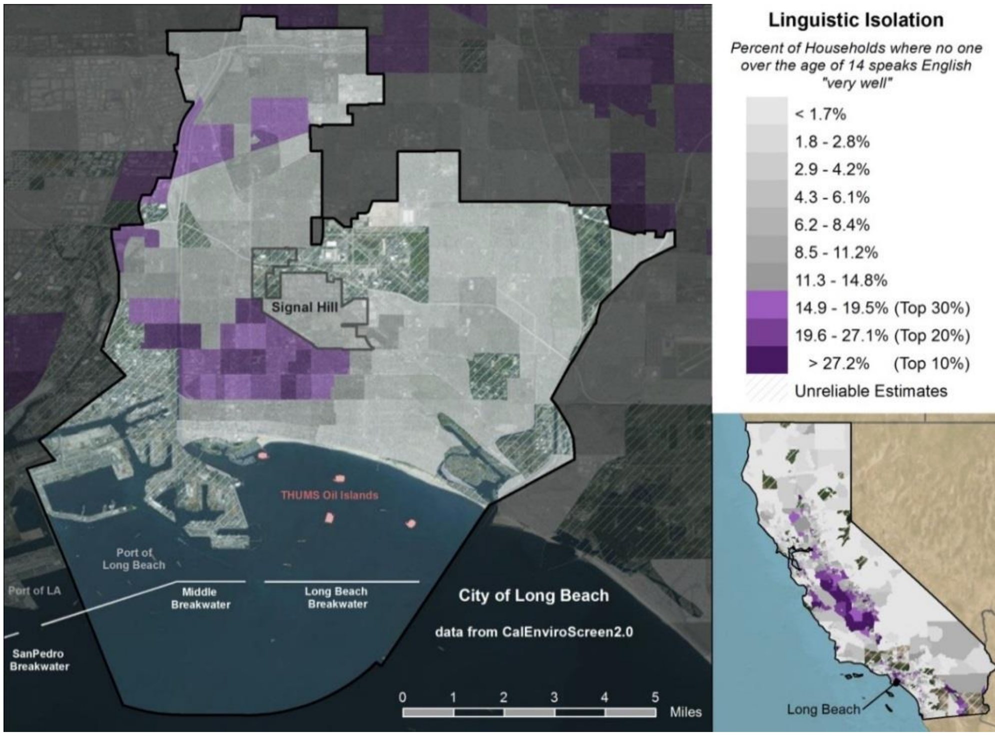
CalEnviroScreen 2.0 **Educational Attainment** Values are used as a **SocioEconomic Factor Indicator** in census tracts, calculated as the Percent of the Population over 25 years old without a high school degree.

"Educational attainment is an important element of socioeconomic status and a social determinant of health. Numerous studies suggest education can have a protective effect from exposure to environmental pollutants that damage health. Information on educational attainment is collected annually in the U.S. Census Bureau's American Community Survey (ACS). In contrast to the decennial census, the ACS surveys a small sample of the U.S. population to estimate more detailed economic and social information for the country's population.

Educational attainment is an important independent predictor of health (Cutler and Lleras-Muney, 2006). As a component of socioeconomic status, education is often inversely related to the degree of exposure to indoor and outdoor pollution. Several studies have associated educational attainment with susceptibility to the health impacts of environmental pollutants.

The ways in which lower educational attainment can decrease health status are not completely understood, but may include economic hardship, stress, fewer occupational opportunities, lack of social support, and reduced access to health-protective resources such as medical care, prevention and wellness initiatives, and nutritious food." (OEHHA 2014, page 107)

