City of Long Beach

Climate Resiliency

Assessment Report

Prepared by

Aquarium of the Pacific

December 2015

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Executive Summary

When responding to climate change, there have been many approaches proposed, tested, and reviewed. The options are many. This report outlines the approaches best suited to Long Beach's geographical location, its multiple strengths, and most importantly, its diverse population.

It has been determined that drought, extreme heat, sea level rise and coastal flooding, deteriorating air quality, and public health and social vulnerability, are the primary threats that climate change presents to Long Beach. This report lays out these major threats in the context of California and Los Angeles County, to give perspective.

This report delves into the more rigorous subject of describing and defining the threats of climate change most relevant to Long Beach. By highlighting the issues that clearly impact the City, priorities can be reviewed to address adaptation sooner rather than later, while there is still an opportunity to be proactive on matters of urgency.

Each climate threat has its own potential detrimental effect on the City; taken together they magnify risks to citizens, the business community, and City functions (economy, mobility, emergency response, etc.). Threats range from virtually immediate (coastal flooding and public health impacts from El Niño this winter), to the progressively rising sea level and deteriorating air quality as the climate warms. Combining poor air quality with extreme heat spells causes disproportionately negative impacts on the already vulnerable (including children, elderly, asthmatic or otherwise ailing, outdoor runners, and those working in already hot conditions such as construction).

It was found that the City has begun adaptive behaviors responding to climate conditions such as drought and poor air quality. Historical evidence shows activity in response to coastal flooding and erosion, such as the building of a jetty and replenishing beach sand. There are preemptory plans in place for extreme heat days and public health outbreaks. The precedence for a more urgent, sustained approach to climate countermeasures is set.

Finally, this report describes and recommends a plan of action that city leaders and community stakeholders can use as a template for making Long Beach a model of a climate resilient city, responsive to varying levels of temporary, gradual, and permanent changes to the environment. Given the City's size, population demographics, infrastructure, geographical location, regional economic impact, and leadership, it has the opportunity to become a model of resiliency. As many people are aware, climate change is a global issue, one where only massive change on a global scale could mitigate a worldwide problem. Yet it must happen at a smaller scale, city by city, region by region, that when scaled up results in a similar outcome – a sustainable earth.

Part 1: Introduction

Overview

In his January 2015 State of the City address, Mayor Robert Garcia announced that he wanted to make Long Beach a model of a climate resilient city (CLB 2015a; Ruiz 2015). The Mayor went on to say that he had asked the Aquarium of the Pacific to take a lead in assessing the primary threats that climate change poses to Long Beach, to identify the most vulnerable neighborhoods and segments of the population, and to identify and provide a preliminary assessment of options to reduce those vulnerabilities. Over the course of this last year the Aquarium has hosted and participated in a number of meetings and workshops with academic and government scientists, business and government leaders, local stakeholders, and Long Beach residents to discuss key issues facing our community as the result of climate change. This report represents the culmination of these efforts. It begins with an introduction to what it means to be a "Climate Resilient City," followed by detailed assessments of the five main threats of climate change to our community, an overview of what is currently being done to mitigate and/or adapt to these threats, and other options to consider. It ends with a summary and review of our findings. It is our hope that this report will provide the City of Long Beach with some of the information and tools needed to move toward becoming a climate resilient city.

Characteristics of a Climate Resilient City

Climate Resilient Cities are generally considered to be those cities that are able to continue to function in the face of challenging circumstances due to climate change, and to recover quickly from disruptions.

The Four Dimensions of Community Resilience:

1. Leadership and Strategy

The processes that promote effective leadership, inclusive decision-making, empowered stakeholders, and integrated planning.

2. Infrastructure and Environment

The man-made and natural systems that provide critical services, protect, and connect urban assets enabling the flow of goods, services, and knowledge.

3. Economy and Society

The social and financial systems that enable urban populations to live peacefully, and act collectively.

4. Health and Well-Being

Everyone living and working in the city has access to what they need to survive and thrive.

The threats of climate change vary widely from one region to the next and it is important to identify the greatest threats to Long Beach. We first outline keys to making Long Beach a model of a climate resilient city.

Three Keys to Creating Resilient Coastal Cities

1. A Broadly Shared Vision

Resiliency starts by developing a compelling broadly-shared vision of a resilient community through inclusive and sustained community conversations to identify valued qualities they want to sustain, and an explicit statement of the underlying assumptions. These forums should be conducted throughout Long Beach's neighborhoods.

2. Accurate and Timely Data and Information at Local and Regional Scales

Many of the required climate data are already being collected (weather and air quality data, and data on sea level, for example), but they will need to be supplemented by other data and all will need to be transformed into information on a continuing basis to reveal important trends relevant to Long Beach. The most data deficient areas for Long Beach relevant to climate change are in Long Beach Harbor and areas directly bordering the Harbor. The data needed include observations on waves, storm surges, detailed bathymetry, and detailed topography of shorelines—all required for diagnostic modeling to forecast the impacts of storm surges. The socio-economic data are only intermittently gathered, mainly by decadal censuses. This makes identifying trends difficult without making broad assumptions. Fortunately, the next key, Powerful Diagnostic and Forecasting Tools, can assist in this regard.

3. Powerful Diagnostic and Forecasting Tools

Numerous diagnostic and forecasting tools are currently being developed for Los Angeles County to better understand the current and future risks facing the LA area as the result of climate change. Many of these tools are quite robust, based on the latest scientific research, and use models that have been specifically formulated for the LA region. This report reviews these models, along with other methods, to see which, if any, have sufficient resolution to be used effectively in Long Beach.

The Primary Threats of Climate Change to Long Beach

Based upon these analyses, interviews of experts, our own analysis of the literature, and previous experience, we conclude that the greatest threats of climate change to the Long Beach area are the following:

- **Drought** (and subsequent freshwater shortages)
- **Extreme Heat** (increases in average air temperature and number of very hot days)
- **Sea Level Rise and Coastal Flooding** (from coastal storms superimposed upon a rising sea)
- **Deteriorating Air Quality**
- **Public Health** and **Social Vulnerabilities**

While the consequences of drought (primarily in the form of freshwater shortages) will impact the entire City fairly uniformly, the negative impacts of the other four threat categories will vary as a function of geography. For example, the increase in the number of hot days will affect inland neighborhoods of the City more than coastal neighborhoods, because of the cooling effects of ocean breezes along the shoreline. Deteriorating air quality will have its greatest impacts on neighborhoods close to the Port of Long Beach and along the 710 Corridor, due to the pre-existing social vulnerabilities present in those areas. Sea level rise and coastal storms obviously will have their greatest impact on neighborhoods directly bordering the ocean and Alamitos Bay. The compound impacts of drought, heat, flooding, and poor air quality threats, along with socio-economic variables, will ultimately result in the diminished health of the community (**Figure 1**).

We address each of these threats in the sections that follow.

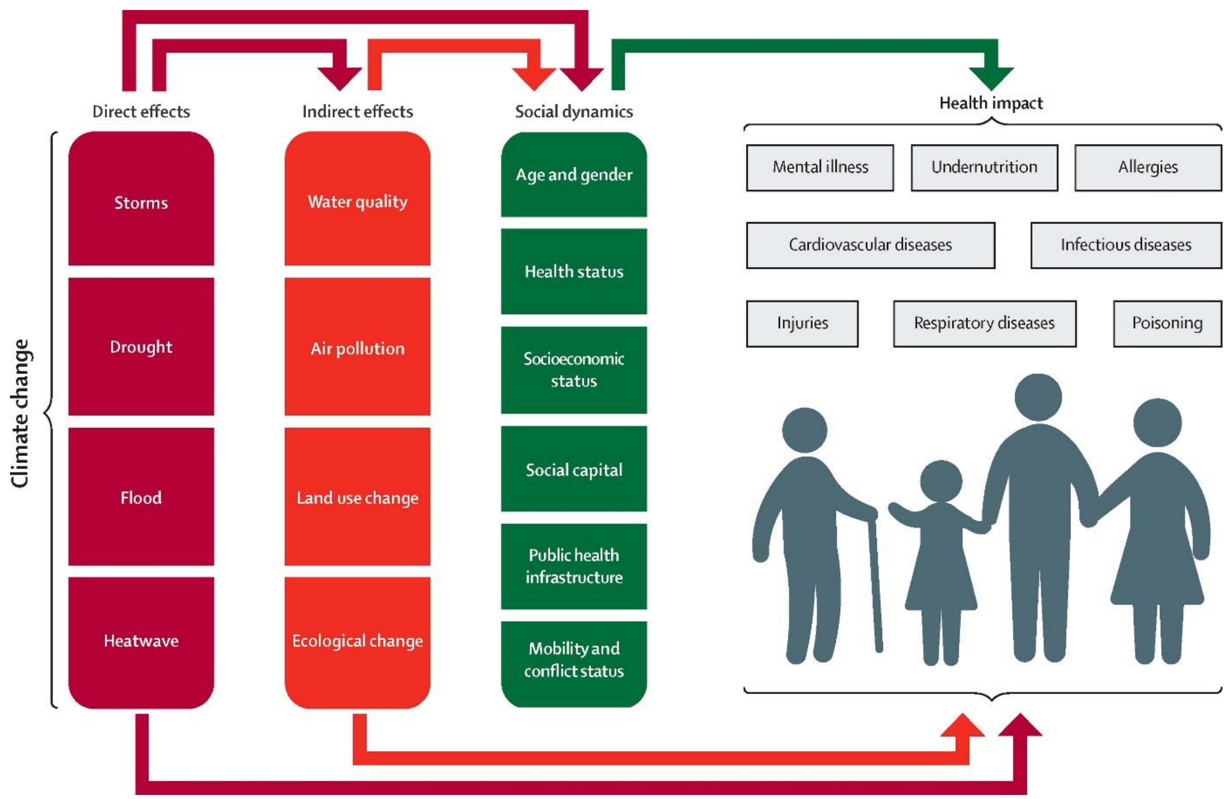


Figure 1. The Direct and Indirect Threats of Climate Change and their effects on human health and wellbeing. *Note: the above diagram is from Figure 2 in the Lancet's (2015) Health and Climate Change Report.*

Part 2: Assessment at the Local Level

This section provides brief discussions of the greatest climate threats impacting Long Beach accompanied by implications for risk management and ongoing planning.

Drought

A "drought" is a period of time in which a region experiences below average precipitation, resulting in a decrease in the supply of surface and ground water. A shortage in the water supply can be devastating: it affects natural vegetation and wildlife, biodiversity, agricultural yields, and water reserves. For the City of Long Beach, this will result in less available freshwater locally and in water piped in from outside sources. The following content was taken directly (with only slight modifications) from Pagan et al.'s (2015) drought report, which was commissioned as part of this project. Their drought report is included in its entirety as **Appendix A**. The authors of that report are included as coauthors of this report.

Regional Impacts

Climate models project an increase from today's average surface temperatures of the Western United States (U.S.) by 1- 3°*F* (0.5-1.7°*C*) by the year 2030, and rise 2- 4.5°*F* (1.2 -2.5°*C*) by the year 2050. The reliability of Southern California's imported supplies is highly dependent on the amount of precipitation in the watersheds of the Colorado River and the Sierra Nevada, specifically in the form of precipitation as rain or snow (Christensen & Lettenmaier 2007; Diffenbaugh et al. 2005; IPCC 2007a; Rauscher et al. 2008). Imported supplies becomes less reliable as more precipitation comes in the form of rainfall and as the snowpack melts earlier in the year (Dettinger & Hayhoe 2008). Warmer temperatures will exacerbate both of these factors: more precipitation will come in the form of rain, and what little snowpack is formed will melt earlier in the year (He et al. 2013; Rauscher et al. 2008). Projections of climate change suggest the western and southwestern U.S. are particularly vulnerable due to their heavy reliance of temperature sensitive snowpack (Christensen & Lettenmaier 2007; Diffenbaugh et al. 2005; IPCC 2007a; Rauscher et al. 2008). The various climate models predicted a range of possible changes in annual average precipitation and runoff by the year 2050 (Christensen & Letternmaier 2007; Costa-Cabral et al. 2013). However, there is broad consensus that the intensity and frequency of daily maximum runoff and precipitation events will increase (Cayan et al. 2008; Diffenbaugh et al. 2013; Gao et al. 2006; Hennessy et al. 1997; Pal 2004). For example, the current 100-year runoff event becomes approximately nine times more likely in the Colorado River watershed (i.e. nine "100-year events" per 100 years) and twice as likely in other basins that contribute to the Long Beach imported water supply. Total annual runoff also shifts to more extreme magnitudes. The increased frequency of abnormally low annual runoff increases the region's susceptibility to droughts. Regardless of positive or negative changes in annual runoff or precipitation, the region's imported water supply is projected to decrease by mid-century resulting from a lack of reservoir storage capacity to capture the increased proportion of rainfall derived runoff, more extreme winter runoff events and earlier snowmelt timing as projected by climate change.

Impacts on Long Beach

The City of Long Beach is located in a semi-arid region with limited natural freshwater supplies. Much like the rest of Southern California, Long Beach depends on imported water supplies to meet demand. Climate change will likely decrease the imported water supply availability, potentially leaving the city in shortage conditions (LBWD 2010). Therefore, it is necessary to study water supply in the regional context. Here we take a comprehensive multi-model approach to examine near term climate change impacts on all sources of freshwater supply to Southern California and focus on the specific impacts to Long Beach. At the request of the City of Long Beach Mayor Robert Garcia, the authors and contributors to this report have also evaluated how climate change will impact freshwater supply to the City of Long Beach by the years 2030 and 2050, and considered how Long Beach might become more climate resilient with respect to its freshwater supply (see **Appendix A**'s **Supplemental Information**, pages **A55-A56**).

In an average year, the Long Beach Water Department (LBWD) obtains 40% of its water supply from imported sources, 53% from groundwater (which is partially dependent upon imported sources for recharge), with recycled water making up just 7% of the City's water supply portfolio (communication with Matthew Lyons, from LBWD). To date, plans to expand the recycled water system have not been realized. Currently, purchasing imported water is more cost effective for Long Beach than expanding the recycled water system or constructing a desalination facility (USBR 2013); however, stress on imported water supplies from climate change could drive up prices and make expansions of local supplies more economically attractive (LBWD 2010). Long Beach has established itself as a leader in conservation; achieving a 31% reduction in *gallons per capita per day GPCD* from the 1980's to today (communication with LBWD's Matthew Lyons). In the absence of that conservation, the City's reliance on its least reliable supply of water (i.e. those from imported sources), would be roughly double what it is today (communication with Lyons).

While a portion of the additional precipitation coming off the San Gabriel Mountains can be captured and used to replenish the groundwater basin in lieu of imported supplies (LBWD 2010); without citywide storm water capture efforts, any additional precipitation projected with climate change will not significantly offset demand. Warmer summer temperatures will increase evaporation while also increasing vegetative need for water, thereby increasing outdoor irrigation demand. Drought tolerant conversion efforts will become more important in order to offset this trend, potentially reducing outdoor irrigation requirements by 10-24%. All else being equal, demand for water in Long Beach is not expected to increase significantly by the year 2050 (LBWD 2010), given the City's projected very low rate of population increase (SCAG 2015); however, this will likely change if the imported water supplies become more scarce and less reliable (as anticipated) by the year 2050.

Plans and Efforts Currently Underway

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

- Long Beach was one of the region's leaders on Low Impact Development (LID) and established one of the County's first ordinances. The LID's ability to help with water sustainability, capture, and reuse was considered to be a groundbreaking development (LBDS 2016a).
- In order to help meet the State and Federal stormwater compliance requirements, the City of Long Beach is in the process of developing a stormwater capture and reuse facility, which is currently being referred to as the "Long Beach Municipal Urban Stormwater Treatment (LB-MUST) Facility" (CLB 2014a).
- Certain projects are either underway or under investigation that could potentially eliminate the impact of climate change on the reliability of groundwater supplies (communication with LBWD's Matthew Lyons).
- The use of recycled water continues to increase, with an anticipated increase of 112% over 2010 levels by 2035 (LBWD 2010)
- Per capita water use in Long Beach is very close to 100 *GPCD*; the regional wholesale water supplier has committed to ensure its customers, including the City of Long Beach, 100 *GPCD* during water shortages, <u>contingent on enough water supply being available to meet these minimum demands</u> (LBWD 2010).
- By virtue of its having made annual contributions towards the capital investments in the wholesale water agency since the 1930's, Long Beach has acquired a "preferential right" to limited water supplies from the wholesale agency in excess of reasonable demands Long Beach may place on the agency during shortages (LBWD 2010).
- The State of California is mandating more water conservation through statewide regulation, such as mandating that new construction be extremely water-wise and requiring that only very water-conserving devices, such as toilets, can be sold in California. On May 11, 2015 CLB's Board of Water Commissioners adopted Resolution WD-1339 declaring a stage 2 water supply shortage. These types of State mandates tend to have very little impact when they first become law, but their impact grows over time and will have enormous impacts on water demand by the year 2050.

Additional Approaches to Consider

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

- Continuing the City's commitment to replacing landscapes that are not native to this region and require large amounts of landscape irrigation (i.e., grass used on lawns, street medians, parks, and other large landscapes that provide no functional use). These landscapes should be replaced with drought-tolerant gardens that thrive in the Long Beach semi-arid climate with little to no supplemental irrigation.

- The City should enforce the landscape ordinance they adopted in 2010 (Ordinance No. ORD-10-0031) that "requires new landscapes to include drought-tolerant plants, efficient irrigation systems, and other important measures" (LBWD 2010).
- Long Beach is not well situated to take advantage of the less frequent yet more powerful rain storms that are expected by 2050 because (1) the city is a built-out community filled with artificial surfaces (concrete, asphalt, etc.) and little to no open land in which to entrain large quantities of captured precipitation (Garrison et al. 2014); and (2) the City's underlying natural geology prevents water pooled on the surface from percolating down and potentially recharging the groundwater supply (LBWD 2010). Therefore, to the extent precipitation is captured, most of it will be caught and used on site at homes, street medians, commercial sites, parks and other areas. The City may consider studying the cost-effectiveness of different stormwater capture strategies (such as directing runoff to permeable spaces where it can penetrate the surface to recharge groundwater supplies; green infrastructure; large-scale cisterns, etc.; Garrison et al. 2014).

When landscapes are being converted to drought-friendly vegetation, it typically requires little to no additional cost to build into the new landscape features that also retain stormwater on site. The City should not only encourage turf replacement but also encourage these projects to capture stormwater on site to the extent feasible (and thereby minimizing urban runoff).

Summary

Climate change will result in warmer temperatures over the western U.S. and more extreme precipitation and runoff events impacting imported water supply availability to Long Beach in three main ways: (1) the frequency of extreme precipitation and runoff events will increase; (2) a higher fraction of precipitation will fall as rain (rather than snow), diminishing snowpack and filling storage reservoirs quickly; and (3) the remaining snowpack will melt earlier in the year.

As a result of limitations of current surface water storage systems, and to maintain flood control standards, reservoirs in the western U.S., especially those in Northern California, will not be capable of capturing more frequent, concentrated amounts of rainfall and earlier snowmelt (Cayan et al. 2008; Hayhoe et al. 2004). Consequently, water will have to be released during winter months when demand is low throughout the state (Cayan et al. 2008; Hayhoe et al. 2004). A signficaint amount of water will be lost to the ocean without additional facilities to store or convey surface water for purposes like groundwater recharge, thus leaving the area prone to shortages (Cayan et al. 2008; Hayhoe et al. 2004). Cumulative annual runoff also has an increased probability of being significantly less than historical amounts. The increased frequency of abnormally low annual runoff increases the region's susceptibility to droughts.

Fortunately, the Long Beach Water Department (LBWD) is much less reliant on imported sources compared to other Metropolitan Water District of Southern California (MWDSC) member agencies. However, Long Beach could still be negatively impacted if MWDSC cannot fulfill delivery requirements because of shortfalls in imported water supplies, is plausible under some climate change scenarios. Further reductions beyond LBWD's 100 *GPCD* goal will be difficult to achieve. Although population growth is expected to be very small, it still has the potential to exceed further *GPCD* reductions, resulting in a net increase in water usage. While average annual precipitation may increase for the Long Beach area, precipitation events are more likely to occur as less frequent but more intense events limited to winter months. Irrigation requirements are low in the winter and with lack of city scale stormwater capture, additional rainfall would not significantly offset demand over the rest of the year. Simply equipping residents with rain barrels would also have little effect on demand.

Warmer summer temperatures increase evapotranspiration and plant watering requirements. Large scale drought tolerant conversions could save Long Beach an additional 2,630 *acre feet* of water per year despite a warmer climate. Groundwater makes up over half of LBWD's water supply, but should not be considered a truly local supply resilient to climate change since a portion of the recharge water originiates from the same imported supplies. Plans for recycled water expansion have not been realized. Currently, purchasing imported water is more financially sound for LBWD than expansion of recycled water lines. Investing in recycled water treatment and expansion despite being more expensive than imported water would greatly increase Long Beach's self reliance. Although significant demand reductions have been achieved, there are still a number of ways for Long Beach to further reduce reliance on imported supplies which will be necessary in order to become a truly sustainable and climate resilient city.

Extreme Heat

"Extreme heat" is generally considered to be temperatures that are substantially hotter than average for a given time of year in a specific location. In conjunction with drought, extreme heat events can have a devastating impact on people and the environment. Considering current greenhouse gas concentrations and their increasing nature, temperatures in many heavily populated areas will rise significantly over the next century. As a result, extreme heat events will likely increase in frequency, intensity, and duration.

Regional Impacts

There is a strong consensus among climate scientists that the greater Los Angeles region, including Long Beach, will become warmer as we move deeper into this century, and that hot spells will increase in frequency, intensity, and duration (Sun et al. 2015). The extent to which the effects of climate change can be reduced will be a function of the rate and magnitude of global reductions of greenhouse gas emissions, but regardless of these efforts, only relatively small reductions are expected by mid-century (Sun et al. 2015).

All forecasts are based upon computer models and different greenhouse gas reduction scenarios. Existing global climate models were not designed to forecast changes at the regional scale, and computational costs to add this capacity would be prohibitive. However, Walton et al. (2015) developed a hybrid dynamic-statistical approach that allows downscaling of global climate models to regional scales of 1.2*mi* (≈ 2*km*), and Sun et al. (2015) applied the strategy to the greater Los Angeles region.

