

GUIDANCE FOR INCORPORATING SEA LEVEL RISE INTO CAPITAL PLANNING IN SAN FRANCISCO: ASSESSING VULNERABILITY, RISK, AND ADAPTATION (DRAFT)

Prepared by the Sea Level Rise Committee of SF Adapt
for the San Francisco Capital Planning Committee¹

INTRODUCTION AND GOALS OF THIS GUIDANCE

Seas are rising globally due to climate change and will continue to rise at an accelerating rate for the remainder of the 21st century. As a consequence of rising sea level, San Francisco will experience more frequent and severe coastal flooding than in the past. Areas that currently experience infrequent flooding will be inundated more often and more areas along our shorelines will be exposed to periodic flooding than in the past or today. Sea level rise therefore poses a pervasive and increasing threat along San Francisco's shorelines. As new infrastructure projects are planned along the shoreline, or existing assets are modified or improved, flooding due to rising sea levels – in combination with storm surge and wave run up – must be evaluated.

This Guidance presents a framework for considering sea level rise within the capital planning process for the City and County of San Francisco (CCSF). The Guidance also outlines some key issues related to sea level rise adaptation planning; however, specific adaptation strategies and approaches are not provided. The range of available potential adaptation strategies is ever increasing, and selecting the appropriate adaptation measures requires site and project specific information that will best emerge at a departmental level, informed by this Guidance, and coordinated through the CCSF capital planning processes.

This Guidance provides direction from the Capital Planning Committee (CPC) to all departments on how to incorporate sea level rise into new construction, capital improvement, and maintenance projects. The Guidance identifies and describes four key steps for assessing and adapting to the effects of sea level rise in capital planning:

1. **Sea Level Rise Science Review:** What does the science tell us today?
2. **Vulnerability Assessment:** Which assets are vulnerable to sea level rise?
3. **Risk Assessment:** Which vulnerable assets are at greatest risk to sea level rise?
4. **Adaptation Planning:** For those assets at risk, what can we do to increase their resilience to sea level rise?

This document should be used by CCSF departments to guide the evaluation of projects considered for funding through the CCSF capital planning process. As with seismic and other natural hazards, an assessment of sea level rise vulnerabilities and a plan for addressing those vulnerabilities should be completed before a project is considered for funding.

¹ See Appendix 1 for the Sea Level Rise Committee Members

It should be noted that urban flooding – flooding that occurs inland when the storm sewer system exceeds its capacity – is not specifically addressed by this Guidance. Although sea level rise may exacerbate urban flooding, urban flooding is primarily related to precipitation. This Guidance focuses solely on the contribution of sea level rise to coastal flooding hazards. It is recognized, however, that some projects may require consideration of additional climate change impacts, such as changes in future precipitation events, in order to fully quantify climate change related vulnerability and risk.

THE CAPITAL PLANNING COMMITTEE AND PROCESS

The CPC makes recommendations to the Mayor and Board of Supervisors on all of the City’s capital expenditures. The Committee is chaired by the City Administrator and includes all capital-intensive department heads as well as the President of the Board, the Planning Director, the Controller, and the Mayor’s Budget Director.

Each year the CPC reviews and approves the City’s Capital Budget and any issuances of long-term debt related to infrastructure projects. The CPC is also responsible for approving the City’s 10-Year Capital Plan – a constrained long-term finance plan that prioritizes projects based on an approved set of funding principals. The Capital Plan provides a road map for ensuring the long-term safety, accessibility and modernization of San Francisco’s public infrastructure and facilities. After the CPC approves the Capital Plan it is sent to the Board of Supervisors and the Mayor for final adoption.

This Guidance provides CCSF departments with a step-by-step approach for considering sea level rise vulnerability, risk and adaptation planning within their department Capital Plans. The CPC, in turn, will use this Guidance to determine whether department Capital Plans have adequately addressed sea level rise vulnerabilities, risk and adaptation. If all departments follow this Guidance when developing their individual Capital Plans, the combined CCSF Capital Plan will ensure the resilience of San Francisco’s public infrastructure projects to anticipated sea level rise.

While primary responsibility for developing resilient Capital Plans resides within each department, the CPC and the City Administrator’s Office (CAO) encourage and support collaborative planning across CCSF government. This Guidance facilitates the use of a common approach across all departments. The Guidance recommends using the same underlying science, tools (i.e., inundation maps), and methods, thereby increasing the potential for seamless collaboration and integration. This collaboration is most critical where infrastructure, and the adaptation plans needed to address the vulnerabilities of that infrastructure, cross departmental borders (see sidebars discussing Ocean Beach and the Bayside seawall).

It should be noted that the science related to understanding the impacts of climate change is continually evolving and advancing over time. Therefore, this Guidance will be revisited and updated at regular intervals, most likely every five years, or as significant advancements in the science occur.

SEA LEVEL RISE AND COASTAL HAZARDS

San Francisco is susceptible to coastal flooding and wave hazards along three sides of the city, with the open Pacific Ocean to the west and San Francisco Bay to the north and east. Several areas along the shoreline are already experiencing periodic inundation and erosion, including: Ocean Beach on the Pacific Coast, which is subjected to significant coastal storms and waves; the Port of San Francisco’s Embarcadero, which is overtopped in several areas during the annual extreme high tides, or King Tides; and San Francisco International Airport (SFO), which experiences wave overtopping of flood protection structures and inundation of low-lying areas. Projected sea level rise will worsen these existing hazards by increasing the frequency of flooding, extending the coastal flood hazard zone further inland, and accelerating shoreline

erosion. Areas of the shoreline that have been filled, such as the Embarcadero, Mission Bay, SFO, and Treasure Island, are especially at risk, as rising sea levels may influence groundwater levels, resulting in increased subsidence and liquefaction hazards.

The following coastal flood hazards may increase due to sea level rise:

- **Daily tidal inundation:** as sea level rises, the amount of land and infrastructure subjected to daily inundation by high tides will increase. This would result in increased *permanent* future inundation of low-lying areas.
- **Annual high tide inundation (King Tides):** King Tides are abnormally high but predictable astronomical tides that occur approximately twice per year. King Tides are the highest tides that occur each year when the Moon and the Sun simultaneously exert their gravitational influence on the Earth (typically the two solstices). When King tides occur with winter storms, the effects are particularly pronounced and make these events more dramatic. King Tides result in *temporary* inundation, particularly associated with nuisance flooding, such as inundation of low-lying roads, boardwalks, and waterfront promenades. The Embarcadero waterfront (Pier 14) and the Marina area in San Francisco experience inundation under current King Tide conditions (see Port seawall sidebar, which highlights inundation that occurs under King Tides).
- **Extreme high tide inundation (storm surge):** When Pacific Ocean storms coincide with high tides, storm surge due to meteorological effects can elevate Pacific Ocean and San Francisco Bay water levels and produce extreme high tides, resulting in *temporary* inundation. Such storm surge events occurred on January 27, 1983, December 3, 1983, February 6, 1998, January 8, 2005, and December 31, 2006. Extreme high tides can cause severe inundation of low-lying roads, boardwalks, and promenades; exacerbate coastal and riverine flooding and cause upstream flooding; and interfere with stormwater outfalls. The Ocean Beach area is prone to inundation and erosion associated with extreme high tides and storm surge.
- **El Niño winter storms:** During El Niño² winters, atmospheric and oceanographic conditions in the Pacific Ocean produce severe winter storms that impact the San Francisco shorelines. Pacific Ocean storms follow a more southerly route and bring intense rainfall and storm conditions to the Bay Area.



