AECOM

Climate Change Vulnerability Assessment Results

Long Beach Climate Action and Adaptation Plan

FINAL | November 12, 2018

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Section 1. **Introduction**

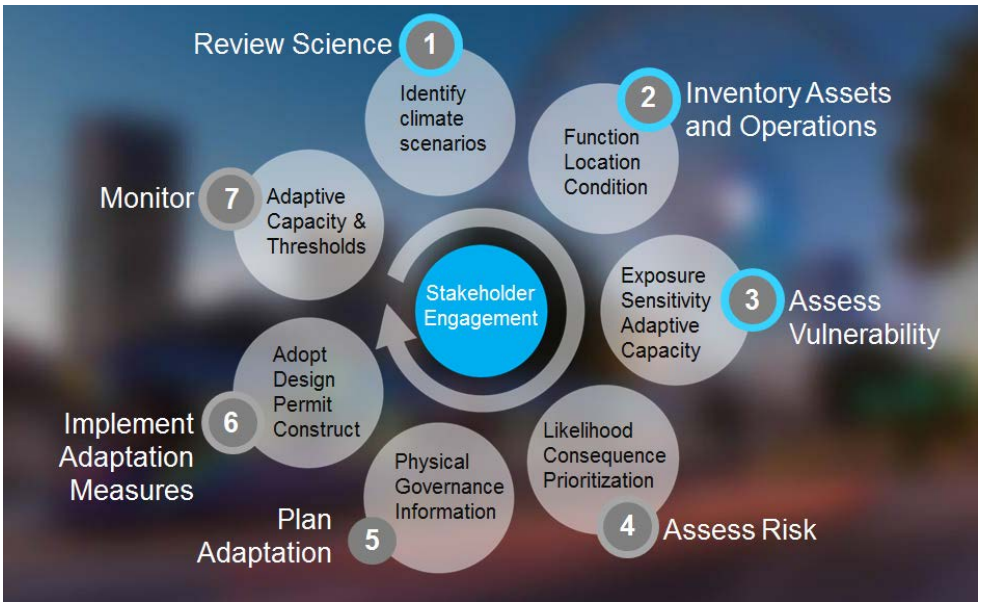
1.1 Purpose of the Vulnerability Assessment

The purpose of the vulnerability assessment is to understand to what extent climate stressors will impact various assets in Long Beach in order to prioritize in the development of adaptation strategies, as well as to inform decision making for future capital investment.

This assessment analyzed the vulnerability of assets to several climate stressors: Sea level rise (SLR) and coastal flooding, riverine flooding, extreme heat, drought, and poor air quality. The SLR and Coastal Flooding assessment was done with a relatively greater level of detail compared to other stressors given the detailed modeling available, the high level of risk in Long Beach, and the level of detail needed to understand the potential impacts of sea level rise and coastal flooding. Generally, more detailed data was available on City-owned assets, so they were assessed in greater detail. However, privately-owned assets, such as buildings and energy infrastructure were assessed at a high level.

Climate adaptation planning typically follows a cyclical process. This report represents steps one, two and three of the adaptation process depicted in Figure 1. The results of this assessment will inform the development of adaptation strategies in the next phase of the project.

Figure 1: Climate Adaptation Planning Process



1.2 Organization of the Assessment

Section 2: This chapter describes the methodology of the assessment.

Section 3: This chapter summarizes the data collection process and asset inventory.

Section 4: This chapter describes the SLR mapping methodology used in the assessment and the results of a subarea assessment of SLR exposure.

Section 5 to 12: These chapters present the findings from the vulnerability assessment by asset sector.

Section 2. **Vulnerability Assessment Methodology**

This section outlines the approach and methodology for the climate vulnerability assessment component of the Long Beach Climate Action and Adaptation Plan. The climate vulnerability assessment is based on an assessment of exposure, sensitivity, and adaptive capacity for critical[1] physical assets and vulnerable populations. The purpose of the vulnerability assessment is to understand which assets and populations are the most vulnerable in order to prioritize those assets and communities for adaptation strategy development in the next phase of the project.

2.1 Sea Level Rise and Coastal Flooding Assessment Methodology

2.1.1 Exposure

The exposure assessment for SLR and coastal flooding considered permanent inundation from the daily high tide and temporary flooding from the annual king tide and 100-year coastal storm conditions (100-year storm surge).

- Timeframes: As required by AB 691, timeframes include 2030, 2050 and 2100.
- Projection Scenarios: 11, 24, 37, and 66 inches, based on National Research Council (NRC) 2012 report on West Coast SLR (described in greater detail below).
- Mapping source: U.S. Geological Survey Coastal Storm Modeling System (CoSMoS)[2]

Sea Level Rise Projection Scenarios

Up until recently, the state of California utilized the National Research Council (NRC) 2012 sea level rise projections as best available science in state policy and guidance. In 2017, a new study was released by Griggs et al. (2017) with updated SLR projections for the California coast. The Griggs study informed the

[1] Critical assets are those that are important in providing core services and functions of City departments.
[2] CoSMoS, a Coastal Storm Modeling System created by the USGS, is a source for wave run up, sea level rise, and shoreline change modeling data.

development of the Ocean Protection Council's (OPC) new sea level rise guidance document that was adopted in March 2018.

OPC developed future sea level rise projections at each tide station along the California coast. Table 1 presents sea level rise projections for Los Angeles. The OPC study incorporated a range of global emissions scenarios ranging from aggressive emissions reductions to no emissions reductions through end of century.

Table 1. Sea Level Rise Projections at Los Angeles, CA from OPC (2018)

Year (Emissions Scenario)	Inches Above 1991-2009 Mean Sea Level (in)			
	Median (50% probability of exceedance)	Likely Range (67% percent likely range)	1-In-20 Chance (5% probability of exceedance)	1-In-200 Chance (0.5% probability of exceedance)
2030	4	2 to 6	7	8
2050	8	6 to 12	14	22
2100 (low emissions)	16	8 to 25	36	65
2100 (very high emissions)	26	16 to 38	49	80

Source: OPC (2018)

Not only were the OPC (2018) SLR projections not yet available at the time of the vulnerability assessment, but the SLR projections from NRC (2012) show higher potential SLR for near-term planning horizons (2030 and 2050). Given the differences in projections, it was determined that for the sake of being conservative in developing a plan to preserve life and property, that the more aggressive forecast should be utilized. To understand the implications of a worst-case scenario, and to include a factor of safety, particularly for critical assets, the high-end of the NRC (2012) SLR range was selected for each planning timeframe. This rationale aligns with the State Guidance from the Ocean Protection Council (2011) and California Coastal Commission (2015). Because there is increased uncertainty (wider ranges of SLR) after 2050, both the projection (mid-range) and high-range magnitudes were selected to guide planning for 2100. In addition, including the mid-range 2100 allows for a range of SLR scenarios to better understand thresholds for exposure of assets or subareas of the city.

Table 2: Sea Level Rise Projections for Los Angeles, CA from NRC (2012)

Year	Southern California	
	Projection	Range
2030	5.8 ± 2.0 in	4.6 – 11.8 in
2050	11.2 ± 3.5 in	5.0 – 23.9 in
2100	36.7 ± 9.8 in	17.4 – 65.6 in

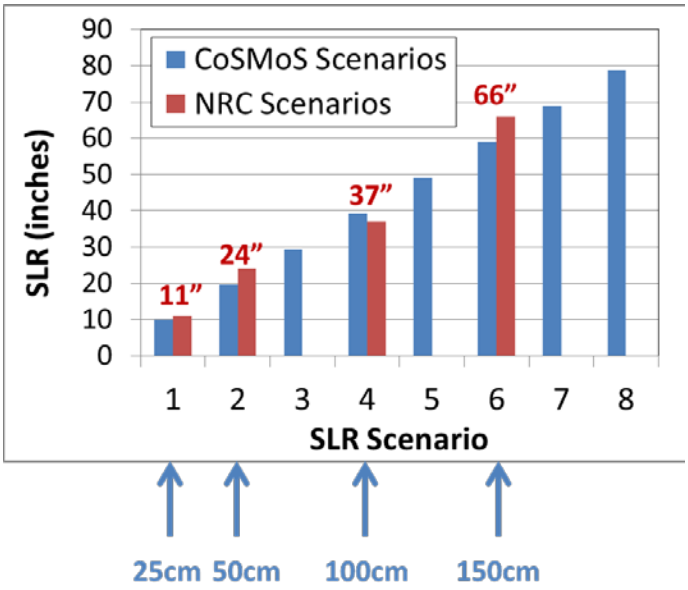
Source: NRC (2012)

In summary, the following SLR scenarios were adopted for use in this study and Figure 2 shows how these scenarios align with the available SLR mapping layers from CoSMoS, which are measured in centimeters.

- 11 inches for year 2030 (high-range) or year 2050 (mid-range) = 25 cm SLR CoSMoS scenario*
- 24 inches for year 2050 (high-range) = 50 cm SLR CoSMoS scenario
- 37 inches for year 2100 (mid-range) = 100 cm SLR CoSMoS scenario
- 66 inches for 2100 (high-range) = 150 cm SLR CoSMoS scenario

*Note that the 25 cm (11 inches) CoSMoS scenario exceeds the projected amount of SLR for 2030 for both the NRC (2012) and OPC (2018) projections; however, it is the lowest SLR scenario available from the CoSMoS modeling and was therefore selected to evaluate near-term SLR impacts in Long Beach.

Figure 2: CoSMoS and NRC Sea Level Rise Scenarios



2.1.2 Sensitivity

Sensitivity of physical assets (buildings, facilities, infrastructure, etc.) was assessed using a qualitative approach based on asset types. Assets that are found to not be exposed to sea level rise and coastal flooding are not assessed for sensitivity. Table 3 provides the criteria for the sensitivity ratings, and further details regarding specific asset-type sensitivities are provided in the asset section.

Table 3: Sensitivity Rating Scale for Physical Assets

None	Low	Moderate	High
No impact to asset function	Asset impacted but still functional	Asset function temporarily compromised	Asset damaged and no longer functional

2.1.3 Adaptive Capacity

The adaptive capacity of physical assets was assessed using a qualitative approach by asset type. Table 4 provides the criteria for the sensitivity ratings, and further details regarding specific adaptive capacity considerations by asset-type are provided in the asset section.

Table 4: Adaptive Capacity Rating Scale for Physical Assets

High	Moderate	Low
Asset is easily repaired, modified, or relocated.	Asset may be repaired, modified or relocated, but with some challenges.	Asset may be repaired, modified, or relocated, but with significant challenges.

2.2 Riverine and Urban Flooding

Precipitation can generate flooding in two distinct ways. *Riverine flooding* occurs during extreme, regional rainfall events as rivers, creeks, and channels discharge excess water from an entire watershed. The Los Angeles and San Gabriel rivers drain much of the Los Angeles Basin and discharge into San Pedro Bay. This type of flooding could impact the City of Long Beach if high flows overtop and/or compromise the levees bordering these rivers. Precipitation can also generate localized *urban flooding* during high rainfall events if the City's local stormwater collection system is overwhelmed and cannot drain the excess stormwater. This type of flooding tends to be localized near storm drains and other stormwater collection system components.

Riverine Flooding

Reliable modeling on how riverine floodplains will be impacted by changes in seasonal and extreme precipitation patterns does not exist for Long Beach. Therefore, asset exposure to riverine flooding was assessed based on location within the Federal Emergency Management Agency's (FEMA) 100 and 500-year riverine floodplains, which were adopted in 2008.[3] With precipitation events projected to increase in intensity as a result of climate change, riverine flooding may increase. These FEMA floodplains serve as proxies for areas that may be at risk to increased exposure to riverine flooding in the future. Additional hydrologic and hydraulic analysis of watersheds and drainages that flow through Long Beach, accounting for future projected changes in precipitation, would be required to conduct a more detailed evaluation of future riverine flooding vulnerabilities.

Urban Flooding

Climate change and SLR can also exacerbate localized urban flooding if stormwater collection, conveyance, and discharge systems are not sized appropriately for future conditions precipitation. In addition, discharge of stormwater to tidally-influenced waters such as Alamitos Bay may be impeded by higher water levels in the future. The vulnerability of the stormwater system to climate change and SLR was evaluated at a high level in this assessment by identifying stormwater outfalls that discharge to

[3] Flood Insurance Rate Maps available here: http://www.longbeach.gov/pw/resources/engineering/flood-zone/

tidally-influenced waters; however, a more detailed assessment of potential flooding impacts within the streets and neighborhoods would be required to evaluate this hazard in more detail.

Sensitivity and adaptive capacity of physical assets were assessed in the same way as described above for SLR and Coastal Flooding.

2.3 Extreme Heat

The number of extreme heat days (over 95 ℉) in Long Beach per year is projected to increase from an average of four in the baseline period (1980-2000) to 11-16 days by mid-century and 11-37 by end-of century, depending on the emissions scenario (Sun et al. 2015). The impact of this change on both physical assets and on vulnerable populations was assessed qualitatively.

2.4 Drought

Climate change, through its impacts on precipitation and temperature, is predicted to increase the severity and length of future droughts statewide (CEC 2012). By the end of the century, all climatic models included in the California Climate Change Center's Third Assessment predict regional drying, primarily from decreased precipitation and compounded by warming (CEC 2012). The impact of drought on physical assets and vulnerable populations was assessed qualitatively.

2.5 Air Quality

Higher temperatures are expected to increase the frequency, duration, and intensity of conditions conducive to air pollution formation (CNRA 2014). Specifically, studies have shown that ozone concentrations increase when maximum daytime temperatures increase (Kleeman et al. 2010). Since climate models project higher temperatures in the future for Long Beach, a "climate penalty" exists for ground level ozone, which means that greater State and regional emissions controls will be needed to meet a given air quality standard. The impacts of poor air quality were assessed qualitatively for vulnerable communities only, as air quality does not have direct impacts on physical assets.

Section 3. **Asset Data Collection**

One of the first steps of the vulnerability assessment is to compile an inventory of the assets that are to be evaluated.

3.1 Data Collection Process

The first step in the asset inventory was a review of the departmental surveys to understand what assets Long Beach City departments consider critical to providing core services/functions. AECOM reviewed that list and developed an asset data request list for the City departments and collected publically available data for privately-owned assets, such as electricity assets and buildings. AECOM also reviewed publically available demographic data for vulnerable populations in Long Beach.

3.2 Sectors and Asset / Population Types

As summarized in Table 5, assets and populations were assessed across eight different sectors. Each sector focused on asset types of particular importance in Long Beach.

Table 5: Asset Sectors and Asset / Population Types

Sector	Asset / Population Types
Buildings and Facilities	City-Owned Buildings, Privately-Owned Buildings
Parks and Open Space	City Parks, Beaches, Wetlands, Marinas
Transportation	Roads, Bike Paths, Bridges
Energy	Substations, Transmission, Generation Facilities, Natural Gas Mains
Wastewater	Pump Stations, Sewer Main, Sewer Forced Main
Stormwater	Stormdrain Outfalls, Stormdrain Carriers, Stormwater Pump Stations
Potable Water	Potable Facilities, Potable Mains
Public Health	Vulnerable Populations

3.3 Port of Long Beach Harbor District

Because the Port of Long Beach has its owns climate adaptation plan and has its own governance body and revenue sources, this vulnerability assessment focuses on the parts of the City of Long Beach that are not within the Port of Long Beach Harbor District (Harbor District). As such, the asset inventory does not specifically include Port-assets. However, City-owned infrastructure, such as buildings and facilities, that are located within the Harbor Districts were included. While adaptation strategy development will generally focus on assets outside the Harbor District, coordination between the Harbor District and the City of Long Beach on climate adaptation will be an on-going priority.

Section 4. **Mapping Sea Level Rise and Coastal Flooding**

This section describes the SLR Mapping and analysis that was used to evaluate the exposure of assets to permanent inundation (daily high tide), frequent temporary flooding (annual king tide), and rare temporary flooding (100-year storm surge).

4.1 Sea Level Rise Mapping

Daily, Annual, and Extreme Coastal Water Levels

A description of the daily high tide, annual king tide, and 100-year storm surge water levels is provided below:

- **Daily high tide inundation.** There are two high tides each day of unequal height in Long Beach. A commonly used measure of the average high tide is referred to as mean higher high water (MHHW), which is the average elevation of the higher of the two high tides each day. MHHW represents the typical high tide elevation on a daily basis. Areas that are exposed to daily high tide inundation are considered to be “permanently inundated” because of the frequency at which they are flooded (daily).

- **Annual king tide flooding**. King tides are the largest annual tide events and occur several days each year when a spring tide coincides with the moon being in its closes position to the Earth. In Long Beach, king tide events are approximately 1.5 feet above the average daily high tide. They can cause flooding of low-lying coastal areas, particularly if coinciding with a storm event that elevates tides above normal levels. Assets that are exposed to king tide flooding are considered to be “frequently flooded” because they would be temporarily flooded two to three times each year.

- **100-year storm surge flooding.** The 100-year storm surge has a 1-percent chance of occurring in any given year. The 100-year storm surge event includes the effects of the astronomical tide, storm conditions (due to atmospheric pressure and meteorological effects), and precipitation. The influence of temporary flooding caused by wave runup is not included. Assets that are exposed to 100-year storm surge flooding are considered to be “rarely flooded” because they would be temporarily flooded only during very infrequently occurring extreme coastal storm events. The 100-year storm surge elevation is commonly used as an indicator to inform assessments of flood risk and includes the following components in Long Beach:

- **Sheltered embayments** (such as within Port of Long Beach and Alamitos Bay): inundation extents include high tide and storm surge inundation of the shoreline; runoff from larger watersheds is also included.
- **Open coast** (such as Long Beach): inundation extents include high tide and storm surge inundation of the shoreline and inundation caused by storm wave conditions (i.e., wave setup); temporary flooding caused by wave runup is not included.

