APPENDIX E

Appendix E: Data Sources

Dataset or Asset Type	Description	Data Source	Date	Notes
Airports		County of San Mateo	2015	
Beaches		California Coastal Trail Association, San Mateo County Parks Department	2008, 2015	
Boat Launches		California Department of Fish and Wildlife, Marine Region GIS Unit	2012	
Buildings with Affordable Rental Units	Buildings with rental units for extremely low-income families or families with incomes below the poverty line in San Mateo County.	County of San Mateo Department of Housing	2015	
Caltrans Maintenance Facilities		California Department of Transportation, via David Ford Consulting Engineers	2013	Report from David Ford Consulting Engineers completed in 2013.
Coastal Erosion	Erosion hazard under a 1.4-meter sea level rise scenario (predicted for year 2100).	Phil Williams & Associates, LTD	2009	Developed and used in the Pacific Institute study (2012).
Communication Towers	Consists of cell phone, land mobile, paging, radio, and television towers.	Federal Communications Commission, Wireless Telecommunications Bureau	2010	
Eelgrass Habitat		California Department of Fish and Wildlife, Marine Region GIS Unit	2014	
Electric Substations		California Energy Commission	2014	
Emergency Operations Centers		California Department of Water Resources, Risk Characterization Study	N/A	Source date unavailable at time of publication.

Dataset or Asset Type	Description	Data Source	Date	Notes
Emergency Shelter Sites	Includes a general shelter inventory and any Human Services Agency offices or partner locations designated as emergency shelters.	County of San Mateo	2015	
Fire Stations		County of San Mateo	2015	
Fishing Piers		California Department of Fish and Wildlife, Marine Region GIS Unit	2012	
Hazardous Material Sites	Includes sites where recent or historical unauthorized releases of pollutants to the environment, including soil, groundwater, surface water, and sediment, have occurred, as well as locations that are relevant to emergency response risk planning.	California Water Board; United States Environmental Protection Agency, via David Ford Consulting Engineers; California Department of Water Resources, Risk Characterization Study	2015, 2013	Data from San Mateo County provided in 2015; Report from David Ford Consulting Engineers completed in 2013; Source date for the Risk Characterization Study is unavailable at the time of publication.
Healthcare Facilities (emergency)	Healthcare facilities with emergency rooms and inpatient accommodations; includes public and private hospitals.	California Office of Statewide Health Planning and Development	2012	
Healthcare Facilities (inpatient)	Healthcare facilities without emergency rooms but with inpatient accommodations; includes hospitals and long-term care facilities.	California Office of Statewide Health Planning and Development	2012	
Healthcare Facilities (outpatient)	Healthcare facilities without emergency rooms or inpatient accommodations; includes clinics, hospice, and home health agencies.	California Office of Statewide Health Planning and Development	2012	

Dataset or Asset Type	Description	Data Source	Date	Notes
Highway and Railway Bridges		California Department of Water Resources, Risk Characterization Study	N/A	Source date unavailable at time of publication.
Highways	Federal and State Highways.	United States Census Bureau	2015	
Human Services Agency Facilities	Locations of Human Service Agency offices and partner agencies that are not also potential emergency shelter sites.	County of San Mateo Human Services Agency	2015	
Jails		County of San Mateo	2015	
Kelp Habitat		California Department of Fish and Wildlife, Marine Region GIS Unit	2009	
Lakes		County of San Mateo	2015	
Levees and Floodwalls	Includes bayside levees and floodwalls and coastal floodwalls.	San Francisco Estuary Institute, National Oceanic and Atmospheric Administration	2016, 2013	
Marinas		California Department of Fish and Wildlife, Marine Region GIS Unit	2012	
Mobile Home Parks		County of San Mateo Office of Sustainability	2015	
Natural Gas Pipelines		National Pipeline Mapping System, California Energy Commission	2015, 2015	NPMS data requested in October 2015; said to be updated every 12 months.
Natural Gas Storage	Includes natural gas stations and breakout tanks.	National Pipeline Mapping System, California Energy Commission	2015, 2014, 2015	NPMS data requested in October 2015; said to be updated every 12 months.
Oil, Gas, & Geothermal Wells		California Energy Commission	2015	

Dataset or Asset Type	Description	Data Source	Date	Notes
Other Built Shorelines	Includes bayside berms, embankments, shoreline protection structures, transportation structures, and water control structures, as well as structures, as well as coastal revetments and breakwaters.	San Francisco Estuary Institute, Coastal Commission, National Oceanic and Atmospheric Administration	2016, 2012, 2013	
Outfalls		City/County Association of Governments of San Mateo County	2015	
Parcels	Assessed value and type of parcels in the hazard zone of the project area.	County of San Mateo	2015	
Parks		County of San Mateo Parks Department	2015	Park footprints were converted to points in order to count discrete parks. A park that overlaps jurisdictional boundaries will be counted for each city or town it is in.
Police Stations		County of San Mateo	2015	
Population	Number of people potentially exposed to inundation or erosion.	United States Census Bureau	2010	Counted at the census block level. Portions of a census block population were counted based on the percentage of the block's land in the particular hazard zone.
Population in Vulnerable Communities	Number of people living in communities that are less able to prepare, respond and recover from natural hazards.	Association of Bay Area Governments, Resilience Program (Communities at Risk)	2014	Counted at the census block level. Portions of a census block population were counted based on the percentage of the block's land in the particular hazard zone.
Ports		California Department of Fish and Wildlife, Marine Region GIS Unit	2012	
Power Plants		California Energy Commission	2015	