Linguistic Isolation



City of Long Beach		
Mean	Min	Max
10.766 %	0 %	36.3 %

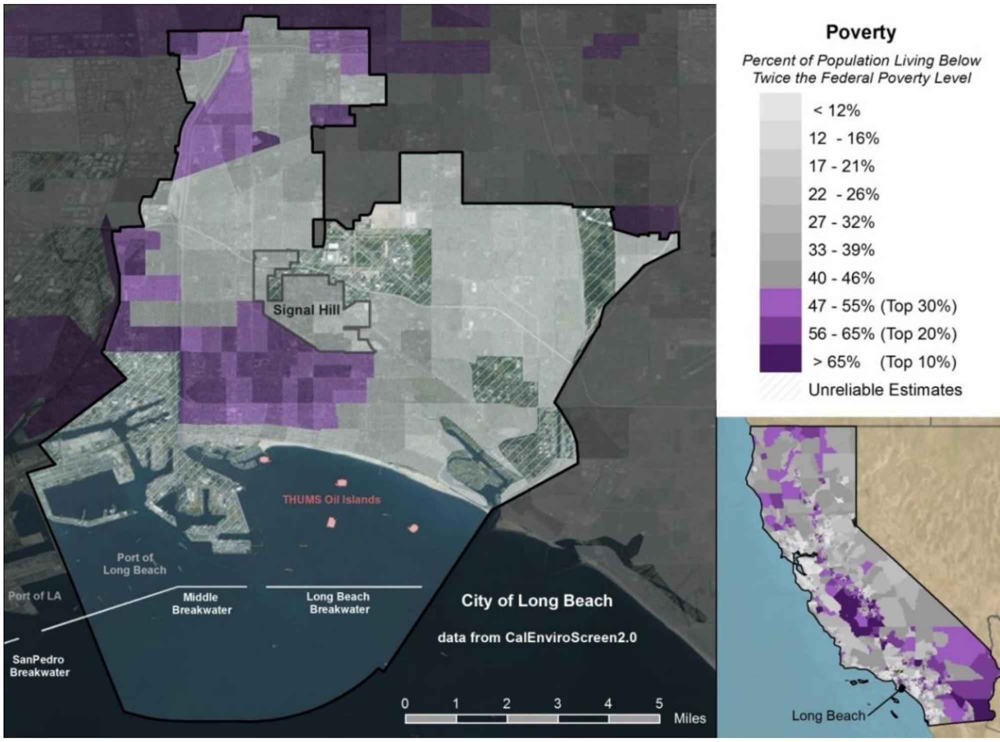
State of California		
Mean	Min	Max
11.205 %	0 %	79.1 %

CalEnviroScreen 2.0 **Linguistic Isolation** Values are used as a **SocioEconomic Factor Indicator** in census tracts, calculated as the Percent of households where no one over the age of 14 speaks English "very well."

"According to the most recent U.S. Census Bureau's 2008-2012 American Community Survey (ACS), nearly 43% of Californians speak a language at home other than English, about 20% of the state's population speaks English "not well" or "not at all," and 10% of all households in California are linguistically isolated. The U.S. Census Bureau uses the term "linguistic isolation" to measure households where all members 14 years of age or above have at least some difficulty speaking English. A high degree of linguistic isolation among members of a community raises concerns about access to health information and public services, and effective engagement with regulatory processes. Information on language use is collected annually in the ACS. In contrast to the decennial census, the ACS surveys a small sample of the U.S. population to estimate more detailed economic and social information for the country's population.

From 1990 to 2000 the number of households in the U.S. defined as "linguistically isolated" rose by almost 50% (Shin and Bruno, 2003). California has a higher proportion of immigrants than any other state and the immigrant population has increased by 400% since 1970 (Johnson, 2011). The inability to speak English well can affect an individual's communication with service providers and his or her ability to perform daily activities. People with limited English are less likely to have regular medical care and are more likely to report difficulty getting medical information or advice than English speakers. Linguistic isolation is also an indicator of a community's ability to participate in decision-making processes and the ability to navigate the political system." (OEHHA 2014, pages 111-112)