SLR Mapping Layers

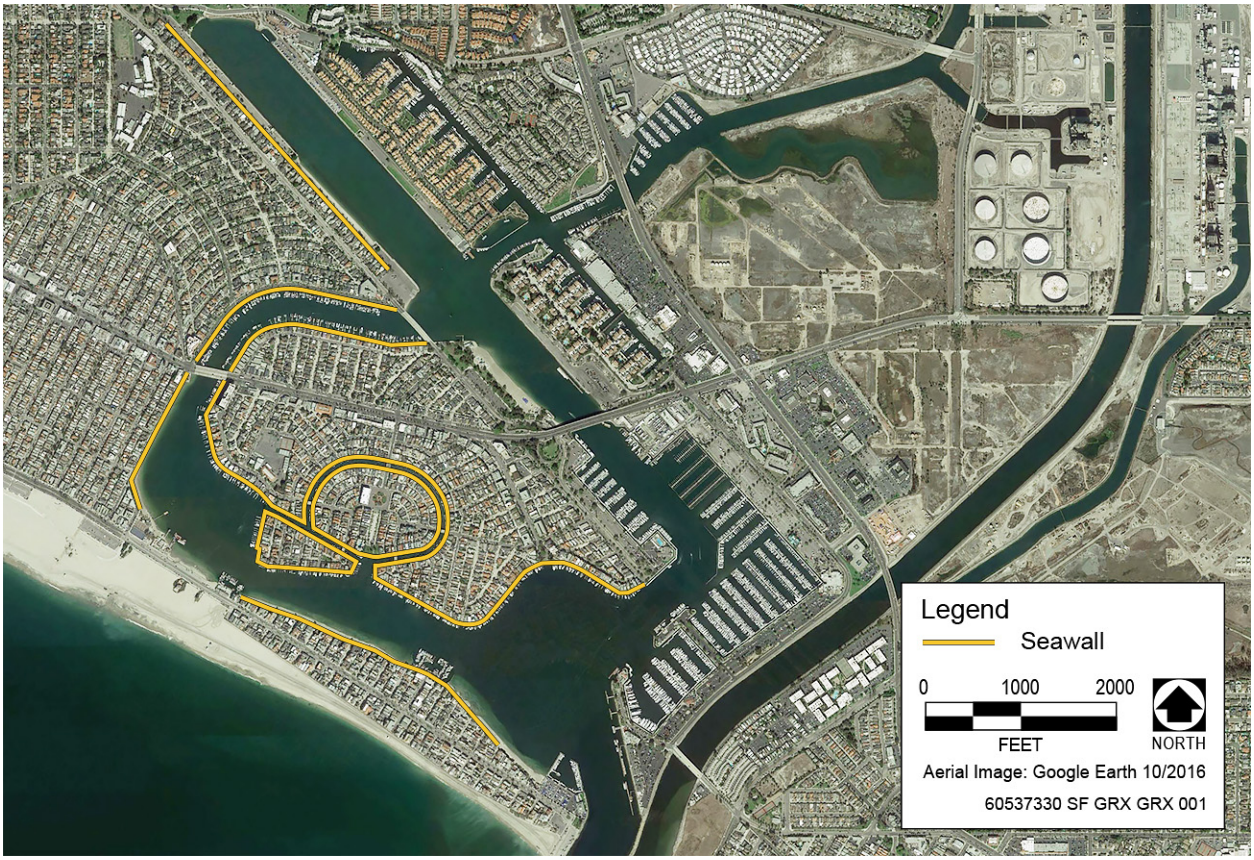
Coastal flooding layers from the CoSMoS 3.0 model results in southern California were used to evaluate asset exposure to temporary flooding events by annual king tides and 100-year storm surge events for each SLR scenario (see chapter 2 for more detail). Data layers can be viewed online through the Our Coast our Future[4] data viewer or downloaded through the USGS website.[5] SLR inundation layers and maps were not produced for permanent inundation scenarios as part of this assessment because Long Beach is not projected to be impacted by permanent inundation until higher amounts of SLR (greater than approximately 37" of SLR); however, the vulnerability analysis for each asset category includes discussion of permanent inundation impacts and asset sensitivity and adaptive capacity.

Limitations and Inundation Layer Revisions

The annual king tide and 100-year storm surge inundation layers developed by the USGS using the CoSMoS model provide a solid starting point to evaluate existing and future flood risk in Long Beach. It should be noted, however, that small-scale topographic features such as seawalls may not be accurately captured in the flood modeling and mapping. As a result, projected flooding in areas protected by seawalls may be overstated by the CoSMoS model. Areas protected by seawalls include the sheltered shorelines within Alamitos Bay, including Belmont Shore, Naples, and the Peninsula. To help address this issue, the SLR inundation mapping in these areas was modified as part of the vulnerability assessment by obtaining topography information on the crest elevation of the seawalls. Crest elevations were estimated by examining Lidar-based elevation data and field measurements of existing seawall heights relative to adjacent ground elevations. Approximate locations for seawalls within Alamitos Bay are shown in Figure 3. This information was used to update the SLR inundation maps to better reflect future flood risk in these areas by comparing the projected future water level scenarios for annual king tide and 100-year storm surge to the seawall elevations and removing low-lying areas of inundation located behind seawalls in cases where the typical elevation of the seawall exceeded the projected water level. Estimated seawall elevations were approximately 8 to 11 ft NAVD88.

[4] ourcoastourfuture.org
[5] https://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/

Figure 3: Approximate locations of Seawalls within Alamitos Bay



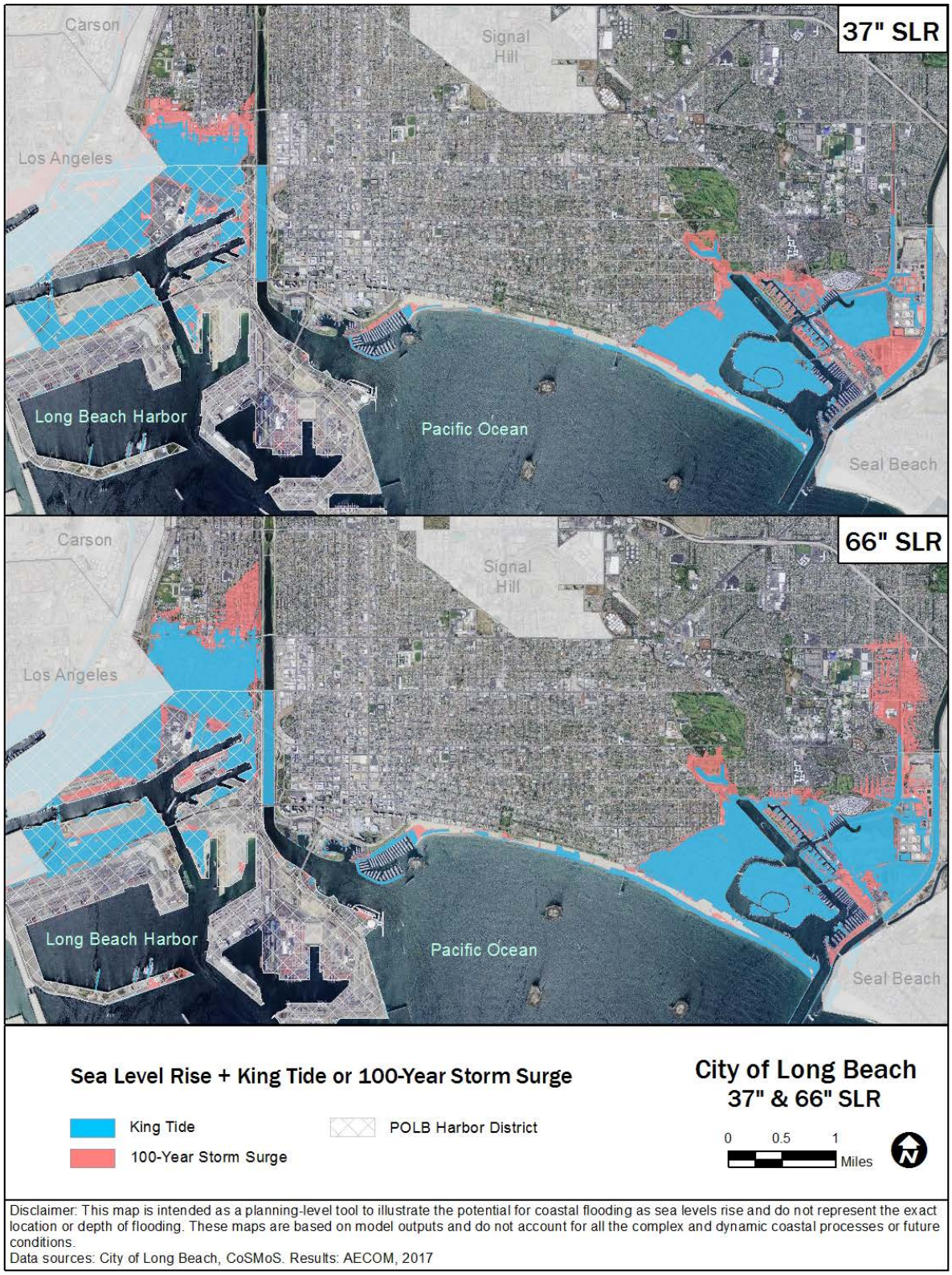
Sea Level Rise Mapping Results

Figure 4 and Figure 5 show the results of the SLR mapping for Long Beach that was used in the exposure assessments described below. The maps show the projected extent of flooding for the King Tide and 100-year storm surge scenarios – both temporary flooding events that could impact Long Beach assets and communities in the near-term. Permanent inundation is not projected to occur within Long Beach until higher amounts of SLR (approximately the 37" SLR scenario) and was therefore not mapped in detail since the impacts of temporary flooding will be felt first and addressing these impacts would also address permanent inundation impacts as well. The flood extents shown in Figure 4 for the King Tide + 24" SLR scenario are similar to the permanent inundation extents that would occur for the daily high tide (MHHW) + 37" SLR scenario. Similarly, the flood extents shown in Figure 5 for the King Tide + 37" SLR scenario are similar to the permanent inundation extents that would occur for the daily high tide (MHHW) + 66" SLR scenario.

Figure 4: SLR Mapping Results for 11 and 24 Inches of SLR with King Tide and 100-Year Storm

Note: The flooding extents for the King Tide + 24" SLR scenario are similar to the daily high tide (MHHW) + 37" SLR scenario.

Figure 5: SLR Mapping Results for 37 and 66 Inches of SLR with King Tide and 100-Year Storm



Note: The flooding extents for the King Tide + 37" SLR scenario are similar to the daily high tide (MHHW) + 66" SLR scenario.

4.2 Sea Level Rise and Coastal Flooding Subareas

The areas of exposure to SLR and Coastal Flooding in Long Beach can be divided into three different geographic areas: the Southeastern Subarea, Downtown Subarea, and Western Subarea. Figure 6 to Figure 8 were developed to better understand the various assets at risk in those areas and to support the development of neighborhood or district scale strategies that may help provide flood protection or build the resilience of multiple assets.

Figure 6 through Figure 8 show projected areas of temporary flooding due to King Tides with 11, 24, 37, and 66 inches of SLR. The summaries below provide a high-level overview of the areas of flooding and impacts to assets are discussed in greater detail in Sections 5 through 12.

Southeastern Subarea

As can be seen in Figure 6, the areas of darkest blue would be exposed to annual king tides earliest, with 11 inches of SLR. These areas include parts of Marina Pacifica, the Los Cerritos Wetlands Complex, and the Alamitos Bay shoreline of the Peninsula. There are no major roads exposed during this scenario, but the Bayshore Walk along the Peninsula is exposed. With higher levels of SLR, Belmont Shore, Naples, the Peninsula, and the Marina Pacifica area are projected to experience king tide flooding, including the beaches and parks that provide active recreation and boating access.

Downtown Subarea

As can be seen in Figure 7, in the Downtown Subarea, parts of the Shoreline Marina, Rainbow Harbor, and Golden Shore Marine Reserve are projected to be exposed to future annual king tides. The Golden Shore Marine Reserve is projected to be flooded by king tides combined with 11 inches of SLR. The edges of the Marina and Harbor start to experience king tide flooding at 11 inches and with higher levels of SLR, the pedestrian paths and parks also flood. Alamitos Beach also experiences king tide flooding, resulting in a narrowing of the beach, particularly with higher levels of SLR. Assets in this area that may be impacted include the Aquarium of the Pacific, and the bike path around Shoreline Marina, and the sewer lift stations associated with the comfort stations around the Marina.

Western Subarea

As can be seen in Figure 8, the Western Subarea, which is largely an industrial area, is not anticipated to experience flooding due to king tides until end-of-century (37 and 66 inches of SLR) and the flood pathways would likely come through the Harbor District area. Adaptation efforts by the Harbor District may provide flood protection benefits for West Long Beach, and on-going coordination between the Harbor District and City of Long Beach is recommended. Assets in West Long Beach that are at-risk include a potable water facility, two police facilities, and a Health Resource Center serving individuals experiencing homelessness. Within the Harbor District, there are also two potable facilities, a solid waste facility, and multiple fire stations.

Figure 6: Exposure to SLR in the Southeastern Subarea

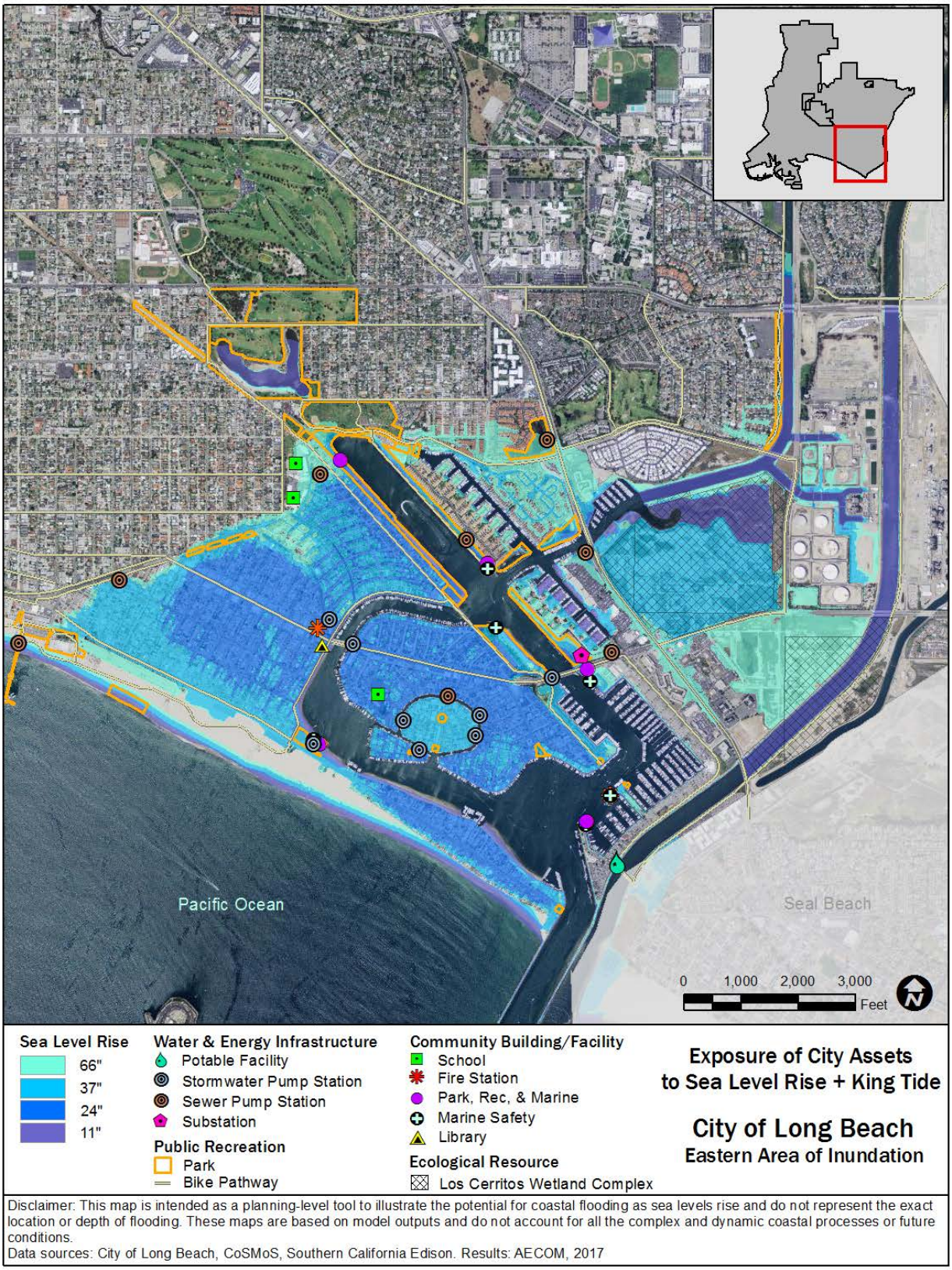
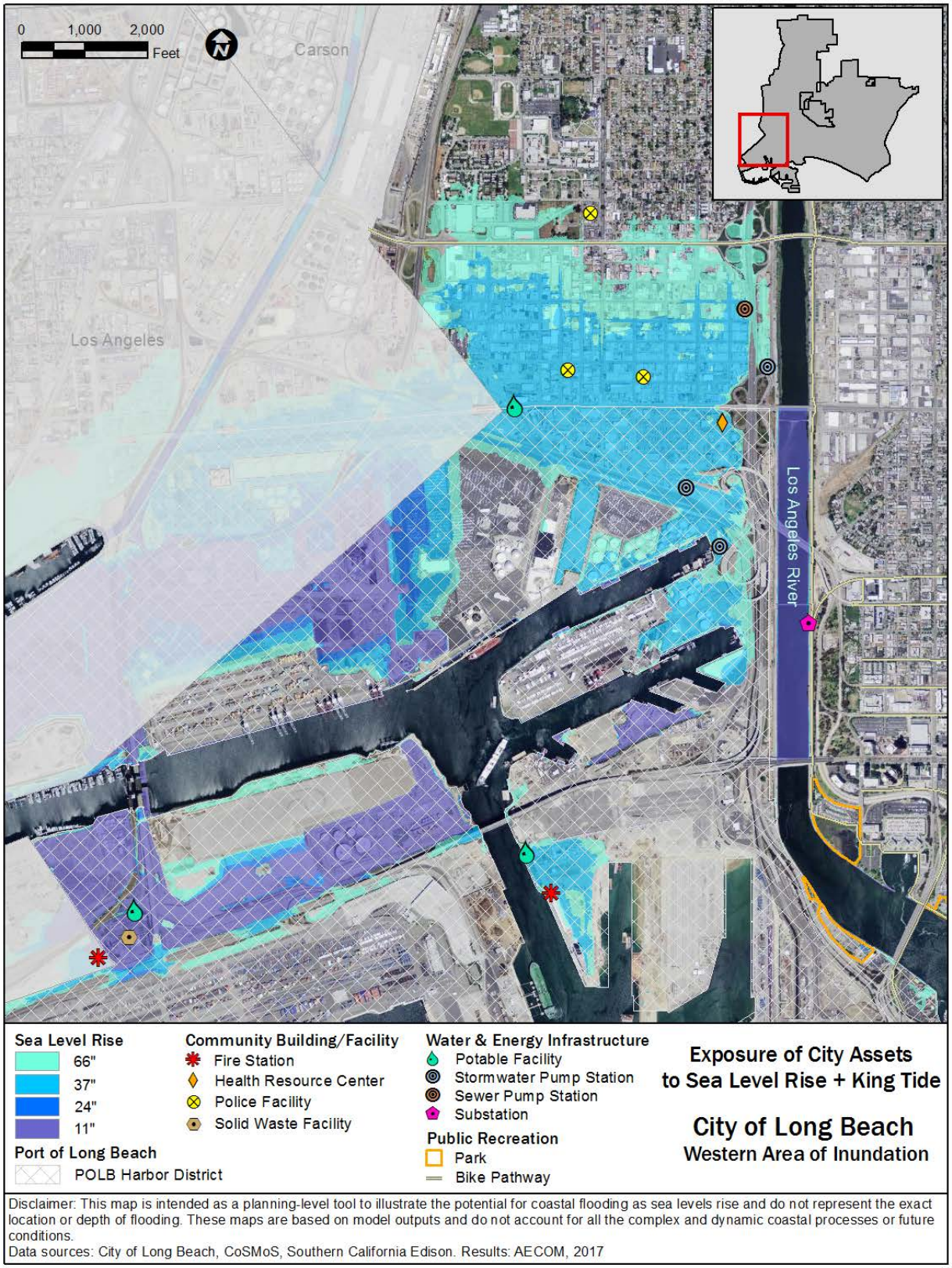


Figure 7: Exposure to SLR in the Downtown Subarea

Figure 8: Exposure to SLR in the Western Subarea



Section 5. **Vulnerability of Buildings and Facilities**

The Buildings and Facilities sector include two asset-types: City-owned buildings and facilities and privately-owned buildings. This section presents a summary of this sector's vulnerabilities to climate stressors.