Ocean Beach, on the open Pacific Coast of San Francisco, is subjected to extreme winter storm surge and wave conditions. The National Park Service and CCSF implemented a sand management project and placed over 70,000 cubic yards of sand south of Sloat Boulevard (completed in September 2012, photo above). By January 2013, the majority of the sand placed was eroded due to severe winter storm surge coupled with large waves (photo below).



Photo credit: Justin Vandever, California Beach Blog

² El Niño–Southern Oscillation (ENSO) is a natural oceanic-atmospheric cycle. El Niño conditions are defined by prolonged warming in the Pacific Ocean sea surface temperatures. Typically, this happens at irregular intervals of two to seven years, and can last anywhere from nine months to two years.¹



The Port's seawall is one of the most important coastal structures along the city's waterfront. The seawall serves as a retaining wall for the adjoining land, which is comprised of significant quantities of fill material that extends hundreds of feet landward from the seawall. The seawall serves as the primary structural support for the Port's piers and wharves, as well as a large network of structures and utilities belonging to the Port and other local agencies such as MUNI, SFPUC, and BART. The seawall's integrity and ability to provide structural support will decrease as sea levels rise. Coastal storm surge and wave hazards also pose a significant threat to the integrity of the seawall.



Photo credit: California King Tides Initiative

Tides are often elevated 0.5 to 3.0 feet above normal along the coast and wave setup can elevate water levels even further. El Niño winter conditions prevailed in 1977-1978, 1982-1983, 1997-1998, and 2009-2010. Typical impacts include severe inundation of low-lying roads, boardwalks and waterfront promenades; storm drain backup; wave damage to coastal structures and erosion of natural shorelines (see Ocean Beach sidebar which highlights the power of coastal erosion).

- **Ocean swell and wind-wave events (storm waves):** Pacific Ocean storms and strong thermal gradients can produce strong winds that blow across the ocean and the Bay. When the wind blows over long reaches of open water, large waves can be generated that impact the shoreline and cause damage. Typical impacts include wave damage along the shoreline, particularly to coastal structures such as levees, docks and piers, wharves, and revetments; backshore inundation due to wave overtopping of structures; and erosion of natural shorelines.

Physical damage from floods could include the following:

- **Inundation of facilities,** causing operational closures at critical transportation facilities such as SFO, the Port, BART, and various facilities operated by MTA.
- **Inundation and damage to various infrastructure** including buildings, roads, bridges, culverts, pump stations, support structures, parks, and open space.
- **Overland flooding** may block access to underground utilities, may damage electrical boxes and substations causing prolonged power outages, and may damage pump stations and other electrical equipment resulting in equipment failure.
- **Release of sewage and hazardous or toxic material** as wastewater treatment plants, storage tanks and other facilities are inundated and compromised.
- **Erosion of natural shorelines** and stream banks that may disrupt wetlands and natural habitats, and also undermine nearby facilities.

OUTLINE OF THIS GUIDANCE

Many state and local governments are already preparing for the impacts of climate change through "adaptation," the practice of planning for anticipated climate change and developing strategies to address potential impacts. Planning efforts can no longer rely on historical ocean levels, or even the rates of sea level rise observed over the past century. Instead, they must incorporate the latest climate science to determine how to protect and modify existing assets and design new assets to be more resilient to rising seas. Adaptation planning requires the consideration of uncertainty and risk, because the science supporting sea level rise and climate change projections has many underlying uncertainties. As such, a robust adaptation plan requires that potential adaptation strategies be revisited as the science progresses and projections are updated.

While adaptation planning can take many forms, the process of assessing sea level rise vulnerability and risk follows some basic steps (see Figure 1):



Figure 1. Sea Level Rise Vulnerability, Risk and Adaptation Planning Process



1. Sea Level Rise Science Review

- a. Sea level rise estimates
- b. Storm surge and waves
- c. Sea level rise scenario selection
- d. Sea level rise inundation mapping

2. Vulnerability Assessment



- a. Evaluate *exposure*: degree to which an asset is exposed (e.g., depth of flooding due to sea level rise, wave run up and/or storm surge)
- b. Assess *sensitivity*: degree to which an asset is affected (e.g., temporary flooding causes minimal impact, or results in complete loss of asset or shut-down of operation)
- c. Determine *resilience*: ability of an asset to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or cope with the consequences

3. Risk Assessment



- a. Evaluate *consequence* to help set priorities for adaption planning (i.e., cost of reconstruction or repair, economic impact of disruption, length of disruption, irreversibility of impact)

4. Adaptation Planning



- a. Assess the *adaptive capacity* of the asset (i.e. can it be modified in the future to respond to new, higher sea level rise projections)
 - Identify adaptation strategies and approaches to protect assets and increase adaptive capacity
 - Prioritize strategies: where do they need to be implemented first, second, third, etc.
 - Timing of strategies: when do they need to be implemented

The following sections provide an overview of each of the above outlined steps above:

1. SEA LEVEL RISE SCIENCE REVIEW

Adaptation to sea level rise begins with an understanding of the current state-of-the-science on sea level rise³. The science associated with sea level rise is continually being updated, revised, and strengthened. Although there is no doubt that sea levels have risen and will continue to rise at an accelerated rate over the coming century, it is difficult to predict with certainty what amount of sea level rise will occur at any given time in the future. The uncertainty increases over time (e.g. the uncertainties associated with 2100 projections are greater than with 2050 projections) because of uncertainties in future greenhouse gas (GHG) emissions trends, the evolving understanding of the sensitivity of climate conditions to GHG concentrations, and the overall skill of climate models. Given these uncertainties, the sea level rise projections presented in this document for use in capital planning draw on the best available science on the potential effects of sea level rise in California as of January 2014.

³ See Appendix 3 for a summary of current sea level rise science

a. Sea Level Rise Estimates

In March 2013, the State of California adopted the 2012 National Research Council Report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past Present and Future* (NRC Report)⁴, as the best available science on sea level rise for the state and published guidance on incorporating sea level rise into state planning.⁵ The California Coastal Commission (CCC) also supported the use of the NRC Report as best available current science. The CCC also noted that the science of sea level rise is continually advancing, and future research may enhance the scientific understanding of how the climate is changing, resulting in the need to regularly update sea level rise projections⁶. The NRC Report includes discussions of historic sea level observations, three projections of likely sea level rise for the coming century, high and low extremes for sea level rise in the coming century, and consideration of local conditions along the California, Oregon, and Washington coast that contribute to “relative sea level rise” (see below). After the release of the both the NRC Report and the CCC Draft Guidance, the Intergovernmental Panel on Climate Change (IPCC) released its 5th Assessment Report (AR5), which provides updated consensus estimates of global sea level rise⁷.