Sun et al. (2015) investigated two greenhouse gas (GHG) emission scenarios. The scenarios correspond to the Representative Concentration Pathways (RCP) of projected radiative forcing, in which "forcing" is a measure of how much heat from the sun warms the Earth because of GHG emissions into the atmosphere over this century. RCPs were developed by the Intergovernmental Panel on Climate Change (IPCC) to ensure consistency and rigor in climate modeling. The first GHG scenario, RCP2.6, represents a "mitigation" scenario in which greenhouse gas emissions peak at 460 *parts per million by volume* (*ppmv*) around the year 2050 and decline thereafter to approximately 420*ppmv* by 2100. The other scenario, RCP8.5, represents a "business as usual" scenario in which GHG emissions continue to increase throughout the twenty-first century. The investigators focused on three time periods: baseline (1981-2000), midcentury (2041-2060), and end of century (2081-2100). They examined the changes in the annual-average temperature, in the daily temperatures, and in the extremes. Their analysis indicated that the two emission scenarios had only a relatively small influence on the warming at mid-century. The increase in temperature under the mitigation scenario (RCP2.6) was 70% of that under the business-as-usual scenario (RCP8.5). The benefits of the mitigation scenario were significant however, by the end of the century. Under the mitigation scenario, there was no further warming beyond the mid-century levels; the warming associated with the "business as usual" scenario almost doubles from mid-century to 2100. The authors characterized the regional climate at the end of the century without mitigation as an entirely new climate regime.

Although the benefit of global reductions in greenhouse emissions would be modest in the coming decades, it would be significant by the end of the century. Their analysis indicates that by mid-century, the Los Angeles region as a whole will be about 3°*F* warmer than today regardless of any global action to reduce greenhouse gas emissions. The most pronounced changes will be in late summer and early fall. Without mitigation, the average temperature across the Los Angeles region at the end of the century would be more than 7°*F* warmer than today, while with mitigation it would still be at the mid-century level of +3°*F*.

Sun et al. (2015) also analyzed for changes in the number of "hot days" under the two emission scenarios (hot days are defined as days in which the maximum temperature exceeds 95°*F*). For their baseline (1981-2000), they report the number of days exceeding 95°*F* in Long Beach at 4 days per year. By mid-century their calculations indicate that number would increase to 11 under the mitigation strategy (RCP2.6) and to 16 under the business-as-usual strategy (RCP8.5). By end of century, the number of hot days under the mitigation strategy would remain at 11, but the number would increase to 37 under the business-as-usual strategy. Comparison of Long Beach with some other cities within the region can be found in **Figure 2**. It's clear that that being close to the ocean has significant benefit in modulating temperature effects of climate change.

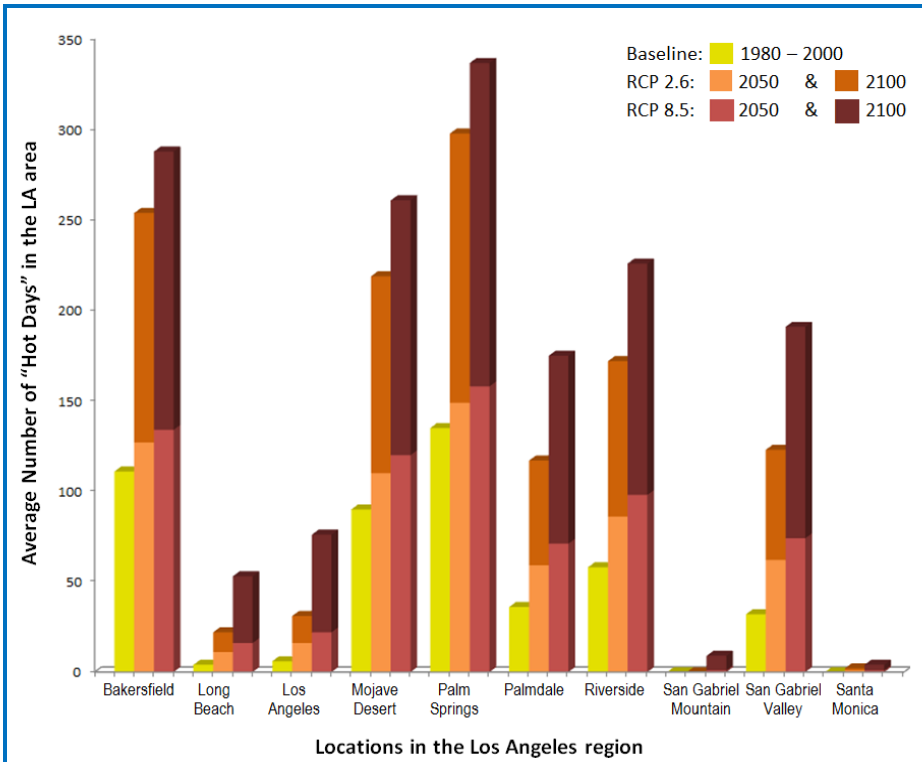


Figure 2. Average number of "Hot Days" for different locations within the Los Angeles area. Hot days are defined as days in which the maximum temperature is exceeds 95°*F* (>35°*C*). Results are shown for present day conditions, and predicted mid-century and end-of-century conditions. The current conditions (depicted in yellow) are based on baseline temperature data from1980-2000, while the predicted future conditions are based on the IPCC's mitigation (RCP2.6, depicted in shades of orange) and business-as-usual (RCP8.5, depicted in shades of red) emissions scenarios. *Note: this graph is based on data from Table 1 on page 4629 of Sun et al.'s (2015) study.*

Estimates are that by mid-century the greater Los Angeles region will be about 3°*F* warmer than today regardless of any global actions taken to reduce greenhouse gas emissions (Sun et al. 2015). The LA region will experience higher than normal temperatures, particularly in late summer and early fall. If there is a significant global effort to reduce greenhouse gas emissions, some warming by mid-century is inevitable, but end of century warming would be significantly less than in the absence of a serious global effort (Sun et al. 2015).

Impacts on Long Beach

While the impacts on Long Beach are near the low end in the region (because of the City's proximity to the ocean), if Long Beach is to be a model of a climate resilient city, it needs to take steps to make it less vulnerable to increases in temperatures, particularly in the increase in the number of very hot days. The uncertainty of global efforts to reduce greenhouse gas emissions gives this greater urgency, particularly for Long Beach's most vulnerable populations (which will be discussed in detail in the **Public Health** and **Social Vulnerability** section).

Plans and Efforts Currently Underway

In recognition of the threat heat poses to its residents, the City of Long Beach has provided a list of the buildings recognized by Long Beach as "cooling centers" on their website (**Table 1**). Cooling centers are generally considered to be places that give respite from the heat outside. This is not a comprehensive list by any means, but does provide the location and hours of community centers with air conditioning around the city. In addition to the community centers listed in Table 1, all Public Libraries in the Long Beach area serve as cooling centers. The City's Health Department also monitors the heat index, extending the hours of current cooling centers and making additional cooling centers available when needed (CLB 2014b). It will be important to make these widely known, particularly to Long Beach's most vulnerable populations, and in some cases to provide transportation.

The amount of open and green space impacts both heat and air quality. Planting trees has the direct effect of reducing atmospheric CO_2 because each tree directly sequesters carbon from the atmosphere through photosynthesis. However, planting trees in cities also has an indirect effect on CO_2. By reducing the demand of power plants, Akbari (2002) showed that the amount of CO_2 avoided via the indirect effect is considerably greater than the amount sequestered directly. Similarly, trees directly trap ozone precursors and indirectly reduce the emission of these precursors from power plants (by reducing combustion of fossil fuels and hence reducing NOx emissions from power plants; Taha et al. 1996). Data on measured energy savings from urban trees are scarce. In the summer of 1992, Akbari et al. (1997) monitored peak-power and cooling-energy savings from shade trees in two houses in Sacramento, California. The shading and microclimate effects of the trees at the two monitored houses yielded seasonal cooling energy savings of 30%. Taha et al. (1996) estimated the impact on ambient temperature resulting from a large-scale tree-planting. On average, trees can cool down cities by about 0.3°*C* to 1°*C* at 2 pm.

Even more planting should be accomplished in densely-populated areas (Akbari et al. 2001; di Milano 2009; Taha et al. 1996).

Table 1. Long Beach Cooling Center Locations. *Note: this table was adapted from the list provided online at: http://longbeach.gov/park/business-operations/about/cooling-center-locations/.*

Cooling Centers	Address	Non-Summer Hours	Summer Hours
El Dorado West Community Center	2800 Studebaker Road	Mon-Fri 9am-6pm	Mon-Fri 9am-6pm
Silverado Community Center	1545 West 31st Street	Mon-Fri 9am-7pm	Mon-Fri 9am-7pm
Houghton Community Center	6301 Myrtle Avenue	Mon-Fri 9am-7pm	Mon-Fri 9am-9pm
McBride (Cal Rec) Community Center	1550 Martin Luther King Avenue	Mon-Fri 9am-7pm	Mon-Fri 9am-7pm
Cesar Chavez Community Center	401 Golden Avenue	Mon-Fri 9am-8pm	Mon-Fri 9am-7pm
Ramona Community Center	3301 East 65th Street	Mon-Fri 3pm-6pm	Mon-Fri 10am-4pm
Veterans Park Community Center	101 East 28th Street	Mon-Fri 3pm-6pm	Mon-Fri 10am-4pm
Wardlow Community Center	3457 Stanbridge Avenue	Mon-Fri 3pm-6pm	Mon-Fri 12pm-6pm
Admiral Kidd Community Center	2125 Santa Fe Avenue	Mon-Fri 3pm-6pm	Mon-Fri 10am-9pm
Bixby Community Center	130 Cherry Avenue	Mon-Fri 3pm-6pm	Mon-Fri 10pm-9pm
Drake Community Center	951 Maine Avenue	Mon-Fri 3pm-6pm	Mon-Fri 12pm-9pm
Martin Luther King Community Center	1950 Lemon Avenue	Mon-Fri 3pm-6pm	Mon-Fri 12pm-9pm
Long Beach Senior Center	1150 East 4th Street	Mon-Fri 8am-4:30pm, Sat 10am-4pm	Mon-Fri 8am-4:30pm, Sat 10am-4pm

Additional Approaches to Consider

Given that the region will warm by mid-century despite reductions in greenhouse gas emissions and that the warming that actually occurs by the end of the century is a function of global efforts to reduce greenhouse gas emissions (not controllable by Long Beach), Long Beach and the greater LA Region should plan for an increase in average temperature and responses to an increase in the number of hot days if they are to be climate resilient.

Summary

Climate change and GHG emissions will have a profound impact on the Los Angeles region, including Long Beach. Sun et al. (2015) examined two emission scenarios: RCP2.6, the "mitigation" scenario; and RCP8.5, the "business as usual" scenario. The researchers focused on three time periods for their temperature rise comparisons: 1981-2000, 2041-2060, and 2081-2100. The study concluded that under the RCP2.6 "mitigation" scenario, GHG concentrations would peak by 2040 and would decrease over time, slowing down the corresponding increase in temperature. Under the RCP8.5 "business as usual" scenario, however, GHG concentrations would continue to rise well into 2100. In both scenarios, mid-century warming is unavoidable, but late-century warming due to GHG emissions can be reduced if the right steps are taken.

The number of hot days is another factor that was investigated by Sun et al. (2015). Under the "mitigation" scenario, the number of hot days in Long Beach rises from 4 days per year in 1981-2000 to 11 days per year in 2041-2060. Under the "business as usual" scenario, that number increases to 16 days per year in 2041-2060, and increases further to 37 days per year by the end of the century. While the ocean breeze provides a mild cooling effect for the city, it is no match for rising GHG concentrations and their effect on the temperature.

Cooling centers are currently the most effective method to provide the public with some relief on hot days. These facilities provide an air-conditioned environment where people can rest and stay out of the heat. In addition to the community centers and public libraries that are recognized by the city as cooling centers, there are many other public stores and businesses that can provide relief from the heat.

To become a climate-resilient city, Long Beach should continue planning for these extreme heat events and the hot days that come with it. Strategies such as the cooling centers are one effective solution to the problem, but the city cannot be solely reliant on them. Adding more trees and shade structures to public spaces would have the additional benefit of lessening urban heat island effects (discussed later on), while also serving as refuge from the heat (even during power outages when cooling centers may not have electricity). Ultimately, further planning and action must be taken to help the community stay safe against extreme heat events.

Sea Level Rise and Coastal Flooding

"Coastal flooding" is a temporary condition caused by storms or very high tides, while "inundation" is a permanent condition caused by relative sea level rise (the net result of changes in sea level and changes in land level). Both flooding and inundation are a function of the topography of areas directly bordering the coast. It follows that low-lying areas near the coast are at the highest risk. Over the next few decades, the primary concern is with flooding from coastal storms. Over the longer term, the rise of sea level from climate change will compound the effects of flooding and inundation since storms will be superimposed upon a progressively higher stand of sea level. The primary cause of coastal flooding events related to climate change is the combination of large scale increases in sea level, commonly referred to as "sea level rise" (SLR), and more localized coastal storms (see **Figure 3**). As pointed out, this threat increases over time as sea level continues to rise.

The primary two factors leading to global SLR are (1) the melting of glaciers and ice sheets, and (2) thermal expansion due to increased ocean temperatures (CA Coastal Commission 2015; Church et al. 2013; Ekstrom & Moser 2013; Flick 2013; NRC 2012a; Wei & Chatterjee 2013). Over time the relative contribution from the addition of melt water will increase relative to thermal expansion. As depicted in **Figure 3**, additional factors that can temporarily influence sea level on regional and local scales include: (3) groundwater extraction which can cause the land to sink (apparent sea level to rise); (4) other vertical land movements caused by tectonics and earthquakes; and (5) atmospheric circulation patterns combined with oceanographic phenomena such as El Nino Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO), as well as storm surges and high tides (CA Coastal Commission 2015; Church et al. 2013; IPCC 2007a;

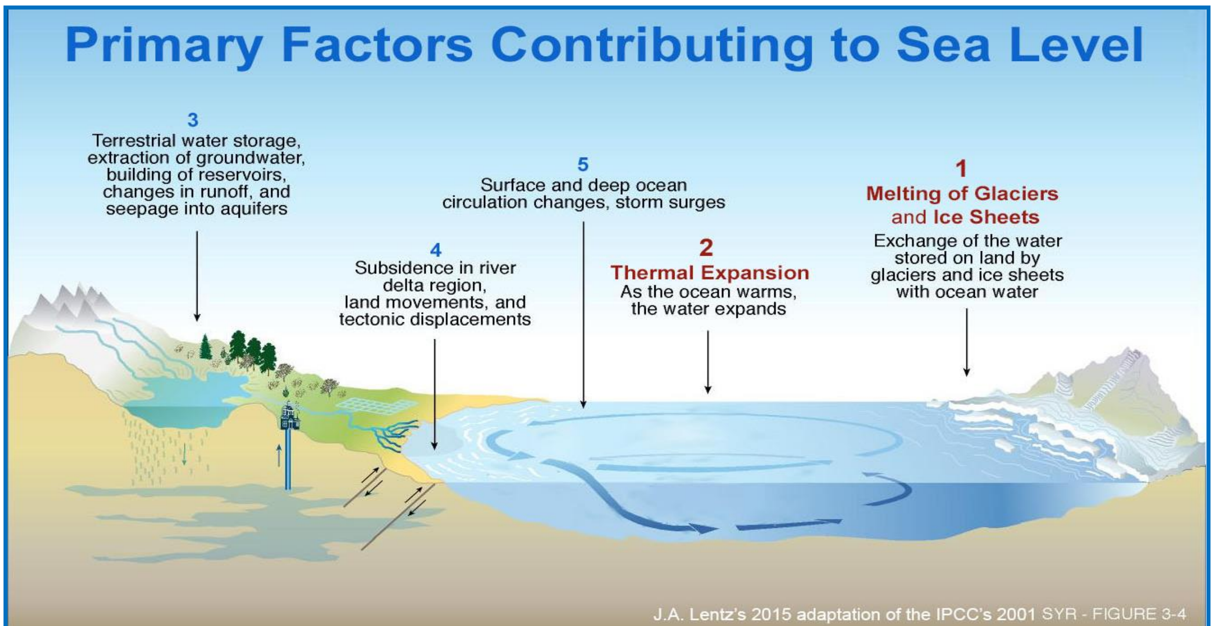


Figure 3. The primary factors contributing to changes in sea level. The driving factors of long term, global sea level rise are depicted in red, while other factors that can temporarily influence SLR at local and regional scales are depicted in blue. *Note: this image was adapted from the IPCC's (2001) Synthesis Figure 3-4.*

NRC 2012a; Russell & Griggs 2012; Wei & Chatterjee 2013). Just as the factors contributing to sea level vary according to location and scale (i.e. global vs local), so too does the amount of sea level change experienced. For example, the IPCC's Climate Change 2013 report found that "rates of regional sea level change as a result of climate variability can differ from the global average rate by more than 100% of the global average rate" (page 1140 of Church et al. 2013).

While global sea levels have risen and fallen over 400*ft* (122*m*) throughout Earth's geologic history, the last few thousand years had relatively stable sea levels (NRC 2012a). Starting sometime between the late 19th and early 20th century, global sea levels began to increase (NRC 2012a). Tide gage measurements from around the world indicate global sea levels rose about 0.66*ft* (20*cm*) between 1700 and 1975, with the majority of that increase occurring during the 20th century at the rate of global SLR around 0.0056 $\frac{ft}{yr}$ (0.17$\frac{cm}{yr}$; IPCC 2007a; NRC 2012a). The rate of global SLR began to rapidly increase in the 1990s, with satellite and tide gauge measurements from 1993 to 2003 showing global SLR rates were almost twice as high as they had been over the previous century (IPCC 2007a; NRC 2012a). The IPCC's most recent report estimated the current rate of global SLR was around 0.012$\frac{ft}{yr}$ (0.37$\frac{cm}{yr}$; Church et al. 2013) with projected sea levels estimated to have risen between 2.30-3.28*ft* (70-100*cm*) above 1700 sea levels (see **Figure 4**).

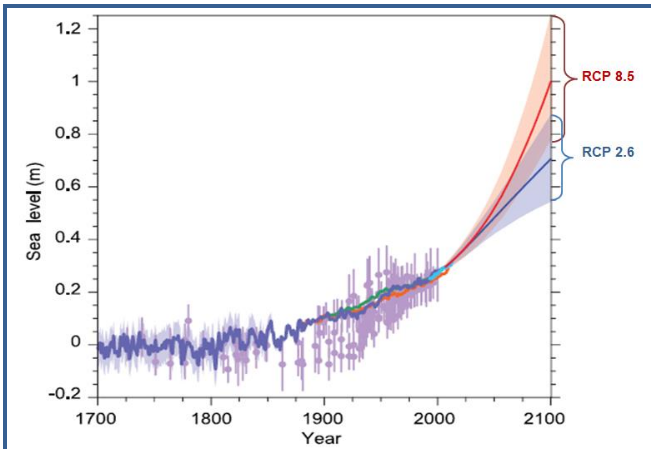


Figure 4. Global sea level estimates based on past sea level data (from paleo sea level data, tide gauge data, and altimeter data) and projected estimates of global mean sea level based on Representative Concentration Pathway (RCP) emission scenarios RCP2.6 and RCP8.5.

Note: this figure was adapted from the IPCC's 5th Assessment "Climate Change 2013" Report (Figure 13.27 on page 2104 of Church et al. 2013)

The physical impacts of SLR include: coastal flooding (temporary wetting); coastal inundation (permanent wetting); increased bluff erosion and collapse; increased tidal prism (volume of water between mean high tide and mean low tide); increased wave heights and force; increased saltwater intrusion into potable water sources; and changes in sediment movements (CA Coastal Commission 2015). In addition to SLR, seasonal and storm-induced dynamic coastal water levels, particularly in wave and storm-dominated settings such as the US West Coast, should be included when assessing coastal hazard vulnerability (Barnard et al. 2014). Especially given that most of the damage along the California coast is caused by storms, "particularly the confluence of large waves, storm surges, and high astronomical tides during a strong El Niño" (NRC 2012a).

The NRC's (2012a) report found that "along the west coast of the United States, climate patterns such as the El Niño-Southern Oscillation and, to a lesser extent, the Pacific Decadal Oscillation, affect winds and ocean circulation, raising local sea level during warm phases (e.g., El Niño) and lowering sea level during cool phases (e.g., La Niña)." Large El Niño events are capable of raising coastal sea levels by 10-30*cm* (0.33-0.95*ft*) for several winter months (NRC 2012a); these prolonged increased sea levels combined with severe storms can be quite devastating. For example, the 1982-83 El Niño resulted in 36 casualties, destruction of numerous piers, coastal infrastructure, and other damages to the State of California totaling over $1.2 billion dollars (Barnard et al. 2014; NWS 2015a). Cool climate phases have less influence on local sea level than warm climate phases. The measurements show no statistically significant trend in sea level since 1980 (Flick 2013), consistent with the Pacific Decadal Oscillation phase changes. When combined with high tides, short-term events such as El Niño storms that generate large storm waves will produce local water level increases along the coast that are far larger than the projected increases in global or regional sea level rise for at least the next 40-50 years (Barnard et al. 2015a). The effects of high tides, storm waves, and a rising sea level are additive; they combine to increase coastal flooding, inundation, and erosion, with potentially significant damage to human development.

In addition to SLR, climate change is also expected to increase the frequency, intensity, and overall severity of high tides and coastal storms, resulting in devastating coastal flooding events superimposed upon progressive inundation (CA Coastal Commission 2015; Russell & Griggs 2012; Wei & Chatterjee 2013). In order to better understand and prepare for these imminent coastal threats, city managers must assess the vulnerabilities of their communities, identifying what areas and assets are currently at risk, as well as those that will be at risk in the future. Powerfully diagnostic coastal flooding and erosion models play a critical role in this process.

Coastal Hazard Modeling

There are two main types of coastal flood models: ***Static***, also known as "bathtub" models, and ***hydrodynamic*** models.

Static models are widely used in coastal planning studies because of their simplicity and ease of construction (Spaulding & Isaji 2014). These models add a given estimate of SLR to the existing sea level and then assume that all areas below this newly calculated sea level will flood instantaneously and remain flooded, much like water filling a bathtub (Gallien et al. 2014; Spaulding & Isaji 2014;). An example of a static SLR model for the U.S. is NOAA Coastal Services Center's *Sea-Level Rise and Coastal Flooding Impacts Viewer*, which is publicly available through NOAA's Digital Coast Website (NOAA 2015). While cheap and fairly easy to implement, static models tend to significantly overestimate actual flooding, and "fail to account for the critical temporal dynamics, drainage and flood defense infrastructure" (Gallien et al. 2014). Ultimately, static modeling may be useful to illustrate potential topographic vulnerability, but could lead to less diagnostic management and adaptation decisions, as well as undermine flood risk management efforts by failing to identify how resources should be optimally allocated (Gallien et al. 2014).

Conversely, ***hydrodynamic*** models are much more complex and yield more reliable results (Gallien et al. 2014). By using physics-based models to solve the equations of mass and momentum to route overland flows, they can account for the time-dependence of actual flooding, flow around obstacles like buildings, and drainage that may be available (Gallien et al. 2014). Hydrodynamic models are powerful tools for assessing exposure and vulnerability under different scenarios, and for evaluating options to reduce vulnerability of different areas to occasional coastal flooding. The *Coastal Storm Modeling System (CoSMoS)* is an example of a hydrodynamic model for the California coast (Barnard et al. 2014). Although uninvestigated at the time of this report, we have learned that the City, through the assistance of Moffatt and Nichol, has developed a hydrodynamic model of Alamitos Bay (CLB 2015b).