Asset Overview

The Buildings and Facilities sector includes City-owned buildings and facilities and privately-owned buildings. Depending on the height and use, buildings may be constructed out of wood, masonry, concrete, and/or steel and glass. In addition to the building structure, this assessment considers their mechanical, electrical, and plumbing systems.

City-owned buildings and facilities include critical emergency response facilities, such as fire and police stations as well as buildings that serve vulnerable populations, such as health resource centers and schools. In addition to over 150 schools, there are over 160 City-owned buildings and facilities in Long Beach. Privately-owned buildings include residential, commercial, and industrial structures. Private hospital buildings were also assessed.

5.1 Sea Level Rise and Coastal Flooding

Exposure of City-Owned Buildings and Facilities

Table 6 shows that a total of 10 City-owned buildings and facilities are projected to be exposed to annual king tides with 11 inches of SLR. These buildings are located along the Alamitos Bay Marina or within the Harbor District. Two of these 10 buildings are fire stations, which are critical for emergency response. One of the fire stations is located in the Harbor District while the other fire station is located along the Alamitos Bay Marina (Figure 9).

A solid waste facility is also exposed to annual king tide flooding with 11 inches of SLR. This facility is the Southeast Resource Recovery Facility, which is owned by a joint powers agreement between the Sanitation Districts and the City of Long Beach and is located within the Harbor District. Several Marine Safety and Park, Recreation, & Marine facilities are also projected to be exposed to king tide flooding with 11 inches of SLR.

With 11 inches of SLR, in addition to the 10 buildings exposed to king tide events, seven additional buildings are projected to be exposed to the 100-year storm surge. These are a fire station, the Belmont

Shore Library, the Naples Bayside Academy, and four Marine Safety and Park, Recreation & Marine Facilities.

With 66 inches of SLR (2100 high-range), up to 26 City buildings are exposed to annual king tides and an additional 13 are projected to be exposed to the 100-year storm surge.

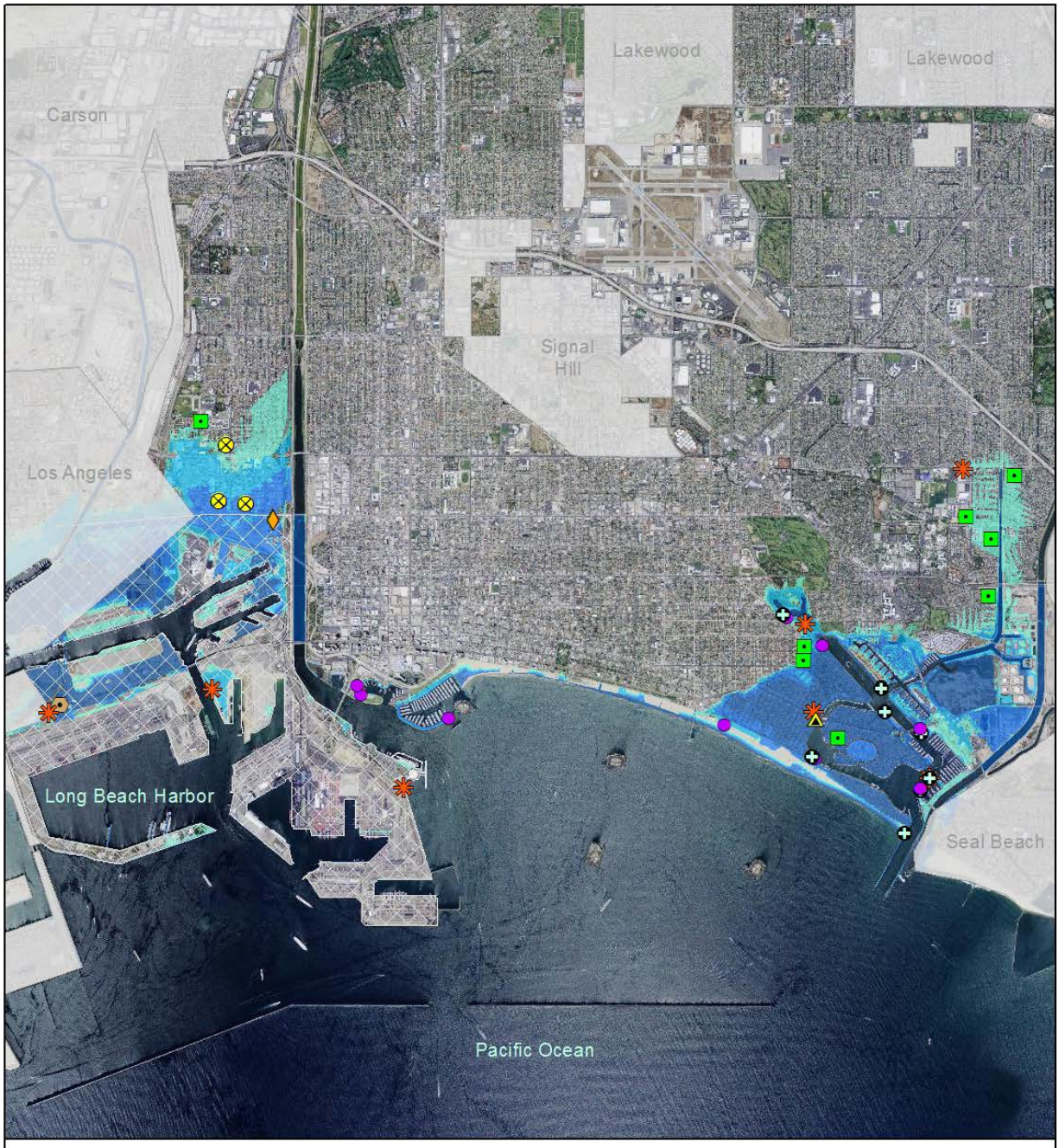
The City's Emergency Communications and Operations Center is not projected to be exposed to the studied levels of SLR and storm surge.

Table 6: Number of City Buildings and Facilities Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		**2050 (24" SLR)**		**2100 (37" SLR)**		**2100 (66" SLR)**	
	Annual King Tide	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide	Additional Exposure Due to Storm Surge
Fire Station	2	1	3	1	4	1	4	3
Health Resource Center	0	0	0	1	1	0	1	0
Library	0	1	1	0	1	0	1	0
Marine Safety	3	2	5	0	5	3	6	2
Park, Rec, and Marine	3	2	4	1	5	3	7	2
Police Facility	0	0	0	2	2	0	3	0
Schools	0	1	1	2	3	0	3	5
Solid Waste Facility	1	0	1	0	1	0	1	0
Other	0	0	0	0	0	1	0	1
Total	**10**	**7**	**15**	**7**	**22**	**8**	**26**	**13**

*****Note: The exposed assets for the King Tide + 24" SLR scenario are similar to the daily high tide (MHHW) + 37" SLR scenario. The exposed assets for the King Tide + 37" SLR scenario are similar to the daily high tide (MHHW) + 66" SLR scenario.

Figure 9: Exposure of City Buildings to Sea Level Rise + 100 Year Storm Surge



Exposure of City Facilities to Sea Level Rise + 100-Year Storm Surge

Sea Level Rise
- 66"
- 37"
- 24"
- 11"

City Building/Facility
- School
- Library
- Park, Rec, & Marine
- Health Resource Center
- Solid Waste Facility
- Fire Station
- Police Facility
- Marine Safety

Port of Long Beach
- POLB Harbor District

City of Long Beach

0 0.75 1.5 Miles

Disclaimer: This map is intended as a planning-level tool to illustrate the potential for coastal flooding as sea levels rise and do not represent the exact location or depth of flooding. These maps are based on model outputs and do not account for all the complex and dynamic coastal processes or future conditions.

Data sources: City of Long Beach,CoSMoS. Results: AECOM, 2017

Exposure of Privately-Owned Buildings

With 11 inches of SLR, approximately 1.3 million square feet of buildings are projected to be exposed to annual king tides. Approximately half of these buildings are residential (624,100 square feet) and half are commercial (689,600 square feet). These buildings are primarily located in Marina Pacifica and along Shoreline Drive south of Ocean Boulevard. An additional 9.5 million square feet of buildings, primarily residential, are exposed to flooding from a 100-year storm surge with 11 inches of SLR. These buildings are primarily located in Naples Island, Belmont Shore, and the Peninsula.

Excluding buildings within the Harbor District, industrial buildings are not exposed to annual king tides until 37 inches of SLR, and none are exposed to the 100-year storm surge until 24 inches of SLR.

Without adaptation, by 2100, up to 17 million square feet of buildings are exposed to annual king tide flooding and an additional 4 million square feet are exposed to the 100-year storm surge.

No hospitals are projected to be exposed to the evaluated levels of SLR and storm surge.

Table 7: Square footage of Privately-Owned Buildings Exposed to Sea Level Rise and 100-year Storm Surge*

	2030		**2050**		**2100**		**2100**	
	(11" SLR)		**(24" SLR)**		**(37" SLR)**		**(66" SLR)**	
	Annual King Tide	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide	Added Exposure Due to Storm Surge
Residential	624,100	8,520,200	7,226,300	3,661,800	10,458,200	1,599,900	11,923,200	3,112,900
Commercial	689,600	930,500	1,106,800	741,900	1,875,200	698,800	2,189,900	837,400
Industrial	0	0	0	1,186,800	2,035,500	866,200	2,946,100	69,100
All others	0	117,300	112,800	48,500	165,200	17,000	185,000	3,700
Total	**1,313,700**	**9,568,000**	**8,445,900**	**5,639,000**	**14,534,100**	**3,181,900**	**17,244,200**	**4,023,100**

Note: Excludes buildings located in the Harbor District

***Note: The exposed assets for the King Tide + 24" SLR scenario are similar to the daily high tide (MHHW) + 37" SLR scenario. The exposed assets for the King Tide + 37" SLR scenario are similar to the daily high tide (MHHW) + 66" SLR scenario.

Sensitivity and Adaptive Capacity of Buildings and Facilities

Buildings that are exposed to temporary floodwaters are likely to sustain damage to the building fabric and mechanical and electrical components. Buildings that are exposed to permanent inundation by daily high tides may lose functionality due to repeated flooding events and loss of access. Therefore, as illustrated in Table 8, buildings have high sensitivity to both permanent inundation and temporary flooding.

Buildings have moderate adaptive capacity to temporary flooding as flood proofing measures or elevating structures may be effective in protecting the structure even if access may be temporarily compromised. Buildings that are already located within the FEMA 100-year floodplain may already have some adaptive capacity built in due to floodplain regulations. However, for permanent inundation, only elevation or relocation of structures provide effective adaptation, but are more costly and challenging to implement than flood proofing of structures. If buildings are elevated, surrounding access modes, such as roads, driveways, and sidewalks would also need to be elevated to maintain access, pointing to the need for district or neighborhood-scale infrastructure solutions.

Table 8: Sensitivity and Adaptive Capacity of Buildings

	Sea Level Rise (Permanent Inundation)*	← Rationale	Sea Level Rise (Temporary Flooding)*	← Rationale
Sensitivity	High	Buildings cannot be accessed or used if permanently inundated.	High	Building fabric will be damaged with flooding. Wave energy and erosion could cause structural damage.
Adaptive Capacity	Low	Elevating or relocating buildings is difficult and costly.	Moderate	Flood proofing buildings is somewhat challenging.

*Note: Permanent inundation refers to inundation by the daily high tide (MHHW) and temporary flooding refers to flooding by the annual king tide or 100-year storm surge.

5.2 Riverine Flooding

In general, 100-year flood flows along the primary riverine waterways are contained within their channels by existing levees. Detailed modeling of the effect of SLR on riverine flood profiles was not conducted; however, such analysis could be conducted in the future to better understand combined riverine and coastal flood events within Long Beach. The list of buildings and facilities exposed to the FEMA 100-year storm is very similar to the 11 inches SLR + 100-year storm surge scenario described above. Figure 10 shows City-owned facilities, schools, and hospitals that are within the 100 and 500-year FEMA floodplain. Given the large extent of the 500-year floodplain, considerably more buildings and facilities are at-risk to that scenario, including two hospitals, 11 fire stations, one police station, and 96 schools.

The sensitivity and adaptive capacity considerations are similar to the temporary flooding (SLR + Storm Surge) described considerations above.

5.3 Extreme Heat

Given the projected increases in extreme heat events, buildings may require additional energy for cooling. Buildings without air conditioning or with insufficient air conditioning could be uncomfortable and potentially unsafe for occupants during extreme heat events. If electrical outages are caused due to area-wide brownouts, building heating and cooling could be disrupted, in addition to all other electronic systems.

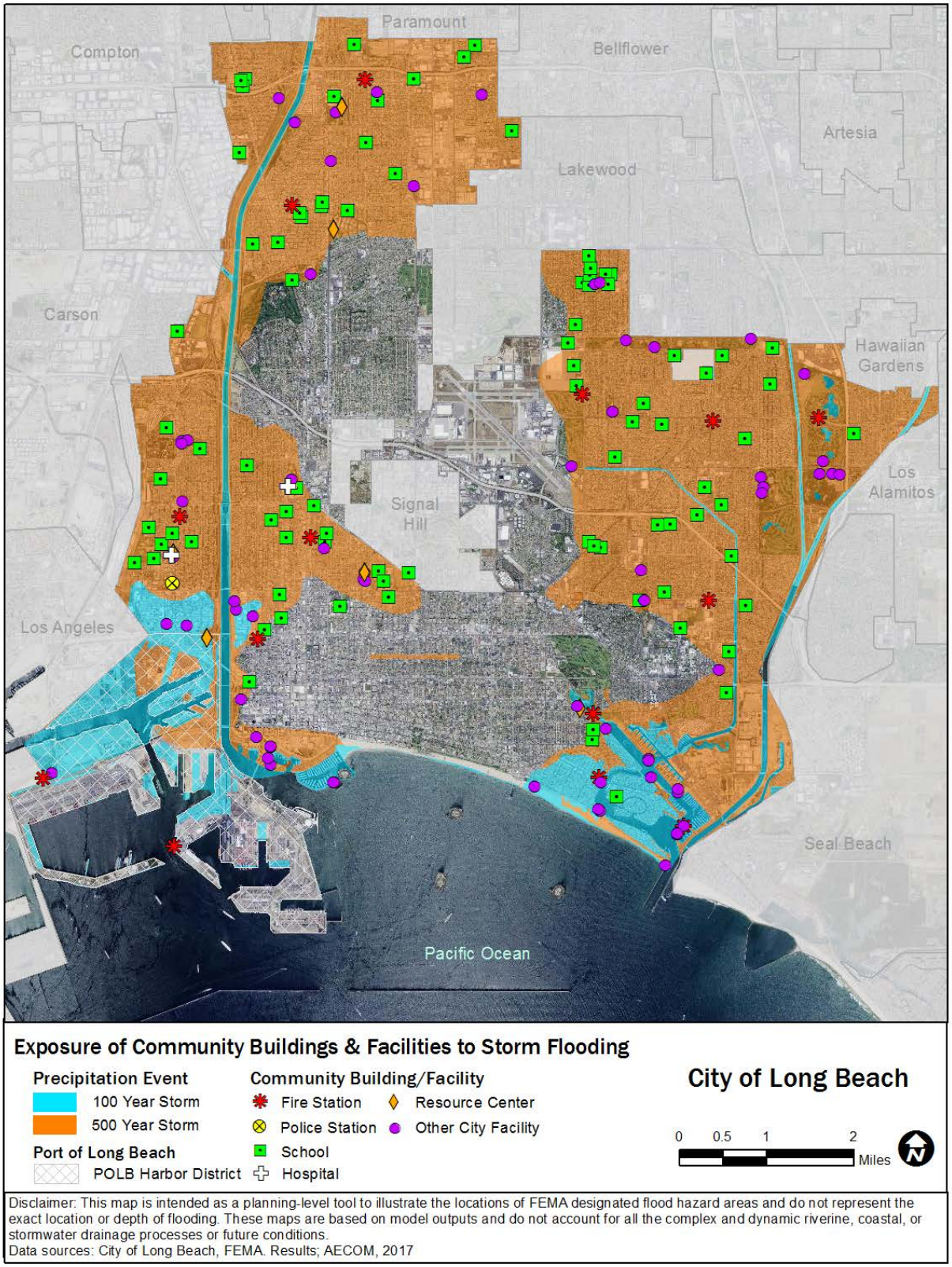
5.4 Drought

Under extreme conditions, foundations may be affected if the ground shrinks. This is most likely to happen with expansive soils that contain a large percentage of silt or clay. Damage to buildings may include cracks in the structure and sloping floors.