Table 1 presents the NRC Report’s sea level rise estimates for San Francisco relative to the year 2000. The table presents the local *projections* (mean \pm 1 standard deviation). These projections (for example, 36 \pm 10 inches in 2100) represent the *likely* sea level rise values based on a moderate level of greenhouse gas emissions and extrapolation of continued accelerating land ice melt patterns, plus or minus one standard deviation⁸. The extreme limits of the *ranges* (for example, 17 and 66 inches for 2100) represent *unlikely but possible* levels of sea level rise utilizing both very low and very high emissions scenarios and, at the high end, including significant land ice melt that is not anticipated at this time but could occur. The NRC Report is also notable for providing regional estimates of *relative sea level rise* for the west coast which include the sum of contributions from the local thermal expansion of seawater, wind driven components, land ice melting, and vertical land motion. The chief differentiator among relative sea level rise projections along the west coast derives from vertical land motion estimates, which show uplift (reducing relative sea level rise) of lands north of Cape Mendocino and subsidence (increasing relative sea level rise) of lands south of Cape Mendocino.

⁴ *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past Present and Future*. Prepared by the Committee on Sea Level Rise in California, Oregon, and Washington; Board on Earth Sciences and Resources; Ocean Studies Board; Division on Earth and Life Studies; National Research Council 2012.

⁵ *State of California Sea-Level Rise Guidance Document*. Developed by the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), with science support provided by the Ocean Protection Council’s Science Advisory Team and the California Ocean Science Trust. March 2013 Update.

⁶ California Coastal Commission Sea Level Rise Policy Guidance, Public Review Draft. October 14, 2013.
http://www.coastal.ca.gov/climate/slr/guidance/CCC_Draft_SLR_Guidance_PR_10142013.pdf

⁷ Climate Change 2013, the Physical Science Basis. Intergovernmental Panel on Climate Change, 2013.
www.ipcc.ch/report/ar5/wg1/

⁸ One standard deviation roughly corresponds to a 15%/85% confidence interval, meaning that there is approximately 15% chance the value will exceed the high end of the projection (46 inches for the 2100 example) and a 15% chance the value will be lower than the low end of the range (26 inches in the 2100 example).

Table 1: Sea Level Rise Estimates for San Francisco Relative to the Year 2000

Year	Projections	Ranges
2030	6 ± 2 in	2 to 12 in
2050	11 ± 4 in	5 to 24 in
2100	36 ± 10 in	17 to 66 in

Source: NRC (2012)

The NRC *ranges* are substantially higher than the global estimates presented in IPCC’s AR5, while the *projections* in the NRC report are similar to IPCC estimates. At this time, the use of NRC projections and ranges as presented in this Guidance is appropriate for capital planning purposes because they encompass the best available science, have been derived considering local and regional processes and conditions, and their use is consistent with current state guidance (See Appendix 3). Approaches for using these figures in planning are provided in subsequent steps outlined below.

b. Storm Surge and Waves

Beyond mean sea level rise, consideration must also be given to storm surge, storm waves and wave run up along the San Francisco shorelines (see Figure 2).

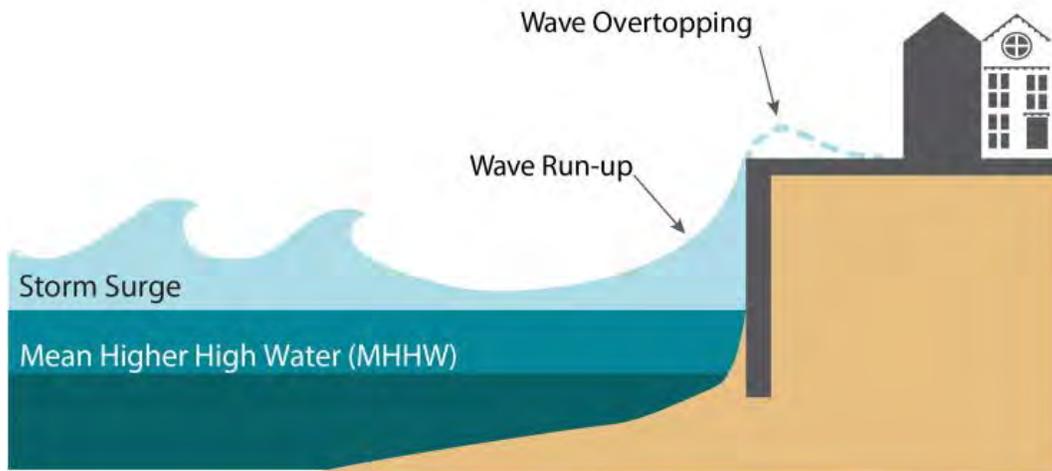


Figure 2. Storm Surge and Waves along the Shoreline

Understanding the additive impact of large waves and high tides to produce inundation and flooding is crucial for planning in the coastal environment. Table 2 provides an overview of factors in addition to sea level rise affecting existing water levels on the San Francisco open Pacific Coast and in San Francisco Bay.

Table 2: Factors that Influence Local Water Level Conditions in Addition to Sea Level Rise

Factors Affecting Water Level	Typical Range CCSF Pacific Shoreline a	Typical Range CCSF Bay Shoreline b	Period of Influence	Frequency
Tides	5 to 7 ft	5 to 7 ft	Hours	Twice daily
Storm Surge	0.5 to 3 ft	0.5 to 3 ft	Days	Several times a year
Storm Waves	10 to 30 ft	1 to 4 ft	Hours	Several times a year
El Niños (within the ENSO cycle)	0.5 to 3 ft	0.5 to 3 ft	Months to Years	Every 2 to 7 years

Sources: a) Typical ranges for tides, storm surge, and storm waves for the CCSF Pacific Coast: BakerAECOM 2012. Intermediate Data Submittal #1. Scoping and Data Review. San Francisco County, California. California Coastal Analysis and Mapping Project / Open Pacific Coast Study. Submitted to FEMA Region IX. February 13, 2012. b) Typical ranges for tides, storm surge, and storm waves for the CCSF Bay shoreline: DHI. 2010. Regional Coastal Hazard Modeling Study for North and Central Bay. Prepared for FEMA. September 2010.

c. Sea Level Rise Scenario Selection

During project planning, the selection of the appropriate sea level rise scenario, or scenarios, for the vulnerability and risk assessment of a particular asset or set of assets can be challenging. Scenario selection is the first suggested step on the included checklist (see Appendix 5). There are several factors that should influence scenario selection:

- **Lifespan** – how long will the project be in use?
- **Location** – is the project located in a more exposed and vulnerable area or a more sheltered location?
- **Consequence of failure** – if the project is inundated, what are the overall consequences?

Capital project planners should consider all of the above as they evaluate sea level rise vulnerabilities and risks, and plan to accommodate or adapt to future sea level rise. They may choose to plan now for the high end of the uncertainty range (i.e., 66 inches by 2100) – particularly for critical assets that must maintain their function if inundated – or it may be appropriate to plan for the most likely scenario by 2100 (i.e., 36 ± 10 inches) while completing sensitivity testing and developing appropriate adaptation strategies that could accommodate higher sea level rise estimates. This approach accommodates uncertainties in the science and allows for flexibility should the higher-end of the sea level rise projections become more likely.