CoSMoS 3.0

The *Costal Storm Modeling System* (*CoSMoS*) was developed by the U.S. Geological Survey (USGS) as a universally applicable model train for assessing the impact of sea level rise in combination with future storms influenced by climate change (Barnard et al. 2014). *CoSMoS* employs a predominantly deterministic numerical modeling approach to make detailed visual predictions (*meter* scale) of coastal flooding, erosion, and cliff failures over large geographic scales (100s of *kilometers*) caused by SLR and storms driven by climate change (Barnard et al. 2014; Sea Grant 2015). While static models such as NOAA's *SLR Viewer* are limited 1st order screening tools, based on elevation and tidal data, *CoSMoS* incorporates Global Climate Model (GCM) ensemble forcing with wind, waves, sediment transport, fluvial discharge, vertical land movement rates data, and a range of SLR and storm scenarios (Barnard et al. 2015b). The final data products of the model are intended to provide coastal managers with future critical storm hazard information that can be used to increase public safety, mitigate physical and ecological damages, and more effectively manage and allocate resources (Barnard et al. 2014).

The *CoSMoS 3.0* model has so far only been used to model different portions of the California coast, though it could be used to model regional inundations of sandy and cliff-backed coasts worldwide. The first and third versions of *CoSMoS* (*CoSMoS 1.0* and *3.0*) were developed to model coastal flooding within the California Bight (from Point Conception to the Mexican border); while *CoSMoS 2.0* was focused on the San Francisco region. The first round of *CoSMoS 3.0* results were release on November 15 of this year (some of which will be shown later on in this report), the complete suite of results is planned to be released sometime during the Summer of 2016 (more information on the *CoSMoS 3* model and its intended output is provided in **Appendix B**).

Regional Impacts

Sea level rise is not uniform around the world, the nation, or even along the coast of California (Church, et al. 2013; NRC 2012a). It is affected not only by the rise of global mean sea level, but also by local and regional movements of the land and by regional differences in oceanic and atmospheric circulation patterns (Church et al. 2013). Among the best estimates for SLR along the west coast of the U.S. in the future are those from a 2012 National Research Council (NRC) report, in which they made SLR estimates for the west coast of the U.S. relative to global mean sea level in 2000 (**Table 2**).

Table 2. Sea Level Rise (SLR) estimates for the California Coast, relative to global sea levels relative to 2000 sea level estimates. Negative values are projected sea level relative to vertical land motion expected to occur north of Cape Mendocino. *Note: the data provided in this table was derived from the NRC's (2012a) Report.*

Year	Los Angeles	California Coast (south of Cape Mendocino)	Northern West Coast (WA, OR, and CA coasts North of Cape Mendocino)	Global
2030	4.6-30.0*cm* (0.15-0.98*ft*)	4-30*cm* (0.13-0.98*ft*)	-4-23*cm* (-0.13-0.75*ft*)	8-23*cm* (0.26-0.75*ft*)
2050	12.7-60.8*cm* (0.42-1.99*ft*)	12-61*cm* (0.39-2.00*ft*)	-3-48*cm* (-0.10-1.57*ft*)	18-48*cm* (0.59-1.57*ft*)
2100	44.2-166.5*cm* (1.45-5.46*ft*)	42-167*cm* (1.38-5.48*ft*)	10-143*cm* (0.33-4.69*ft*)	50-140*cm* (1.64-4.59*ft*)

NRC's estimates for 2100 are considerably higher than the IPCC's (2007a-b) projections, because continental ice has been melting more rapidly in recent years than had been documented prior to the IPCC's 2007 report (Church et al. 2013; NRC 2012a). The major sources of uncertainty in all estimates of sea level rise are related to assumptions about the increase in the rate of ice loss and the growth of future Green House Gas (GHG) emissions (Church et al. 2013).

For the U.S. West Coast seasonal storms have been found to have a far greater impact on temporary sea levels than SLR (Barnard et al. 2014). For example, during El Niños mean coastal water levels can be 0.5*m* above normal for the same time of year, coastal storm surges can be 1.4*m* above average sea levels, wave setup can approach 2*m* during extreme events with wave run-up elevating coastal water levels several additional meters (Allan & Komar 2006; Allan et al. 2011; Barnard et al. 2014; CDIP 2013; Guza & Thornton 1981; Stockdon et al. 2006). Numerous studies have documented increased wave heights over the last few decades, suggesting that the rate of SLR is being outpaced by the rate of increase in wave-driven water levels along certain portions of the U.S. West Coast certain areas for at least several more decades (Allan & Komar 2006; Barnard et al. 2014; Gemmrich et al. 2011; Menendez et al. 2008; Ruggiero 2013; Ruggiero et al. 2010; Young et al. 2011).

Impacts on Long Beach

Sea level is rising and will continue to rise, posing increasingly greater risk of coastal hazards, temporary flooding, and long-term inundation to the Long Beach area. This section provides an initial assessment of the vulnerability of the City of Long Beach (CLB) to coastal flooding, compounded by future sea level rise.

With an estimated population of 473,577 people, based on the U.S. Census Bureau's 2014 American Community Survey (ACS) 5 year estimate (2010-2014), Long Beach is the 7th largest city in California and the 36th largest city in the U.S. (ACS 2015; Bradley 2015a). Nicknamed the "Aquatic Capital of America" (Long Beach Post 2008), Long Beach is a city largely defined by its temperate year-round climate and intimate relationship with the coast, beaches, bays, the open ocean, and a diversity of ocean-related activities. Long Beach is home to a thriving manufacturing sector, numerous on and off shore active oil wells, and the Port of Long Beach (POLB) which is the 2nd busiest container port in the U.S. and one of the world's largest shipping ports, (AAPA 2006; POLB 2015a). The shores of Long Beach also host some of the city's most famous attractions, such as: the RMS Queen Mary, the Aquarium of the Pacific, the Long Beach waterfront, and Rosie's Dog Beach. However, rising sea level threatens the coast of Long Beach: it is predicted that sea level may increase up to 5.5*ft* (1.7*m*) above current levels by 2100, which would inundate many areas along the coast, in addition to disrupting the operation of the POLB (NRC 2012a).

Even though tropical storms are a rare phenomenon in the eastern Pacific, there have been a number of storms that have had a considerable impact on both coastal and inland cities along the West Coast. The 1939 California tropical storm (aka "El Cordonazo" and "The Lash of St. Francis") is considered to be among the most costly storms in the history of Southern California (Kalstrom 1952; WRCC 2008). It was the last of four tropical storms that hit Southern California in the month of September, and the only tropical storm in Southern California's history to hit the region with tropical storm strength (WRH 2010). The storm caused heavy flooding in low-lying areas of Long Beach and the surrounding areas. Belmont Shore had ten houses completely washed away by storm-surge waves over 6*ft* high, and the houses that remained, experienced severe flooding and shattered windows from the strong winds (**Figure 5**, Herald-Examiner Collection 1939). The storm also scattered large quantities of trash and debris along the shores of the beaches. At the time, this storm caused an estimated \$2 million in damages, which is equivalent to \$34.1 million, based on today's inflation rates (BLS 2015; WRH 2010).

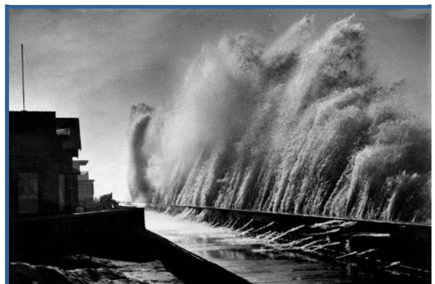


Figure 5. 1939 tropical storm causes extreme high tides (>6*ft* high) and high waves to hammer the sea walls along the Belmont Shore area. This photograph was taken in the 6000 block of East Ocean Boulevard (Herald-Examiner Collection 1939).

More recently, Hurricane Marie caused large increases in water levels along the coast of Southern California (atmospheric tide level as opposed to astronomical tide level), and swells of up to 20*ft* battered the coastline resulting in massive flooding in southeastern Long Beach between August 22 and September 2nd, 2014 (Zelinsky & Pasch 2015). This hurricane is considered to be part of the El Niño event we are currently experiencing. Marie caused an estimated \$20 million in damages across Southern California (Zelinsky & Pasch 2015). Repairs for just the Middle Breakwater were estimated at \$10 million (Fuderer 2014; Meeks 2015).

With so much of the city's key economic assets located along the coast, high resolution, hydrodynamic flood models are critical to being able to accurately identify areas most at risk from SLR and storm-related flooding. At present, the USGS's *CoSMoS 3.0* is the best model available. While the results from NOAA's *SLR Viewer* were not considered to be robust enough to include in this study given the limitations of static flood models, flood maps for each of their 0-6*ft* SLR scenarios are included for the Long Beach area in **Appendix C**.

CoSMoS 3.0's results for Long Beach

On November 15, 2015 USGS and USC's Sea Grant made the preliminary findings of *CoSMoS 3* publically available online (USGS 2015); however, the full suite of results will not be available until next summer (2016). *CoSMoS 3*'s flood hazard projections for the Long Beach area based on the occurrence of a 100 year storm with 0, 50, 100, and 150*cm* of SLR are shown in **Figure 6**, with close-ups of the southwestern and southeastern corners of Long Beach depicted in **Figures 7** and **8**, respectively.

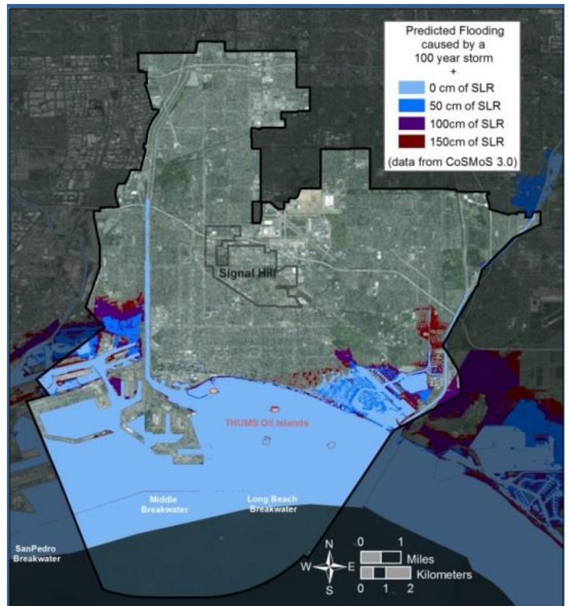


Figure 6. Predicted flooding caused by a 100 year storm with 0, 50, 100, or 150*cm* of Sea Level Rise (SLR). Flooding estimates are based on the November 2015 preliminary results of USGS's *CoSMoS 3.0* model.

Based on *CoSMoS 3*'s findings, the western and eastern corners of southern Long Beach are at high risk of flooding during a 100 year Storm with no rise of sea level. Under the 50-150*cm* sea level rise scenarios, these areas are subject to increased inundation and flooding. Based on 2010 population estimates at the Census Block level, roughly 22,492 people are at currently at risk of flooding during a 100 year storm (**Table 3**). As SLR continues there is a gradual increase in the people at risk of flooding, with almost 3,000 more people predicted to be impacted during a 100 year storm with 100*cm* of SLR than with a 100 year storm alone. As sea level rises an additional 50*cm*, the number of people at risk of flooding goes up substantially with almost 15,000 more people impacted by flooding with a 100 year storm and 150*cm* of SLR than during the same storm with only 100*cm* of SLR.

Table 3. Number of people in the Long Beach area (including Signal Hill) at risk of inundation based on *CoSMoS 3.0*'s 100 year storm plus Sea Level Rise (SLR) model results. Population estimates are based on data from the US Census Bureau's 2010 census.

Population Boundary Units (*n*)	**Total LBC area Population**	**0cm SLR** ≈ 0ft SLR	**50cm SLR** ≈ 1.64ft SLR	**100cm SLR** ≈ 3.28ft SLR	**150 cm SLR** ≈ 4.9ft SLR
Census Blocks* (*n* = # of Census Blocks)	475,109 (*n* = 5,439)	22,492 *4.73 %* (*n* = 629)	22,750 *4.79 %* (*n* = 692)	25,440 *5.35 %* (*n* = 778)	40,411 *8.51 %* (*n* = 960)

**Census block units were chosen because they are the smallest geographic areas sampled and therefore provide more accurate population estimates than those based on Census Block Groups, Census Tracts, Zip Codes, etc.*

As shown in **Figure 7**, extensive flooding is predicted for the southeastern portion of Long Beach during a 100-year storm, including the backside of the Peninsula, Alamitos Bay, Belmont Shore, and the lot just north of the Marina. As sea level rises to *50cm*, flooding expands to cover almost the entire Peninsula, all of Belmont Shore and Alamitos Bay, the Marina, and large portions of the beach south of Belmont Shore. With 100*cm* of SLR flooding expands to cover most of the beach, Colorado Lagoon, and large portions between the Marina and Colorado Lagoon. With 150*cm* of SLR, the Belmont Heights and College Estates areas begin flooding. Depictions of this same area with each of the four SLR scenarios shown separately are provided in **Appendix D**.

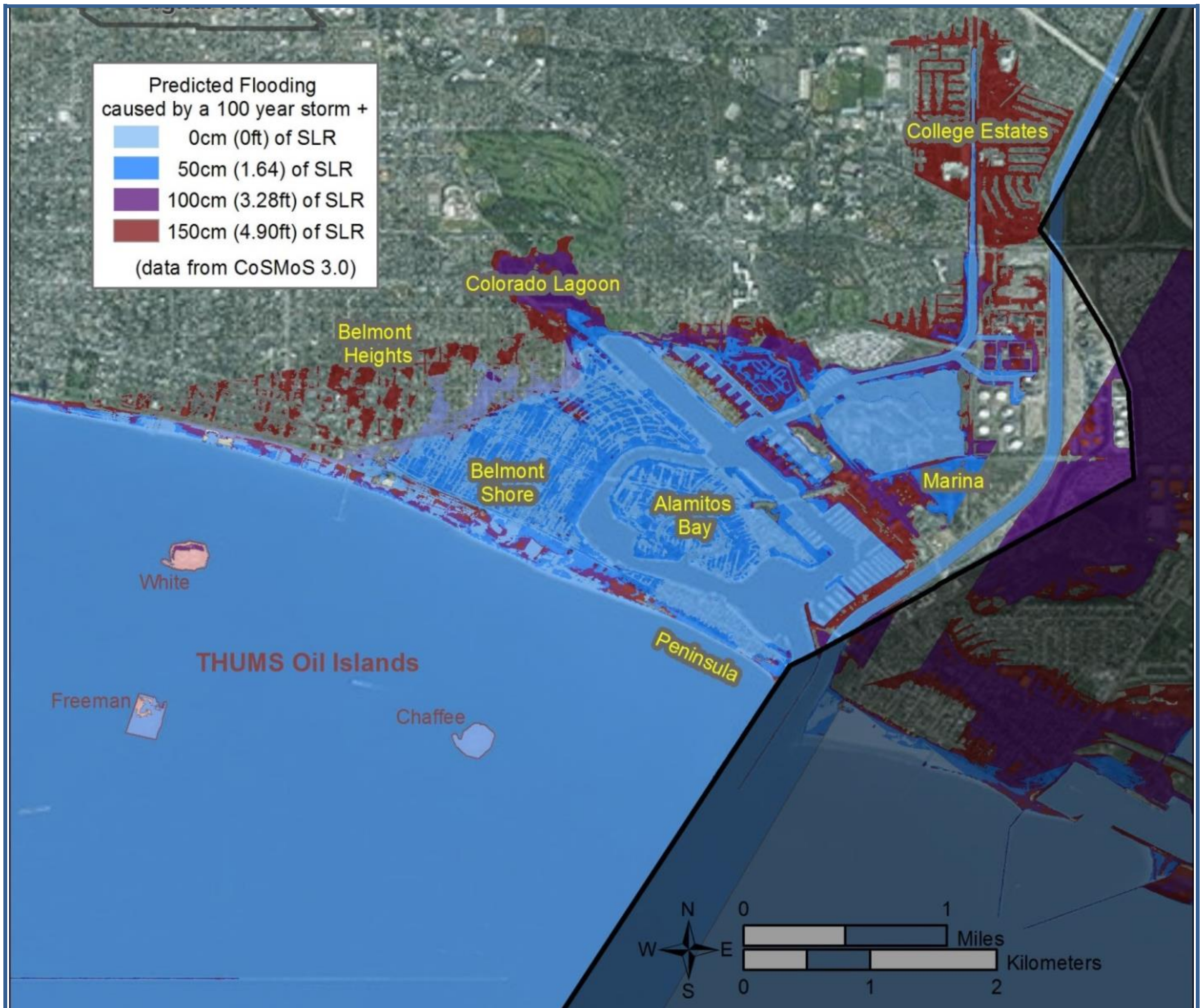


Figure 7. Close-up of the southeast portion of Long Beach predicted to be flooded during a 100 year storm plus 0, 50, 100, or 150*cm* of Sea Level Rise (SLR). Flooding data is based on *CoSMoS 3.0's* November 2015 preliminary results.

As shown in **Figure 8**, extensive flooding is predicted during a 100 year storm for large portions of northern section of the Port of Long Beach (POLB), including Piers A, A West, D, E, and S, along with portions of the Long Beach Shore Marina and the southwestern most stretch of beach (located just east of the Marina and north/northeast of Grissom Island). As sea level rises to *50cm*, flooding expands to cover more of Piers A, D, E, and S, and begins to flood Pier B (and areas north of the pier), and a larger stretch of the beach. With 100*cm* of SLR flooding expands to cover a larger area north of Pier B, and most of Long Beach Shore Marina. With 150*cm* of SLR, flooding expands throughout the port and covers almost all of beach (from the Long Beach Shore Marina to the Peninsula). Depictions of this same area with each of the four SLR scenarios shown separately are provided in **Appendix D**.

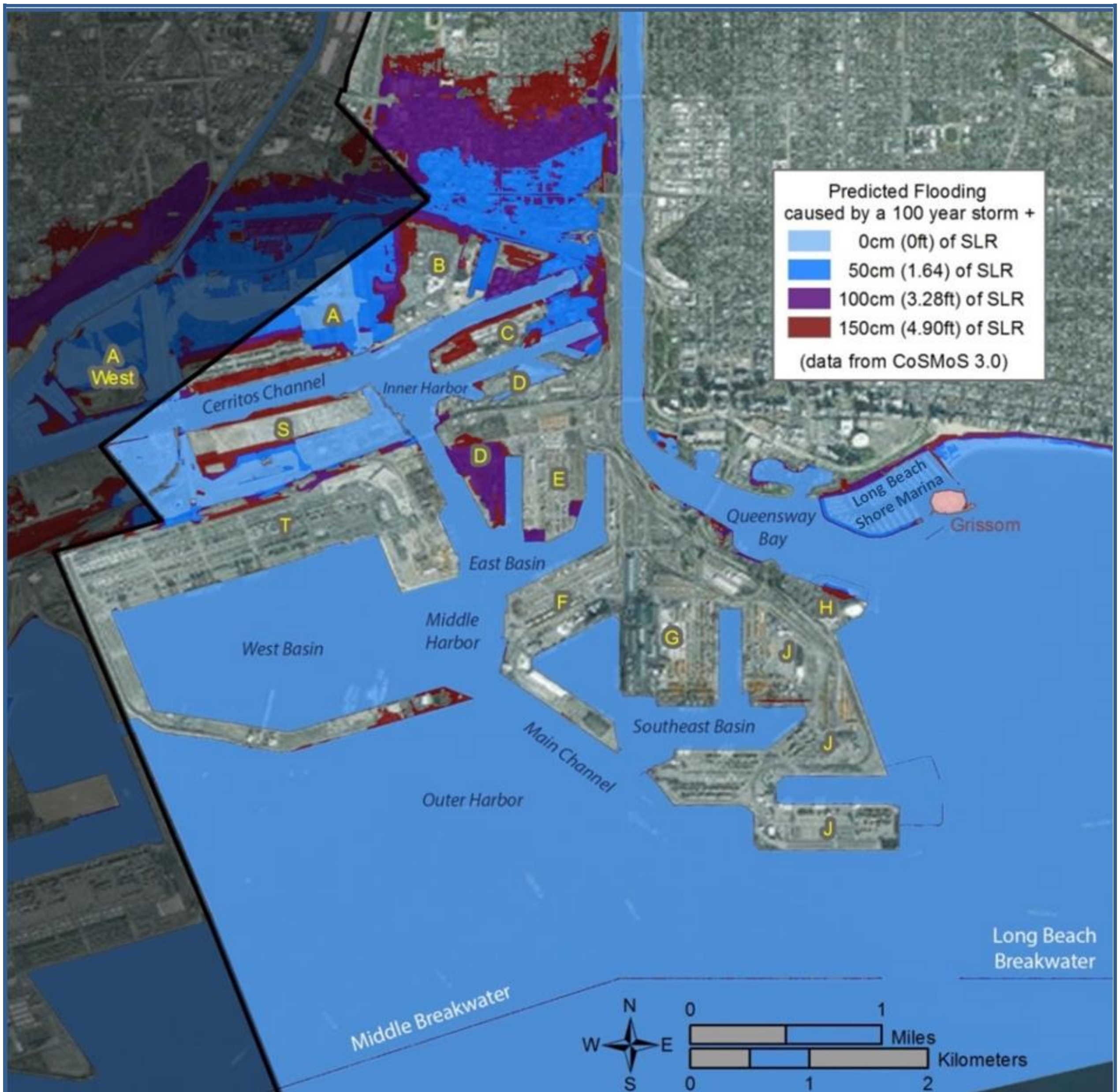


Figure 8. Close-up of the southwest portion of Long Beach predicted to be flooded during a 100 year storm plus 0, 50, 100, or 150*cm* of Sea Level Rise (SLR). Pier locations for the Port of Long Beach (POLB) are labeled in yellow. Flooding data is based on *CoSMoS 3.0's* November 2015 preliminary results.