5.5 Vulnerability Summary for Buildings and Facilities

- With 11 inches of SLR, 10 City-owned buildings, 624,100 square feet of residential buildings, and 689,600 square feet of commercial buildings are projected to be exposed to annual king tides.
- No hospitals are projected to be exposed to the studied levels of SLR and 100-year storm surge.
- Several critical emergency response facilities are located in the 500-year floodplain.
- Buildings have high sensitivity and low adaptive capacity to permanent inundation. Buildings have high sensitivity and moderate adaptive capacity to temporary flooding (king tide, 100-year storm surge, and riverine flooding).
- Buildings may require additional energy for cooling due to an increase in extreme heat.

Figure 10: Exposure of Buildings and Facilities to Riverine Flooding



Disclaimer: This map is intended as a planning-level tool to illustrate the locations of FEMA designated flood hazard areas and do not represent the exact location or depth of flooding. These maps are based on model outputs and do not account for all the complex and dynamic riverine, coastal, or stormwater drainage processes or future conditions.
Data sources: City of Long Beach, FEMA. Results; AECOM, 2017

Section 6. **Vulnerability of Parks & Open Space**

The Parks and Open Space assets include City parks, beaches, and wetlands. These asset types are not mutually exclusive. For example, several City-owned parks feature wetlands and several beaches include parks. Assets that overlap different asset-types have been noted below.

6.1 Sea Level Rise and Coastal Flooding

City Parks

Asset Overview

The City of Long Beach has over 200 parks citywide. City parks range in type from active recreation parks with playgrounds, courts, playing fields, and/or boating facilities while others are more passive with lawns, paths and/or native habitat. Other parks are more urban and include hardscaped plazas or promenades. In addition to various types of landscaping sensitive to saltwater exposure, parks often include electrical components, such as lighting.

Exposure

With 11 inches of SLR, portions of 17 parks are projected to experience annual king tide flooding while an additional five are projected to experience temporary flooding due to 100-year storm surge (Table 9 and Figure 11). Out of the 17 parks that are projected to be exposed to king tide flooding with 11 inches of SLR, one (Rosie's Dog Beach) is projected to be 50% exposed to flooding, three are projected to be 20% exposed, and the remaining parks are projected to be 10% or less exposed (Table 10).

In Southeast Long Beach, several parks are projected to be exposed to annual king tides by 2030. Active recreation parks include Marine Stadium, Leeway Sailing Center, Bayshore Playground, and Jack Nichol, and Rosie's Dog Beach. Urban parks with hardscaping include Belmont Pier and Plaza. Parks with native habitat include Jack Dunster Marine Reserve.

The Downtown Long Beach area also has several parks that are projected to experience annual king tide flooding with 11 inches of SLR. These are primarily passive recreation parks, featuring pedestrian paths and lawns, such as Rainbow Harbor Esplanade, Shoreline Aquatic, and Downtown Marina Mole. The Jack Dunster Marine Reserve features natural habitat for public recreation and education and is also projected to begin to experience flooding due to annual king tides when combined with 11 inches of SLR.

Table 9: Number of City-Owned Parks Exposed to Sea Level Rise Combined with King Tide and 100-year Storm Surge

	2030 (11" SLR)		2050 (24'' SLR)		2100 (37" SLR)		2100 (66" SLR)	
	Annual King Tide	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide	Additional Exposure Due to Storm Surge
Number of Parks	17	5	20	8	31	7	36	5

*****Note: The exposed assets for the King Tide + 24" SLR scenario are similar to the daily high tide (MHHW) + 37" SLR scenario. The exposed assets for the King Tide + 37" SLR scenario are similar to the daily high tide (MHHW) + 66" SLR scenario.

Table 10: Percent of Park Area Exposed to Annual King Tide with 11 inches SLR

Park Name	**Percent** (rounded to nearest 10%)
Rosie's Dog Beach (Beach)	50%
Leeway Sailing Center	20%
Marine Stadium	20%
Maurice 'Mossy' Kent	20%
Downtown Marina Mole	10%
Harry Bridges Memorial Park At The Queen Mary	10%
Jack Dunster Marine Reserve (Wetlands)	10%
Marine Park (Mother's Beach)	10%
Alamitos At 72nd	Less than 5%
Alamitos Heights	Less than 5%
Belmont Pier And Plaza	Less than 5%
Davies Launch Ramp	Less than 5%
Golden Shore Marine Reserve (Wetlands)	Less than 5%
Jack Nichol	Less than 5%
Rainbow Harbor Esplanade	Less than 5%
Shoreline Aquatic	Less than 5%
South Shore Launch Ramp	Less than 5%

Figure 11: Exposure of Parks to Sea Level Rise + 100-Year Storm Surge

Exposure of Parks to Sea Level Rise + 100-Year Storm Surge

City of Long Beach

Sea Level Rise
- 66"
- 37"
- 24"
- 11"

Parks
- Park Area

Port of Long Beach
- POLB Harbor District

0 0.5 1 1.5 Miles

Disclaimer: This map is intended as a planning-level tool to illustrate the potential for coastal flooding as sea levels rise and do not represent the exact location or depth of flooding. These maps are based on model outputs and do not account for all the complex and dynamic coastal processes or future conditions.
Data sources: City of Long Beach, CoSMoS. Results: AECOM, 2017

Sensitivity and Adaptive Capacity

Parks have high sensitivity to permanent inundation because they cannot be accessed and function as a park when inundated, and therefore permanent inundation would result in loss of the park. Parks have moderate sensitivity to temporary flooding from king tides and storm surge as access to the park may be lost temporarily, and damage to landscaping, architectural, and electrical components is possible. Unless designed to be salt-water resistant, park landscaping is generally sensitive to salt-water exposure. However, when floodwaters recede, the park can be repaired, damaged vegetation replaced, and the park can be returned to use.

Parks have moderate adaptive capacity to permanent inundation, as it can be challenging to elevate or relocate a park. Elevating a large park would be particularly difficult given the amount of fill needed and the disruption/destruction to the existing vegetation. In addition, protecting or relocating mature trees is challenging. However, some parts of the parks could be converted to flooded landscapes and other parts of the park protected. Parks have high adaptive capacity to temporary flooding due to storm surge as modifications to landscaping, such as use of a salt tolerant planting palette, and flood proofing of architectural and electrical features may be possible to accommodate temporary flooding with minimal disruption.

Table 11: Sensitivity and Adaptive Capacity Ratings for Parks

	Sea Level Rise (Permanent Inundation)*	← Rationale	Sea Level Rise (Temporary Flooding)*	← Rationale
Sensitivity	High	Cannot function or be accessed if permanently inundated.	Moderate	Loss of access temporarily. Damage possible to landscaping, architectural, and electrical components.
Adaptive Capacity	Moderate	Somewhat challenging to elevate or relocate park. Portions of park could be sacrificed to floodwaters while others portions are elevated.	High	Modifications to landscaping (salt tolerant plant species) and architectural features available to accommodate temporary flooding.

*Note: Permanent inundation refers to inundation by the daily high tide (MHHW) and temporary flooding refers to flooding by the annual king tide or 100-year storm surge.

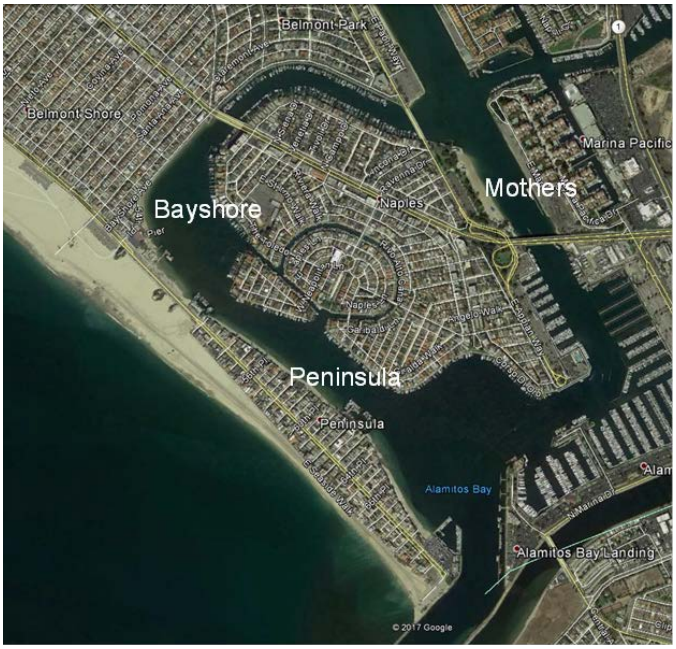
Beaches

Asset Overview

Long Beach has four open coast beaches: Alamitos, Junipero, Belmont, and Peninsula, which are shown in Figure 12. Long Beach has three beaches within Alamitos Bay: Bayshore, Peninsula, and Mothers, which are shown in Figure 12.

Figure 12: Open Coast Beaches

Figure 13: Alamitos Bay Beaches



Exposure

The exposure assessment for beaches focuses on beach width change at 11 inches (2030), 24 inches (2050), 37 inches (2100), and 66 inches (2100) of SLR. Change in beach width for open coast beaches was evaluated using CoSMoS 3.0 sandy shoreline projections for the “hold the line, no nourishment” scenario. Change in beach width for Alamitos Bay beaches was evaluated using permanent inundation projections obtained from the National Oceanic and Atmospheric Administration (NOAA) Sea Level Rise Viewer[6].

Beach width, as shown in Table 12, varies due to coastal dynamics and the presence of backshore features, such as parking lots that are built on the beach. When the sandy shoreline retreats up against a developed backshore feature, the beach width decreases to zero, and there is potential for complete loss of the sandy beach. Without interventions (such as beach nourishment), parts of Bayshore and Peninsula beaches in Alamitos Bay are projected to have zero width with 24 inches of SLR. All three Alamitos Bay beaches are projected to have zero width (complete loss) with 66 inches of SLR.

The open coast beaches are somewhat less susceptible to losses, but Junipero and Peninsula are projected to have zero width in some places (such as along beaches with backshore parking lots) under the 24 inches of SLR by 2050 scenario.

Table 12: Beach Exposure Assessment: Projected Beach Width*

Beach	Existing Width (feet)	Projected Beach Width (feet)			
		2030 (11 "SLR)	2050 (24” SLR)	2100 (37” SLR)	2100 (66” SLR)
Open Coast					
Alamitos	200 to 400	250 to 500**	200 to 400**	150 to 400	50 to 300
Junipero	100 to 550	50 to 500	0 to 350	0 to 400	0 to 250
Belmont Shore	350 to 850	300 to 800	250 to 750	200 to 650	100 to 600
Peninsula	150 to 700	100 to 700	0 to 600	0 to 600	0 to 350
Alamitos Bay					
Bayshore	35 to 100	20 to 90	0 to 50	0	0
Peninsula	50 to 80	40 to 70	0 to 60	0 to 30	0
Mothers	110 to 160	95 to 145	85 to 120	75 to 105	0

*Note this does not account for active sand management currently undertaken by the City
**The width for Alamitos Beach is projected to grow until approximately 2030 in line with observed historical beach growth trends. Beyond 2030, the rate of sea level rise is projected to be higher than the rate of beach growth, at which point retreat is expected to occur.

Sensitivity and Adaptive Capacity

As described above, Long Beach generally has two different types of beaches: open coast and sheltered. Both types of beaches have high sensitivity to permanent inundation, as they cannot be used or function as beaches when underwater. They have moderate sensitivity to temporary flooding from king tides and

[6] https://coast.noaa.gov/slr/; Accessed September 2018.

storm surge. Although flooding, erosion, and debris may impair the use of the beach temporarily, the beach can return to functionality through natural recovery of sand and after repair and clean up.

Beaches generally have low adaptive capacity to SLR for a number of reasons. Beaches in southern California typically have developed backshores (such as parking lots, roads, and homes), which impede the natural landward migration of the beach in response to SLR. In addition, the California coastline is generally sediment starved as a result of decades of reductions in sediment supply due to damming and coastal armoring, which trap sediment. As a result, beaches cannot respond to rising seas as they would under more natural conditions. Interventions such as sand re-nourishment are challenging and expensive. Open coast beaches have greater adaptive capacity than sheltered beaches because wave action and currents can help bring in new sand and redistribute it naturally to help the beach respond to SLR and recover from storm events. In contrast, the Alamitos Bay beaches are especially susceptible to SLR inundation because natural processes such as waves are less able to redistribute sediment within the sheltered embayment. Table 13 summarizes the sensitivity and adaptive capacity ratings for beaches.

Table 13: Sensitivity and Adaptive Capacity Ratings for Beaches

	Sea Level Rise (Permanent Inundation)*	← Rationale	Sea Level Rise (Temporary Flooding)*	← Rationale
Sensitivity	High	Cannot be used or accessed if permanently inundated.	Moderate	Flooding, erosion, and debris can impair use temporarily.
Adaptive Capacity	Low	Challenging and expensive to renourish beach. Backshore development impedes natural landward migration of beach.	Moderate	Sand eroded off the beach during storms can be transported onshore by waves and help beach recover from storm damage.

*Note: Permanent inundation refers to inundation by the daily high tide (MHHW) and temporary flooding refers to flooding by the annual king tide or 100-year storm surge.

Wetlands/Natural Habitats

Asset Overview

Wetlands in the City of Long Beach occur along the coastline, rivers and waterways, and in small scattered pockets amid developed areas. These present day wetlands are representative of remnant wetlands that historically occurred over much larger surface areas. Wetlands in Long Beach can be divided into freshwater wetlands and estuarine (part saline, part freshwater) wetlands. Riverine wetlands, a third category, are a combination of freshwater and estuarine wetlands, depending on the location in the river the wetland is, and whether it is upstream of the salt-zone (boundary line of tidal/salt water influence). Wetlands provide important habitat for wildlife and fish species. In addition to wildlife habitat, marshes provide coastal stability to reduce erosion, and act as nature's sponges to absorb rising tides and reduce wave energy during storm events. Marshes play an important role in carbon storage capacity, chemical nutrient uptake, and as biofiltration for pollutants that occur in surface water runoff, treating the water onsite before the pollutants spread.

There are six named wetland and natural area sites that are assessed in this evaluation: The Jack Dunster Marine Biological Reserve, the Golden Shore Marina Reserve, Los Cerritos Wetlands Complex, the San Gabriel River, the Los Angeles River, and the Colorado Lagoon. These wetlands can be divided

into estuarine: Jack Dunster Marine Biological Reserve, Golden Shore Marina Reserve, and the lower stretches of the San Gabriel and the Los Angeles rivers; and freshwater: the Colorado Lagoon, and the upstream portions of the San Gabriel and Los Angeles rivers. Several additional wetlands occur throughout the City, such as the freshwater pond south of the Del Lago gated community at Loynes Drive and Highway 1, and east of Highway 1 in the Bixby Village Golf Course, along with the freshwater wetlands associated with the El Dorado Nature Center.

Exposure

With 11 inches of SLR, wetlands that occur from the coastline and harbors, upriver to the 405 on the Los Angeles River and upriver to the 605 on the San Gabriel River will be impacted. These include the estuarine wetlands associated with the Los Angeles River and the Port of Long Beach area, and the estuarine wetlands associated with the San Gabriel River and Alamitos Bay.

The Jack Dunster Marine Reserve estuarine wetlands will be exposed to annual king tide flooding with 11 inches of SLR. This area is an important remaining wetland habitat in the City of Long Beach because it is some of the last remaining wetland habitat and provides a suite of ecosystem services.

The Los Cerritos Wetlands Complex is composed of estuarine and freshwater wetlands. The northern portion of the complex north of East 2nd Street and consisting of estuarine and freshwater wetlands is exposed to SLR at 11 inches. South of East 2nd Street, in the Los Cerritos Wetlands Complex, freshwater wetlands are exposed to SLR at 66 inches. The freshwater pond south of the Del Lago gated community at Loynes Drive and Highway1 is exposed to annual king tide flooding at 66 inches.

The Colorado Lagoon is tidally connected to Marine Stadium through culverts under Marina Vista Park. An evaluation of SLR impacts within Colorado Lagoon was not possible because the CoSMoS model does not simulate flow through water control structures (such as culverts) and information on the tidal characteristics within the lagoon was not available. The Colorado Lagoon Restoration Project will remove the culverts and construct an open channel connection to Marine Stadium, introducing full tidal exchange. Components of the restoration project such as grading, foot bridge deck and supports, road crossings and elevations, etc. have been designed with considerations for SLR.

Sensitivity and Adaptive Capacity

<u>Estuarine Wetlands</u>

Estuarine wetlands in Long Beach have a high sensitivity to SLR (permanent inundation). As the sea level rises, these wetlands will become inundated with sea water, which will ultimately drown the vegetation if natural sedimentation is unable to keep pace with SLR. Little to no upslope undeveloped land cover is present for upslope migration. As a result these estuarine wetlands may transition to open water habitat over time. The response of estuarine wetlands to SLR is an area of active research and could be explored further to better understand their vulnerability to SLR.

Estuarine wetlands in Long Beach have a low adaptive capacity to SLR (permanent inundation) because little to no undeveloped areas exist up slope for marsh migration. As a result, these wetlands would likely convert to open water environments. At the Jack Dunster Marine Biological Reserve, adaptive capacity is increased by a floating breakwater, which reduces the erosive currents from the Los Cerritos Channel.

Estuarine wetlands are generally less sensitive to temporary flooding by king tides and 100-year storm surge because they can tolerate occasional temporary flooding events.