Poverty



City of Long Beach		
Mean	Min	Max
41.667 %	6.640 %	87.2 %

State of California		
Mean	Min	Max
35.282 %	0 %	99.074 %

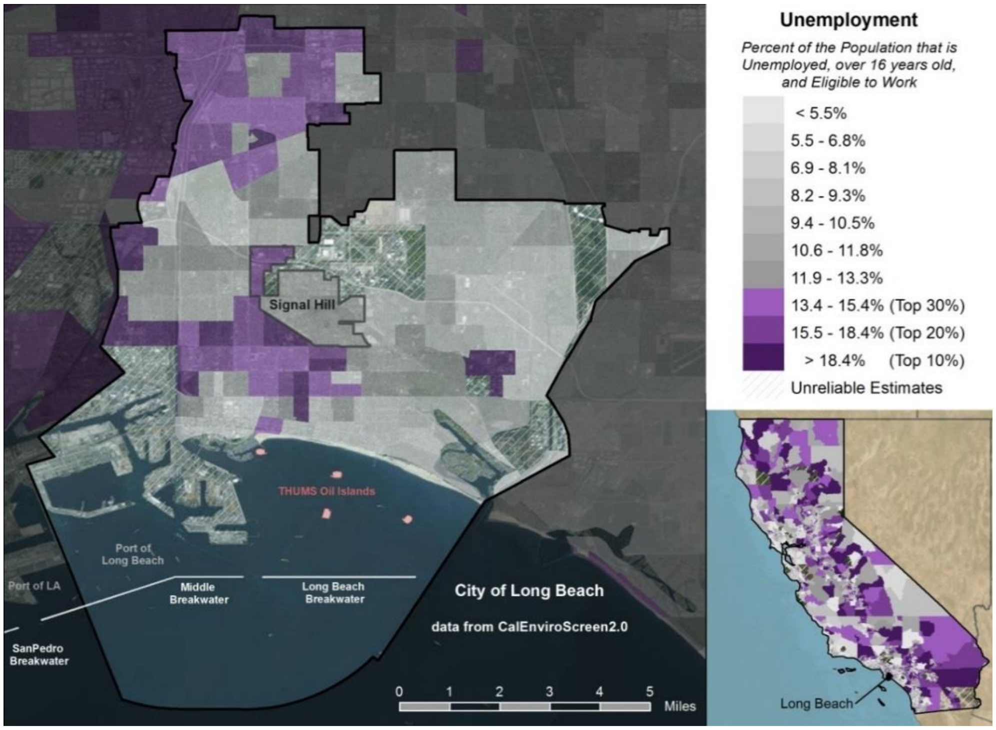
Red indicates High Values for the Long Beach area compared to the overall state values

CalEnviroScreen 2.0 **Poverty** Values are used as a **SocioEconomic Factor Indicator** in census tracts, calculated as the Percent of the Population **living below twice the federal poverty level.**

"Poverty is an important social determinant of health. Numerous studies have suggested that impoverished populations are more likely than wealthier populations to experience adverse health outcomes when exposed to environmental pollution. Information on poverty is collected annually in the U.S. Census Bureau's American Community Survey (ACS). In contrast to the decennial census, the ACS surveys a small sample of the U.S. population to estimate more detailed economic and social information for the country's population. The Census Bureau uses income thresholds that are dependent on family size to determine a person's poverty status during the previous year. For example, if a family of four with two children has a total income less than $21,938 during 2010, everyone in that family is considered to live below the federal poverty line. A threshold of twice the federal poverty level was used in this analysis because the federal poverty thresholds have not changed since the 1980s despite increases in the cost of living, and because California's cost of living is higher than many other parts of the country.

One way by which poverty may lead to greater susceptibility is from the effects of chronic stress on the body (Wright et al., 1999; Brunner and Marmot, 2006). Differential underlying burdens of pre-existing illness and co-exposure to multiple pollutants are other possible factors (O'Neill et al., 2003). " (OEHHA 2014, pages 116-117)

Unemployment



City of Long Beach		
Mean	Min	Max
12.381 %	1.45 %	47.97 %

State of California		
Mean	Min	Max
11.335 %	0 %	72.34 %

Red indicates High Values for the Long Beach area compared to the overall state values

CalEnviroScreen 2.0 **Unemployment** Values are used as a **SocioEconomic Factor Indicator** in census tracts, calculated as the Percent of the Population that is unemployed, over the age of 16, and eligible to work.

"Because low socioeconomic status often goes hand-in-hand with high unemployment, the rate of unemployment is a factor commonly used in describing disadvantaged communities. On an individual level, unemployment is a source of stress, which is implicated in poor health reported by residents of such communities. Lack of employment and resulting low income often oblige people to live in neighborhoods with higher levels of pollution and environmental degradation. Percent of the population over the age of 16 that is unemployed and eligible for the labor force. Excludes retirees, students, homemakers, institutionalized persons except prisoners, those not looking for work, and military personnel on active duty (5-year estimate, 2008-2012).

There is evidence that an individual's health is at least partly determined by neighborhood and regional factors. Unemployment is frequently used as a surrogate for neighborhood deprivation, which is associated with pollution exposure as well as poor health (Voigtlander et al., 2010). Studies of neighborhood socioeconomic factors have found stress to be a major factor in reported poor health among residents of disadvantaged communities, and both financial and emotional stress are direct results of unemployment (Turner, 1995)." (OEHHA 2014, page 120)