It is important to note that based on these findings, the entire eastern half of the Long Beach Breakwater and large portions of the Middle and San Pedro Breakwaters could become at least partially compromised (and possibly overtopped) during a 100 year storm with no SLR, and completely overtopped during a 100 year storm with just 50-100*cm* of SLR. The THUMS Oil Islands were built after the breakwaters were completed and were not designed to withstand direct exposure to ocean waves or endure major offshore storms, because of the sheltering effect of the breakwaters (AOP 2015a). Based on *CoSMoS 3*'s findings, the breakwaters could become compromised as early as this winter if the El Niño storms are as strong as recent studies have predicted (Barnard et al. 2015b). These results also indicate that all of Chaffee and most of Freeman Island could be overtopped during a 100 year storm with no SLR. Grissom and White could begin to see some flooding with a 100-year storm and 100-150*cm* of SLR. These findings should not come as a surprise to the THUMS islands, given that the 1983 El Niño storms caused significant damage to both White and Freeman islands, and even after repairs were made White Island continues to have problems with surge from storm-related wave events (AOP 2015a). *CoSMoS 3*'s predicted flooding of both the breakwaters and oil islands is especially troubling given the representatives from the THUMS Oil Islands have said on several occasions that they are relying on the breakwaters to protect them from any adverse impacts of climate change and that they would only consider developing adaptation plans if there were a threat of the breakwaters being removed.

It should be noted that while *CoSMoS 3* is currently the most robust coastal flood hazard model available, it does have some limitations that could impact the accuracy of its flood predictions for the Long Beach area:

- **Total Water Level** (**TWL**)—their 100 year storm data are based on a TWL proxy that is reasonable for large scale analyses, but is less scalable to local levels; for instance, Long Beach, Seal Beach and Newport are all highly responsive to southern swell which appears unrepresented by the TWL proxy.
- **Waves**—it is unclear how they calculated waves inside the breakwater.
- **Flooding**—the ocean side model appears to use a static (bathtub) method. Wave overtopping flooding is fundamentally impulsive, related to the time varying instantaneous water level (i.e. the overflow volume). Nothing in the literature supports that the bathtub method is a good proxy for this.
- **XBeach model implementation—** "XBeach is a two-dimensional model for wave propagation, long waves and mean flow, sediment transport and morphological changes of the nearshore area, beaches, dunes and backbarrier during storms" (XB 2015). The absence of certain assumption details likely means they were left out of the model, which leaves us to conclude that they are probably running a hydrostatic (long wave only) model, which is not ideal for the Long Beach area.
- **Beach**—beach profiles are fundamental to modeling backshore flood risk. It appears *CoSMoS 3* included a few profiles, but it is unclear whether the beach width, elevation, and berming (which are crucial when modeling backshore flooding) are complete for the Long Beach area.

- **Validation**—while the documentation describes how the *CoSMoS 3* model was validated with data from a January 2010 storm, it is unclear how the model's output for Long Beach compared to the actual flooding experienced during this storm.
- **Bathymetry**—it is unclear what bathymetry data were used. How recently these data were collected and the accuracy of them are critical to model reliability.

Additionally, it does not appear that *CoSMoS 3.0* included beach change. This is important because water run-up acts much differently on beaches than it does on pavements (AOP 2015a). This may be an important flaw in the model's design because currently the majority of California's coastlines have been so extensively developed and modified that they are now classified as "urban systems" (rather than natural ones). For example, here in Long Beach, the original beach line (prior to coastal development) was located where Pine Avenue meets the Convention Center; everything from there seaward (~1*mile*) was built up (see **Figure 9**). Once these systems have been altered to this extent, they are no longer able to be saved through natural system responses (like beach retreats); instead humans must act to adapt these areas to withstand the anticipated environmental changes.

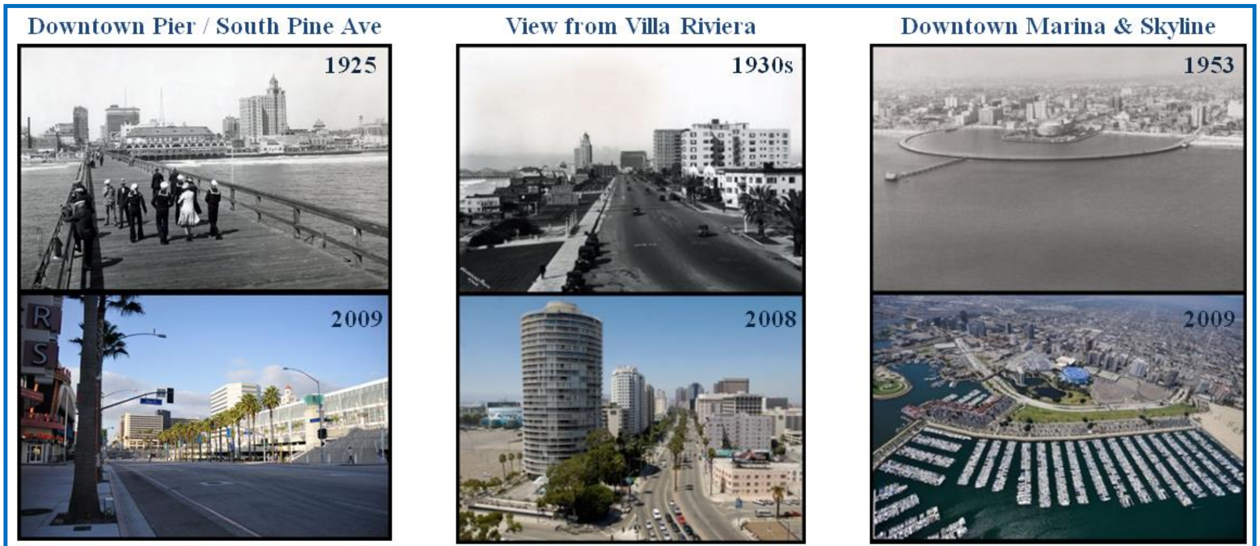


Figure 9. Then and Now pictures of Long Beach. Pictures were taken from *http://longbeachseen.com*

Ongoing AdaptLA Research

CoSMoS 3.x – the full suite of *CoSMoS 3* results are planned to be released sometime next summer (2016), which will include modeling of 40 different SLR scenarios, each with 1, 20, and 100 year storm situations. In addition, through a grant from the Ocean Protection Council and led by the City of Santa Monica, *CoSMoS* will be bolstered by additional studies by two consultant groups, TerraCosta Consulting Group (TCG) and Environmental Science Associates (ESA). TCG will analyze and project short-term and long-term beach changes and ESA will conduct a backshore characterization and shoreline change analysis as well as provide flood hazard data. Just as with hydrodynamic flood models, reliable beach change models are just now being developed and implemented. Recent research at Scripps Institution of Oceanography (SIO) has provided the most advanced models that deal separately with the rapid seasonal and inter-annual wave-driven beach accretion-erosion cycles, and the long-term sea level rise induced shoreline retreat. These models will be implemented as part of a Los Angeles County-wide sea level rise vulnerability study being funded through the City of Santa Monica. Scripps Institution scientists Drs. Reinhard Flick and Adam Young are lead investigators and have been advisors to the Aquarium in developing the background information for this report.

Hazard Maps – "The coastal flood regions will be merged with the dune and cliff erosion hazard zones, providing a single map that includes all areas that become hazardous due to future erosion and future flooding. The level of hazard will be quantified by spatial aggregation. This consists of overlaying the individual hazard zone maps and counting the number of scenarios that affect any specific location. This results in a location being identified by its hazard frequency. This is a way to visualize the full range of scenarios assessed and understand, qualitatively, how projected future hazards vary (e.g. if a site is hazardous regardless of the scenario, or whether the site is only hazardous for the most extreme scenarios)." (Battalio et al. 2015)

Vulnerability Assessment – "The hazard mapping will then be analyzed with georeferenced infrastructure and habitat data to assess the vulnerability of property, infrastructure, and habitats across the region. The infrastructure datasets will be compiled and queried to determine what is inside the identified hazard zones, nearly adjacent to them, and summarize the potential vulnerabilities by sector. This information will provide the assessment of the likelihood of damages based on the number of hazard zones that encroach on the particular asset." (Battalio et al. 2015)

Port of Long Beach's SLR Program

The Port of Long Beach (POLB) has a comprehensive study underway to develop a Coastal Resiliency Strategic Plan (CRS) that "incorporates adaptive measures related to projected climate change into policymaking and planning processes, environmental documents, infrastructure design, construction practices, and community outreach and education efforts" (APA 2014). The Port's CRS plan looks at near-term, mid-century, and end-of-century sea level rise predictions, as well as impacts from extreme heat and flooding, to plan ahead for coastal climate change over the next century. The study is restricted to the Port footprint and to some key transportation arteries for the movement of freight close to the Port that may be subject to flooding. The Port is open to further discussions with the City of Long Beach to assess climate impacts city-wide as well.

Plans and Efforts Currently Underway

A number of studies have been done for the City of Long Beach by consulting firms over the years. The value of these studies has never been fully realized because they have never been integrated into a comprehensive analysis nor translated into a comprehensive plan to deal with chronic problems that will increase in intensity and geographic scope as sea level continues to rise. A big issue is the limited awareness of these studies and their results. Past studies discovered the existence of now defunct timber jetties; trial installation of artificial kelp and tethered milk jugs to dampen waves; k-rails (highway crash barriers) as sea walls; and a variety of other approaches. Periodic beach nourishment by moving the sand back near the Alamitos Bay jetty (sand back-passing) and the sand berm are the only approaches that have been endorsed as providing protection. However, back-passing requires a lot of movement of sand by trucks that create noise, dust, and vibrations. And the berm reduces ocean views, makes beach access challenging, and requires constant maintenance.

Beach Nourishment and Berms

The Peninsula is one of the areas of Long Beach most vulnerable to sea level rise and coastal flooding. The city has responded to potential Peninsula flooding events by building a sand berm (**Figure 10**) on the beach by trucking sand from areas of accretion (located primarily along the southwest end of the beach) to the southeast end of the beach where the peninsula experiences the most erosion (**Figure 11**). This has been the practice for several decades; however, residents are becoming fed-up with the constant convoy of trucks, reporting that it's noisy, dirty, and causes vibrations that disturb the road and the houses (AOP 2015b).

Figure 10. Sand berms being made along the Long Beach Peninsula in preparation of high surf. *Photograph by Chris Carlson* (AP 2014)

Figure 11. Beach accretion and erosion areas in Long Beach.

Sand is moved by wave-driven currents from the jetty at the entrance to Alamitos Bay northwest areas closer to Downtown Long Beach. What makes the situation for this segment of beach unusual is that the sand does not escape from this coastal cell allowing the City to retain overall custody of it (**Figure 11**), making this beach cell unlike most other coastal areas in California where sand moved along shore is lost to the ocean. A number of efforts have been tried to interrupt this flow of sand (such as using artificial kelp, sand bags, and even milk jugs); however, to date no hard structures (such as toe jetties) have been used because of opposition, real or perceived, by environmentalists and the California Coastal Commission. Present practices provide important protection, but are costly, require almost constant activity, and are not without impacts on residents.

The City has made a substantial investment in protecting homes on the Peninsula; including nourishing the beach, regularly back-passing sand, and maintaining a long linear berm that runs parallel to the shore (**Figure 10**). However, given the anticipated rise in sea level and the projected increase in the frequency and severity of storms, continuing to maintain the berm, or even attempts to elevate the berm crest, are not likely to provide sufficient protection, and if the berm's contact with water becomes chronic it would be vulnerable to rapid avalanching and deterioration (Gallien et al. 2015; Schubert et al. 2015). While continued beach nourishment would almost certainly be required to maintain present levels of protection, nourishment plans must be carefully considered as recent evidence suggests sand nourishment may, in some cases, increase flooding of homes (Gallien et al. 2015; Moreno 2013).

Shoreline Armoring

Another possibility to protect structures close to the shore is shoreline armoring. This could involve building seawalls, additional breakwaters, and riprap (rock used to armor shorelines) to help prevent the landward retreat of the beach. However, armoring can restrict the natural flow of sediments along the beach, resulting in erosion and beach loss (Flick 2015). Eventually, the only course of action that can be taken if projected sea level rises are realized will be to retreat further inland. In time, sea levels will rise to the point where it will be dangerous to live where it was once safe, and strategic relocation will be necessary. Until then, coastal cities must invest resources into protecting shorelines and shorefront properties (**Table 4**). As pointed out earlier, coastal flooding is an issue now and may get much worse during the winter of 2015-16 because of El Niño. Inundation from sea level rise is a longer-term issue. Potential solutions should be looked at from at least two different time scales—the next few decades and beyond 2050.

Table 4. Adaptation strategies for existing and new developments

Strategies for *EXISTING* Developments	Strategies for *NEW* Developments
• Rolling easements or setbacks • Relocation incentives • Seawalls or other shoreline protection structures for protection of critical infrastructure • Elevation of facilities • Planned retreat • Rebuilding restrictions for vulnerable structures following SLR-related disasters	• Mandatory setbacks for restriction of development in vulnerable areas • Required warning notices for developers and buyers regarding the potential impacts of future SLR • Smart growth & clustered development in low-risk areas • Designing for increased resiliency following SLR-related disasters • Development of expendable or mobile structures in high-risk areas

LBC's NEW El Niño Alert System

In preparation for the flooding predicted from the current El Niño, the City of Long Beach has launched "Alert Long Beach," which is an emergency notification system used by the City to issue emergency alerts (in the form of text messages, voice mails or emails) to the Long Beach community (CLB 2015c-d).

Sustainable City Action Plan (SCAP)

The City of Long Beach takes the threats posed by climate change and sea level rise (SLR) very seriously. The threats posed by climate change and SLR, along with the mitigation and adaptation strategies to counter them are currently included under the City's Sustainability program. As part of this effort "Long Beach was one of the first cities to create a Sustainable City Commission (2007), organize an Office of Sustainability (2008), adopt a Sustainable City Action Plan (2010) and, as a result, has been in the process of incorporating sustainability into all of its major policy goals to build the resilience to ensure Long Beach still thrives in 100 years and beyond" (CLB 2015b). Long Beach's Sustainable City Action Plan (SCAP) is organized into the following seven focus areas: (1) Buildings and Neighborhoods; (2) Energy; (3) Green Economy and Lifestyle; (4) Transportation; (5) Urban Nature; (6) Waste Reduction; and (7) Water. The SCAP is intended to be the "first step of a comprehensive effort to incorporate sustainable city principles into all new or updated plans and strategies" (CLB 2015b).

As part of the SCAP the City has been working with the University of Southern California's Sea Grant Office and their *AdaptLA Regional Initiative* (which included the USGS's *CoSMoS* modeling efforts). The City has also been working with Moffatt and Nichol on developing a hydrodynamic model for the Alamitos Bay, and plans to incorporate the results from *CoSMoS 3* into this model as they become available over the course of the next year (CLB 2015b). The *Alamitos Bay Hydrodynamic Model* is currently being used by the City to evaluate the potential impacts of the Alamitos Bay Power Plans to the local water quality, along with the anticipated impacts of SLR to the Los Cerritos Wetlands and the Southeast Area Development and Improvement Plan (SEADIP) planning areas (CLB 2015b).

The City is also in the process of applying for grant funds so that a Vulnerability Assessment and Adaptation Strategy Study can be performed. The results of this study are planned to be used in public outreach efforts and to update the City's Local Coastal Program (LCP, which was adopted in 1980 and due for an update). As part of this effort the City has been working closely with the Port of Long Beach on their Climate Adaptation and Coastal Resiliency Strategic Plan, so that the results and lessons learned from the port's study can be used to help guide the City's Vulnerability Assessment. (CLB 2015b)

Additional Approaches to Consider

1. Conduct a Comprehensive Review of Existing Studies and Historical Accounts

An appropriate first step would be to make a comprehensive inventory and review of relevant studies and data sets that exist and to make these readily available. This would include collecting all information on the community's historical vulnerability to and damage from coastal hazards such as: reports, maps, surveys, photographs, newspaper archives or any other relevant historic information on storm inundation and flood damage, historical storm surge maximum heights and duration, cliff erosion, and beach loss or shoreline retreat, etc.

2. Delineate Historically Flooded, Inundated, and Damaged Areas

Upload these boundaries into a GIS so they can be used to validate coastal hazard models. As part of this effort, collect information on historical short-term increases in sea level, exposure to El Niño events and changes in wave climate. Compare this to *CoSMoS 3*'s projected coastal hazards flood zones (**Figures 6-8**, and **Appendix D**). Also, collect (or obtain all) data on historic coastal or shoreline erosion rates. Upload these boundaries into a GIS so they can be used to validate shoreline change models and compared to projected shoreline changes.

3. Collect Additional Data and Perform a Long Beach Specific Hydrodynamic Costal Flood Hazard Assessment

While the City probably has surveys of the sea walls and the drainage infrastructure currently in place along the City's coast, we recommend that these be resurveyed to account for any variations that may have occurred over time, particularly in coastal areas that have likely experienced subsidence since they were last surveyed. It is important that close attention be paid to the resolution and accuracy of the data collected. We suggest that before any resurveying is performed that our contacts from Scripps Institution of Oceanography (namely Drs. Gallien and Flick) review the proposed collection methods to insure that the resulting data collected using these methods will be appropriate for use in more detailed dynamic modeling. Documenting beach change, updating the sea wall elevation surveys, and collecting field validation data when overflows occur may be achieved through citizen and municipal efforts. Near shore bathymetry, collecting wave data for a peninsula wave model and building a hydrodynamic model would have to be embedded in a research program conducted by professionals.

4. Perform a Comprehensive Review all Infrastructure and Assets at Risk of Flooding

This would include: roads, power lines and outlets, sewer and water lines, storm drains, railways, wastewater treatment facilities, power plants, airports, hospitals, etc. These locations (and their associated attributes) should be uploaded into a GIS so they can be used to perform comprehensive risk and vulnerability assessments.

We have made our assessment of the most vulnerable areas, but most of the steps listed above could not be immediately done because of inadequacy of relevant data and information, and inability to access the studies that have already been done by the City. Therefore, we suggest that the City consider taking the above actions, and recommend starting with the southeastern area of the City for the following reasons. First, this is the area of the City most vulnerable to damage from coastal erosion and flooding. Second, a number of studies have been done and approaches tried, that have never been integrated into a coherent document, and such a document might go a long way in outlining the most effective strategies for dealing with erosion and flooding of the Peninsula. Third given that these studies are complete, the compilation could perhaps serve as a template for a City-wide plan of action.

Summary

Storm waves superimposed upon high tides will continue to be the dominant threat to our coastal environments over the next few decades just as they have been over the past century. The impacts of sea level rise (SLR) will become more noticeable during the second half of this century, particularly when combined with large El Niño-driven storm waves and high tides.

The Port of Long Beach (POLB) is conducting important work on SLR and coastal flooding impacts and possible adaptation to ensure that it can adapt to these changes without any loss of service. Their geographic scope is within the Port boundaries and areas close to the port where the movement of goods might be impacted.

The USGS's *Coastal Storm Modeling System* (*CoSMoS*) is a powerful tool that can provide important information on storm waves and total sea level rise for Long Beach as a whole, but may not provide the level of detail needed to assess flooding for site-specific projects in local areas of the City, such as the Peninsula and Alamitos Bay. That may require using some of the results of *CoSMoS 3*, along with additional types of data, as input to localized hydrodynamic models, such as those being developed by SIO's Dr. Timu Gallien. Some, but certainly not all, of the data required to formulate and execute these high-resolution diagnostic flooding models could be generated by citizen scientists. Dr. Gallien has expressed willingness to work with the Aquarium of the Pacific's SLR working group to train dedicated citizen scientists to develop these data.

If Long Beach is to be a model of a climate-change resilient city, it will have to prepare for greater temporary coastal flooding, erosion, and eventual permanent inundation of low-lying areas. These are already problems that will increase in intensity and extend to a larger geographical area as sea level continues to rise. The Peninsula and Alamitos Bay are Long Beach's most vulnerable areas to coastal flooding and erosion.

While uncertainty exists as to how climate change and sea level rise will play out in Long Beach in detail, we know enough to begin to take action. Planning for climate change is fundamentally a risk management strategy against an uncertain future.

Deteriorating Air Quality

The quality of the air around us is dependent on the pollution emitted by stationary and mobile sources. These sources can emit a variety of pollutants. These pollutants are monitored by the EPA, with The Clean Air Act setting the framework for efforts to protect air quality. Ground-level ozone and airborne particles are the two pollutants that pose the greatest threat to human health. Ozone (O_3), often called smog, at ground level can harm human health. Ozone forms when two types of pollutants, volatile organic compounds (VOCs) and nitrogen oxides (NOx), react in sunlight. These pollutants come from sources such as vehicles, industries, power plants, and products such as solvents and paints. Particle pollution, or particulate matter (PM), is a mixture of solids and liquid droplets floating in the air. They can be emitted directly from cars, trucks, buses, power plants and industries, and wildfires. But they can also form from the chemical reactions of other pollutants in the air. Coarse dust particles (PM10) are 2.5 to 10 micrometers in diameter and sources include dust, pollen, mold, etc. and can get trapped in the lungs. Fine particles (PM2.5) are 2.5 micrometers in diameter, or less, and consist of combustion particles, organic compounds, metals, etc. and are even more detrimental because the particles are small enough to pass through the lung tissue into the blood stream (**Figure 12**).

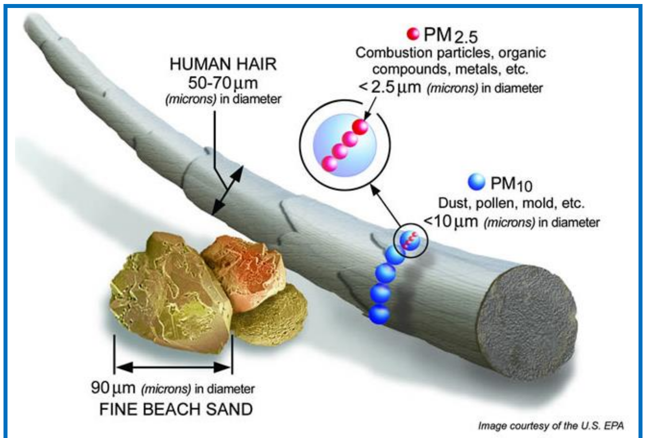


Figure 12. Comparable sizes of coarse to fine scale particulate matter (PM10 to PM2.5, respectively). *Note: this graphic is courtesy of the EPA.*

Regional Impacts

Californians currently experience the worst air quality of any state in the nation (UHF 2015), with more than 90% of the region's population living in areas that violate state air quality standards for ground-level ozone and small particles (Karl et al. 2009). According to the Union of Concerned Scientists "these pollutants cause an estimated 8,800 deaths in California every year and cost over a billion dollars per year in health care" (UCS 2009). Warmer temperatures are expected to further worsen air quality conditions. Under a low emissions scenario the number of days violating standards could increase by 25-35% in Los Angeles and the San Joaquin Valley by the end of this century, or as much as 75-85% under a high emissions scenario (Karl et al. 2009; UCS 2009). Wildfires, resulting from the combination of increasing temperatures and prolonged severe droughts, will further contribute to poor air quality in the Los Angeles region (Karl et al. 2009; UCS 2009). While the air quality in the Greater Los Angeles (LA) region has vastly improved since a decade ago (in large part due to California having the toughest regulations in the country); according to the American Lung Association's 2015 "State of the Air" report the Greater LA region still ranks fifth for cities most polluted by long-term, year-round particle pollution. The biggest polluting sources are vehicles and industries such as oil refineries and industrial facilities but there are additional factors within the Los Angeles region that exacerbates the conditions:

Topography – With a population of over 18 million, the Greater LA area is a large basin with the Pacific Ocean to the west, and several mountain ranges with 11,000 *foot* peaks to the east and south where air gets trapped.