Freshwater Wetlands

Freshwater wetlands in Long Beach overall have a high sensitivity to SLR. These wetland types would likely convert to estuarine wetlands, because the freshwater-saltwater zone edge on the surface and in the ground water would move upstream as the sea level rises. Associated freshwater species, including vegetation and wildlife, would not sustain in a saltwater influenced environment because their salt tolerance would be exceeded.

Freshwater non-riverine wetlands have a low adaptive capacity to salt water intrusion.

Riverine Wetlands

Riverine wetlands have high sensitivity to SLR. The downstream estuarine portion of riverine wetlands have high sensitivity to sea level rise because they would become inundated and generally lack the open upslope landscape to migrate upslope. The upstream freshwater stretch of riverine wetlands has high sensitivity to SLR due to salt water intrusion.

Riverine wetlands have a moderate adaptive capacity to sea level rise because these areas are refreshed by upstream runoff. Storm surges will bring in salt but then the freshwater flows from upriver would rinse these areas, allowing them more adaptive capacity than the other isolated freshwater wetlands.

Table 14: Sensitivity and Adaptive Capacity Ratings for Wetlands

	Sea Level Rise (Permanent Inundation)*	← Rationale	Sea Level Rise (Temporary Flooding)*	← Rationale
Sensitivity	High	Vegetation would become regularly inundated. In a constrained urban environment, there is limited room for habitat migration.	Moderate	Erosion and debris can impair wetlands temporarily, but wetlands can tolerate occasional extreme storm flooding.
Adaptive Capacity	Low	In a constrained urban environment, there is limited room for habitat migration.	Moderate to High	Healthy wetlands can generally recover and regenerate following occasional extreme storm flooding.

*Note: Permanent inundation refers to inundation by the daily high tide (MHHW) and temporary flooding refers to flooding by the annual king tide or 100-year storm surge.

Marinas

Vulnerability Summary

Marina assets typically include boat slips, docks, showers and restrooms, pump out stations, fuel services, equipment supply stores, storage, and shipyard facilities. There are a number of public marinas along the Long Beach shoreline (such as the Alamitos Bay Marina and Long Beach Shoreline Marina) that may be impacted by sea level rise and elevated water levels in the future. Sailing, fishing, boating, and waterfront bars and restaurants are an important part of Long Beach's economy that could be impacted.

High water levels from king tides, storm surge, and sea level rise may impact marina operations in a number of ways. High tide events that overtop the marina shorelines may affect access to marina docks and boat slips. In addition, shoreline facilities such as showers, restrooms, and marina offices, etc. may be damaged by floodwaters. In addition, Long Beach Shoreline Marina is home to fire rescue, lifeguard

rescue, and police boats. Higher water levels during extreme events could impact marine emergency response if these facilities are impacted. While most marina areas have floating docks and can therefore accommodate moderate water level fluctuations within their design range, during extreme water level events, docks may float off their pilings or gangways may become separated from docks and limit access.

During combined wave and high tide events, protective structures such as breakwaters may become less effective as waves overtop the crest of these structures and allow waves to enter protected areas. The Long Beach Shoreline Marina has an offshore detached breakwater and an attached breakwater at Grissom Island that could lose effectiveness in the future due to sea level rise unless their crest elevations are raised. There is also a breakwater within the Alamitos Bay Marina that could be overtopped by high tides and boat wakes during future high water level events as a result of sea level rise.

6.2 Riverine Flooding

Parks, beaches, and wetlands exposed to the FEMA 100-year storm is very similar to the 11 inches SLR + 100-year storm surge scenario described above. Figure 14 shows City-parks that are within the 100 and 500-year FEMA floodplain. Given the large extent of the 500-year floodplain, considerably more parks are at-risk to that event.

The sensitivity and adaptive capacity considerations for riverine flooding are similar the temporary flooding (SLR + Storm Surge) described considerations above.

6.3 Extreme Heat Events

Vegetation in Parks and Open Space may be impacted by extreme heat events, but parks are likely to remain operational. The use of additional irrigation and/or change of vegetation to heat and drought tolerant plants may reduce the impact of extreme heat. Extreme heat often coincides with periods of drought, so increased irrigation may not be a preferred option. Parks and Open Spaces may experience loss of some species that are not able to tolerate higher temperatures. Parks and Open Spaces, in particular beaches, may experience increased visitation during extreme heat days, which could put stress on associated facilities such as parking and waste management.

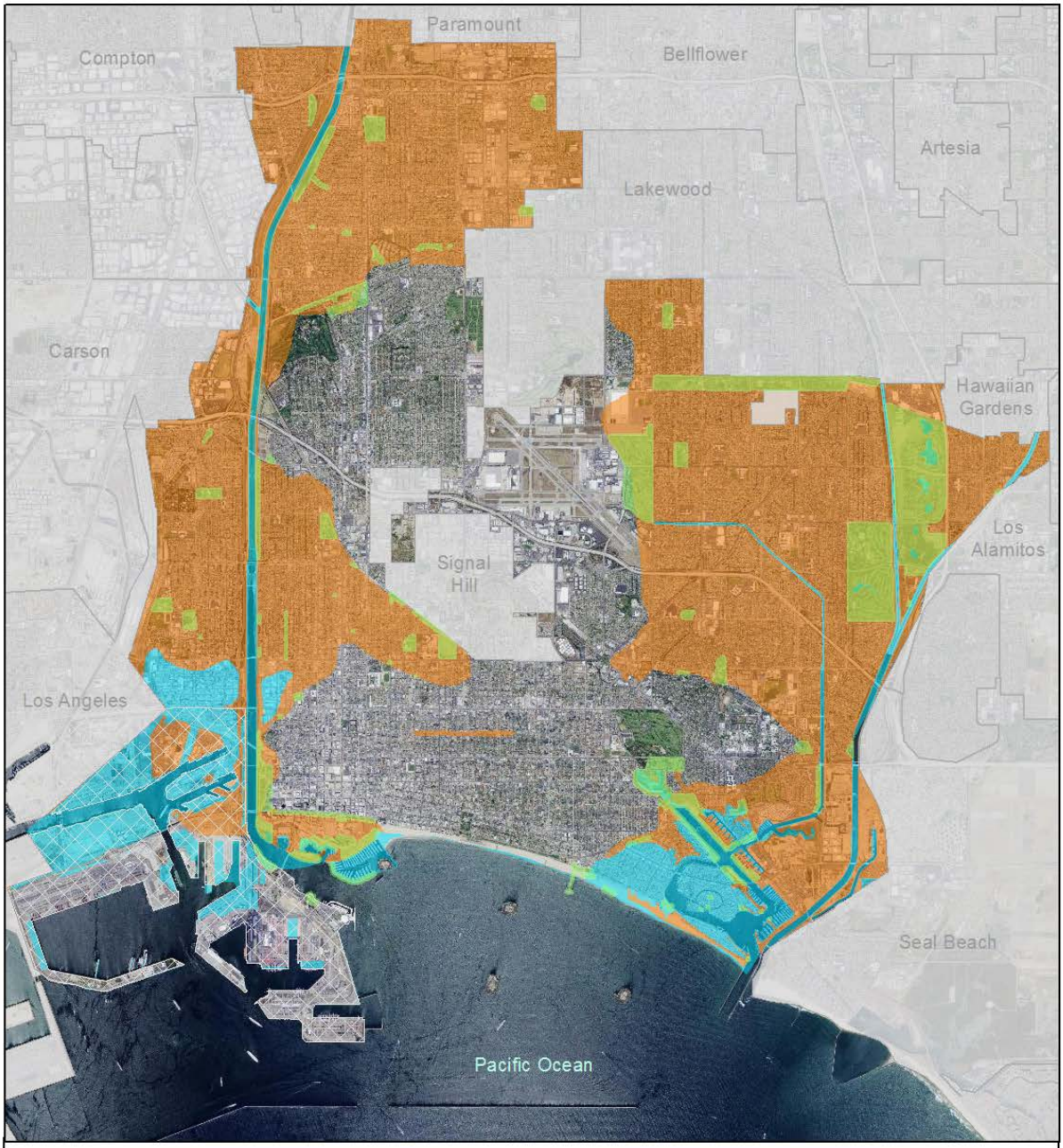
6.4 Drought

Vegetation in Parks and Open Space may be impacted by drought, but parks are likely to remain operational. The use of additional irrigation and/or change of vegetation to heat and drought tolerant plants may reduce the impact of drought. The use of irrigation may not be preferred as water restrictions may be in place during a drought. The use of non-potable water for irrigation may be a preferred option. Parks and Open Spaces may experience loss of some species that are not able to tolerate drought.

6.5 Vulnerability Summary for Parks and Open Space

- With 11 inches of SLR, portions of 17 parks are exposed to annual king tides. One of those parks is projected to have 50% of the park area flooded, three are projected to have 20% exposed, and the rest are projected to have 10% or less exposed.
- Although parks have high sensitivity to permanent inundation, they have moderate sensitivity and high adaptive capacity to temporary flooding due to king tides and storm surge.
- With 24 inches of SLR, there is potential for loss of portions of the Bayshore and Peninsula beaches within Alamitos Bay.
- Beaches in this highly urbanized context have high sensitivity and low adaptive capacity to permanent inundation. They have moderate sensitivity and moderate adaptive capacity to temporary flooding due to king tides and storm surge.
- The Jack Dunster Marine Reserve estuarine wetlands and the Los Cerritos Wetlands Complex north of East 2nd Street will be exposed to annual king tides with 11 inches of SLR.
- Vegetation in Parks & Open space may be impacted by extreme heat and drought, but functionality of the parks is unlikely to be impacted.

Figure 14: Exposure of Parks and Open Space to Riverine Flooding



Exposure of Parks to Storm Flooding

Precipitation Event
- 100 Year Storm
- 500 Year Storm

Parks
- Park Area

Port of Long Beach
- POLB Harbor District

City of Long Beach

0 0.5 1 2 Miles

Disclaimer: This map is intended as a planning-level tool to illustrate the locations of FEMA designated flood hazard areas and do not represent the exact location or depth of flooding. These maps are based on model outputs and do not account for all the complex and dynamic riverine, coastal, or stormwater drainage processes or future conditions.
Data sources: City of Long Beach, FEMA. Results: AECOM, 2017

Section 7. **Vulnerability of Transportation Assets**

The transportation asset sector includes roads, bike paths, and bridges.

7.1 Sea Level Rise and Coastal Flooding

Roads

Asset overview

Roads in Long Beach consist of highways, arterials, and neighborhood streets. Roads are constructed from asphalt or concrete. Roads also include lighting and other electrical equipment.

Exposure

With 11 inches of SLR, four miles of road are projected to be exposed to annual king tides. The majority of the roads that will be impacted at 11 inches are in the Long Beach Harbor District. Impacted roads in other areas are generally only slightly affected along portions in close proximity to existing water levels. Impacted areas include stretches of Seaside Freeway, Highway 47, Pier A Way and Carrac Avenue. These roads provide access to Port facilities, the NRG Power Station and other industrial operations. An additional 45 miles of road would be exposed to 100-year storm surge flooding with 11 inches of SLR.

Without adaptation, up to 98 miles of road could be exposed to annual king tide flooding by the end-of-century.

Table 15: Miles of Roads Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		**2050 (24'' SLR)**		**2100 (37" SLR)**		**2100 (66" SLR)**	
	Annual King Tide	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide	Additional Exposure Due to Storm Surge
Roads (miles)	4	45	41	32	74	16	89	27

*****Note: The exposed assets for the King Tide + 24" SLR scenario are similar to the daily high tide (MHHW) + 37" SLR scenario. The exposed assets for the King Tide + 37" SLR scenario are similar to the daily high tide (MHHW) + 66" SLR scenario.

Sensitivity and Adaptive Capacity

As described in Table 16 below, roads that are permanently inundated cannot be used, as vehicles will not be able to navigate them and inundation would lead to degradation of the road and subgrade. As such, roads are highly sensitive to permanent inundation. Roads are moderately sensitive to temporary flooding by king tides or 100-year storm surge. They could be used as normal other than when temporary flooding occurs over a certain depth depending on vehicle clearance (for example cars have lower clearance than emergency vehicles). It should be noted, however, that over time, temporary flooding could lead to erosion and degradation of the roadway, thus requiring additional maintenance above a baseline amount in order to maintain functionality.

In terms of adaptive capacity, roads have low ability to change in response to permanent inundation, as the cost of elevating or relocating a road is high. Roads have more adaptive capacity when it comes to temporary flooding because, while challenging, measures can be taken to temporarily flood-proof the road, such as inflatable flood barriers. In addition, temporarily re-routing traffic because of flooding is also an option, drawing on the redundancies within the road network. In evaluating both sensitivity and adaptive capacity, several nuances should be considered. For one, low inundation depths on a temporary basis may affect the functionality of a road in only very minor ways. In such a scenario, there could be little impact other than a slow-down of traffic, making the road's sensitivity to temporary flooding only minor. Similarly, the adaptive capacity of the road system might be high if a road that experiences temporary flooding is a minor road and if there are other roads in the system that provide essentially the same function.

Table 16: Sensitivity and Adaptive Capacity of Roads

	Sea Level Rise (Permanent Inundation)	← Rationale	Sea Level Rise (Temporary Flooding)	← Rationale
Sensitivity	High	Roads cannot be used if permanently inundated.	Moderate	Roads would not be usable during flood events but would return to normal once the flooding subsides. Erosion damage possible.
Adaptive Capacity	Low	Elevating or relocating roads is difficult and costly.	Moderate	Temporary flood proofing for storm events is somewhat challenging.

*Note: Permanent inundation refers to inundation by the daily high tide (MHHW) and temporary flooding refers to flooding by the annual king tide or 100-year storm surge.

Bikeways

Asset Overview

Bikeways include Class I, II, and III bikeways. Class I are separated from the street or highway. Class II is a striped lane on a street, and Class III provides for shared use with motor vehicle traffic and is identified by signage. Bikeways are important for providing safe travel for bicyclists.

Exposure

With 11 inches of SLR, one mile of bikeway is projected to be exposed to annual king tides and an additional three miles are projected to be exposed 100-year storm surge flooding. The main bikeway that

will be exposed to annual king tides with 11 inches of SLR is along Boathouse Lane next to the Jack Dunster Marine Biological Reserve (see Figure 6).

Sections of the bike path along the Alamitos, Junipero, and Belmont Shore Beaches would experience inundation at 37 inches of SLR (see Figure 6 and Figure 7).

The bike path around the Shoreline Marina is projected to experience inundation at 37 inches of SLR (see Figure 7).

Table 17: Miles of Bike Paths Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		**2050 (24'' SLR)**		**2100 (37" SLR)**		**2100 (66" SLR)**	
	Annual King Tide	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide	Additional Exposure Due to Storm Surge
Bike paths (miles)	1	3	3	4	6	5	10	5

*****Note: The exposed assets for the King Tide + 24" SLR scenario are similar to the daily high tide (MHHW) + 37" SLR scenario. The exposed assets for the King Tide + 37" SLR scenario are similar to the daily high tide (MHHW) + 66" SLR scenario.

Sensitivity and Adaptive Capacity

Bike paths are highly sensitive to permanent inundation because inundation would result in permanent loss of use of the bike path. Bike paths are moderately sensitive to temporary flooding events as the paths can be used once flood waters recede. In exposed areas, wave action associated with a coastal storm event could damage bike paths, especially if the concrete path is built on a surface that is prone to erosion, such as sand.

In terms of adaptive capacity, depending on the length and width of the path, as well as the material it is made of, bike paths have some amount of adaptive capacity in both permanent and temporary flooding contexts. An adaptive measure focused on elevating the bike path certainly has costs associated with it, especially if such a measure requires bringing in materials from afar and / or laying new pavement surface, but bike paths tend to be relatively narrow, which means that the cost of elevating a bike path would be low in comparison to, for example, raising a road. Relocating bike paths as an adaptation measure also has costs associated with it, but if a suitable alternate road or surface is readily available, relocating the path could be as simple and cheap as painting markers in the new lane and putting up signage.

Table 18: Sensitivity and Adaptive Capacity of Bike paths

	Sea Level Rise (Permanent Inundation)*	← Rationale	Sea Level Rise (Temporary Flooding)*	← Rationale
Sensitivity	High	Cannot be used if regularly flooded.	Moderate	Path could not be used during temporary flooding event. Storm surge could damage or destroy paths.
Adaptive Capacity	Moderate	Elevating or relocating paths is somewhat challenging.	Moderate	Elevating or floodproofing paths is somewhat challenging.

*Note: Permanent inundation refers to inundation by the daily high tide (MHHW) and temporary flooding refers to flooding by the annual king tide or 100-year storm surge.

Bridges

Asset Overview

Bridges are made primarily of concrete and are comprised of distinct components such as approaches, a deck, a superstructure, and sub-structure (including piers). They may also have auxiliary equipment such as streetlights and other electrical and mechanical components, and often support some utility crossings. Some bridges are owned by the City and others are owned by the State Department of Transportation (Caltrans). There are over 120 City-owned and over 110 State-owned bridges citywide. The bridges asset data used in this assessment is from Caltrans, which generally identifies the location of the bridge approach. This tends to represent the lowest part of the bridge.