Although the sea level rise estimates presented in Table 1 are presented relative to specific time horizons (i.e., 2030, 2050, and 2100), these estimates can be interpolated for alternate time horizons (i.e., 2080) if needed to consider different project planning horizons (See Appendix 4).

d. Sea Level Rise Inundation Mapping

Inundation maps are a valuable tool for evaluating potential exposure to future sea level rise and storm surge conditions and the most up-to-date maps should be referenced during project planning and design. (Note that these maps, however, do not consider precipitation and runoff-driven flooding.) The maps are typically used to evaluate when (under what amount of sea level rise and/or storm surge) and by how much (what depth of inundation) an asset will be exposed. A variety of inundation maps exist today for evaluating potential future sea level rise exposure. At the time of publication of this Guidance, the following inundation maps represent state-of-the-art products and should be used by CCSF departments in planning near the San Francisco Bay and Pacific Coast shorelines. These inundation maps were prepared by the San Francisco Public Utilities Commission (SFPUC) in conjunction with the Sewer System Improvement Program (SSIP) and provide the highest resolution, most comprehensive inundation mapping to date for the entire

CCSF shoreline, with the exception of SFO which is located within San Mateo County. (Additional inundation map sources are available for SFO, such as the NOAA Sea Level Rise and Coastal Flooding Impacts Viewer⁹, or the Our Coast Our Future inundation maps¹⁰).

For the Pacific Coast shoreline (i.e., Westside):

SFPUC Westside Inundation Maps: SFPUC is producing sea level rise inundation maps for the open Pacific Coast shoreline (from the Golden Gate Bridge to the Westside CCSF/San Mateo County border). The inundation maps use a 1-meter horizontal grid resolution DEM¹¹ based on the 2010/2011 California Coastal Mapping Program (CCMP) LiDAR¹². Along the open Pacific Coast, the importance and magnitude of coastal storm surge and wave hazards (see Table 2) requires an approach that capture these dynamic processes as they propagate landward. The Westside inundation maps will leverage Federal Emergency Management Administration (FEMA) water level and storm surge data and coastal hazard analysis methods that consider shoreline types (i.e., sandy beaches, dunes, bluffs), presence of coastal structures, and erosion potential¹³. The inundation maps will include a range of sea level rise estimates from 12 inches to 66 inches, and will account for the dynamic overland water levels associated with sea level rise-driven changes to the 100-year coastal storm surge and wave hazards. These maps are anticipated to be published in June 2014.

For the San Francisco Bay shoreline (i.e., Bayside):

SFPUC Bayside Maps: SFPUC is producing sea level rise inundation maps for the contiguous CCSF Bay shoreline, including Treasure Island, but not including SFO (from the Golden Gate Bridge to the Bayside CCSF/San Mateo County border). The inundation maps will utilize a 1-meter horizontal grid resolution DEM based on the same 2010/2011 CCMP LiDAR used for the Westside inundation mapping. The water level analysis leverages data from FEMA's California Coastal Mapping and Analysis Project. Inundation maps will consider static sea level rise on top of mean higher high water (MHHW) in one-foot increments, as well as a range of storm surge and wave hazard events ranging from the 1-year to the 100-year storm surge event. These maps and the associated digital data are expected to be published in May 2014.

It should be noted that all inundation maps, including those produced by SFPUC for SSIP, are associated with caveats and uncertainties. Inundation maps, and the underlying associated analyses, are intended as planning level tools to illustrate the *potential* for flooding under future sea level rise and storm surge scenarios. Although this information is appropriate for conducting vulnerable and risk assessments, finer-grained information may be needed for detailed engineering design and implementation. The maps depict *possible* future inundation that could occur if nothing is done to adapt or prepare for sea level rise over the next century. The SFPUC SSIP maps relied on a 1-m digital elevation model created from LiDAR data

⁹ <http://csc.noaa.gov/slr/viewer/>

¹⁰ <http://data.prbo.org/apps/ocof/>

¹¹ The horizontal grid resolution of a digital elevation model (DEM) defines the scale of the features which are resolved within the terrain. In order to resolve levees, berms, and other topographic features which are important for impacting floodwater conveyance, a 1-meter resolution DEM is recommended. Coarser grid resolutions (i.e., 2-meter, 5-meter) may not fully resolve these features, resulting in an over estimation of potential inundation extents.

¹² LiDAR (Light Detection and Ranging) is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. LiDAR is commonly used to create high-resolution terrain models, topography data sets, and topographic maps.

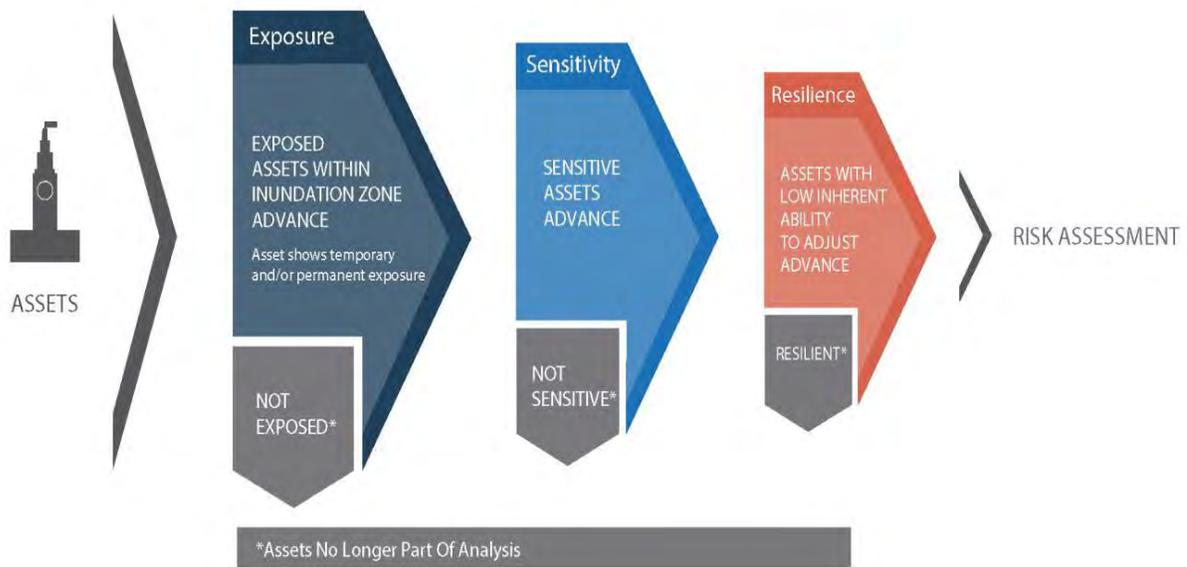
¹³ Federal Emergency Management Agency (FEMA) California Coastal Analysis and Mapping Project (CCAMP). See www.r9coastal.org.

collected in 2010 and 2011. Although care was taken to capture all relevant topographic features and coastal structures that may impact coastal inundation, it is possible that structures narrower than the 1-m horizontal map scale may not be fully represented. The maps are based on model outputs and do not account for all of the complex and dynamic San Francisco Bay and Pacific ocean coastal processes or future conditions such as erosion, subsidence, future construction or shoreline protection upgrades, or other changes to the region that may occur in response to sea level rise.

2. VULNERABILITY ASSESSMENT

The vulnerability assessment phase utilizes the results of the climate science review, including inundation mapping, to help guide identification of the *exposure*, *sensitivity*, and *resilience* of an asset in order to understand that asset’s vulnerability to sea level rise. By screening for vulnerability, the groundwork is laid for adaptation planning. Assets found to be vulnerable move on to the risk assessment and adaptation planning phases, while the analysis is complete in this phase for assets found not to be vulnerable.