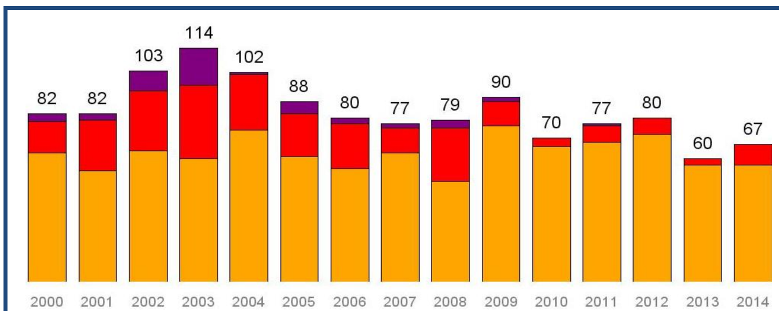
Intense Traffic – Los Angeles County is home to two of the largest container ports in the country—the Port of Los Angeles (POLA) and Port of Long Beach (POLB). Over 80% of all U.S. imports from Asia come through these ports and about 40% of those imports are moved by diesel trucks (Pettit 2014). The freeways cater to these trucks as well as an increasing number of passenger vehicles – there are almost 7.5 million cars registered to 10 million people in Los Angeles County (Los Angeles Almanac 2014).

Urban Heat Island – Not only do summer heat islands increase system-wide cooling loads, they also increase smog production because of higher urban air temperatures (Taha et al. 1994). Smog is created by photochemical reactions of pollutants in the air; and these reactions are more likely to intensify at higher temperatures. For example, in Los Angeles, for every 1°*C* the temperature rises above 22°*C*, the incidence of smog increases by 5%. As a result the months between May and September have the most hazardous air conditions (Akbari 2005).

The California Air and Resources Board (CARB) is responsible for regulating mobile sources while the South Coast Air Quality Management District (SCAQMD) is responsible for measuring, reporting, and improving the air quality of the Greater Los Angeles region for stationary sources of air pollution. Ambient air quality standards for ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter (PM10 and PM2.5), and lead (Pb) have been set by both the State of California and the federal government.

Ozone Pollution

In 2014, there were 67 days when ozone levels reached "code orange" (unhealthy for sensitive groups) or above (**Figure 13**) on the Air Quality Index (AQI). According to the *State of the Air* report the Los Angeles-Long Beach region ranked #1 for the worst ozone pollution. The current



Ozone Air Quality Standards	
California	**Federal**
0.070*ppm* per 8*hr* period 0.09 *ppm* per 1*hr* period	0.070*ppm* per 8*hr* period

Graph Legend: Air Quality Index Categories

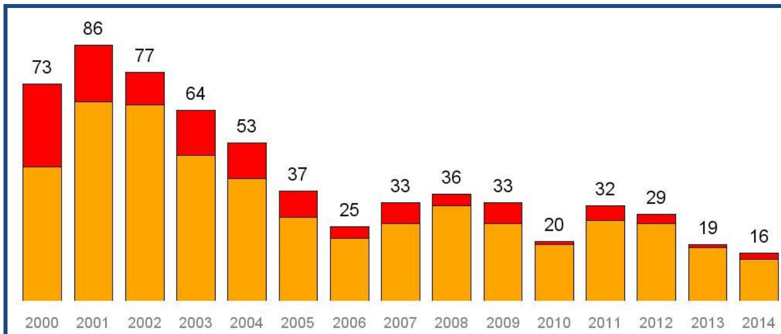
- Unhealthy for Sensitive Groups
- Unhealthy for All Groups
- VERY Unhealthy for All

Figure 13. Number of days the Los Angeles–Long Beach–Santa Ana area reached unhealthy Ozone levels between 2000 and 2014. *Note this graphic is based on preliminary air quality data reported by AirNow (2015).*

state national ambient air quality standard for ozone is 0.070*ppm* measured over eight hours (which is less than previous 2008 ozone standard of 0.075*ppm*). According to SCAQMD the South Coast Basin is designated extreme nonattainment for ozone and they estimate it will take until 2030 to meet the new ozone standard. The EPA recognizes that California has unique challenges in addressing ozone pollution because of its topography, high population, wildfires, agricultural areas, and ports. As a result the South Coast Air Basin is not required to meet the 2008 standards till 2032 (EPA 2015a). Federal rules, including the Mercury and Air Toxics Standards, the Tier 3 Vehicle Emissions and Fuels Standards, and the Clean Power Plan, is expected to significantly reduce ozone-forming pollution in the years ahead for the region.

Particulate Matter (PM2.5)

While Particulate Matter ≤ 2.5 $\mu g/m^3$ (PM2.5) has decreased by a large margin since 2000, there were still 16 days in 2014 when PM2.5 levels reached "code orange" levels or above on the AQI, which was the highest for all cities monitored in the U.S. (**Figure 14**; AirNow 2015). The State of the Air report ranked Los Angeles-Long Beach region #3 for long-term particle pollution (annual average) and #4 for short term particle pollution (24 *hour*). The state and national standard limits for PM2.5 are 12$\mu g/m^3$ for annual average and federal limit of 35$\mu g/m^3$ for a 24 *hour* period.



PM2.5 Air Quality Standards

California	Federal
12.0$\mu g/m^3$ per year	12.0$\mu g/m^3$ per year 35$\mu g/m^3$ per 24*hr* period

Graph Legend: Air Quality Index Categories

- Unhealthy for Sensitive Groups
- Unhealthy for All Groups
- VERY Unhealthy for All

Figure 14. Number of days the Los Angeles–Long Beach–Santa Ana area reached unhealthy PM2.5 levels between 2000 and 2014. *Note this graphic is based on preliminary air quality data reported by AirNow (2015).*

It is estimated that 9,200 premature deaths occur annually as a result of high PM2.5 pollution levels (CARB 2010). The results of a 16-year investigation (Pope et al. 2002) of exposure to fine particulate matter among adults age 30 years and older found that for each 10 micrograms per cubic meter ($\mu g/m^3$) increase in PM2.5, the risk of death from all causes increased by 4%, and thus for every reduction of 10 $\mu g/m^3$ PM2.5 in the general population, there was an estimated increase in life expectancy of about half a year. Long-term exposure to PM2.5 also increased hospital admissions for all respiratory issues (4%), heart disease (3%), stroke (3.5%), and even diabetes (6.3%; Pope et al. 2009).

Impacts on Long Beach

In Long Beach the air quality is impacted by the 710 freeway along the West, the Long Beach/Los Angeles port complex along the Southwest, the 103 freeway and major oil refineries in the West, the 405 freeway through the center of the City, and major industrial sectors, mainly in the South. The Southern California Air Quality Management District (SCAQMD) currently has 4 stations monitoring air quality within Long Beach (**Figure 15**).

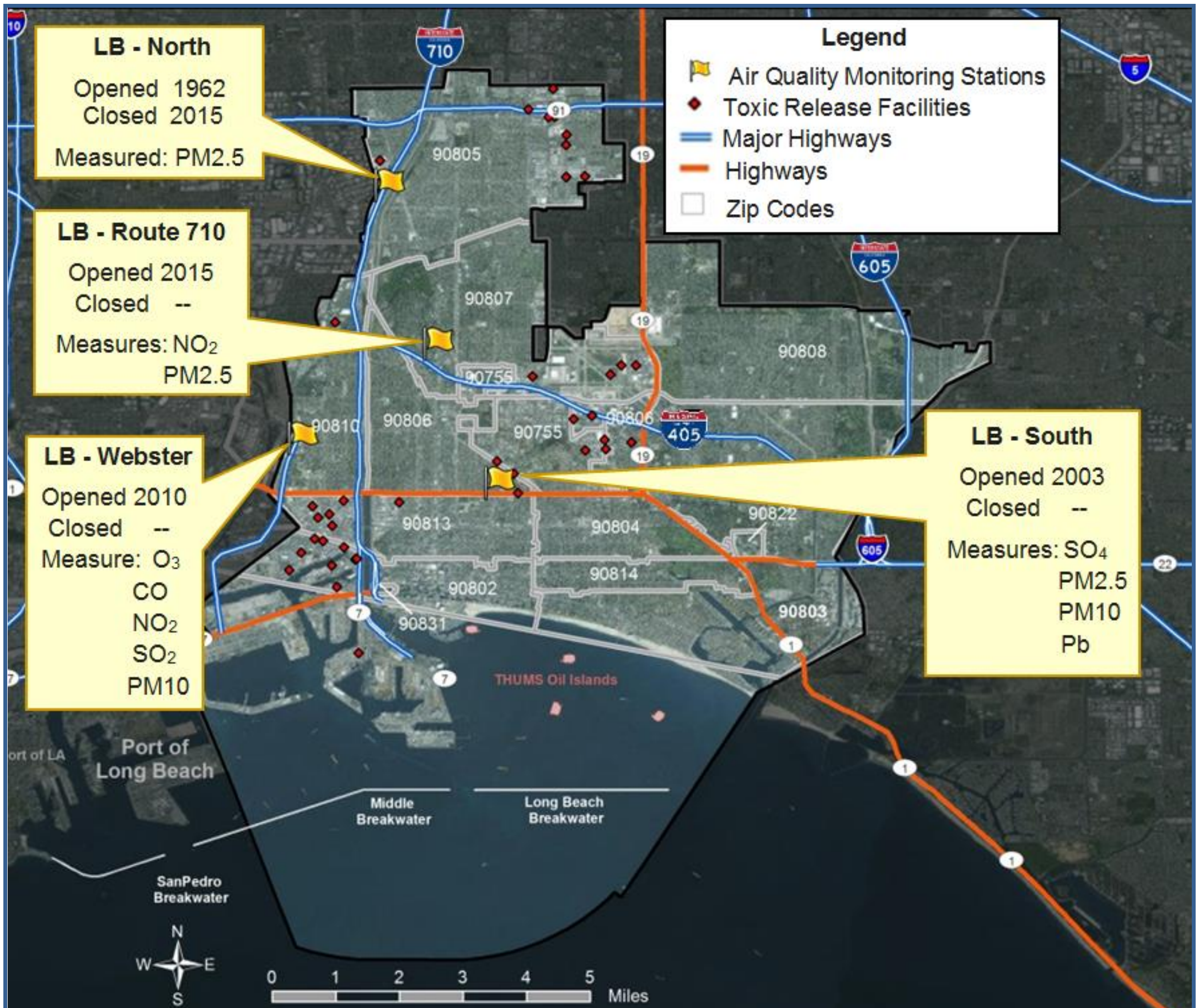


Figure 15. Map of the Long Beach area showing the locations of the Southern California Air Quality Management District (SCAQMD)'s four air quality monitoring stations (yellow flags), along with the locations of some of the factors contributing to air quality deterioration (such as highways and toxic air facilities).

In the last decade, the Port of Long Beach has taken steps to significantly improve the air quality of the region while still increasing economic activity and economic impact of its operations. Between 2005 to 2014, the Port had increased its container volume by 2% and lowered diesel particulate matter by 85%, nitrogen oxides by 50%, sulfur oxides by 97%, and greenhouse gas emissions by 21% (POLB 2014).

Of all the initiatives taken by the Ports the two with the most impact were the Green Port Policy and the Clean Air Action Plan (CAAP). The Green Port Policy, established in 2005, is a comprehensive guide to reduce the negative impacts of Port operations. Goals set for six program elements (wildlife, air, water, soils/sediments, community engagement, and sustainability) set the framework for an all-encompassing plan that includes several programs and activities each with its own principle, goal, metrics, and incentives (POLB 2005). Projects under this policy include, among others, investing $11.4 million towards the Bolsa Chica wetlands restoration project, the Technology Advancement Program (TAP) to identify emerging emission reduction technologies for the port industry, scholarships for local college students preparing for careers in international trade, and using green building principles in the design of all new buildings.

The CAAP is a joint sustainability strategy developed and followed by both the Port of Long Beach and the Port of Los Angeles in cooperation with the EPA, CARB, and SCAQMD. The plan was approved in 2006 and included significant target reductions by 2011 for particulate matters, nitrogen oxides, and sulfur oxides which were all met. Recent updates to the plan identify health-risk reduction goals through 2020 and emissions reduction goals through 2023 (CAAP 2010).

Ozone Pollution

While the Los Angeles-Long Beach region ranks the highest in ozone pollution in the country, Long Beach actually has some of the cleaner air in the Los Angeles basin. In 2014 Long Beach had no days in which the federal ozone standards were exceeded (ARB 2014). Most of the ozone in Long Beach results from a photochemical process whereby volatile organic compounds (VOCs) created from fossil fuel combustion reacts with oxides of nitrogen under the presence of sunlight. Ozone particles therefore are created only during the day, peak in the afternoon, and are elevated with higher temperatures (April to October). The photochemical process takes several hours. By the time it is completed the prevailing winds from the west travel east and pushes the smog up against the hills. As a result areas such as San Bernardino and Riverside receive the bulk of the smog. Ozone conditions can remain high within Long Beach during times of the Santa Ana winds or during wildfires that are close in proximity (2015 interview with Kevin Durkee, Senior Meteorologist at SCAQMD). The South Coast Basin had a total of 74 days in 2014 that were above the ozone 1-hour standard and 92 days above the 8-hour standard (**Table 5**). However Long Beach had zero days for both. The cities that suffered the most were the inland areas (such as Pomona, Santa Clarita, Crestline, etc).

EPA Concludes Ozone Pollution Poses Serious Health Threats

- Causes **Respiratory Harm** (*e.g. worsened asthma, worsened COPD, inflammation*)
- Likely to cause **Early Death** (*both short-term & long-term exposure*)
- Likely to cause **Cardiovascular Harm** (*e.g. heart attacks, strokes, heart disease, congestive heart failure*)
- May cause harm to the **Central Nervous System**
- May cause **Reproductive** and **Developmental** harm

— EPA (2013)

Table 5. Ozone Levels. *Note this data was obtained from the Air Resources Board.*

	CARB/SCAQMD Monitoring Stations	# Days Ozone Levels > State Levels based on 1-*hour* standard 2011	2012	2013	2014	# Days Ozone Levels > National '08 based on 8-*hour* standard 2011	2012	2013	2014
LA County	**LB - North**	**0**	**0**	**0**	*****	**0**	**0**	**0**	*****
LA County	**LB - Webster**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
LA County	LA - N Main St	0	0	0	3	0	1	0	2
LA County	LA - Westchester Parkway	0	1	1	1	0	0	1	3
LA County	Pomona	15	21	12	22	16	15	15	33
LA County	Santa Clara	31	45	30	32	31	57	40	45
LA County	WLA - VA Hospital	2	0	0	1	0	0	0	4
Crestline (San Bernardino County)		58	56	45	50	84	86	72	68
South Coast Air Basin		90	97	70	74	105	111	88	92

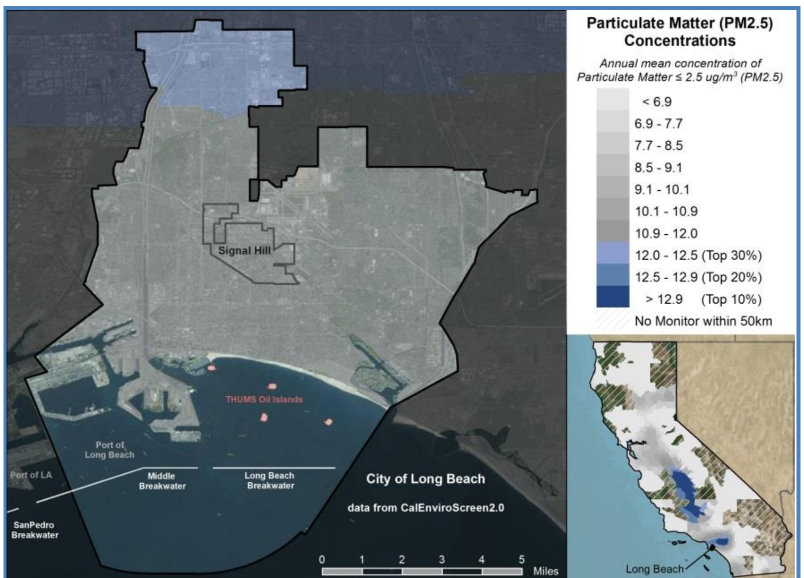
** insufficient (or no) data available to determine value*

Though ozone concentrations are less than in other Los Angeles areas, asthma rates in Long Beach are one of the highest in the state (UCLA 2013). The vulnerable populations who are at risk from breathing ozone include children and teens, those 65 and older, people who work or exercise outdoors, people with existing lung diseases (such as asthma and chronic obstructive pulmonary disease) and cardiovascular disease (State of the Air 2015).

Particulate Matter (PM2.5)

During the past decade parts of Long Beach experienced over 40% decrease in PM2.5, however the annual average still exceeded the California clean air standard (**Figure 16**). Some of this decline may be the result of the pollution control measures such as the Clean Air Action Plan diesel truck replacement program. The annual average is still above the state standard (**Table 6**), and increasing economic activity may contribute to higher PM2.5 emissions in coming years (van Meijgaard et al. 2012).

PM2.5, unlike ozone, can occur anytime of the day. The major sources of PM2.5 in the Long Beach region are nitrates (cars, trucks, and power plants) and carbon (formed from reactive organic gas emission from cars, trucks, industrial facilities, and biogenics) and the emissions can be primary (ports and freeways) or secondary (atmospheric reactions). PM2.5 is at their peak



PM2.5 Levels for the CLB			PM2.5 Levels for the State of CA		
Mean	Min	Max	Mean	Min	Max
11.475μg/m³	**10.690**μg/m³	12.209μg/m³	10.014μg/m³	2.303 μg/m³	17.044 μg/m³

Figure 16. Particulate Matter ≤ 2,5 μg/m³ (PM2.5). Red indicates High Values for the Long Beach area compared to the overall state values. *Note: this data is based on CalEnviroScreen 2.0 results (OEHHA2014)*

during rush hour and at night when the air is cooler and air is denser. PM2.5 is also higher during winter months when the air is denser and wood stove and fireplaces are more in use. PM2.5 concentrations were at their lowest levels in 2012 but since have risen slightly. The increase is attributed to conditions of drought and lack of storms which normally helps to dissipate the particles. The economy has also picked since then resulting is more economic activity.

Table 6. Particulate Matter ≤ 2,5 µg/m3 (PM2.5). *Note this data was obtained from the SCAQMD.*

SCAQMD Monitoring Stations	# Days PM2.5 > Federal Levels based on 24-hour standard 2011	2012	2013	2014	Annual. Average Conc. (AAM) µg/m³ 2011	2012	2013	2014
LB - South Coastal LA County 1	**1**	**4**	**2**	**2**	**11**	**10.37**	**11.95**	**11.42**
LB - South Coastal LA County 2	**3**	**4**	**1**	**2**	**10.7**	**10.57**	**10.97**	**10.72**
LB - South Coastal LA County 3	*	*	*	*	*	*	*	*
Central LA	4	4	1	6	13	12.55	11.95	12.36
East San Fernando Valley	5	2	4	2	13.2	12.17	12.15	12.08
South Central LA County	0	1	1	1	13	11.69	11.95	12.64
Mira Loma (Riverside County)	8	7	9	9	15.3	15.06	14.12	14.48
Southwest San Bernardino County	2	0	1	1	13.2	12.41	11.98	12.96
South Coast Air Basin	17	15	13	15	15.3	15.06	14.12	14.48

Vulnerable populations are infants, children, and teens; people over the age of 65; people with lung disease (such as asthma and chronic obstructive pulmonary disease), people with heart disease or diabetes; people with low incomes, and people who are active outdoors (State of the Air 2015).

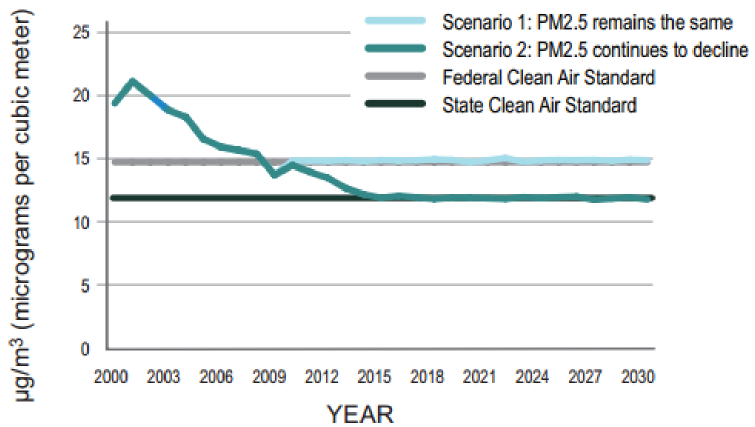
The UCLA Fielding School of Public Health in a 2012 study titled "Air Pollution and Community Health in Central Long Beach" examined various air quality scenarios for PM2.5 and the potential to improve health outcomes for Central Long Beach (van Meigaard et al. 2012). Over the course of a 20 year time horizon, they estimated the direct and indirect community-wide impact on health as a result of a reduction in PM2.5 which adequately met the California clean air standard. They investigated two forecasting scenarios. Scenario 1 assumed the levels of PM2.5 pollution remained the same as in 2010 using the average ambient level of PM2.5 of 14.9$\mu g/m^3$ till 2030. Scenario 2 assumed PM2.5 pollution fall to California's new clean air standard of 12 $\mu g/m^3$ by the year 2015 (**Figure 17**).

EPA Concludes Fine Particle Pollution Poses Serious Health Threats

- Causes **Early Death** (*both short-term & long-term exposure*)
- Causes **Cardiovascular Harm** (*e.g. heart attacks, strokes, heart disease, congestive heart failure*)
- Likely to cause **Respiratory Harm** (*e.g. worsened asthma, worsened COPD, inflammation*)
- May cause **Cancer**
- May cause **Reproductive** and **Developmental** harm

— EPA (2009)

Central Long Beach PM2.5 Air Quality Trends & Clean Air Standards for the years 2000-2030



The results showed that in Scenario 2 in central Long Beach in the next 20 years there would be:

- 190 fewer deaths
- 39,800 fewer days of work lost due to hazardous PM2.5 pollution on health, accumulating to approximately $7.6 million in lost wages
- 1,600 additional years of life

Figure 17. Central Long Beach PM2.5 Air Quality Trends & Clean Air Standards (van Meigaard et al. 2012)

Diesel Emissions

Diesel PM is the particle phase of diesel exhaust emitted from diesel engines such as trucks, buses, cars, trains, and heavy duty equipment. The AQMD estimates that more than 90% of diesel PM is one micron or smaller (AQMD 2014). Diesel PM includes known carcinogens, such as benzene and formaldehyde (Krivoshto et al. 2008) and as the particle size decreases, they have increasing potential to deposit in the lungs particularly those $0.1\mu m$ or smaller which are more biologically reactive (Betha & Balasubramanian 2013; Nemmar et al. 2007). In urban areas, diesel PM is a major component of the particulate air pollution from traffic (McCreanor et al. 2007). Diesel PM levels tend to be very dense within 300 meters of freeways because of diesel exhaust from trucks. Levels of diesel particulates are highest in the late fall and early winter, when stagnant atmospheric conditions allow the tiny specks to linger in the air.