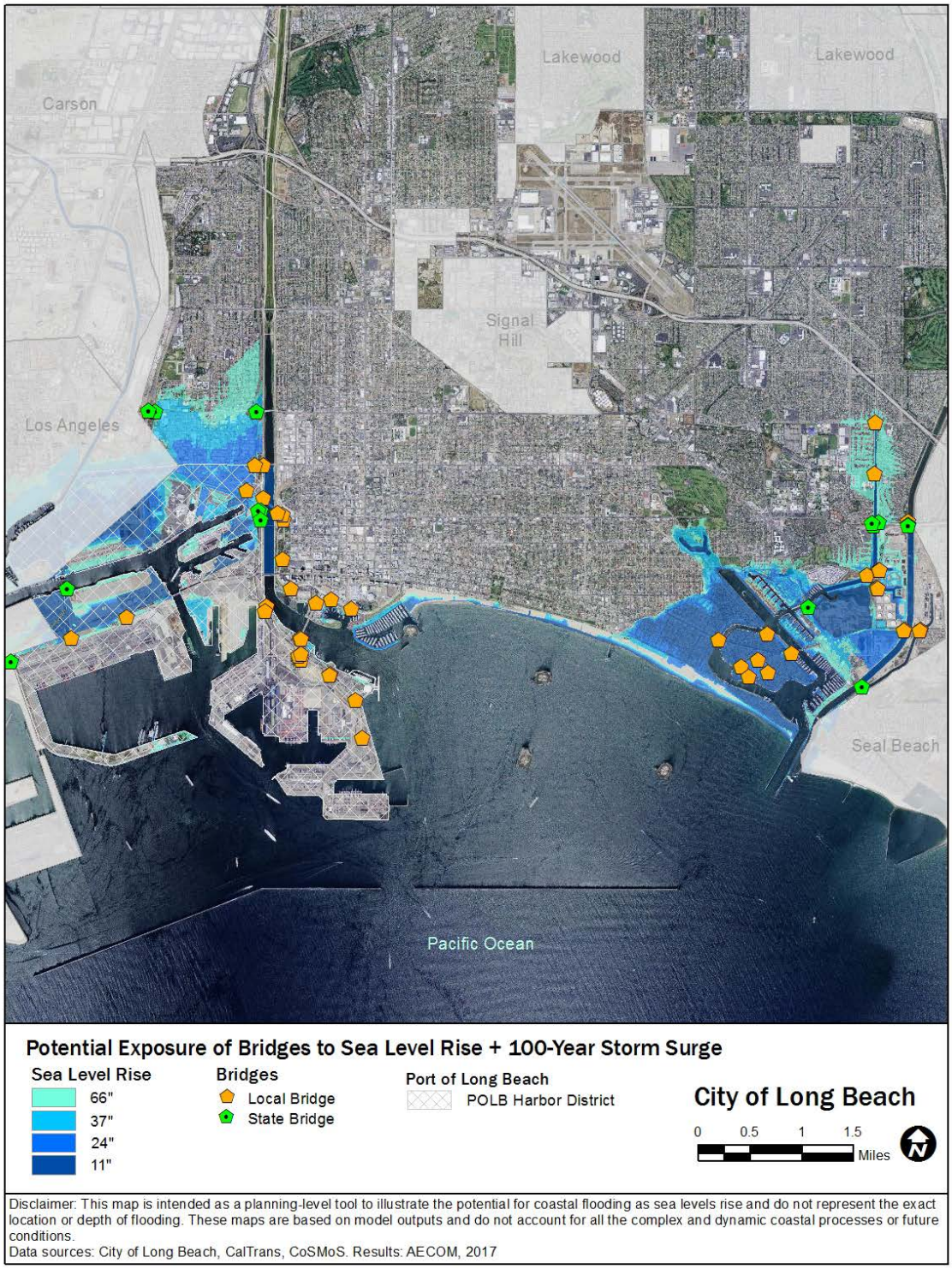
Exposure

The available bridge data represents single points approximately located at the bridge approaches. Because this data is not detailed enough to accurately assess flood impacts to bridges, a simplified approach was taken to identify bridges that may be exposed to future flood hazards. A 500-foot search radius was applied to the highest SLR scenario (66” SLR + storm surge) to assess which bridges are within a zone of vulnerability and would benefit from further analysis to evaluate exposure to future sea level rise-related inundation and flooding. 44 local bridges and 16 state bridges were identified within this SLR vulnerability area (Table 19). More detailed asset data and further analysis is required to identify which of these will be potentially impacted at each SLR scenario – for example, by comparing projected future water levels to bridge deck or soffit elevations and reviewing structural design plans to evaluate sensitivity to marine floodwaters. This level of analysis would require a comprehensive dataset of structural details related to the bridge design, which was not feasible to compile or evaluate as part of this study

Table 19: Number of Bridges Within 500 Feet Buffer of 66” of Sea Level Rise Plus 100-year Storm Surge

	Number of Bridges Within 500ft of 66” SLR + 100-year Storm Surge (2100)	
	Local Bridges	State Bridges
Bridges	44	16

Figure 15: Potential Exposure of Bridges to Sea Level Rise and Storm Surge



Note: Map identifies local and state bridges located within 500 foot buffer zone of the 100-year storm surge plus 66" SLR flooding area.

Sensitivity and Adaptive Capacity

Bridge components can exhibit different kinds of sensitivities to permanent inundation and temporary flooding and the extent of sensitivities depends on the depth of inundation and the elevation of components. For example, inundation or flooding of bridge approaches and decks could cause service disruption to on-road vehicular and pedestrian traffic as traffic would need to be rerouted. If the overtopping is shallow and isolated to the approach, traffic would have to slow down to use the bridge, but the bridge might be otherwise unaffected.

Other potential impacts of inundation or flooding on decks include debris overflow and pavement damage. Continuous exposure to salt water by permanent inundation could lead to more rapid degradation of bridge components (such as pavement and reinforcing steel), thus requiring an additional level of maintenance. In particular, salt water could infiltrate electrical and mechanical components of traffic control/signal boxes and cause immediate or latent damage through degradation and corrosion. Scouring and erosion (washout) around the bridge abutments or piers due to storm events could also compromise the bridge.

Some of the affected bridges span water channels that are used by recreational and commercial vessels. Depending on the extent of SLR and storm surge event, the water level may rise to a point where high mast vessels don't have adequate clearance to pass underneath the bridges.

The sensitivity of bridges to permanent inundation is high. The sensitivity of bridge approaches and decks to temporary flooding is moderate as the bridge could potentially return to normal operation once the floodwaters recede.

In terms of adaptive capacity, adapting a bridge approach or deck to permanent inundation would require rebuilding and elevating it, which is quite costly. As such, bridges are considered to have low adaptive capacity to permanent inundation. Bridges have slightly higher adaptive capacity to temporary flooding because, in addition to potentially elevating the approaches and touchdowns, there are options for flood-proofing the components that would be inundated. Furthermore, the overall transportation system that includes these bridges offers limited redundancies or alternative routes if the bridges were to go out of service, particularly if other routes are similarly vulnerable to SLR and storm surge.

Table 20: Sensitivity and Adaptive Capacity of Bridges

	Sea Level Rise (Permanent Inundation)*	← Rationale	Sea Level Rise + Storm Surge (Temporary Flooding)*	← Rationale
Sensitivity	High	Access likely to be impacted permanently; scouring and erosion likely.	Moderate	Access likely to be impacted temporarily. Scouring and erosion likely.
Adaptive Capacity	Low	Elevating bridges is difficult and costly.	Moderate	Elevating bridges is costly. Temporary floodproofing is somewhat challenging.

*Note: Permanent inundation refers to inundation by the daily high tide (MHHW) and temporary flooding refers to flooding by the annual king tide or 100-year storm surge.

7.2 Riverine Flooding

The transportation assets exposed to the FEMA 100-year storm is very similar to the 11 inches SLR + 100-year storm surge scenario described above. Given the large extent of the 500-year floodplain, considerably more transportation events are at-risk of exposure to flooding in that scenario. Over 600 miles of road are located in the 500-year floodplain.

The sensitivity and adaptive capacity considerations for riverine flooding are similar to the temporary flooding (SLR + Storm Surge) considerations described above.

7.3 Extreme Heat

The number of extreme heat days (over 95℉) in Long Beach per year is projected to increase from an average of four in the baseline period (1980-2000) to 11-16 days by mid-century and 11-37 by end-of century, depending on the emissions scenario (Sun et al. 2015). Based on a report completed by the United States Department of Transportation, it is estimated that the risk of asphalt pavement softening increase when temperatures remain over 100 °F without cooling at night, particularly in areas with high truck traffic (USDOT 2012). Asphalt pavement softening may result in damage. If electrical outages were caused due to area-wide brownouts, traffic signals and streetlights could be affected, temporarily disrupting traffic movement.

7.4 Drought

Under extreme conditions, paving materials may be affected if the ground shrinks. This is most likely to happen with expansive soils that contain a large percentage of silt or clay. Damage to transportation assets may include cracks and warping of pavement. Subsidence due to the extraction of groundwater from an aquifer faster than it can be recharged can also damage transportation assets.

7.5 Vulnerability Summary for Transportation Assets

- With 11 inches of SLR, 4 miles of road and 1 mile of bikeway are projected to be exposed to annual king tides.
- Transportation assets generally have high sensitivity and low adaptive capacity to permanent inundation, but moderate sensitivity and moderate adaptive capacity to temporary flooding. However, bikeways may have high sensitivity to temporary flooding if they are constructed on a land that could be prone to erosion from storm surge, such as on a sandy beach or river levee (a condition that exists in Long Beach).
- 44 local bridges and 16 state bridges are located in an area that could potentially be exposed to a 100-year storm surge event with 66” of SLR.
- Extreme heat may result in an increase in damage due to asphalt pavement softening, particularly in areas of high truck traffic.

Section 8. **Vulnerability of Energy Assets**

The Energy asset sector includes Generation Facilities, Transmission Lines, Electrical Substations, and Natural Gas Mains.

Asset Overview

Long Beach has over 200 miles of transmission lines citywide. They are owned and operated by Southern California Edison. Transmission lines carry high voltage power from generation facilities to substations. They are most often carried on overhead lines.

Long Beach has approximately 42 substations citywide. They are owned and operated by Southern California Edison. Substations serve to transform electricity from the high voltage transmission network to the lower voltage distribution network. They consist of electrical equipment and may be on a pad outdoors or within a structure.

Long Beach has three generation facilities. The NRG Long Beach Generating Station is located in the Harbor District and is owned and operated by NRG. Hayes Generating Facility, located East of the San Gabriel River, is owned and operated by the Los Angeles Department of Water and Power. The Alamitos Energy Station, located West of the San Gabriel River, is owned and operated by AES California. It is being redeveloped and is anticipated to include improvements that would make it more resilient to sea level rise.

Long Beach also has several smaller storage containers and over 900 miles of natural gas mains citywide. They are owned and operated by the Long Beach Energy Resources Department and deliver natural gas to homes and businesses. Natural gas mains are located underground.

8.1 Sea Level Rise and Coastal Flooding

Exposure

With 11 inches of SLR, the NRG Generating Station is projected to be exposed to annual king tides. During a 100-year storm event with 11 inches of SLR, the Alamitos Generating Station would also be exposed, although it is being redeveloped.

One substation is projected to be exposed to annual king tide with 11 inches of SLR. It is called “Seabright” and is located near the Los Angeles River. With 66 inches of SLR, the “Marina” substation is projected to be inundated. It is located near the Davies Boat Launch in Alamitos Bay.

With 11 inches of SLR, eight miles of transmission lines could be exposed to annual king tides. While transmission lines are generally carried on overhead lines, the bases of the transmission towers supporting the lines may be exposed. They may not have been designed for regular inundation, which could cause access issues for maintenance purposes.

With 11 inches of SLR, one mile of natural gas mains would be exposed to annual king tide flooding with an additional 25 miles exposed during a 100-year storm surge with 11 inches of SLR.

Table 21: Energy Sector Assets Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		**2050 (24'' SLR)**		**2100 (37" SLR)**		**2100 (66" SLR)**	
	Annual King Tide	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide	Added Exposure Due to Storm Surge
Generation Facilities (number)	1	1	1	1	2	0	2	0
Electrical Substations (number)	1	0	1	1	1	2	2	2
Transmission Lines (miles)	8	0	9	3	13	2	15	5
Natural Gas Mains (miles)	1	25	21	19	41	11	53	21

*****Note: The exposed assets for the King Tide + 24" SLR scenario are similar to the daily high tide (MHHW) + 37" SLR scenario. The exposed assets for the King Tide + 37" SLR scenario are similar to the daily high tide (MHHW) + 66" SLR scenario.

Sensitivity and Adaptive Capacity

Energy infrastructure has high sensitivity to permanent inundation and temporary flooding, as extensive damage to electrical components is possible even with temporary exposure to salt water. Overhead transmission lines are generally not exposed to SLR, but if the base of the tower was not designed for permanent or temporary exposure to salt water, it could result in damage and problems with access for maintenance. Natural gas mains, which are underground pipes could be damaged by erosion or high groundwater.

The adaptive capacity of energy infrastructure to permanent inundation is generally moderate to low as elevating or relocating infrastructure is difficult and costly. Although still very costly to elevate, smaller pieces of energy infrastructure (e.g. substations) generally have higher adaptive capacity than large pieces of infrastructure, (e.g. generating facilities). Adaptive capacity for temporary flooding is somewhat higher and flood proofing mechanisms could help protect infrastructure at a lower cost.

Table 22: Sensitivity and Adaptive Capacity of Energy Assets

	Sea Level Rise (Permanent Inundation)	← Rationale	Sea Level Rise (Temporary Flooding)	← Rationale
Sensitivity	High	Cannot operate if inundated	High	Electric power systems may be damaged or destroyed from exposure to water.
Adaptive Capacity	Low	Elevating or relocating energy infrastructure is difficult and very costly.	Moderate	Elevating energy infrastructure is very costly. Flood proofing energy infrastructure, especially large assets, is somewhat challenging.

*Note: Permanent inundation refers to inundation by the daily high tide (MHHW) and temporary flooding refers to flooding by the annual king tide or 100-year storm surge.

8.2 Riverine Flooding

The transportation assets exposed to the FEMA 100-year storm are very similar to the 11 inches SLR + 100-year storm surge scenario described above. Given the large extent of the 500-year floodplain, considerably more energy assets are at-risk of exposure to flooding in that scenario. For example, an estimated 26 substations are located in the 500-year floodplain.

The sensitivity and adaptive capacity considerations for riverine flooding are similar to SLR + 100-year storm surge described in the considerations above.

8.3 Extreme Heat

Extreme heat events may result in higher electricity demand. At the same time, during extreme heat events electricity supply may be reduced due to reduced hydropower output and reduced transmission line and power plant efficiency. As a result, there is an increased risk of demand exceeding supply, which could result in area-wide brownouts or blackouts.

8.4 Drought

Generation facilities are sensitive to the loss of cooling water supply. The loss of hydropower generation during a drought may result in a greater reliance on fossil fuel powered energy generation, such as the generating facilities located in Long Beach.

8.5 Vulnerability Summary for Energy Assets

- With 11 inches of SLR, 1 generation facility, 1 substation, 8 miles of transmission lines, and 1 mile of natural gas mains are projected to be exposed to annual king tide flooding.
- Energy assets generally have high sensitivity and low adaptive capacity to permanent inundation. They have high sensitivity and moderate adaptive capacity to temporary flooding.
- Extreme heat may increase energy demand and could result in brownout if demand exceeds supply.

Section 9. **Vulnerability of Stormwater Assets**

The stormwater assets assessed include storm drain outfalls and storm drain carriers.

Asset Overview

Stormwater assets are part of the urban drainage system that conveys stormwater away from buildings and streets into pipes, channels, and finally through outfalls into water bodies, such as the ocean, bay or rivers. Storm drain carriers include pipes and open channels. There are over 440 miles of storm drain carriers in the city. Storm drain outfalls are the discharge point from the carrier to a body of water. There are over 400 storm drain outfalls citywide in Long Beach. Stormwater pump stations are used to pump away large volumes of water to prevent flooding. There are 55 stormwater pump stations in Long Beach.

9.1 Sea Level Rise and Coastal Flooding

Exposure

With 11 inches of SLR, 18 storm drain outfalls may be exposed to annual king tides. An additional five may be exposed to 100-year storm surge flooding. It should be noted that this is a preliminary assessment of potential exposure and more detailed analysis would need to be conducted to determine exact elevations of outfalls with respect to projected sea level rise and the outfall conditions, such as whether they have backflow prevention devices. Exposure of outfalls to SLR could result in stormwater flooding upstream as the outfall is blocked from discharging, and water backs up into the drainage system. Many of the storm drain outfalls that would be exposed earliest are around Alamitos Bay (which drain Belmont Shore and Marina Pacifica) and along the Los Cerritos Channel. Other outfalls that would be exposed earliest are around the mouth of the Los Angeles River and Queensway Bay (which drain the downtown area).

With 11 inches of SLR, one stormwater pump station may be exposed to annual king tides. This pump station is located on the northeastern side of Naples Island at E 2nd Street. An additional six may be exposed to 100-year storm surge flooding. Five of these are located around Naples Island and Belmont Shore.

Exposure of storm drain carriers to sea level rise reduces their capacity and can cause upstream flooding. Approximately 1 mile of storm drain carriers are projected to be exposed at 11 inches of SLR. An additional 14 miles would be exposed to 100-year storm surge flooding with 11 inches of SLR. Overland flooding of buried storm drain carriers can saturate soils and lead to increased infiltration into stormwater pipes or flooding of catch basins and reduce conveyance capacity.

Table 23: Stormwater Assets Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		2050 (24'' SLR)		2100 (37" SLR)		2100 (66" SLR)	
	Annual King Tide	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide	Added Exposure Due to Storm Surge
Storm Drain Outfalls (number)	18	5	23	13	30	13	39	28
Stormwater Pump Stations (number)	1	6	5	4	10	2	11	3
Storm Drain Carriers (miles)	1	14	12	17	29	10	38	11

*****Note: The exposed assets for the King Tide + 24" SLR scenario are similar to the daily high tide (MHHW) + 37" SLR scenario. The exposed assets for the King Tide + 37" SLR scenario are similar to the daily high tide (MHHW) + 66" SLR scenario.

Sensitivity and Adaptive Capacity

Stormwater infrastructure has high sensitivity to permanent inundation as it can result in a permanent loss of drainage capacity near the coast. Stormwater infrastructure has moderate sensitivity to temporary flooding due to storm surge as there is a temporary loss of drainage capacity near the coast during the event, but the infrastructure can continue to function when floodwaters recede.