Development and adoption of a standardized approach for performing a vulnerability assessment for both existing and future projects is critical to ensure that vulnerabilities are assessed consistently amongst all



CCSF departments.

Figure 3. Vulnerability Assessment Process

Each asset in a capital plan should be evaluated to identify these factors:

- a. **Exposure:** The exposure of an asset is the degree to which an asset is susceptible to hazards (i.e., depth of flooding due to sea level rise, storm surge and wave run up). Exposure can be evaluated based on the type, magnitude and duration of flooding by either selecting readily available inundation mapping at an appropriate scale and resolution, or by completing site-specific modeling and mapping of an accepted range of current and future sea level rise projections and storm surge conditions and wave hazards (including wave runup). Exposure can be evaluated by overlying the asset footprint with the inundation mapping and extracting the necessary information, such as depth of inundation, area inundated, and percent of area inundated. In addition, evaluation of multiple scenarios for static sea

level rise and/or storm surge and wave hazards can help determine asset vulnerability under a variety of future conditions. Assets that are not exposed do not need to be evaluated further in the vulnerability assessment.

- b. **Sensitivity:** Assets that are exposed should progress to the next step: evaluating the sensitivity of the asset to sea level rise impacts. Sensitivity is the degree to which an asset is affected (i.e., temporary flooding causes minimal impact, or results in complete loss of asset or shut-down of operation). For example, a roadway may be temporarily inundated under a storm surge scenario, but once the floodwaters recede, the roadway can resume useful service without the need for repair. Such a roadway would have a low sensitivity to periodic flooding; therefore it may not need to be carried further in the process. Assets with low sensitivity may still benefit from adaptation measures, such as infrastructure improvements and/or operational adjustments; therefore the inclusion or exclusion of exposed assets with low sensitivity should be considered on a case by case basis. On the other hand, an electrical substation may be taken completely out of service if it experiences even minor temporary inundation, requiring either major repairs or complete replacement. This asset would be considered highly sensitive to flood impacts and would be the subject of more complex analysis.
- c. **Resilience:** Finally, the asset's resilience is evaluated. As part of the vulnerability assessment, resilience is defined as the asset's *inherent* ability to adjust to sea level rise impacts, to moderate potential damage, to take advantage of opportunities, or to cope with the consequences without the need for significant intervention or modification. An asset with high resilience is less vulnerable to sea level rise impacts. For example, an asset that was designed and constructed with the ability to adapt may have a high degree of resilience. A boardwalk or building may have been designed with an ability to be easily raised in the future, or a floodwall may have been designed to accommodate future increases in height without the need for significant modifications. These assets are said to have "adaptive capacity" and therefore score high for resilience. (Adaptive capacity will also be an objective for some assets in the Adaptation Planning phase below). For transportation systems, the presence of redundancy in the system can also increase its inherent resilience. If one section of roadway is impacted by flooding but another section could provide at least a portion of the impacted level of service, the system is able to take advantage of existing opportunities to minimize impacts, and therefore might score high for resilience.

At the completion of the vulnerability assessment, each asset¹⁴, or project component, will have an associated rating (i.e., low, medium or high) for exposure, sensitivity, and resilience. The ratings are useful in the risk assessment phase for assessing the consequence of the vulnerabilities, and ultimately, in setting priorities for adaptation planning. Table 3 presents a simple example of a vulnerability assessment matrix for one sea level rise scenario. As part of the vulnerability assessment phase, the low, medium and high ratings must be defined using thresholds that are appropriate for the group of assets. For example, exposure thresholds can be defined using inundated depth or inundation duration.

The rating scale presented in Table 3 was developed so that a low score (1) is associated with limited exposure, minimal sensitivity, and high resilience to sea level rise. A low score for all three characteristics would result in an asset with very low overall vulnerability. A high score (3) would represent an asset that is significantly exposed, highly sensitive, or with limited resilience to sea level rise. A high score for all three

¹⁴ A project can be evaluated as a whole, if appropriate. For example, the project may consist of a single building or structure. More complex projects may be divided into a suite of assets, or project components, so that the project components can be assessed individually.

characteristics would result in a highly vulnerable asset. Thresholds for the ratings may vary based on different asset types and their tolerance for inundation.

Table 3: Example Vulnerability Matrix for One Sea Level Rise Scenario

Asset	Exposure to 2050 Sea Level Rise ^a		Sensitivity ^b		Resilience ^c		Total Score
	Sea Level Rise	Storm Surge	Sea Level Rise	Storm Surge	Sea Level Rise	Storm Surge	
Asset #1	None	None	N/A	N/A	N/A	N/A	0
Asset #2	None	Low (1)	N/A	Low (1)	N/A	High (1)	3
Asset #3	Low (1)	Low (1)	Low (1)	Med (2)	Med (2)	Med (2)	9
Asset #4	Med (2)	Med (2)	Med (2)	High (3)	Low (3)	Med (2)	15
Asset #5	High (3)	High (3)	High (3)	Med (2)	Low (3)	Low (3)	17

As stated above, assets that are not exposed to sea level rise or storm surge do not need to be considered further as they are not impacted by the sea level rise stressors. Assets that score low for sensitivity or high for resilience may also not warrant further consideration at the risk assessment phase as these assets are either not sensitive to the sea level rise impacts, or they have a high ability to adapt without the need for the identification, design, and implementation of new adaptation strategies (see example Asset #2). On the other hand, Assets #3 through #5 in Table 3 are exposed, sensitive to some degree, and have moderate to low resilience to sea level rise. Because they are at risk, these assets must be considered in the risk assessment phase, during which the consequence determination is made. In sum, the vulnerability assessment will produce a final list of assets, or project components, that warrant further evaluation in the risk assessment phase.

Note that an evaluation of multiple sea level rise and storm surge scenarios to accommodate different time scales or different assumptions about sea level rise may be needed to adequately assess overall vulnerability and to provide useful information to inform the consequence rankings and adaptation planning.

3. RISK ASSESSMENT

Risk is typically evaluated by comparing the probability that impacts would occur (or *likelihood*) to the *consequence* of these impacts. However, likelihood can be difficult to quantify when considering sea level rise related impacts, as most current scientific studies cannot calculate the probability of a sea level rise projection occurring in any given year or at any particular level. Therefore, when assessing the risk associated with sea level rise vulnerabilities identified through the vulnerability assessment, the most important component of classical risk assessment methods is the evaluation of consequence.

Calculating the consequence of failing to address sea level rise for a particular asset or project is useful in prioritizing assets for adaptation planning. Consequence considers the magnitude of the impact that would occur under the selected sea level rise and storm surge scenarios. Information about the asset, such as its age, condition, and materials are often informative when considering the consequences. The questions below can be useful in framing the consequence of sea level rise related impacts.

- What is the level of damage to the asset? Can the asset be repaired, or would the asset require complete replacement?
- What is the cost to repair or replace the asset?
- Is there a disruption in service? If yes, what is the length of that disruption (i.e., hours, days, weeks)?
- What are the economic (or healthy and safety) costs associated with the disruption in service?
- Are there secondary impacts that need to be considered (i.e., costs to other sectors, such as the environment and public recreation)?