AQMD's 2014 report on "Multiple Air Toxics Exposure Study in the South Coast Air Basin" using the MATES IV methodology found that on average diesel particulates contribute about 68% of the total air toxics risk.

The areas of the Los Angeles Basin that are exposed to the most risk continue to be those near the Ports of Los Angeles and Long Beach. A majority of the risk reduction resulted from a 66% reduction in diesel emissions from 2005 to 2012. The emissions reductions of benzene (11%), 1,3-butadiene (50%), arsenic (43%) and other air toxics also contribute to the overall reduction in 2012/2013 simulated risk. However with the projected future growth in goods movement, diesel source activity may increase. See also *CalEnviroScreen 2.0* Traffic Density values in **Appendix E**.

MATES IV found that diesel particulates emitted from diesel trucks and other diesel-powered vehicles and equipment were responsible for 68% of the total cancer risk (**Figure 18**). Fully 90% of the risk is due to mobile sources, which include everything from cars and trucks to ocean-going ships, locomotives, aircraft and construction equipment.

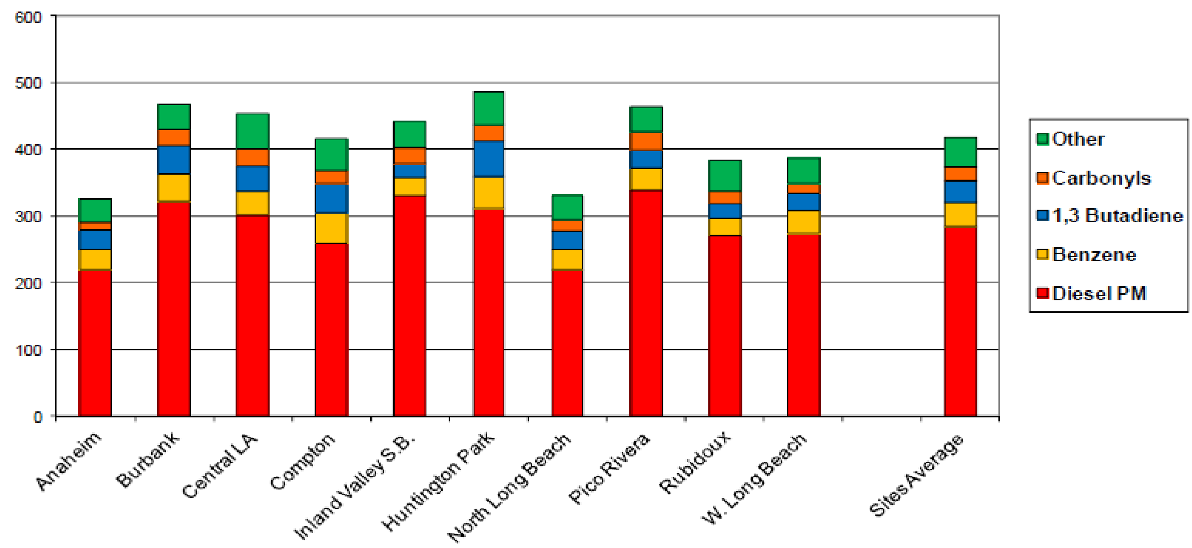
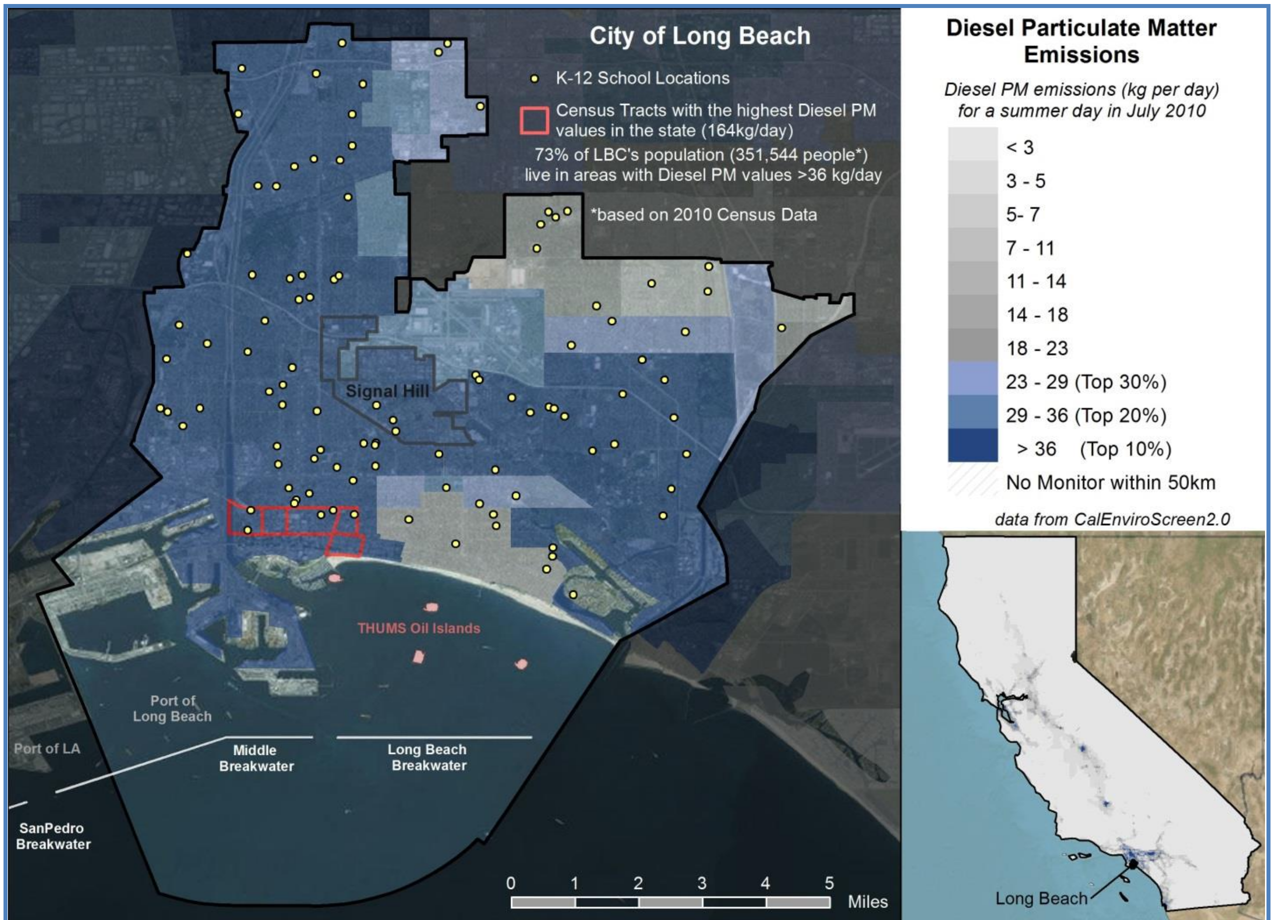


Figure 18. Air Toxics Risk per million people *(SCAQMD 2014)*

"Children and those with existing respiratory disease, particularly asthma, appear to be especially susceptible to the harmful effects of exposure to airborne PM from diesel exhaust, resulting in increased asthma symptoms and attacks along with decreases in lung function (McCreanor et al. 2007; Wargo 2002). " (OEHHA 2014, p28-29).

The South Coast Air Basin, a highly urbanized area that includes Long Beach, is home to over 17 million people who own and operate about 11 million motor vehicles. The Basin contains some of the highest concentrations of industrial and commercial operations in the country adversely contributing to poor environmental quality (SCAQMD 2014). The majority of Long Beach (73% of the population) live in areas with diesel particulate matter (Diesel PM) emission values greater than 36*kg/day*, which is higher than the Diesel PM values for 90% of California (**Figure 19**, OEHHA 2014).



DieselPM Levels for the CLB			DieselPM Levels for the State of CA		
Mean	Min	Max	Mean	Min	Max
51.630 *kg/day*	**6.51** *kg/day*	**164.4** *kg/day* *= State Max*	18.240 *kg/day*	0 *kg/day*	**164.4 *kg/day***

Figure 19. Diesel Particulate Matter (Diesel PM) Emissions by census tract for the Long Beach area compared to those of the entire state. Census tracts outlined in red have the highest Diesel PM emissions values in the state. To show how this may impact local youth, the locations of k-12 (kindergarten through high school) schools are depicted in yellow. Red indicates High Values for the Long Beach area compared to the overall state values. The majority of Long Beach (86 out of 116 total census tracts which is >75%) has diesel PM emissions >36 kg/day which is higher than 90% of California. The Census Tracks outlined in red have Diesel PM values equal to the state maximum (164.4 kg/day). *Note: the above maps are based on data from CalEnviroScreen 2 (OEHHA 2014)*

Plans and Efforts Currently Underway

- **Port of Long Beach Efforts**: The Port has made great strides to lower its emissions. Strategies include cleaner engines, engine retrofits, cleaner fuels, shorepower, through programs such as the Clean Air Action Plan, Green Flag Program, Technology Advancement Program, and the rest of the Green Port Policy. While the Port areas have the worst air quality, they have also had the greatest improvements. In addition, the Port also helps the community with programs such as *The Port Community Mitigation Grant*. The grant funds projects to address air pollution risks to vulnerable populations. By 2013 the Port had awarded $2.6 million to schools, parks, and clinics for projects such as health education for families with asthma, mobile medical clinics, and new air-filtering systems for classrooms (POLB 2015b). Most recently the Port awarded the City funds to launch an LED streetlight retrofit program to replace 1,750 intersection lights which would reduce greenhouse gas emissions and save in energy costs (Dulaney 2015).
- **Increasing Mobility**: Enhancing mobility is a priority for the City of Long Beach and some programs designed to reduce use of passenger vehicles are noted below:
  - ***Mobility Element Report*** of the City's General Plan which addresses all modes of travel and serves as a 20-year guide for future decision making to improve resident's quality of life, reduce air pollution, and improve transportation network (LBDS 2013).
  - ***Bicycle Master Plan*** which has allowed for significant increase in bike paths and facilities in efforts to decrease use of passenger vehicles. The Alliance for Biking & Walking in 2014 named Long Beach the third most bike friendly city in the U.S. Long Beach is home to 4.5 miles of biking facilities per square mile (Addison 2014).
  - Downtown and Transit-Oriented Development (TOD) ***Pedestrian Master Plan*** which will provide policies, guidelines, and standards for pedestrian design and infrastructure projects in the areas of downtown and between the Metro Blue Line stations in Long Beach (LBDS 2016b).
- **Green Space Initiatives**: The City of Long Beach has a goal to plant 10,000 trees in the City by 2020. To date they have planted 30% of their goal with trees selected from a plant palette that focuses on low water using, zero-VOC releasing trees. The City has increased their square footage of green space in the form of new and expanded parks resulting in 19.6 acres of additional open space since 2011 (2016 communication with Tom Modica, Assistant City Manager, CLB). A large park space planned for the future is the Green Terminal Island (TI) Freeway project which will transform the TI Freeway between Pacific Coast Highway to Willow Street into a 25 acre pedestrian-friendly park in the western area of the city that is deprived of valuable green space and is identified as a vulnerable population with a high pollution burden. A project to benefit the north-western part of Long Beach is the restoration of the 39 acre DeForest Park Wetlands which began in November 2015 (Rivera 2015). The City's overall goal according to the 2007 *Long Beach River Link* report, which they plan to update to include more recent efforts such as the *Los Angeles River Revitalization Master Plan* (Morris 2015), is to acquire 1,100 acres of additional open space particularly in the northern and western quadrants of Long Beach to their existing open space of approximately 2,900 acres (CLB 2007).

- **Complying with Regulations**: Long Beach, under the umbrella of the Gateway Council of Governments (Gateway COG), will be complying with AB 32 (Global Warming Solutions Act of 2006) which requires California to reduce its greenhouse gas emissions to 1990 levels by 2020. AB 32 is supported by SB 375 (Sustainable Communities and Climate Protection Act of 2008) which aims to reduce greenhouse gas emissions from cars and light trucks. Long Beach's participation in SB 375 is through the regional metropolitan planning agency—the Southern California Regional Council of Governments' (SCAG). Also Long Beach will be complying with the Carbon Target and Adaptation (California Executive Order B-30-15) which was issued in April 2015 and establishes a California greenhouse gas emission reduction target of 40 percent below 1990 levels by 2030 and 80 percent under 1990 levels by 2050 to meet or exceed IPCC's recommended limiting global warming to 2°*C* or less.

Additional Approaches to Consider

Long Beach should strengthen data collection with additional air quality stations throughout the City with sites that include: schools, hospitals, and transportation corridors such as the 405. Additional sites throughout the local region will ensure the most vulnerable areas are identified. Many of the existing stations provide insufficient data and need to be monitored more closely. There are very few studies that evaluate the air quality of Long Beach alone—most evaluate conditions within the Basin. The pollution levels of Long Beach are quite different (and better) than the average levels of the Basin, but it is hard to assess City conditions as there are no reports which study only the City's pollution levels. Additional monitoring sites, along with data on heat, drought, and economic activity specific to Long Beach would allow for forecasting of the changes in air quality as a result of climate change for this century.

- Comply with AQMD's Vision for Clean Air: A Framework for Air Quality and Climate Planning. The document focuses on strategies to meet California's air quality and climate goals for the future for mobile sources and associated energy productions including transitioning to zero and near-zero emission technologies to meet the 2023 and 2032 air quality standards.
- Inform and engage the public about the knowledge, progress, concerns, actions needed to prepare and safeguard against poor air quality. Develop comprehensive communications plan to implement during periods of high health risk for the vulnerable populations such as children, the elderly, and those who work outdoors.
- Seventy percent of air pollution in the region is related to mobile sources (per 2015 interview with Kevin Durkee, SCAQMD meteorologist). While there are many initiatives in place to promote mobility, more efforts need to be made to get people out of their cars and into public transportation or to use alternative transportation methods. Newer, more efficient emission standards will improve air quality and the Ports' efforts to promote zero-emissions freight transport systems will help.

Summary

The improvements of air quality in the Southern California region are one of the great environmental success stories of the U.S. It is proof that with effective regulations, cooperation among agencies, and assistance from environmental and research communities, positive changes in the environment can be made. Despite this success, the Los Angeles-Long Beach region is still ranked as one of the most polluted metropolitan regions in the nation. The City of Long Beach fares better than most cities within this region in terms of ozone and particulate matter emissions as a result of geography and weather patterns, but in the last few years there were still some "non-attainment days," days that exceeded state and federal air quality standards.

While ozone levels are good in Long Beach and the emissions do not linger within the geographic region, the City, its Port, and transportation corridors are responsible for much of the pollution. In terms of PM2.5 and diesel PM **Table 7** shows that the mean values are near state and federal standards on a regular basis and therefore need additional control measures.

Table 7. Estimated air pollution levels measured between 2009 and 2011 (Diesel PM was only measured in 2010) throughout the state of California. Red indicates areas where Long Beach levels ≥ State-wide levels.
Note: the data provided in this table is based on CalEnviroScreen 2.0's results (OEHHA 2014)

Exposure Indicators	**California**			**City of Long Beach** (inc.Signal Hill)		
	Mean	Min	Max	Mean	Min	Max
Ozone concentration *Amount of the daily max 8hr ozone concentration over the CA 8hour standard (0.070ppm), averaged over 3 yrs (**2009-2011**)*	0.104 *ppm* over CA limit = 0.174 *ppm Total*	0 *ppm* over CA limit ≤ 0.070 *ppm Total*	1.277 *ppm* over CA limit = 1.347 *ppm Total*	0.0003 *ppm* over CA limit = 0.0703 *ppm Total*	0 *ppm* over CA limit ≤ 0.070 *ppm Total*	0.00289 *ppm* over CA limit = 0.0729 *ppm Total*
Particulate Matter (PM 2.5) *PM2.5 **annual mean** monitoring data for was extracted all monitoring sites in California from CARB's air monitoring network database for the years **2009-2011**. Note: the US Ambient PM2.5 standard is 12 $\mu g/m^3$*	10.014 $\mu g/m^3$	2.303 $\mu g/m^3$	17.044 $\mu g/m^3$	**11.475** $\mu g/m^3$	**10.690** $\mu g/m^3$	12.209 $\mu g/m^3$
Diesel PM Emissions *Diesel PM emissions from on-road & non-road sources for a day in **July 2010** (kg/day)*	18.240 *kg/day*	0 *kg/day*	***164.4 kg/day***	**51.630** *kg/day*	**6.51** *kg/day*	**164.4** *kg/day = State Max*

The effects of climate change on air quality have not been studied broadly. It is thought that with higher temperatures, persistent drought conditions, increased economic activity, and higher populations, the air quality will deteriorate in the future compared to current conditions.

Public Health and Social Vulnerability

As stated by Dr. Jonathan Fielding (former director of the LA County Department of Public Health), "Climate change is arguably the biggest health threat of this century" (CADrought 2014).

"Public health" has two generally accepted meanings; the term refers to the health of a population as a whole, and to the science of protecting and improving the health of families and communities through promotion of healthy lifestyles, research for disease and injury prevention, and detection and control of infectious diseases (CDC 2015). "Social vulnerability" refers to the socioeconomic and demographic factors that affect the resilience of communities. Studies include socioeconomic characteristics in order to better understand and communicate climate change impacts on health.

The impacts on human health by earth warming and a changing climate can be deadly, and include direct and indirect effects (**Figure 20**). Direct effects include injury and increased morbidity resulting from an increase in the frequency and intensity of hot days and flooding. Indirect effects include chronic health conditions exacerbated by deteriorating air, water, and food quality (Rudolph et al. 2015).

The poor, elderly (especially those who are socially isolated), the very young, homeless, and those with compromised health are most vulnerable to the impacts of climate change. Along with mitigation efforts, adaptation awareness among these groups is critical to becoming and sustaining a climate resilient city (Rudolph et al. 2015).

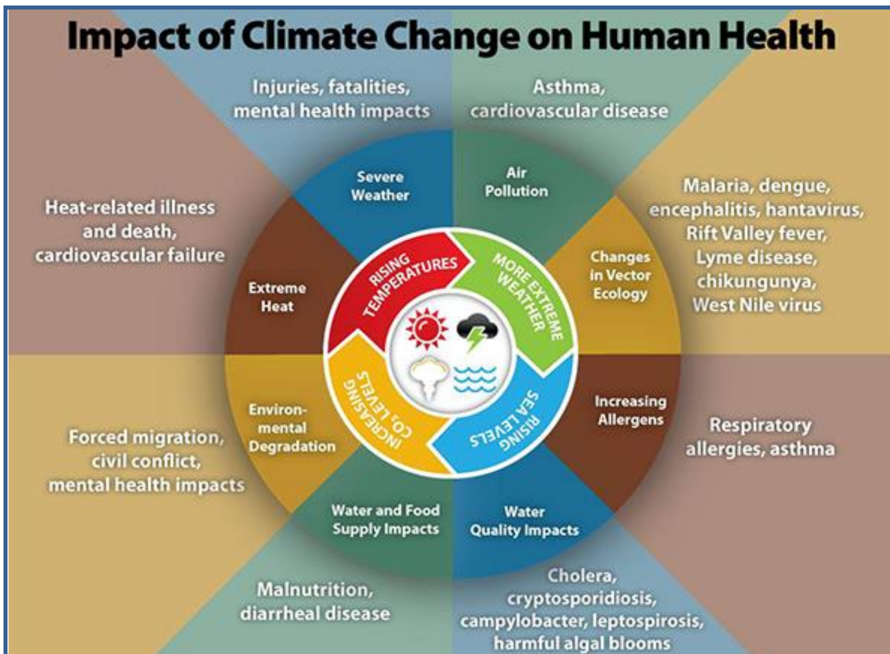


Figure 20. Impacts of Climate Change on Human Health.
Note: this graphic was taken directly from CDC (2015).

The California Department of Public Health (CDPH) summarized the negative health effects of climate change for people in California in **Table 8** (CDPH 2012).

Table 8. **Human Health Effects of Climate Change in California**. The climate change impact categories are listed in the order that they appear in this report, for consistency, not necessarily in the order of importance. In addition, two of the impact categories form CDPH (2012)'s report, Wildfires and Agriculture, were omitted from this table because while they are important issues for the state of California, they are less important to the Long Beach area. *Note: The content in this table was adapted from the table on page 9 of CDPH 2012.*

Climate Change Impacts	Human Health Impacts	Populations Most Affected
Drought	• Hunger and malnutrition caused by disruption in food and water supply, increased cost and conflict over food and water • Food- and water-borne disease • Emergence of new contagious and vector-borne disease	• Low income • Children & the Elderly
Extreme Heat & Increased Average Temperature	• Premature death • Cardiovascular stress and failure • Cardiovascular disease • Heat-related illnesses such as heat stroke, heat exhaustion, and kidney stones Increased number and range of: - Vector-borne diseases (West Nile virus, malaria, etc.) - Water-borne disease, such as cholera and *E. coli* - Food-borne disease, such as *salmonella* poisoning - Harmful algal blooms causing skin disease & poisoning - Allergies caused by pollen, and rashes from plants (such as poison ivy or stinging nettle) - Vulnerability to wildfires and air pollution	• Children & the Elderly • Diabetics • People with respiratory disease • Agricultural workers • Those active outdoors • Poor, urban residents • People with acute allergies
Sea Level Rise, Severe Weather, Extreme Rainfall, Floods, and Water Issues	• Population displacement, loss of home and livelihood • Death from drowning • Injuries • Damage to potable water, wastewater, and irrigation systems, resulting in decrease in quality/quantity of water supply and disruption to agriculture • Water- and food-borne diseases from sewage overflow	• Coastal residents • Residents in flood-prone areas • Children & the Elderly • Low income
Poor Air Quality & Air Pollution	• Increased asthma, allergies, chronic obstructive pulmonary disease (COPD), and other cardiovascular and respiratory diseases	• Children & the Elderly • People with respiratory diseases • Low income • Those active outdoors
All Impacts	**Mental health disorders** (e.g., depression, anxiety, Post-Traumatic Stress Disorder, substance abuse, and other conditions) caused by: - Disruption, displacement, and migration - Loss of home, lives, and livelihood **Health Care impacts**: - Increased rates of illness and disease, emergency room use, and related costs borne by employers, health plans, and residents - Damage to health facilities	• All populations • Low income • Health care staff

Regional Impacts

Climate change has had some effects on public health, and those effects will only grow as we experience more of the impacts of climate change the deeper we go into this century.