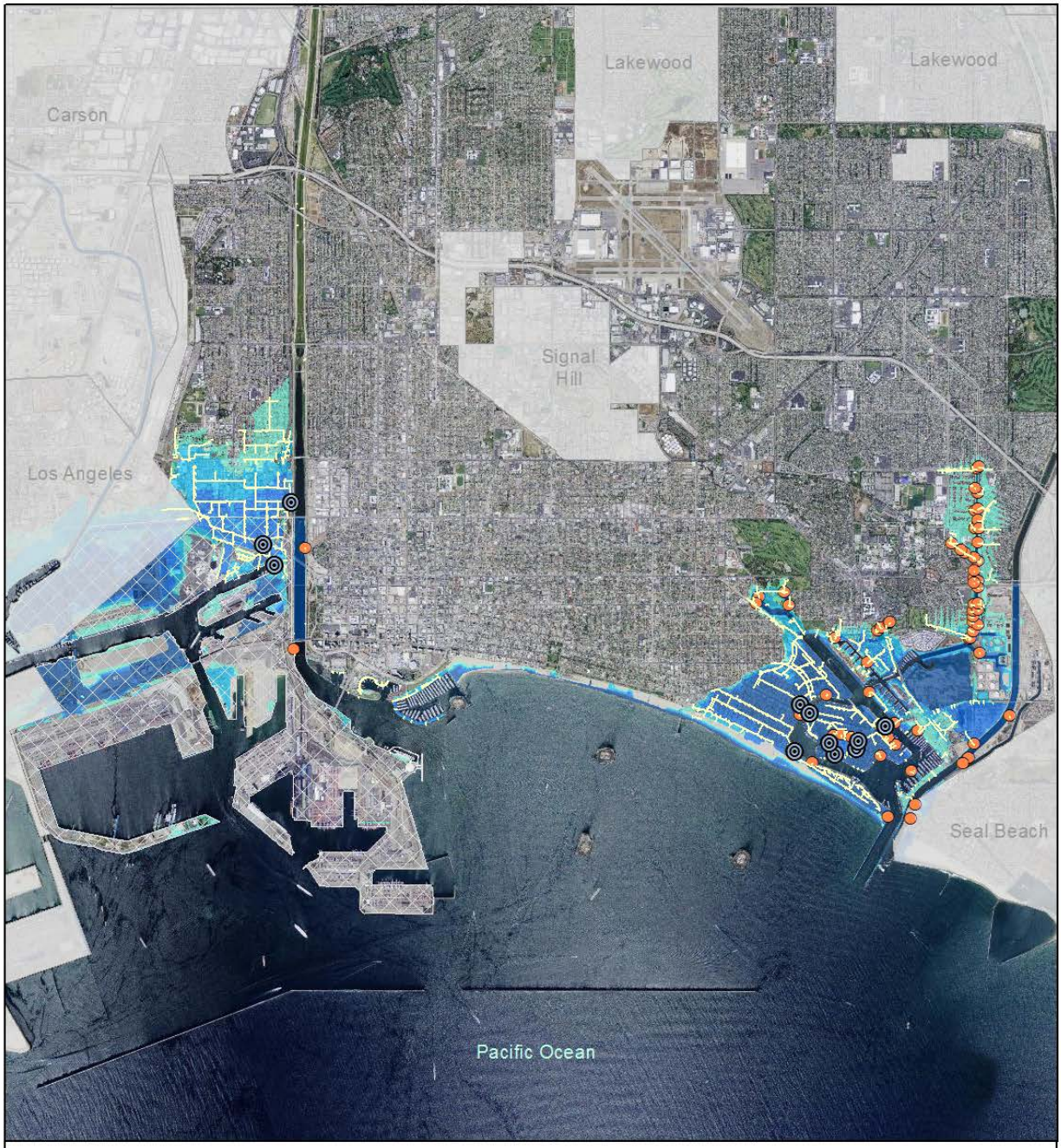
Stormwater infrastructure has low adaptive capacity to permanent inundation due to SLR as replacing or modifying (e.g. enlarging the drainage capacity) is somewhat challenging, particularly in a constrained urban environment. Stormwater infrastructure has better adaptive capacity to temporary flooding events as, in addition to modifying the infrastructure, devices such as backflow preventers can help in a temporary flood event.

Table 24: Sensitivity and Adaptive Capacity of Stormwater Infrastructure

	Sea Level Rise (Permanent Inundation)*	← Rationale	Sea Level Rise (Temporary Flooding)*	← Rationale
Sensitivity	High	Permanent loss of stormwater infrastructure capacity near the coast	Moderate	Temporary loss of stormwater infrastructure capacity near the coast.
Adaptive Capacity	Low	Elevating or modifying stormwater infrastructure is challenging.	Moderate	Elevating or modifying stormwater infrastructure is somewhat challenging for storm events. Backflow prevention can be useful for temporary flood conditions.

*Note: Permanent inundation refers to inundation by the daily high tide (MHHW) and temporary flooding refers to flooding by the annual king tide or 100-year storm surge.

Figure 16: Exposure of Stormwater Assets to Sea Level Rise + 100-year Storm Surge



Exposure of Stormwater Assets to Sea Level Rise + 100-Year Storm Surge

Sea Level Rise
- 66"
- 37"
- 24"
- 11"

Stormwater Assets
- Storm Drain Carriers
- Outfalls
- Stormwater Pump Station

Port of Long Beach
- POLB Harbor District

City of Long Beach

0 0.5 1 1.5 Miles

Disclaimer: This map is intended as a planning-level tool to illustrate the potential for coastal flooding as sea levels rise and do not represent the exact location or depth of flooding. These maps are based on model outputs and do not account for all the complex and dynamic coastal processes or future conditions.
Data sources: City of Long Beach, CoSMoS. Results: AECOM, 2017

9.2 Riverine Flooding

The stormwater assets exposed to the FEMA 100-year storm is very similar to the 11 inches SLR + 100-year storm surge scenario described above. Given the large extent of the 500-year floodplain, considerably more stormwater assets are at-risk to that event. There are over 200 stormdrain outfalls located in the 500-year floodplain that could potentially be impacted.

The sensitivity and adaptive capacity considerations for riverine flooding are similar to the temporary flooding considerations described above. An increase in intense precipitation events could case increase flooding due to impacts on the stormwater system, particularly if an intense rainfall event is coupled with SLR or a high tide event, such as a King Tide. It is recommended that additional studies are carried out that model the impacts of combined SLR, storm surge, and heavy storm events on the stormwater system and flooding impacts. As an example, the Port of Long Beach studied the combined impacts of SLR, storm surge, and precipitation based flooding from the Dominguez Channel. The modeling found that under extreme conditions, more intensive riverine storm storms coupled with SLR could cause the Dominguez Channel to overtop its banks, resulting in extensive flooding to Port infrastructure.

9.3 Extreme Heat

No direct impacts.

9.4 Drought

No direct impacts.

9.5 Vulnerability Summary for Stormwater Assets

- With 11 inches of SLR, 18 storm drain outfalls, 1 stormwater pump station, and 1 mile of storm drain carriers are projected to be exposed to annual king tides.
- Stormwater assets generally have high sensitivity and low adaptive capacity to permanent inundation. They have moderate sensitivity and moderate adaptive capacity to temporary flooding (king tide or 100-year storm surge).
- Additional modeling needed to understand the potential flooding impact from combined SLR, storm surge, and riverine flooding events.

Section 10. **Vulnerability of Wastewater Assets**

The wastewater assets assessed include wastewater treatment plants, sewer pump stations, sewer forced main, and sewer gravity mains.

Asset Sector Overview

The wastewater system conveys wastewater from homes and businesses to a wastewater treatment plant for treatment then discharge. The majority of wastewater in Long Beach is treated at the Joint Water Pollution Control Plant, which is located in Carson. Because this plant is not located in Long Beach, its vulnerability could not be assessed as part of this study. SLR impacts to this plant would cascade to the entire wastewater system, so further study of the vulnerability of this plant is recommended. The remaining portion of the City's wastewater is delivered to the Long Beach Reclamation Plant of the Los Angeles County Sanitation Districts, which is located in Long Beach (7400 Willow Street). Where needed, pump stations move wastewater to higher elevations so that they can be transported by gravity flow (in sewer mains) to the wastewater treatment plant. Force mains convey wastewater under pressure to higher elevations from the downstream pump stations.

10.1 Sea Level Rise and Coastal Flooding

Exposure

With 11 inches of SLR, no sewer pump stations are projected to be exposed to annual king tides by 2030. However, with 11 inches of SLR, four pump stations are projected to be exposed to 100-year storm surge flooding. Three of these pump stations are owned by Long Beach Water Department and are located in the southeastern subarea (Marine Stadium, Belmont Shore, and Naples Island), and one is owned by the Parks, Recreation and Marine Department and is located at Shoreline Marina. With 66 inches of SLR, up to 15 pump stations are projected to be exposed to annual king tides.

With 11 inches of SLR, approximately 220 feet of force main and 280 feet of sewer mains are anticipated to be exposed to annual king tide flooding. These are located primarily around Naples Island and Marina Pacifica. By late century with 66 inches of SLR, up to 52 miles of sewer mains and five miles of force mains could be exposed to annual king tides.

The Long Beach Reclamation Plant is not exposed to the evaluated levels of SLR and storm surge.

Table 25: Wastewater Assets Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		2050 (24'' SLR)		2100 (37" SLR)		2100 (66" SLR)	
	Annual King Tide	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide	Added Exposure Due to Storm Surge
Pump Stations (number)	0	4	2	8	9	6	14	3
Force Mains (miles)	<1	2	2	2	4	0	4	2
Gravity Mains (miles)	<1	24	18	21	40	12	52	20

*****Note: The exposed assets for the King Tide + 24" SLR scenario are similar to the daily high tide (MHHW) + 37" SLR scenario. The exposed assets for the King Tide + 37" SLR scenario are similar to the daily high tide (MHHW) + 66" SLR scenario.

Sensitivity and Adaptive Capacity

Wastewater assets have moderate sensitivity to temporary flooding. The mains are closed systems, so they have low sensitivity to temporary flooding. However, pump stations have high sensitivity to temporary flooding because they are often underground and/or located at low elevations and include electrical and mechanical components that can be damaged with exposure to saltwater. Flood damage to the pump stations could result in sewage backflows into homes or businesses, or wastewater overflow onto surface streets.

Wastewater assets have high sensitivity to permanent inundation. Permanent inundation could result in infiltration into the sewer system that could reduce capacity and impact operations. In addition, saturation of the ground due to higher sea levels could result in displacement and potential damage to pipes. Temporary flooding of pump stations may render them inoperable due to damage to mechanical and electrical components and loss of access.

Wastewater assets have moderate adaptive capacity to temporary flooding. Electrical equipment could be elevated and a redundant generator could be provided if located at a higher elevation or a separate storage area. In addition, temporary flood proofing measures, such as sandbags, could be employed.

Wastewater assets have low adaptive capacity to permanent inundation as both the equipment and adjacent ground would need to be elevated to maintain both operations and access.

Note: Wastewater treatment plants have high sensitivity to SLR, but Long Beach's treatment plant is not located within the areas anticipated to be exposed by the of sea level rise and storm surge studied, and the Joint Water Pollution Control Plant is located outside of Long Beach, and further study is recommended.

Table 26: Sensitivity and Adaptive Capacity of Wastewater Assets*

	Sea Level Rise (Permanent Inundation)*	← Rationale	Sea Level Rise (Temporary Flooding)*	← Rationale
Sensitivity	High	Cannot operate if regularly inundated. Electrical components particularly sensitive. Access would be impaired.	Moderate	Storm damage could temporarily impair functionality, particularly electrical components. Access impaired temporarily.
Adaptive Capacity	Low	Elevating the surrounding ground to allow for access could be expensive and challenging.	Moderate	Elevating electrical components and providing redundant power source could allow for continued operation during temporary flooding. Flood proofing measures could be used.

*Note: Permanent inundation refers to inundation by the daily high tide (MHHW) and temporary flooding refers to flooding by the annual king tide or 100-year storm surge.

Excludes treatment plants as the Long Beach Reclamation Plant is not located within the areas anticipated to be exposed by the levels of SLR and storm surge studied and the Joint Water Pollution Control Plant is located outside of Long Beach and therefore out of the scope of this study.

10.2 Riverine Flooding

The wastewater assets exposed to the FEMA 100-year storm is very similar to the 11 inches SLR + 100-year storm surge scenario described above. Given the large extent of the 500-year floodplain, considerably more wastewater assets are at-risk to that scenario. Over 20 wastewater pump stations and the Long Beach Reclamation Plant are located in the 500-year floodplain.

The sensitivity and adaptive capacity considerations for riverine flooding are similar to the temporary flooding considerations described above.

10.3 Extreme Heat

Extreme heat events may cause minor increase in odor impacts. In addition, if electrical outages result from area-wide brownouts, sewer pumps will be disrupted, unless they are connected to backup generators.

10.4 Drought

Not direct impact, but reduced water usage decreases flows into the wastewater system, increasing sewer cleaning needs and system corrosion.

10.5 Vulnerability Summary for Wastewater

- With 11 inches of SLR, approximately 220 feet of force main and 280 feet of sewer mains are anticipated to be exposed to annual king tide flooding. These are located primarily around Naples Island and Marina Pacifica.
- Wastewater assets generally have high sensitivity and low adaptive capacity to permanent inundation (annual king tide). They have moderate sensitivity and moderate adaptive capacity to temporary flooding (king tide and 100-year storm surge).
- The Joint Water Pollution Control Plant is located outside of Long Beach city limits, and further study of climate change vulnerabilities is recommended.

Section 11. **Vulnerability of Potable Water Assets**

The potable water assets assessed include potable facilities, mains, and hydrants.

Asset Sector Overview

The Long Beach Water Department oversees the infrastructure that provides potable water to Long Beach homes and businesses through a system that includes a treatment plant, reservoirs, tanks, and interconnections (facilities), and main lines (mains). Potable mains are in most cases underground. Hydrants supply water for firefighting purposes.

11.1 Sea Level Rise and Coastal Flooding

Exposure

With 11 inches of SLR, one potable facility (an interconnection) is projected to be exposed to annual king tides. It is located in the Harbor District and is an interconnection with the Los Angeles Department of Water and Power (LADWP) (see Figure 8). With 66 inches of SLR, four potable facilities could be exposed to annual king tides. These facilities are also interconnections with the City of Seal Beach Water District, LADWP, and the Harbor Department. The Groundwater Treatment Plant is not exposed to the studied levels of SLR and storm surge.

With 11 inches of SLR, 1 mile of potable mains are anticipated to be exposed to annual king tides and an additional 25 miles are projected to be exposed to 100-year storm surge flooding.

With 11 inches of SLR, four hydrants are anticipated to be exposed to annual king tides and an additional 213 are projected to be exposed to 100-year storm surge flooding. By late-century with 66 inches of SLR, nearly 500 hydrants may be exposed to annual king tides.

Table 27: Potable Assets Exposed to Sea Level Rise and 100-year Storm Surge

	2030		2050		2100		2100	
	(11" SLR)		(24" SLR)		(37" SLR)		(66" SLR)	
	Annual King Tide	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide	Added Exposure Due to Storm Surge
Potable Facilities (Number)	1	0	1	1	3	1	4	0
Potable Mains (Miles)	1	25	21	21	42	14	56	24
Hydrants (Number)	4	213	160	204	359	135	493	19

*****Note: The exposed assets for the King Tide + 24" SLR scenario are similar to the daily high tide (MHHW) + 37" SLR scenario. The exposed assets for the King Tide + 37" SLR scenario are similar to the daily high tide (MHHW) + 66" SLR scenario.

Sensitivity and Adaptive Capacity

Potable water assets have moderate sensitivity to temporary flooding. The potable water system is a closed and pressurized system, so damage to mains is unlikely. However, facilities, such as interconnections, may include electrical and mechanical equipment that can be damaged with exposure to saltwater.

Potable water assets have high sensitivity to permanent inundation. Prolonged exposure to saltwater could result in corrosion of the pipes. Given the pressurized system, buoyancy of the pipes and intrusion of salt water through cracks or joint connections are less of an issue. However, if there is a break in the system, then contaminated water could be pulled in. In addition, inundation could result in impaired access for maintenance and repairs.

Potable water assets are not likely to be damaged with temporary flooding, but the difficulty of accessing the assets for maintenance and repair may reduce their functionality and could result in safety issues. If the depth of inundation is high enough, access to hydrants may be impaired, which would hinder firefighting efforts.

Potable water assets have moderate adaptive capacity to temporary flooding (king tide and storm surge) as flood proofing sensitive assets is possible. Potable water assets have low sensitivity to permanent inundation, as elevating the surrounding ground or relocating water assets is costly and challenging.

Table 28: Sensitivity and Adaptive Capacity of Potable Water Assets

	Sea Level Rise (Permanent Inundation) *	← Rationale	Sea Level Rise (Temporary Flooding)*	← Rationale
Sensitivity	High	Access impaired if permanently inundated; potential water safety issues.	Moderate	Damage to mains unlikely, but damage to electrical and mechanical components of pump stations possible.
Adaptive Capacity	Low	Elevating or relocating potable water assets is costly and challenging.	Moderate	Flood proofing water supply infrastructure is somewhat challenging for storm surge events.

*Note: Permanent inundation refers to inundation by the daily high tide (MHHW) and temporary flooding refers to flooding by the annual king tide or 100-year storm surge.

11.2 Riverine Flooding

The potable assets exposed to the FEMA 100-year storm is very similar to the 11 inches SLR + 100-year storm surge scenario described above. Given the large extent of the 500-year floodplain, considerably more potable water assets are at-risk in that scenario. Over 20 potable water facilities are located in the 500-year floodplain.

The sensitivity and adaptive capacity considerations for riverine flooding are similar the temporary flooding considerations described above.

11.3 Extreme Heat

No direct impacts, but extreme heat may result in higher water use for irrigation. If electrical outages result from area-wide brownouts, pumps will be disrupted, unless they are connected to backup generators.

11.4 Drought

The provision of water services could be compromised due to reduced water supply. Conservation measures and the development of alternative water sources, such as recycled water for non-potable uses, can reduce the impact.

11.5 Vulnerability Summary for Potable Water Assets

- One potable facility (an interconnection), 1 mile of mains, and 4 hydrants are projected to be exposed to annual king tides with 11 inches of SLR.
- Over 20 potable facilities are located in the 500-year floodplain
- Potable water assets have high sensitivity and moderate adaptive capacity to both permanent inundation and temporary flooding.
- Drought may impact the provision of water services due to constrained water supply.

Section 12. **Public Health**

The Public Health asset sector focuses on vulnerable populations.

Overview

More coastal flooding, increased extreme heat events, and worsened air quality may negatively affect human health. While all people are vulnerable to the impacts of climate change, the degree of vulnerability is a function of demographic, socio-economic, health, and place-based conditions that influence an individual or community's sensitivity to environmental change. Factors, such as age, race, income, and existing health conditions affect the ability of an individual to prepare, respond, and recover from an extreme weather event or climate stressor. Low-income communities and communities of color are particularly susceptible to natural disasters. Long Beach is very diverse, which is a source of strength, vibrancy, and resiliency. However, it has also has racial and economic disparities that are manifested spatially across the City. The following are some key considerations with regards to vulnerable populations in Long Beach.