The best questions for framing consequence may vary depending on the department, and depend upon asset function or the type of service the asset provides (i.e., essential infrastructure, flood protection, health and safety, public access). The intent of the consequence determination is to develop a means to prioritize assets for adaptation plan development. It is not necessary (or useful) to use a consistent CCSF-wide approach for developing consequence ratings, as the desired outcome is to help prioritize a specific department’s needs, and to inform its departmental Capital Plan.

Table 4 presents a simple example of a consequence matrix for one sea level rise scenario; however, additional consequence factors may also be considered in practice, such as factors that consider economics, secondary impacts, or interdependencies. Table 4 presents the same hypothetical assets subject to the vulnerability matrix in Table 3 above. As noted in Table 3, Asset #1 was not considered vulnerable (see Table 3), so it was not evaluated in the risk assessment phase. For this selection of assets, Asset #4 is associated with the highest consequence rating; therefore the development of an adaptation plan for Asset #4 may be a high priority. As part of the risk assessment phase, the low, medium and high ratings must be defined using thresholds that are appropriate for the department and the group of assets.

Note that an evaluation of multiple sea level rise and storm surge scenarios to accommodate different time scales or different assumptions about sea level rise may be needed to adequately assess consequences and to develop a prioritized list of short-term and long-term adaptation planning needs.

Table 4: Example Consequence Matrix for one Sea Level Rise Scenario

Asset	Damage		Cost (Repair/Replace)		Disruption		Total Score
	Sea Level Rise	Storm Surge	Sea Level Rise	Storm Surge	Sea Level Rise	Storm Surge	
Asset #1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Asset #2	N/A	Low (1)	N/A	Med (2)	N/A	High (3)	6
Asset #3	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)	6
Asset #4	Med (2)	High (3)	Med (2)	High (3)	Med (2)	High (3)	14
Asset #5	High (3)	High (3)	Low (1)	Med (2)	Low (1)	Low (1)	11

4. ADAPTATION PLAN DEVELOPMENT

During this phase, potential adaptation strategies are developed for assets or projects that are identified as vulnerable. The adaptation plan may focus on those assets or projects that also have a high consequence rating. Together, the vulnerability and consequence ratings can help a department develop a prioritized list of assets for adaptation strategy development and implementation. Given that the science of climate change is evolving, and sea level rise projections have a wide range of values, projects should adopt a

planning horizon based on project lifespan (see sea level rise scenario selection discussion) and include appropriate adaptation strategies to accommodate anticipated sea level rise.

In many instances, it is not feasible or cost effective to design and build for long-term potential sea level rise scenarios of a highly uncertain nature, such as at the upper end of the NRC Report range for the year 2100 (i.e., 66 inches of sea level rise). In this case, a project could be designed and constructed to account for likely mid-century sea level rise (i.e., 11 ± 4 inches by 2050), and build in the ability to adapt to more severe sea level rise scenarios over time.

This approach seeks to create or enhance the adaptive capacity of the asset or asset location, thereby making that asset *resilient* (as defined during the Vulnerability Assessment phase). Adaptive capacity defines a project's ability to adapt in a modular, or step-wise, fashion over time. The adaptation plan for the asset or project should include the level of sea level rise appropriate for near-term project planning and implementation, and the adaptation strategies that can be implemented over time if sea level rise exceeds or is anticipated to exceed the original estimate. The adaptation plan should clearly lay out the triggers or time horizons for implementation of the identified adaptation strategies, and the plan should include a means to monitor and respond to changes in the science or the condition of the asset.

In evaluating the adaptive capacity of a project, these questions are often asked: Does the project, project footprint, or adaptation feature(s) have the ability to be modified or changed to accommodate future higher sea level rise as new data and science emerges? In other words, can project resilience be secured for some logical period of time (e.g. through 2050) and *also* accommodate further adaptation measures based on new developments and science in subsequent years? And what are those triggers or time horizons for implementation of adaptation measures (make the project resilient now) and adaptive management approaches (respond to future trends with further measures).

If, however, due to site or project constraints it is determined that the adaptive capacity of a project is low (i.e. the ability to implement future adaptation strategies in response to new projections of additional sea level rise is low), the use of worst-case projections in initial adaptation plan development may be merited.

For example, if an existing flood protection feature was designed and constructed in such a way that its height or location can be easily adjusted or increased in the future to accommodate sea level rise or more severe storm surge events, the project would have some inherent resilience as its ability to accommodate



In 2008, the Treasure Island Community Development laid out an Adaptation Strategy on how to increase the resilience of a new development on Treasure Island to sea level rise and storm surge with a multi-faceted approach, including elevated development areas, wide set-backs and adaptive strategies at the perimeter that allow for increasing the height of levees in the future.



Image credits: Moffat & Nichol Treasure Island Study 2008

future sea level rise is higher than a project that would require substantial reconstruction to increase its level of protection (See Treasure Island side bar as an example).

Accountability

Adaptation plans should include clear accountability and trigger points for bringing adaptation strategies online. Sea level rise science is a relatively new field that is subject to change as new information and studies become available. A well-defined process should be developed within each department to ensure that milestones are being met, the latest science is being considered, and vulnerability assessments are being completed as part of the capital planning process.

PERMITTING AND REGULATORY CONSIDERATIONS

Note: Zoning maps accompanying this section are in a separate document

Public and private development and infrastructure projects located in the City's bay and ocean shoreline areas are regulated by local controls in the City's General Plan and Planning Code as well as by California's two coastal zone management agencies: the San Francisco Bay Conservation and Development Commission (BCDC) and the California Coastal Commission (CCC). These agencies are required to ensure that projects and plans subject to their jurisdiction avoid or minimize hazards related to sea level rise. As such, CCSF departments should consider the applicable state regulations, policies and guidance concerning sea level rise and coordinate with the relevant department staff.

San Francisco Bay Conservation and Development Commission

BCDC has permit jurisdiction over San Francisco Bay and the land lying between the Bay shoreline and a line drawn parallel to, and 100 feet from, the Bay shoreline known as the 100-foot shoreline band.

In October 2011, BCDC adopted amendments to the San Francisco Bay Plan addressing sea level rise. These policies require sea level rise risk assessments when planning in shoreline areas or designing larger shoreline projects. If sea level rise and storm surge levels that are expected to occur during the life of the project would result in public safety risks, the project must be designed to cope with flood levels expected by mid-century. If it is likely that the project will remain in place longer than mid-century, the applicant must have a plan to address the flood risks expected at the end of the century.

California Coastal Commission

All public and private projects in the City's coastal zone must be undertaken in accordance with an approved coastal development permit from either the City Planning Department or the CCC.

The CCC oversees a grant program to support local government planning efforts addressing sea level rise, and released Draft Sea-Level Rise Policy Guidance for public review and comment on October 14, 2013. In that Draft Guidance, consistent with this CCSF Guidance, the CCC considers the NRC 2012 report as the best available science on sea level rise in California, though this Guidance treats the NRC 2012 report somewhat differently than the draft CCC Guidance.

City departments with assets in the Coastal Zone should refer to the Coastal Commission's Sea-Level Rise Policy Guidance for a detailed discussion of relevant Coastal Act policies and regulations.