During drought conditions, food production reductions impact population health via malnutrition (see **Figure 20** and **Table 8**; CDC 2015; CDPH 2012) and malnutrition increases susceptibility to infection and other illness. Additionally, related crises can trigger a collapse in food supply systems. In times of shortage, water is used for cooking rather than hygiene, increasing the risk of fecal contamination of food and utensils. Outbreaks of malaria can occur due to changes in vector breeding sites (Hales et al. 2003).

Heat is far and away the greatest cause of weather-related death in the U.S. and in the world (Berko et al. 2014). The average fatality count over 30 years indicates that there have been more U.S. deaths from heat than deaths from natural disasters such as earthquakes, volcanic eruptions, floods, blizzards, etc. (NWS 2014, 2015b, 2016). The impact of heat was also cited as the primary health concern by both County and City government staff per interviews with members of both. Every degree increase in temperature adds about 500 megawatts to the air conditioning load in the Los Angeles Basin (Akbari 2005).

The urban heat island (UHI) effect is the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island." UHI is exacerbated by a lack of vegetation and the proliferation of impervious surfaces. The UHI effect contributes to significantly higher daytime and nighttime temperatures in Los Angeles (called "downtown temperatures" in nightly weather reports on television) than in surrounding rural areas (**Figure 21**). Recent research has indicated that the Los Angeles area has the greatest urban heat island effect in the state of California (Totten 2015).

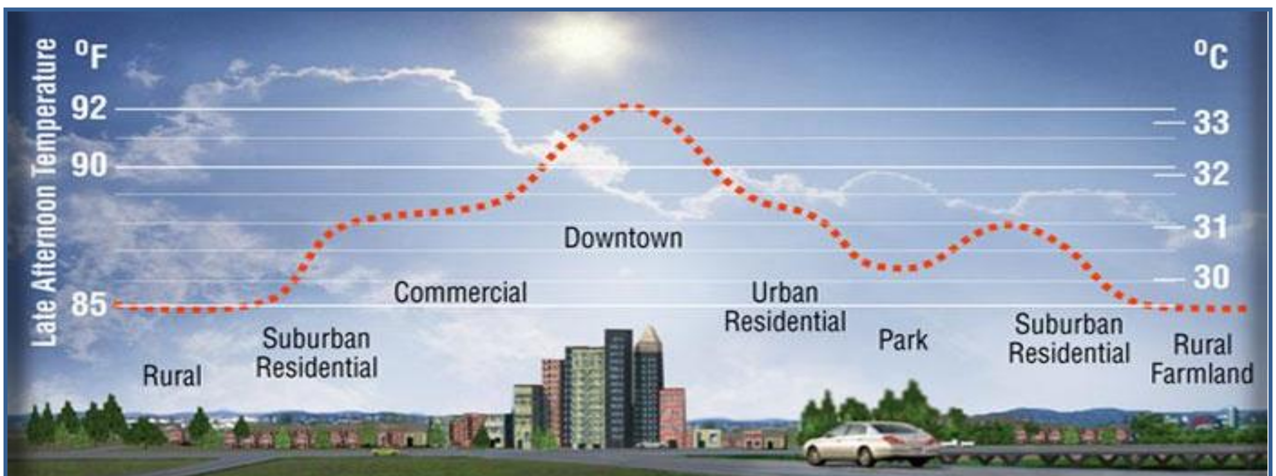


Figure 21. Urban Heat Island (graphic taken directly from Berkley's Heat Island Group, *https://heatisland.lbl.gov/*).

The number of heat-related deaths is expected to increase as the frequency, intensity and duration of hot spells increases (Davis et al. 2003). As explored in the **Extreme Heat** section of this report, modeling data predict a rise in heat, hot days, and heat-related deaths. These predictions are not an inevitable outcome of climate change; they can be tempered by resiliency efforts.

Poor air quality is linked to long-term damage to the respiratory and cardiovascular systems, as well as cancer and premature death (EPA 2015b). Organic gases and nitrogen oxides contribute to regional haze and smog while also reacting with sunlight to form ozone, a risk factor for respiratory illness (EPA 2015b). These pollutants cause an estimated 8,800 deaths in California every year and over a billion dollars per year in health care costs (UHF 2015). Vulnerable populations are often times located in regions with the worst air quality. Decreasing air pollution is an important step in creating a healthy environment.

The public health community can play a critical role in communicating the impacts of climate change on the health of its citizens. The Los Angeles County Department of Public Health (LADPH) serves the entire Los Angeles County area, except for the three cities that provide their own health services. One of those three cities is Long Beach, through its Department of Health and Human Services (HHS).

Impacts on Long Beach

Drought will have ongoing direct health effects as California continues to experience historic drought conditions. Long Beach has already seen an increase in food costs and water rationing. An additional threat to public health is Impaired Water Bodies, as defined and mapped by the California Water Resources Board and approved by the Environmental Protection Agency. The designated water bodies contain unsafe levels of pollutants that cannot be used as potable water in times of shortage.

With high temperatures and humidity, people may develop heat-related conditions such as cramps, exhaustion, or heat stroke (where the core temperature of the body reaches 105°*F* or higher). Especially susceptible are individuals working outside or participating in outdoor activities, the elderly, those with chronic illnesses, infants and young children, athletes, the homeless, low-income residents and residents without air conditioning, as well as people residing in areas with minimal tree canopy and/or vegetation (LARC 2015).

The EPA recommends a target risk level between 1 to 100 cancer cases per million over a life-long exposure of 70 years, in which the number of cases is dependent on the level of pollution a population is exposed to with one case representing an unexposed population (CEPA 2001; EPA 1996; Niemi 2013). The highest cancer risk, about 1,050 in 1 million, was detected in and around the ports of Los Angeles and Long Beach, a magnet for thousands of pollution-belching diesel trucks, ships and locomotives (Barboza 2014; see **Figure 22** and **Table 9**). Central Los Angeles and communities near freeways and rail lines also had some of the region's highest risks

(Barboza 2014). However, according to Julia Heck (an assistant professor of epidemiology at UCLA's Fielding School of Public Health) the number of actual cancer cases attributed to air pollution is small relative to other causes such as tobacco and alcohol use (Barboza 2014).

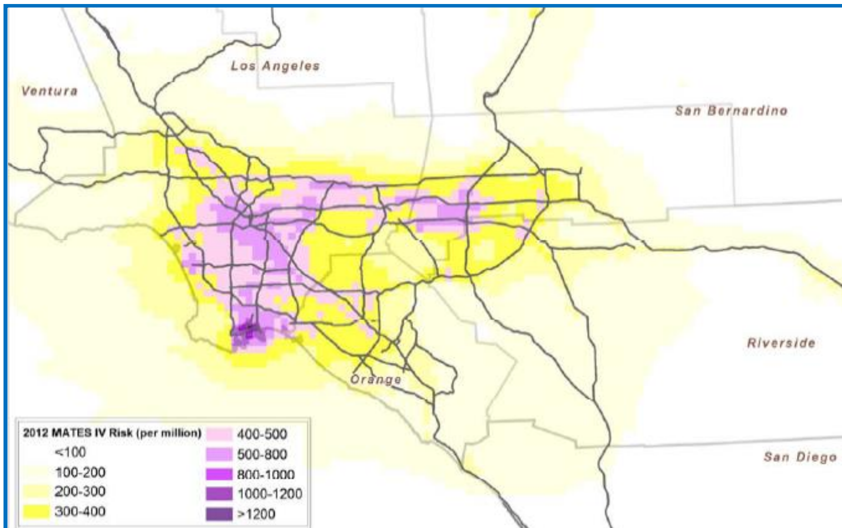


Figure 22. Simulated Toxic Air Cancer Risk for the Ports area in 2012, based on MATES IV. *Note this figure was taken directly from SCAQMD (2014)'s Figure 4-12.*

Table 9. Basin and Ports area population-weighted cancer risk, based on MATES IV. *Note: this table was adapted from SCAQMD (2014)'s Table 4-4.*

Region	2012 Population (average risk per million)
Basin	15,991,150 (367)
Ports Area	998,745 (480)
Basin (w/o ports)	14,992,806 (359)

Approximately 300 acres of joint-use open space including 330,000 trees in parks, sidewalks, and urban forest exists in Long Beach. Long Beach's green space varies greatly by zip code (CLB 2010). East and Southeast (coastal) Long Beach has a significantly higher number of protected areas per person while the entire North and West parts of Long Beach have significantly fewer green spaces (CLB 2013). This lack of green space coupled with the population growth that has occurred in the North, West Central and Southwest sections of the City makes access to recreational open space problematic for much of the youth population in these areas, and adds to the UHI effect (CLB 2013). According to the City's 2007 *Long Beach River Link* report the goal of the City is to provide 8.0 acres of recreational open space per 1,000 residents. To achieve this, the City has a goal to acquire approximately 1,100 acres to its existing inventory of approximately 2,900 acres of green open space.

Asthma and lung cancer are worsened by the poor air quality of many areas of Long Beach (**Figure 23**). According to the Long Beach Alliance for Children with Asthma (LBACA 2015), 15% of Long Beach children suffer from asthma, compared to 9% of children across the nation (LBACA 2015). In addition, recent studies by scientists at the University of Southern California's Keck School of Medicine, found that children living close to freeways have a two-fold increase in risk for asthma. Teens growing up in southern California communities with high rates of pollution from traffic have a five-fold risk of experiencing reduced lung function. Nurses in the Long Beach Unified School District report that asthma is the leading cause of missed school days. In 2000, the latest period for available information, there were 879 hospital days and 1,254 emergency room visits due to asthma for children under the age of 18. The average cost of hospitalization for a child with asthma on Medi-Cal is $12,395.

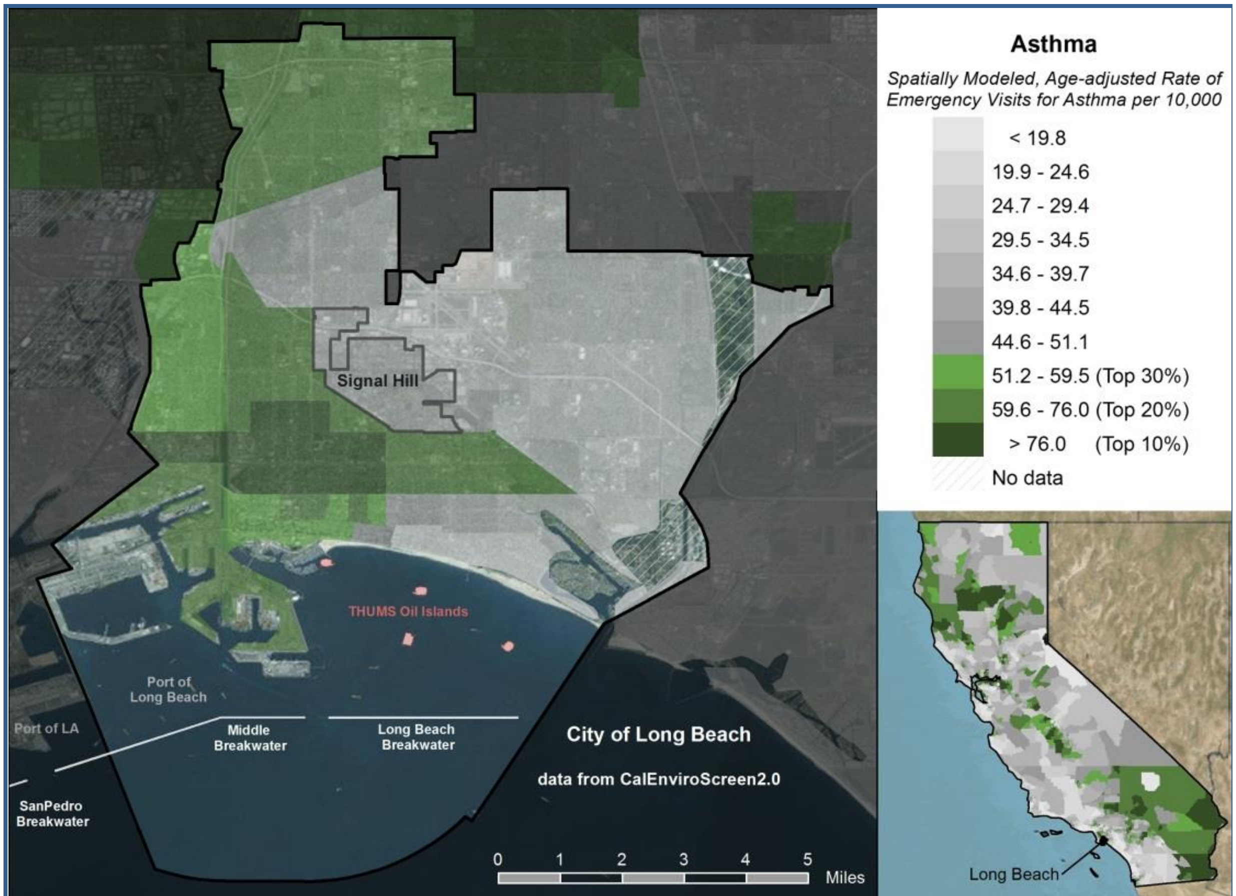


Figure 23. Asthma rates by census tract for the Long Beach area compared to those of the entire state. *Note: the above maps are based on data from CalEnviroScreen 2.0 (OEHHA 2014).*

Long Beach consists of a higher percent of individuals living in poverty (19.1%) than either Los Angeles County or the State of California (15.7% and 13.7%, respectively), raising the potential number of people at risk (CLB 2013). The 2015 census of Long Beach homeless individuals counted 2,345 people, 926 chronically homeless persons, and 255 homeless children (Bradley 2015b). While all counts were down from 2012 numbers, this still remains a vulnerable population to be included when reaching out with climate change adaptation messages.

This report uses *CalEnviroScreen 2.0* as a tool to identify areas of Long Beach that are most susceptible to pollution and its adverse effects, and to identify the areas with increased social vulnerability. The purpose of this tool is to see how certain regions compare to the rest of the state, in terms of exposure to various environmental risks and the underlying vulnerability of the local communities (OEHHA 2014). *CalEnviroScreen* creates a "total score" for each census tract in California by first identifying and calculating the *Pollution Burdens* (**Figure 24A**) and underlying *Population Characteristics* (**Figure 24B**) of each census tract.

- **Pollution Burdens**: the potential degree of exposures to pollutants and the adverse environmental conditions caused by pollution. Total Pollution Burden scores are calculated as the average percentiles of seven Exposures Indicators (ozone and PM2.5 concentrations, diesel PM emissions, pesticide use, toxic releases from facilities, traffic density, and drinking water contaminants); and five Environmental Effects Indicators (cleanup sites, impaired water bodies, groundwater threats, hazardous waste facilities and generators, and solid waste sites and facilities). The results of each of the 12 indicators used to calculate the Total Pollution Burden Score are provided in **Appendix E** (pages **E6-E17**).

- **Population Characteristics**: biological traits, health status, or community characteristics that can result in increased vulnerability to pollution. Total Population Characteristic Scores are calculated as the average percentiles of three Sensitive Population Indicators (high-risk age groups, asthma, and low birth weights) and four Socioeconomic Factor Indicators (high school education attainment, linguistic isolation, poverty, and unemployment). The results of each of the 7 indicators used to calculate the Total Population Characteristics Score are provided in **Appendix E** (pages **E18-E24**).

Once calculated the *Total Pollution Burden Scores* (**Figure 24A**) are multiplied by the *Total Population Characteristics Scores* (**Figure 24B**) to get the *Total CalEnviroScreen* (CES) Score (**Figure 24C**) for each census tract in the state. For the Long Beach area, the map of the Total CES Scores closely resembles the map of the Total Population Characteristics Scores, indicating that the disadvantaged communities in west-central and northern Long Beach (areas with high population characteristic scores are depicted in shades of orange to red in **Figure 24B**) are disproportionately more vulnerable to the risks associated with pollution and climate change (areas with high pollution burden scores are depicted in shades of orange to red in **Figure 24A**).

While the *CalEnviroScreen* tool is currently the strongest tool available to quantify exposure to pollutants and their adverse effects, and identify those areas with populations that are more sensitive to these effects due to their underlying social vulnerabilities; the tool has much room for improvement. Based on the design on the tool, data must be available for all census tracts in California in order to be used. For this reason, many types of pollution and community data could not be used because it was not available for the entire state. Therefore, it is our opinion that the *CalEnviroScreen* tool should be used in much the same way as the *CoSMoS 3* model results; the output provides a robust foundation and means of comparison to the surrounding areas. Adding additional environmental, health, and sociologic data would further strengthen these results.

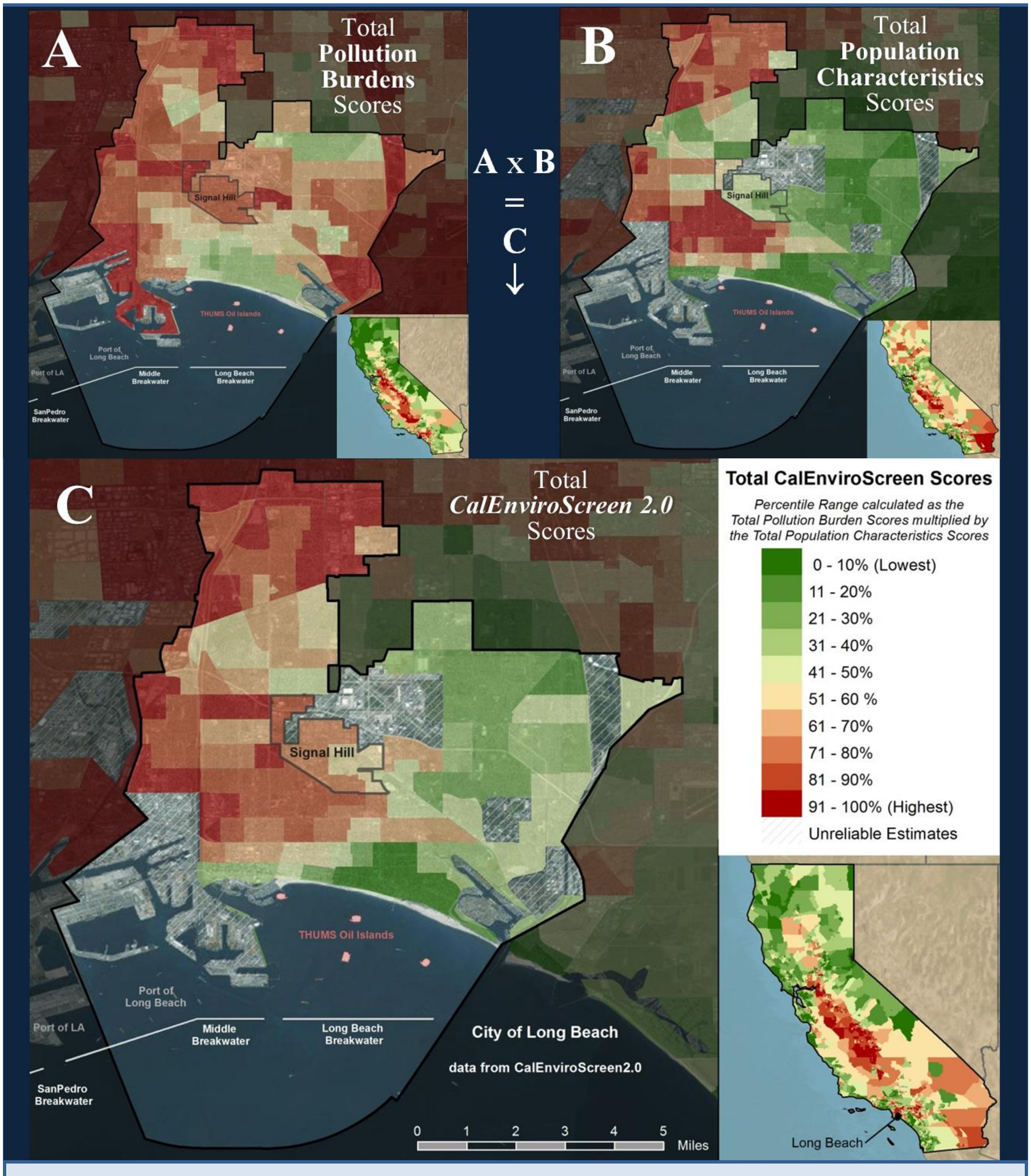


Figure 24. *CalEnviroScreen 2.0* scores for census tracts across California. (**A**) **Total Pollution Burden Scores**, based on the average percentiles of 7 Exposure Indicators (Ozone Concentrations, Particulate Matter $\leq 2.5\mu m/m^3$, Diesel PM Emissions, Pesticide Use, Toxic Releases, Traffic Density, and Drinking Water Contaminants) and 5 Environmental Effects Indicators (Cleanup Sites, Groundwater Threats, Hazardous Waste, Impaired Water Bodies, and Solid Waste). (**B**) **Total Population Characteristics Scores**, based on the average percentiles of 3 Sensitive Population Indicators (High Risk Age Groups, Asthma, and Low Birth Weights) and 4 Socioeconomic Factor Indicators (High School Education, Linguistic Isolation, Poverty, and Unemployment). (**C**) **Total CalEnviroScreen Scores**, based on the percentile range of the Total Pollution Burden Scores multiplied by the Total Population Scores. *Note: the above maps are based on data from CalEnviroScreen 2.0 (OEHHA 2014)*

Plans and Efforts Currently Underway

According to the 2013 CALGreen Building Code, the City has enforced measures to reduce the heat island effect by using alternative hardscape materials, providing shade, high-albedo materials, and construction of green roofs and cool roofs (CALGreen 2013). These enforcements have not been mapped and evaluated to determine their positive effects. The map below (**Figure 25**) was developed by Berkeley Lab Heat Island Group, displays the roof albedo (solar reflectance) estimates for Long Beach which has an average roof albedo of about 0.18. Mapping of the urban heat island effect, which should include data on the microclimates within the City, would be helpful in identifying those areas which are warmer and therefore need additional mitigation efforts.