Communities of Color

A high proportion of Long Beach residents identify as non-white or Hispanic/Latino. As of the 2010 census, the population is 41 percent Hispanic / Latino, 13 percent Black or African American, 13 percent Asian, and 1 percent Native Hawaiian or Pacific Islander (CLB 2013). These communities may experience health disadvantages. For example, the Black or African American community in Long Beach has the highest rates of hospitalization for heart disease, diabetes, and asthma compared to other races/ethnicities (CLB 2013).

Although all the four major racial and ethnic groups are represented in each zip code, certain populations are concentrated in certain parts of the City. Hispanics or Latinos represent nearly 50 percent or greater of the total population in North, West Central and Southwest Long Beach. The greatest concentration of Black or African Americans are in the North, West Central and Southwest neighborhoods. The greatest concentration of Asians are in the West Central and Southwest neighborhoods (CLB 2013).

Age

Elderly populations can be more vulnerable to extreme weather and climate stressors. They may be less able to evacuate as a higher proportion do not drive and may rely on public transportation. They may also have pre-existing health conditions that can be exacerbated by climate stressors. In Long Beach, almost 40 percent of people over the age of 65 report a disability compared to 10 percent of the overall Long Beach population. Approximately 9.3 percent of the Long Beach population is over the age of 65, which is slightly lower than the County of Los Angeles and State of California. Southeast, West Central, and East Long Beach have a higher percentage of older adults compared to other parts of the City (CLB 2013).

Language

The inability to speak English well can affect an individual's ability to communicate with service providers and make use of preparedness, response, and recovery resources. In Long Beach, 34 percent of households speak Spanish at home and 10 percent speak Asian or Pacific Islander Languages at home. In Long Beach, English proficiency varies by age with people over the age of 65 most likely to report speaking English "not well" or "not at all" (38 percent) (CLB 2013).

Income

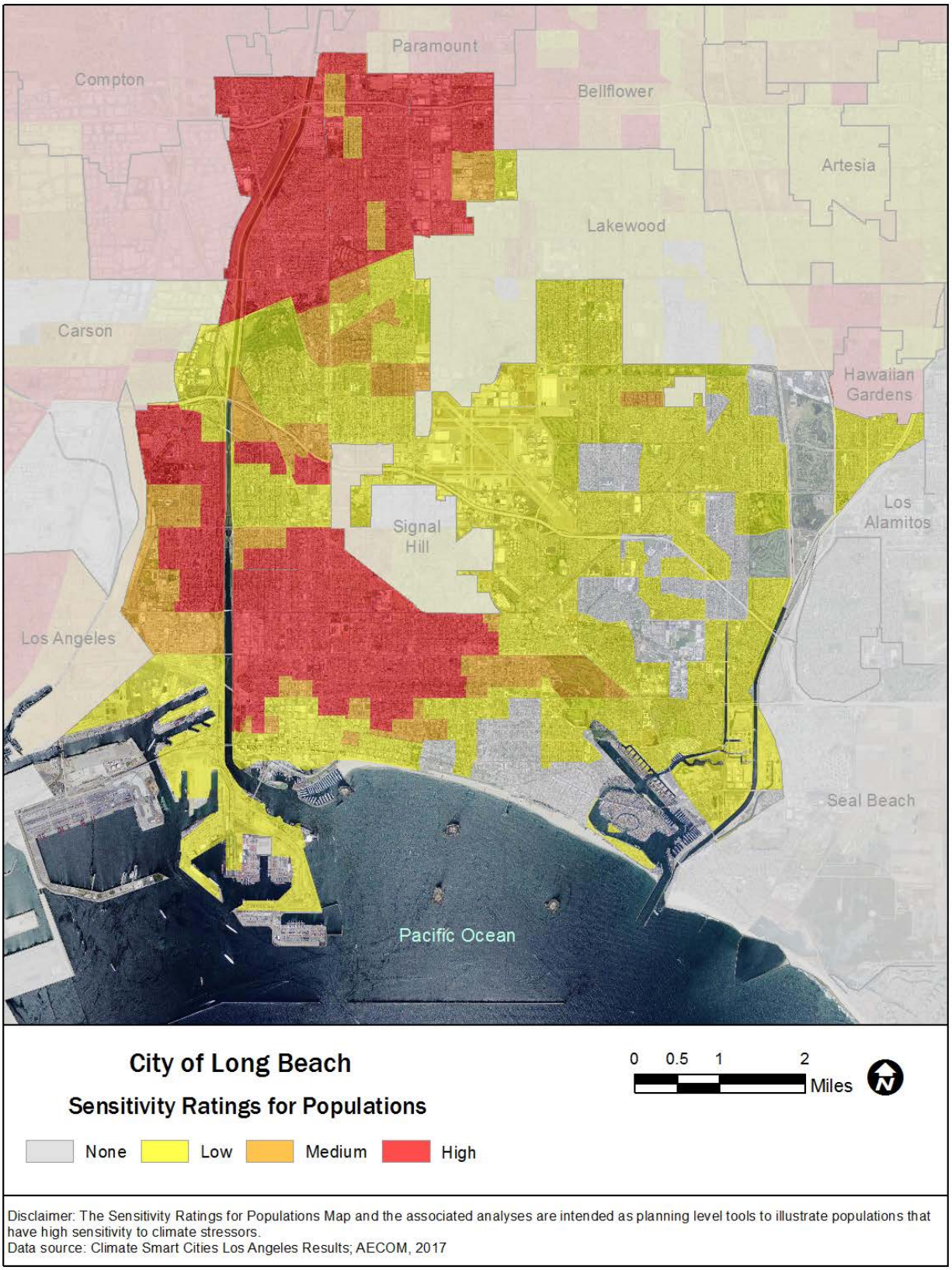
Low income communities face disproportionately higher rates of poor health outcomes and greater obstacles to achieving good health (LADCP 2015). Income varies across race and ethnic groups. Black or African American and Hispanic or Latino households had the lowest median incomes, about $10,000 less than the overall median income in Long Beach. Median income also varies by neighborhood, with higher incomes in the East and Southeast and lower incomes in the North, West Central, and Southwest. In addition, approximately 15.4 percent of all families in Long Beach live below the poverty line, which is 50 percent higher than the statewide poverty rate.

Social Vulnerability

The Climate-Smart Cities Los Angeles Project, with a Technical Advisory Team that included public health experts, local academic and research institutions, and community leaders developed a GIS decision support tool that includes social vulnerability index comprised of ten indicators. This index is based primarily on the Environmental Protection Agency's EJSCREEN[7] definition of demographic factors that indicate a community's potential susceptibility to environmental stressors, which include: people of color, low income, educational attainment less than a high school degree, linguistic isolation, population under 5, and population over 64. The index includes three additional characteristics, which were added based on recommendations from the Technical Advisory Team: unemployment, asthma, and low birth weight. Figure 17 shows the result of this index for Long Beach, demonstrating higher levels of indicators of social vulnerability in Central, West, and North Long Beach.

[7] EJSCREEN refers to Environmental Justice Screening and Mapping Tool. https://www.epa.gov/ejscreen

Figure 17: Indicators of Social Vulnerability



Disclaimer: The Sensitivity Ratings for Populations Map and the associated analyses are intended as planning level tools to illustrate populations that have high sensitivity to climate stressors.
Data source: Climate Smart Cities Los Angeles Results; AECOM, 2017

12.1 Sea Level Rise, Coastal Flooding, and Riverine Flooding

Storm surges and coastal flooding, often closely tied to extreme precipitation events and riverine flooding, have the potential to cause injury, loss of life, displacement and increased mental health burden (CDPH 2012). According to an analysis by the Aquarium of the Pacific, with 24 inches of SLR and a 100-year storm surge, over 22,000 residents are at risk of exposure to flooding (AOP 2015). In addition, the Southeastern portion of Long Beach, which is susceptible to coastal and riverine flooding, has a higher share of residents over the age of 65 than other parts of the City. Elderly people may be less able to evacuate and at higher risk of exacerbation of exiting health conditions as a result of a flooding. Sewage overflows could also result in water-borne illnesses following a flood event (CDPH 2012).

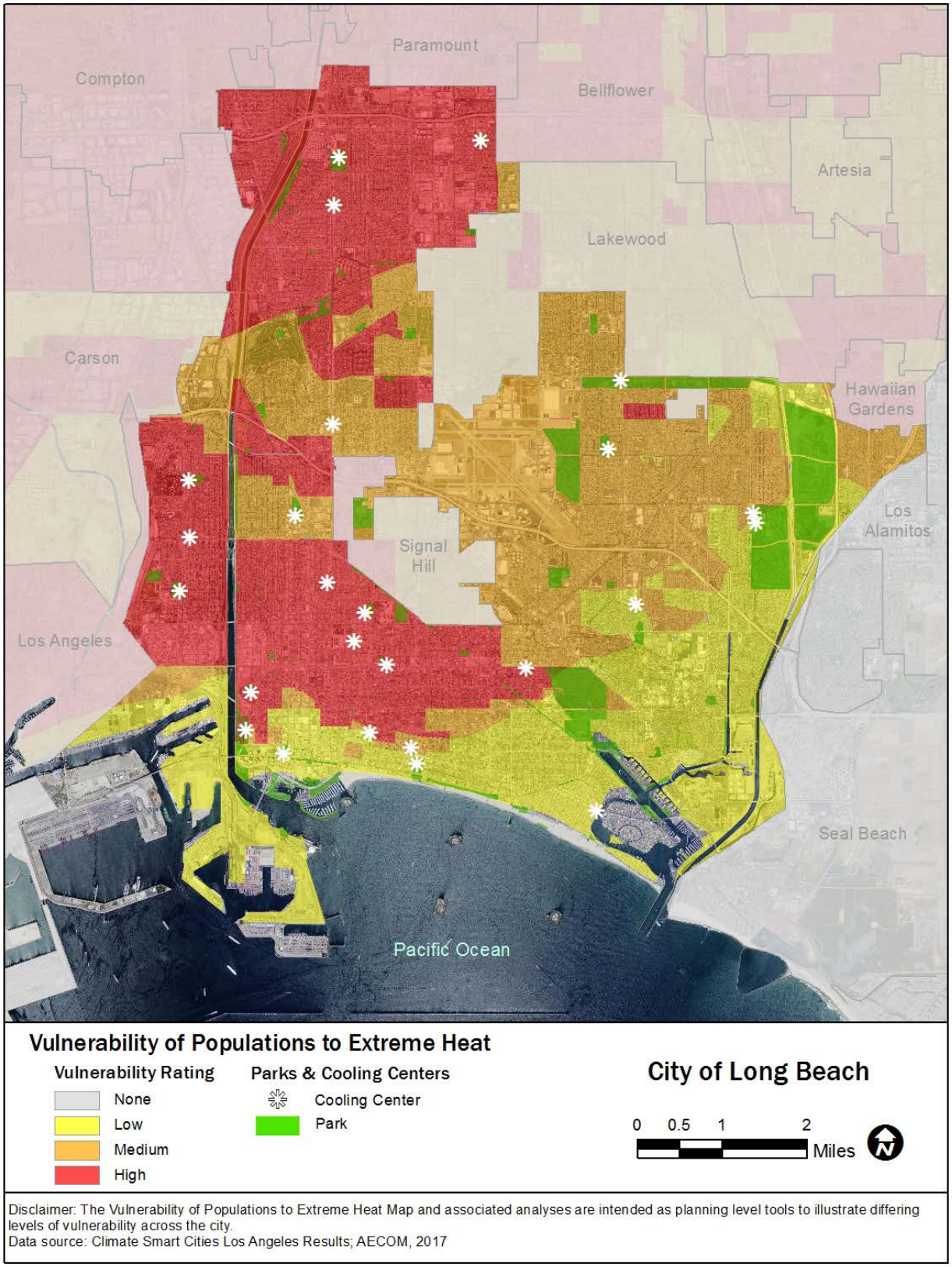
12.2 Extreme Heat

Extreme heat events can increase heat-related mortality, cardiovascular-related mortality, respiratory morality, and increase hospital admission and emergency department visits. A number of factors contribute the vulnerability of an individual to extreme heat. Particularly vulnerable populations include children, the elderly, people with respiratory disease, and those who work outdoors (CDPH 2012; CNRA 2014). Environmental factors also influence vulnerability including neighborhoods with high levels of impervious surfaces and limited green space, and housing units that lack air conditioning or household access to a vehicle. The amount of green space per 1,000 residents varies considerably across Long Beach with Central, West, and North Long Beach having a lowest amount (CLB DHHS 2013). Data from the Climate Smart Cities Los Angeles tool on modeling of the urban heat island effect[8] indicates that North and West Long Beach are more susceptible to high surface temperatures (Figure 18).

Analysis of census population data (from 2010) and the Climate Smart Cities Los Angeles heat vulnerability zone, indicate that approximately 275,000 residents of Long Beach live within the high vulnerability areas shown in Figure 18.

[8] Based on land surface temperatures, weighted 75% daytime, 25% nighttime temperatures.

Figure 18: Urban Heat Island Effect in Long Beach

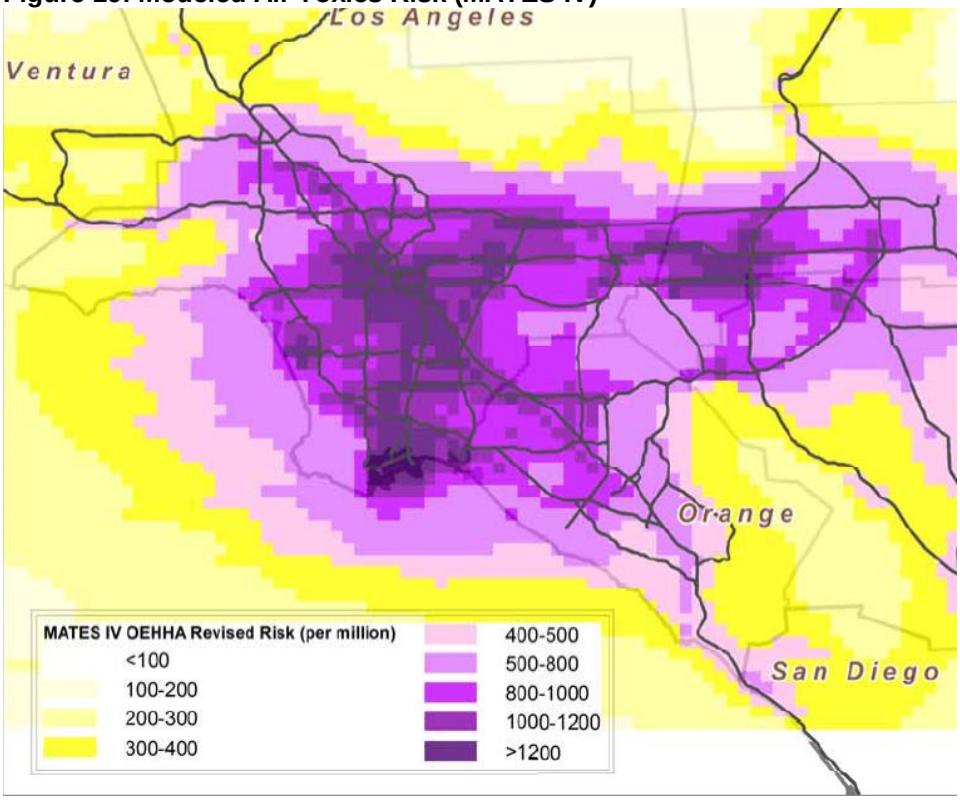


12.3 Air Quality

Air quality is especially relevant as a secondary climate stressor in Long Beach, as there are several sources that impact local air quality, including the 710 and 405 freeways, refineries, the Port of Long Beach, and major industrial sources (AOP 2015) and thousands of people whose health may be impacted by poor air quality. Furthermore, wildfires in Southern California coupled with strong Santa Ana winds can further exacerbate poor air quality in Long Beach, given its coastal location. People who are especially sensitive to poor air quality include the young, elderly, those who have existing respiratory conditions, and those who work outside. Asthma and other cardiovascular and respiratory diseases may increase due to poor air quality (CNRA 2014; CDPH 2012). Asthma hospitalizations rates are highest in West and North Long Beach (CLB DHHS 2013).

Air toxics are pollutants that cause cancer or other serious health effects. Diesel particulate matter (PM) accounts for 68.2% of the carcinogenic risk from exposure to air toxics in the Southern California air basin (SCAQMD 2015). Diesel PM is emitted from diesel engines including trucks, buses, cars, ships, and locomotive engines and is concentrated near ports, rail yards, and freeways. Exposure to diesel PM has been shown to have numerous adverse health effects, including cardiovascular and pulmonary disease and lung cancer (EPA and 2016). As illustrated in Figure 19, the areas of the Los Angeles Basin that are exposed to the most risk to air toxics are those near the Ports of Los Angeles and Long Beach (SCAQMD 2015). According to the AOP (2015) study, 86 out of 116 census tracts in the City of Long Beach have diesel PM emissions in the top 10% of census tracts in California.

Figure 19: Modeled Air Toxics Risk (MATES IV)



Source: South Coast Air Quality Management District

12.4 Drought

Disrupted food and water supplies could result in hunger and malnutrition, particularly in low-income households, children, and the elderly (CDPH 2012).

12.5 Vulnerability Summary for Public Health

- Sea level rise, coastal flooding, and riverine flooding may result in injury, death, displacement, and mental health burden. The Southeastern neighborhoods, which are most susceptible to flooding, exhibit many demographic factors that make them less at risk to the health impacts of climate change (higher income, lower rates of respiratory disease, higher share of residents that identify as white), but also have a higher share of elderly residents, which are more vulnerable in extreme weather events.
- North, Central, and West Long Beach have the lowest amounts of greenspace and high urban heat island effect, which can further stress existing health conditions during extreme heat events.
- West and North Long Beach have poor air quality and high levels of hospitalizations for asthma.

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Contact

Claire Bonham-Carter
Principal
T + 1-415-955-2985
E Claire.bonham-carter@aecom.com

aecom.com