EXAMPLE APPLICATION OF GUIDANCE IN CAPITAL PLANNING

The following example illustrates how a City department could consider the effects of sea level rise in its capital planning process for several public assets in the same area – the construction of a new fire station, the rehabilitation of an existing vacant waterfront building into a visitor center, and the construction of a new shoreline park. Based on a review of the readily-available inundation maps, these assets would be inundated permanently with 48 inches of sea level rise, and inundated periodically by the following flood scenarios:

- 6 inches of sea level rise plus a 100-year flood event
- 12 inches of sea level rise plus a 50-year flood event
- 24 inches of sea level rise plus a 5-year flood event
- 36 inches of sea level rise and a 1-year extreme (King) tide event).

For each asset, the project manager would *select the most appropriate sea level rise scenario*, based on the asset's expected lifespan, location, and other factors, and also determine if using the *most likely* projections is adequate for current planning, or if the *extreme* ranges should be used for more conservative planning or for the development of potential adaptation strategies.

New Fire Station:

- *Sea Level Rise Scenario Selection:* The fire station would not be located directly adjacent the shoreline, but it is within the future inundation zone. The functional lifespan of the asset is 50 years, and the consequence of the structure being flooded is extremely high as the fire station is considered a critical asset that is essential during emergency situations. The project manager selects the *100-year flood* condition and the *2050 upper sea level rise estimate (24 inches)* as the appropriate scenarios for planning. Because of the critical nature of the asset, the project manager also selects *2100 conditions most likely* and *extreme projections* in order to assess the need for future adaptation strategies.
- *Vulnerability Assessment:* Although the fire station will not be permanently inundated with 24" of sea level rise, it would be inundated by the 100-year flood event for all sea level rise projections greater than 6 inches. The asset is given a *medium exposure* rating, and is considered *highly sensitive* due to its function as a critical infrastructure that must be operational during an extreme flood event. The asset is not an existing asset; therefore its inherent resilience is not applicable and is not rated as part of the vulnerability assessment.
- *Risk Assessment:* The likelihood that the fire station would be inundated by a 100-year flood event with 24 inches of sea level rise is considered high based on its location and exposure. If the fire station were inundated, it could be repaired, but the disruption of its function during a flood event could lead to public safety impacts. The overall risk of siting the station in an area subject to this level of flooding is determined to be *high*. This project is a high priority for adaptation planning.
- *Adaptation Planning:* The project manager evaluates raising grades and flood proofing to increase the adaptive capacity of the fire station; however, these improvements are insufficient as the access roads surrounding the asset would also be compromised during an extreme flood event. It would be too costly to build in sufficient adaptive capacity to the fire station and its surroundings. The project manager decides that the fire station should be sited in an alternate location at a higher grade.

Rehabilitated Visitor Center:

- *Sea Level Rise Scenario Selection:* The existing vacant structure is located directly adjacent to the shoreline where it could be exposed to storm surge and wave hazards. The functional lifespan of the rehabilitated structure is 25 years. The consequence of the structure being flooded is low as the

structure is not a critical asset. The project manager selects the *2050 most likely sea level rise estimate* (11 inches) as the appropriate scenario for planning. The project manager also selects the *2050 upper sea level rise estimate* (24 inches) and the *5-year* and *100-year flood* events for the potential development of adaptation strategies.

- *Vulnerability Assessment*: The visitor center would have a *high exposure* rating based on its location, and a *medium sensitivity* rating since it could be temporarily closed after a flood event until it is repaired. It would have *low resilience* since the existing building was constructed without consideration of potential future flooding and may only partially recover from a flood event.
- *Risk Assessment*: Although damage from an extreme flood event could be moderate to high, the building could likely be repaired. Both the cost to repair the building and its potential disruption of service are considered acceptable. The temporary loss of the visitor center after a flood event would have minimal consequence on the public (no health or safety effects), resulting in an overall *low risk*. Although this project may be considered to have a low priority for adaptation planning based on its risk level, adaptation planning is warranted since the rehabilitation of this existing structure is a high priority for the City.
- *Adaptation Planning*: The building is proposed to be retrofitted to meet flood resistant building standards, and shoreline improvements are planned that will make the overall site resilient to inundation by a 5-year flood event with 11 inches of sea level rise. The adaptation plan identifies additional shoreline improvements that can be constructed to make the site more resilient to a 5-year storm surge event if sea level rise tracks with the upper bound of 24 inches sea level rise by 2050. The adaptation plan also identifies short term closure strategies for more severe storm surge events.

New Shoreline Park:

- *Sea Level Rise Scenario Selection*: The shoreline park site is located directly adjacent to the shoreline in a highly exposed area. The shoreline improvements are intended to make the overall shoreline and inland developed areas more resilient to sea level rise through 2050. The project manager selects the *2050 most likely* (11 inches) and *upper bound* (24 inches) sea level rise projections for project planning. The project manager also selects the *10-year* and *100-year flood events* for planning purposes. The park will be planned to be resilient to 10-year flood inundation, and to minimize adverse impacts associated with a 100-year flood event.
- *Vulnerability Assessment*: Based on its location, the park has a *high exposure* rating. The park is given a *low sensitivity* rating since the existing area, and the future park, will accommodate inundation by a range of events. The asset is not an existing asset; therefore its inherent resilience is not applicable and is not rated.
- *Risk Assessment*: The park is expected to require minimal repairs at relatively low cost after being inundated by an extreme event beyond the design event (5-year flood). The consequence to the public of not being able to access the park during repairs is also low; however, some of the park elements are designed to provide protection to inland developed areas, therefore the overall risk rating is selected as *medium risk*.
- *Adaptation Planning*: The park will be constructed to accommodate flooding and provide protection to the adjacent areas. Flood resistant materials will be selected to minimize maintenance and repair requirements due to periodic flooding (e.g. benches are made of concrete and are securely anchored to the ground and the park is landscaped with salt tolerant species). The plan outlines shoreline strategies that could be implemented if a higher level of protection is needed to accommodate either higher sea level rates or flood scenarios.

City & County of San Francisco

The guiding policy document for the City & County of San Francisco is the General Plan. This document, adopted by the Planning Commission and approved by the Board of Supervisors, serves as the embodiment of the community's vision for the future of San Francisco. The Charter establishes that changes of use and public construction projects be consistent with this policy document. The General Plan guides decisions that both direct the allocation of public resources and that shape private development. For this reason, managers of capital projects should confirm that their proposed project is consistent with the General Plan early in the planning process. A part of the General Plan is also our Local Coastal Program. Within the General Plan, the Western Shoreline Plan, combined with the related sections of the San Francisco Zoning Code, and Zoning District Maps, together constitute the City's LCP. Meaning, projects in this area may require review by the City's Planning Commission, the Historic Preservation Commission, the Board of Supervisors, and the Coastal Commission.

Similarly, the Port Commission uses the Waterfront Land Use Plan to govern property under the Port Commission's jurisdiction. The Waterfront Land Use Plan (WLUP) was initially adopted by the Port Commission in 1997. It defines acceptable uses, policies and land use information applicable to all properties under the Commission's jurisdiction. Property under the jurisdiction of the Port may require review by the San Francisco Planning Commission and Board of Supervisors, the San Francisco Bay Conservation and Development Commission (BCDC), and the State Lands Commission to align the various land use plans and policies held by each entity.