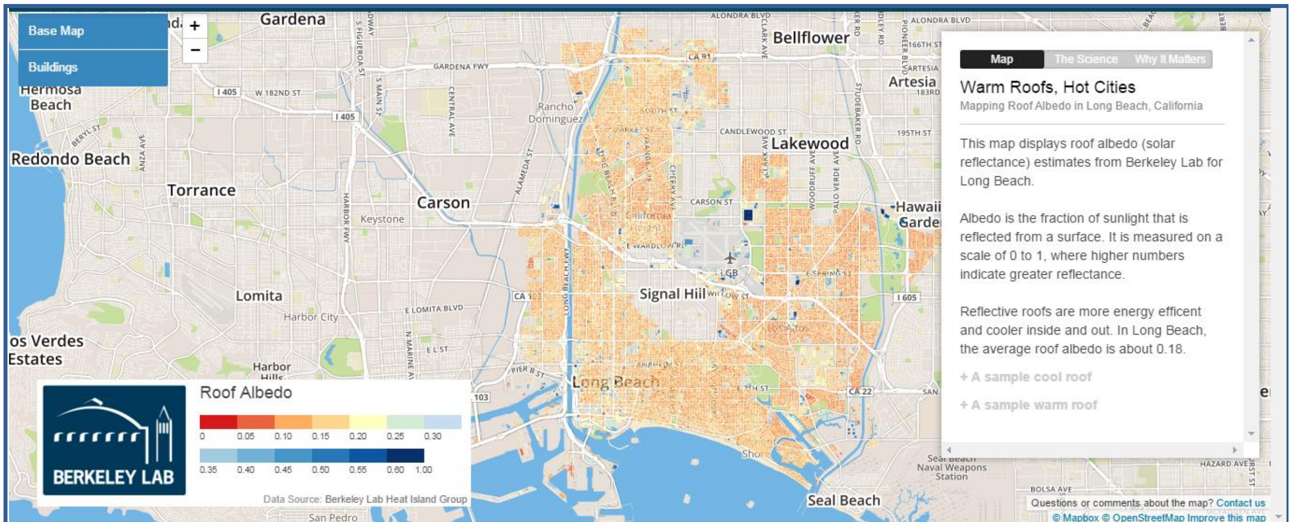


Figure 25. Roof Albeto for Long Beach, mapped by the Berkeley Lab's Heat Island Group and available online at: *http://albedomap.lbl.gov/longbeach.html*.

In an attempt to improve the canopy of trees in the urban setting, Long Beach has undertaken a tree planting project. It has resulted in 3,200 trees being planted, with another 4,000 available to be planted. As these trees mature, the canopy will be denser, and the process of photosynthesis from them will help reduce carbon emissions as well, contributing to better air quality. The addition of trees should also reduce the urban heat island effect by increasing the ratio of vegetation and tree canopy to impervious, artificial surfaces. The City has a goal of planting at least 10,000 trees in Long Beach by 2020 (interviews with Larry Rich regarding the CLB 2005 Sustainability Plan). Additionally, as noted under Air Quality, since 2011, the City has added 13 new parks and expanded 3 existing parks for a total of 19.6 acres of new open space (2016 communication with Tom Modica, Assistant City Manager, CLB).

The City has targeted programs to assist residents in the vulnerable and underserved communities of Long Beach. In North Long Beach, the *HEAL Zone* initiative encourages residents of the area to walk, bike, and make healthier choices for their lives to prevent diseases such as diabetes and heart disease (CLB 2015e). For West Long Beach, the City has developed the *Livable West Long Beach* implementation plan (LBDS 2015) to improve the quality of life for those communities which receive a disproportionate impact from nearby port activities. The implementation plan, with input from the communities, reviewed and prioritized the livability projects revealing air quality and health to be some of the top concerns. The plan also looks at funding mechanisms for the implementation of the projects identified.

As mentioned previously in the **Extreme Heat** section of this report, the City of Long Beach's Department of Health and Human Services advises individuals to seek air-conditioned environments during peak heat, and recommends such sites as stores, malls, libraries, park centers, and theaters. Long Beach also uses city facilities as cooling centers and available hours when necessary. Meeting the targets of California's Carbon Target and Adaptation plan (California Executive Order B-30-15) will help mitigate the impacts of climate change while creating an environment conducive to adaptation behavior modifications throughout the community.

Table 10 provides some recommended strategies for reducing GHG emissions from the California Department of Public Health (CDPH).

Table 10. List of strategies for Reducing Greenhouse Gas (GHG) Emissions.
Note: the following content was adapted from the table provided on page 6 of CDPH 2012.

Strategy for Reducing GHG Emissions	Potential Health Co-Benefits
Reduce Vehicle Miles Traveled	- Increase physical activity - Reduce chronic disease - Improve mental health - Reduce air pollution
Reduce Emissions through Land Use Changes	- Increase physical activity - Reduce chronic disease - Increase local access to essential services (affordable housing, jobs, amenities) - Enhance safety
Reduce Energy Use in Residential Buildings	- Reduce household energy costs (especially for low-income households) - Promote healthy homes - Create local green jobs - Promote cooler communities (e.g., white roofs)
Urban Greening	- Reduce temperature and urban heat island health effects - Reduce air pollution - Reduce noise - Enhance safety
Reduce Energy Intensity in Local Food Systems - Reduce food miles traveled - Promote local agriculture - Encourage less meat consumption - Expand farmer's markets and community/ backyard gardens	- Increase access to healthy, fresh foods - Reduce cardiovascular disease due to saturated fats - Reduce air pollution - Increase local social cohesion - Increase resilience

Additional Approaches to Consider

Describing climate change in terms of health issues and identifying the health benefits of both mitigation and adaptation behaviors is a compelling way to engage the public in climate change resiliency efforts, and should be part of every climate action plan (**Table 11**).

Table 11. **California Department of Public Health (CDPH)'s "Checklist for Integrating Health into Climate Action Planning**." This checklist is designed to help integrate public health into the following stages of climate action planning (CAP): scoping, development, implementation, monitoring progress, and updates. At each stage, local health impacts can be embedded into CAP strategies. Ideally, each jurisdiction would discuss these suggestions with local health partners. *Note: this list was adapted from one provided on page 13 pf CDPH 2012.*
☐ Meet with local health department staff about CAP planning process and implementation
☐ Invite public health and other local health organizations to participate in CAP development and coordinate and collaborate on implementation. Local health partners include hospitals, clinics, Health Plans, the County Medical Society, American Lung Association local chapters, and community health organizations, many of whom are becoming more involved in land use, transportation, and climate and health issues.
☐ Make sure local policymakers understand the health and climate change connections and how these can be part of the overall CAP
☐ Identify and include health goals and co-benefits in a Request for Proposals for consultants, to ensure that health impacts will be integrated in the planning process early on.
☐ Identify relevant local health data and indicators for use in the CAP.
☐ Identify health co-benefits that resonate most with the community's goals to ensure the CAP addresses the unique needs and interests of the local population.
☐ Identify public health co-benefits and potential adverse health consequences early in the screening, development, or implementation phases of the CAP. Health partners may be able to help with this analysis. For any identified negative consequences that may be associated with the CAP, have a clear plan for mitigating or preventing these consequences.
☐ Identify health co-benefits that resonate most with the community's conditions and goals to ensure the CAP addresses the unique needs and interests of the local community.
☐ Include climate change and health information as part of community outreach and engagement during the development, adoption, and implementation phases. Identify health partners who can help with outreach, education, and communication strategies.
☐ As part of evaluation and reporting on CAP progress, make sure that health outcomes are included and measured. Health partners may be able to help with this.
☐ When reporting progress to elected officials, media, partners, and residents, make sure to reinforce the human welfare, equity, and health benefits of measures to reduce GHG and strengthen community readiness.

Summary

Creating a healthy environment is a critical step in creating a resilient city. While caring for its citizens at the basic level, studying and planning for changes to the greater impacts that climate change threatens to bring to public health should be an overarching priority for City leaders. Bringing the Long Beach community together to discuss relevant issues and begin the search for solutions should be accomplished as quickly as possible. Acting on prioritized options ought to begin soon thereafter. In the case of public health, it is a matter of life and death.

Part 3: Building Climate Resilient Communities

Anthropogenic climate change has been well-documented for decades, but mitigation, adaptation, and resilience strategies to address climate risks have only recently become priorities for communities on a large scale. Because climate change impacts are heterogeneous by nature, effective resilience strategies require local communities to understand these impacts and respond accordingly. In 2015 the city of Long Beach joined a coalition of cities around the world committed to combating and adapting to climate change. The Aquarium of the Pacific will support city-wide efforts through education and engagement of leaders representing a cross-section of Long Beach's diverse communities to create experiences that cultivate a shared value of resilience.

The Aquarium will host a series of workshops designed to bring together the area's most active leaders and experts in climate and social sciences to learn, discuss, and plan for a future environment that is prepared for all the risks that climate change poses. Core elements of these workshops will include: (1) understanding the science of a changing climate; (2) identifying specific vulnerabilities and needs; and (3) providing a forum for leaders to discuss solutions. The Aquarium will also provide sustained support for participating leaders to communicate the complexities of climate science and adaptation to their communities. This approach is purposefully iterative and responsive; the Aquarium, is a trusted source for climate science for the foremost leaders in each group. These collective efforts will inform the development of a few potential broader outreach initiatives to elevate climate literacy: a city-wide media campaign and public outreach at district open house events hosted by the Aquarium.

Setting the Stage

NOAA defines resilience as "the capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption" (Climate Resilience Toolkit 2015). As the threat of climate change has become a reality, cities across the United States are starting to take steps to prepare their citizens. The City of Long Beach is poised to expand its efforts to address this problem and take action to build an adaptive and resilient city.

In November 2015, Long Beach signed on to the Compact of Mayors. This three-year program is a coalition of mayors and city officials from across the globe committed to assessing and reducing carbon emissions, addressing vulnerabilities, and creating plans of adaptation and mitigation (CLB 2015d). Long Beach Mayor Robert Garcia has enlisted the Aquarium of the Pacific to reach out to the diverse communities of Long Beach through public education and outreach. As members of the Long Beach community, the Aquarium's leadership understands the importance of tackling climate change and has a responsibility to help prepare people for a changing future.

Preparing and planning for these types of risks presented by climate change starts with building environmental literacy. Educating the public on the science behind climate change and how to build resilience to the changing climate will enable Long Beach communities to prepare for future climate disruptions. A report by the National Research Council (NRC) summarized the need as follows:

> Because no single entity can deliver the complete public good of resilience, resilience becomes a shared value and responsibility. Collaboration in fostering interest in resilience in the community can ensure that the full fabric of the community has the opportunity to be included in the problem-solving endeavor — and that it represents public and private interests and people with diverse social and economic backgrounds.– *NRC 2012b, page 98, Table 5.1*

Engaging the Full Fabric of the Long Beach Community

Long Beach is the seventh largest city in the state of California and is one of the most ethnically diverse and economically diverse cities in the United States (Bradley 2015a). The climate resilience program developed by the Aquarium of the Pacific will engage the diverse citizenry of Long Beach. Through the program Long Beach communities will be educated and empowered to create adaptation plans that work best for their populations. To help reach the people that comprise Long Beach communities the Aquarium will approach leaders and organizations that are considered most impactful and influential. Members of these groups can range from those who are resources or provide services to the city, to others that are cultural organizations and community organizational leaders or non-governmental organizations.

Potential communities include:

- Long Beach Business Leaders
- Greater Long Beach Interfaith Community Organization
- Building Healthy Communities: Long Beach
- Long Beach Community Action Partnership
- Homeowners groups, neighborhood organizations
- Cultural organizations (including those representing different ethnic groups)
- Many of these communities are already connected to the Aquarium and have well-established infrastructure in the area. A review by Norris et al. (2008) concluded that community resilience and recovery relied on economic resources, social capital (leveraging social connections for community gain), information and communication, and community competence (or ability to implement programming). Through our past and present partnerships and diverse programs, the Aquarium of the Pacific is well-positioned to build social capital, to be a trusted source for information on climate change, and to activate the community through climate resilience activities.

Empowering the Grass Tops to Connect to Grassroots

Modeled after NOAA's Climate Resilience Toolkit (2015) approach, the Aquarium's model will gather leaders from selected communities and other stakeholders to participate in a series of workshops that will better prepare these groups to make decisions, communicate, and plan for the future. Tentatively, twenty to thirty individuals will participate in the first cohort of leaders. The goal of the workshop and subsequent community activities will be to develop environmental literacy and to enable informed decision-making necessary for community resilience to climate change impacts, including short- and long-term weather changes. A provisional workshop agenda could include the following elements:

Day One – The workshop will focus on science of climate change, educating participants on the overall picture of climate change and its impacts. At the end of the first day participants will be asked to go out into their community and identify how climate change will affect their community and report back at the second session.

Day Two – Participants will delve deeper into the local impacts identified by the participants and discuss what vulnerabilities exist for each community. They will be presented with case studies from other communities that have put resilience plans into action as resources, ideas and guidelines. The "homework" for participants at the end of the second day will be to brainstorm with other members of their community and create lists of potential solutions.

Day Three – On the last day of the workshop participants will be asked to focus, discuss, and decide based on the risks and costs which solutions are best for individual communities. Participants will decide upon a plan to take back to their community, the "grassroots," and begin to figure out the needs of each community and how to connect them to the right resources.

Follow-up meetings, conference calls, and/or webinars will be held with participants to find out where they are in implementing their climate resiliency plans. This will be an opportunity for participants to discuss their successes, but more importantly, it is an opportunity for participants to share their challenges and brainstorm possible solutions in a group setting. This experience is designed to be iterative to sustain community learning, enable experimentation with new strategies, and collect and analyze experiences.

The Aquarium will convene the resources and experts with the participating leaders to examine the needs, synergies, and solutions required for a resilient Long Beach. These other partners may include climate scientists, Long Beach Community Emergency Response Teams (CERT), the city and state Departments of Public Health, the California Environmental Protection Agency, CalADAPT, NOAA's Climate Program Office, the National Weather Service, and social justice experts and social scientists who contribute to the collective understanding of climate risks and resiliency.

The proposed workshop plan could be extended into multiple cohorts that engage different geographic regions or communities within Long Beach. The pilot group could potentially complete workshops by the end of summer 2016. The workshop is designed to leverage the leadership across the city, and to empower these community leaders to reach the wider populace.

A Broader Strategy

The Aquarium of the Pacific will further support community leaders through broader education initiatives. District Open Houses are established yearly Aquarium events in which residents of each district in the city of Long Beach is invited to enjoy the Aquarium for free. Over the last few years these events have increased in popularity among the districts and have seen as many as 4,100 attendees during a three-hour event. The Aquarium plans to provide more structured educational experiences for these events. Education department staff members are currently receiving professional development on strategic framing and other climate communication strategies to prepare for these (and other) outreach events. During these District Open Houses, education booths, access to resources, and hands-on activities will be available to help bolster climate and scientific literacy skills. During these events community members making a difference could share their stories, and officials from the district could present plans to respond and become resilient in the face of climate change. If external funding can be secured, broader strategies may also include a media campaign on local buses and bus stops and local media outlets. The campaign will draw the attention of the public to the risks of climate change and the benefits of becoming a climate resilient city.

Part 4: Summary and Conclusions

Threats to Long Beach Summary

Drought – California is in a prolonged drought. Climate change complicates reduced water supply with warmer temperatures over the western U.S. and more extreme precipitation and runoff events, decreasing further the availability of imported water supply to Long Beach. Although extreme precipitation may seem to bring relief, there are infrastructure gaps that do not allow for the capture and storage of the concentrated water high volume events that then runoff unabated to the ocean.

Extreme Heat – While ocean breezes provide a mild cooling effect for the City, it is no match for rising greenhouse gas (GHG) concentrations and their effect on the temperature. Recent studies have found that mid-century warming is unavoidable, but late-century warming due to GHG emissions can be reduced if the right steps are taken. GHG concentrations have been shown to increase the number of hot days in Long Beach, which is detrimental to public health, causing declines in health and even death.

Sea Level Rise and Coastal Flooding – Storm waves superimposed upon high tides will continue to be the dominant threat to our coastal environments over the next few decades just as they have been over the past century. The impacts of sea level rise will become more noticeable during the second half of this century, particularly when combined with large El Niño-driven storm waves and high tides. Increased coastal flooding from storms, erosion, and eventual permanent inundation of low-lying areas are predicted for Long Beach, as evidenced by the existing problems of temporary coastal flooding and erosion along the Peninsula and Alamitos Bay. While uncertainty exists as to how climate change and sea level rise will play out in Long Beach in detail, we know enough to begin to take action. Planning for climate change is fundamentally a risk management strategy against an uncertain future.

Deteriorating Air Quality – While the City of Long Beach's air quality is considered much better than that of many other cities in the Southern California region; the City still faces days that exceed state and federal air quality standards. Long Beach is home to the largest port complex in the country, surrounded by major freeways, and near some industrial facilities. As a result, it is the recipient of significant emissions. Long-term exposure to these emissions and particles can result in higher rates of asthma and cancer. Vulnerability analysis have shown that the west and north side of Long Beach are the most effected by poor air quality. These are also the regions that have a higher incidence of poverty, asthma, and low birth weight. There are limited studies which predict air quality in the future and changes to it as a result of climate change but some assumptions may be made that with increase in heat and drought conditions it will be more difficult to further reduce the quality of the air.

Public Health and Social Vulnerability - Long Beach is threatened by a variety of environmental stressors, including drought, extreme heat, deteriorating air quality and other pollution factors, coastal storms and the rising sea. The most visible evidence of environmental impact is in the health and well-being of the City's community. Whether by social, economic, hospital visit, or chronic health quantifiers, whenever public health is depicted as vulnerable, leaders should act to mitigate root causes and adapt to the changing climate.

Summary of Plans and Efforts Currently Underway

The City of Long Beach has already made significant efforts to reduce reliance on imported water supplies through various projects and initiatives. The use of recycled water continues to increase; per capita water use in Long Beach is very close to 100 *gallons per capita per day*. Long Beach has acquired a "preferential right" to limited water supplies from the wholesale agency in excess of reasonable demands Long Beach may place on the agency during shortages through strategic investments. On May 11, 2015 CLB's Board of Water Commissioners adopted Resolution WD-1339 declaring a stage 2 water supply shortage. These types of State mandates tend to have very little impact when they first become law, but their impact grows over time and will have major impacts on water demand by the year 2050.

In recognition of the threat heat poses to its residents, the City of Long Beach has created "cooling centers" for people to retreat to for some heat relief, implemented a tree-planting initiative that will create a cooling tree canopy throughout the heat-impacted areas of the city, and increased its open park spaces.

A number of studies regarding sea level rise have been done by consulting firms for the City over the years that uncovered a history of beach nourishment, trial installations of protective jetties, sea walls, berms, and other approaches to holding back sea changes and coastal flooding. Some of these methods have created erosion and landward retreat of the beaches.

In preparation for the flooding predicted from the current El Niño, the City of Long Beach has launched "Alert Long Beach," which is an emergency notification system used by the city to issue emergency alerts (in the form of text messages, voice mails or emails) to the CLB community.

The Port of Long Beach has implemented air quality improvement programs and strategies with good success. Long Beach promotes decreased use of passenger vehicles by incentivizing bike ridership. The city also aggressively complies with state and federal environmental regulations.

Per the 2013 CALGreen Building Code the City has enforced measures to reduce the urban heat island effect by requiring alternative hardscape materials, provide shade, high-albedo materials, and construction of green roofs and cool roofs.

The City of Long Beach's Department of Health and Human Services advises individuals to seek air-conditioned environments during peak heat periods.

The City of Long Beach has a long history of promoting sustainability policy and reaching out to the local community. Long Beach was one of the first cities to create a Sustainable City Commission (2007), an Office of Sustainability (2008), adopt a Sustainable City Action Plan (2010), and voluntarily report their greenhouse gas emissions inventory. The City offers a host of programs to their residents that foster the creation of a more sustainable and resilient community. These include programs like the *Green Business Recognition Program*, which recognize local organizations that implement green business practices; *Lawn-to-Garden*, incentivizing residents to convert lawns to drought-tolerant gardens, promoting water efficiency; and offering community gardens, edible gardens, free mulch delivery, and free landscaping workshops.

Summary of Additional Approaches to Consider

Managers want vulnerability assessments for their communities. They want to know what and who will be at greatest risk in the future. By identifying what is vulnerable, managers can gain a clearer sense of what they can do in order to reduce possible future impacts of inundation from sea level rise and flooding from coastal storms. Their interests are in *societal vulnerability, economic vulnerability, and ecosystem vulnerability.* All three are important in assessing and adapting to climate change. Managers need information based on reliable data and they need the tools that can transform the data into information and the information into action. Long Beach Harbor is data deficient when it comes to wave climate, the effects of coastal storms, detailed bathymetry and topography, and other data needed for high-resolution hydrodynamic modeling which can be used to calculate risks and evaluate management options.

We recommend that the City of Long Beach form a team that includes representatives of local government (economic development; emergency response; parks, recreation and marine; planning and zoning; etc.); along with key stakeholders and scientists. The team should be kept small, and like all good teams, it should have a "captain" with excellent leadership qualities. The team should communicate often and broadly within government and with external stakeholders. From the outset, the team should involve the best local knowledge and experience.

The team can use the results of this overview to move through the following steps:

- Complete a **Risk Assessment** based on the consequences of each hazard or process and the probability or likelihood of such an event occurring, assess adaptive capacity, develop adaptation strategies, and communicate these strategies with government departments and community.
- Develop an **Adaptation Plan**, in which all adaptation options for each projected hazard are identified, the criteria for assessing each option is specified; all options are evaluated, recommendations are developed, a plan is drafted and internal review of this draft is completed, and last the adaptation options are communicated with government departments and the community.

- **Review, Adopt and Implement Plan**. Begin by having the individual City agencies review it, followed by the public, and then the Planning Commission. Prepare a revised Draft Adaptation Plan. Perform a final review, editing and adoption by the City Council.
- **Implementation of Plan**
- **Monitoring, Review and Update of Plan**, with ongoing update of local data for trend analysis and review.

Ultimately, the city should create a comprehensive plan for making Long Beach a climate resilient city, based on the best available science. These plans should include adaptive management plans based on iterative, flexible planning, with clearly defined, pre-set triggers in place, to signal which protocols should be enacted when various benchmarks are reached.

Conclusions

While uncertainty exists as to how climate change will play out in Long Beach in detail, we know enough to begin to take action. Planning for climate change is fundamentally a risk management strategy against an uncertain future. Climate change will impact almost every city throughout the world to a greater or lesser degree. Cities can become more climate change resilient through on-going awareness and monitoring of their environment, and planning for the expected impacts as the probability of those impacts increase. Thanks to the actions of Mayor Robert Garcia, the City Manager, and the City Council, Long Beach is taking the important first steps towards becoming a city that rebounds and thrives during progressive climate changes and before, during, and after extreme weather-related events.

We hope this report helps the City achieve its goal of becoming a climate resilient community.

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List of Appendices

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

Appendix B: Additional *CoSMoS 3.0* information

Appendix C: NOAA's *Sea Level Rise Viewer's* predicted coastal for Long Beach

Appendix D: Individual flood maps for each of the *CoSMoS* 3's SLR scenarios focused on either the Bellmont Shore and Alamitos Bay areas of southeastern Long Beach, or the Port of Long Beach (POLB) and Downtown areas of southwestern LBC.

Appendix E: Additional *CalEnviroscreen* Public Health and Social Vulnerability results for the Long Beach area