APPENDICES

1. Sea Level Rise Committee Members
2. City and County Projects with sea level rise nexus (partial list)
3. Summary of the Science
4. Projections of Sea Level Rise for other Years
5. Checklist
6. Links to Additional Resources (publications, state adaptation guidance and tools, technical assistance resources, potential grant funding opportunities, etc.)

Appendix 1

The following members comprise the Sea Level Rise Committee of SF Adapt.

David Behar (Chair), Climate Program Director, San Francisco Public Utilities Commission

Lauren Eisele, Senior Environmental Planner, Port of San Francisco

Frank Filice, Manager of Regulatory Affairs, San Francisco Department of Public Works

Chris Kern, Senior Environmental Planner, San Francisco Planning Department

Kris May, Senior Coastal Engineer and Scientist, AECOM

Craig Raphael, Senior Transportation Planner, San Francisco Metropolitan Transportation Agency

Nohemy Revilla, Climate Change Liaison, San Francisco Public Utilities Commission

Anna Roche, Climate Change Adaptation Manager, San Francisco Public Utilities Commission

AnMarie Rodgers, Manager of Legislative Affairs, San Francisco Planning Department,

Brian Strong, Director, San Francisco Capital Planning Program

Dilip Trivedi, Senior Coastal Engineer, Moffat and Nichol

Rosalyn Yu, Senior Engineer, San Francisco International Airport

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Appendix 2 City and County Projects with sea level rise nexus (partial list)

City and County Projects with sea level rise nexus (partial list).

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Appendix 3 Science Summary

Summary of the Science

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Appendix 4 Projections of Sea Level Rise for other Years

If departments want to make sea level rise calculations for years other than 2030, 2050, and 2100, a simple interpolation “best fit” equation may be used. Different equations are required for the low end range, the projection, and the high end range estimates in the NRC Report and this Guidance because each accelerated increase in sea levels has its own curve.¹⁵

The following equations produce SLR estimate *in centimeters* for each type of estimate for years other than 2030, 2050, and 2100:

1. Upper Range (cm) = $0.0093t^2 + 0.7457t$
2. Lower Range (cm) = $0.0038t^2 + 0.039t$
3. Projection – Most Likely (cm) = $0.000045t^3 + 0.00037t^2 + 0.428t$
4. Projection – Most Likely + 1 standard deviation (cm) = $0.000053t^3 + 0.0006t^2 + 0.58t$
5. Projection – Most Likely - 1 standard deviation (cm) = $0.000038t^3 + 0.00013t^2 + 0.276t$

Where “t” is the number of years after 2000

For example, if an asset has an expected life of 60 years and you wanted to know the Upper Range of sea level rise between 2000 (the baseline year for all estimates in this Guidance) and 2060, you would use Equation (1), with t = 60.

$$\begin{aligned}\text{Upper Range (cm)} &= 0.0093 \times (60)^2 + (0.7457 \times 60) \\ &= 33.48 + 44.74 \\ &= 78.22 \text{ cm, SLR in 2060, Upper Range} \\ \text{Convert to inches} &= 78.22 / 2.54 \text{ cm/inch} \\ &= \mathbf{31 \text{ inches, Upper Range for sea level rise in 2060}}\end{aligned}$$

¹⁵ California Coastal Commission Draft Sea-Level Rise Policy Guidance, Public Review Draft. October 14, 2013 (page 123-124).

Appendix 4 Checklist

Copy of the CIP SLR Checklist

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Appendix 5 Links to Additional Resources

This appendix provides a list of links to referenced materials and additional resources. These materials include publications, federal and state guidance and tools, technical assistance resources, and links to potential grant funding opportunities:

Publications

IPCC 2013, Climate Change 2013, the Physical Science Basis. Intergovernmental Panel on Climate Change, 2013. www.ipcc.ch/report/ar5/wg1/

NRC 2012 *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past Present and Future*. Prepared by the Committee on Sea Level Rise in California, Oregon, and Washington; Board on Earth Sciences and Resources; Ocean Studies Board; Division on Earth and Life Studies; National Research Council 2012. http://www.nap.edu/catalog.php?record_id=13389

Additional Resources

CalAdapt Cal-adapt is a web-based climate adaptation planning tool. Cal-adapt allows the user to identify potential climate change risks in specific geographic areas throughout the state. Users can either query by location, or click on an interactive map to explore what climate impacts are projected to occur in their area of interest. The site has been developed by UC Berkeley's [Geospatial Innovation Facility](#) (GIF) with funding and advisory oversight by the [California Energy Commission's](#) Public Interest Energy Research (PIER) Program, and advisory support from [Google.org](#). <http://cal-adapt.org/>

CAKE-Climate Adaptation Knowledge Exchange The Climate Adaptation Knowledge Exchange (CAKE) was founded by EcoAdapt and Island Press in July 2010, and is managed by EcoAdapt. It aims to build a shared knowledge base for managing natural and built systems in the face of rapid climate change. <http://www.cakex.org/>

CCAMP FEMA Region IX flood studies/mapping projects in coastal areas as a result of Congressional appropriations for Flood Hazard Mapping under [Risk MAP](#). Cumulatively, these flood studies/mapping projects are being referred to as the California Coastal Analysis and Mapping Project (CCAMP). (FEMA, www.r9coastal.org); Open Pacific Coast Study Information for San Francisco: <http://www.r9map.org/Pages/ProjectDetailsPage.aspx?choLoco=38&choProj=261>

Georgetown Climate Center Based at Georgetown Law, the Center works extensively with government officials, academics, and an array of stakeholders to strengthen state and federal climate partnerships. The Center analyzes the provisions of federal policy relevant to states and territories, and encourages policymakers to learn from and adopt innovative policies emerging from the states. <http://www.georgetownclimate.org>; Adaptation Tool-Kit: Sea-Level Rise and Coastal Land Use, 2011: <http://www.georgetownclimate.org/resources/adaptation-tool-kit-sea-level-rise-and-coastal-land-use>

Guidance Documents

California Coastal Commission Draft Guidance 2013

California Coastal Commission Sea Level Rise Policy Guidance, Public Review Draft. October 14, 2013. http://www.coastal.ca.gov/climate/slr/guidance/CCC_Draft_SLR_Guidance_PR_10142013.pdf

California Climate Action Team (CO-CAT) Update 2013 *State of California Sea-Level Rise Guidance Document*. Developed by the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), with science support provided by the Ocean Protection Council's Science Advisory Team and the California Ocean Science Trust. March 2013 Update. http://www.opc.ca.gov/webmaster/ftp/pdf/docs/2013_SLR_Guidance_Update_FINAL1.pdf

National Climate Assessment May 2014 The National Climate Assessment summarizes the impacts of climate change on the United States, now and in the future. A team of more than 300 experts guided by a 60-member Federal Advisory Committee produced the report, which was extensively reviewed by the public and experts, including federal agencies and a panel of the National Academy of Sciences. <http://nca2014.globalchange.gov/>

Grant Opportunities (targeted for SLR vulnerability, risk, adaptation or mitigation measures)

Coastal Conservancy

EPA

FEMA Hazard Mitigation Grants

Etc.

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