Dataset or Asset Type	Description	Data Source	Date	Notes
Priority Development Areas		Association of Bay Area Governments	2016	
Rail	Centerlines of BART, Caltrain, and freight railroad tracks.	San Mateo County Transit District	2015	
Rail Stations	BART and Caltrain Railroad stations.	San Mateo County Transit District	2015	
Refined Products Terminals		California Energy Commission	2015	
Roads (local)	Roads not classified as Federal or State Highways.	United States Census Bureau	2015	
Salt Ponds and Crystallizers		San Francisco Estuary Institute	2001	
Satellite Imagery	Satellite background for maps in the report.	Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, Harris Corp, 2016 Microsoft Corporation	2016	Asset Exposure maps use the Esri World Imagery basemap; all other maps use Bing Aerial Imagery.
Schools	Public, private, and charter schools.	County of San Mateo Office of Education	2015	
Sea Level Rise Scenarios	Baseline (0 cm), mid-level (100 cm), and high-end (200 cm) sea level rise scenarios.	United States Geological Survey (Our Coast, Our Future)	2016	
Senior Centers	Facilities that provide multiple services to older adults in San Mateo County.	County of San Mateo Health System	2015	
Solid Waste Facilities		County of San Mateo	2015	

Dataset or Asset Type	Description	Data Source	Date	Notes
Storm Drains		City/County Association of Governments of San Mateo County	2015	
Stormwater Pump Stations		City/County Association of Governments of San Mateo County	2015	
Streams		County of San Mateo	2015	
Surfgrass Habitat		California Department of Fish and Wildlife, Marine Region GIS Unit	2005	
Trails	Trails in San Mateo County.	San Mateo County Parks Department; National Park Service, California Department of Parks and Recreation, California Coastal Commission, California Coastal Trail Association	2015, 2012	
Transmission Lines		California Energy Commission	2015	
Transmission Towers		County of San Mateo	2015	
Underground Chemical Storage Tanks	Permitted Underground Storage Tanks containing hazardous material.	State Water Quality Control Board (Geotracker)	2015	
Urban, Agricultural, Industrial, and Natural Land		California Department of Water Resources, Risk Characterization Study	2012	
Wastewater Pump Stations		County of San Mateo	2016	
Wastewater Treatment Plants		County of San Mateo	2015	

Dataset or Asset Type	Description	Data Source	Date	Notes
Wetlands		California Department of Fish and Wildlife, Marine Region GIS Unit, San Francisco Estuary Institute	2006, 2001	The inventory counts the area of wetlands exposed to the sea level rise ‘footprint.’ This does not take into consideration sediment or wetland accretion rates.

APPENDIX F

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San Mateo County Vulnerability Assessment

Appendix F: Report on Asset Categorization and Classification

September 22, 2015

Tables

Figures

1. Introduction

A critical part of a comprehensive sea level rise (SLR) vulnerability assessment (VA) is categorizing and classifying the built and natural assets that will be exposed to present and future inundation in San Mateo County. Because there are so many different assets and asset types in urban areas like San Mateo County, it could be overwhelming for decision makers to understand what is and will be exposed to inundation, what it could mean if assets were inundated, and whether the vulnerability of some assets warrants action. Asset categories and classes enable us to think about this issue differently and provides a framework to focus on the most critical issues first.

The approach taken in this SLR VA has two parts and is complimentary to (the) regional Adapting to Rising Tides SLR VA methodology.[1] In addition to categorizing assets by their similar function or sector (part I), this method also integrates a risk component whereby prior to any evaluation of an asset, the asset will be assigned to a risk class (1, 2, 3, or 4) according to the severity or magnitude of the consequences if it were to flood (part 2). In the end, this additional step in the methodology will provide a high-level understanding of what kinds of assets are at risk in the County, and where those assets are located. The risk-based criteria described below provide a sense of the criticality in terms of public health, safety, and welfare. It further provides preliminary insight into cross-cutting vulnerabilities, and into the Adapting to Rising Tides (ART) guiding question: *If exposed to climate impacts, what is the expected magnitude of the consequences?*[2]

The approach used in this assessment accounts for all of the built and natural assets within the project boundary, including attention to human assets, and provides a framework for future risk analyses and a flood risk management/sea level rise adaptation strategy. As described below, the overall methodology including the asset classification component was developed to better prepare San Mateo County and its cities to apply for federal funding to reduce flood risk.

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[1] San Francisco Bay Conservation Development Commission (BCDC). (2012). Adapting to Rising Tides project. Accessible: http://www.adaptingtorisingtides.org/

[2] BCDC. (2012). Adapting to Rising Tides: Chapter 1, page 10.

1.1 Purpose

The purpose of this document is to describe the previously defined categories and classes into which San Mateo County assets will be organized, and to explain the rationale and criteria used to classify the assets. This document also provides a preliminary list of San Mateo County's assets, assigned to the appropriate asset class.

1.2 Definitions and Background

To support a better understanding of this document, this section discusses some key terms and background.

Flood risk is the product of the likelihood of inundation and the potential for adverse consequences when inundation occurs. For purposes of this project, the terms *inundation* and *flood* are used interchangeably.

Risk-based criteria means that the consequences to public health and safety of inundation are a determining factor in assigning built assets to classifications.

A *flood risk management strategy* (Figure 1 below) is an overall strategy aimed at reducing flood risk; it is developed based on a clear understanding of risk, and incorporates stakeholder preferences and economic efficiency.

A *flood risk assessment* (Step 1 in Figure 1 below) provides a clear understanding of risk, and involves identifying the likelihood of inundation and the potential consequences of inundation. The consequences are determined by who and what lie in harm's way, and how vulnerable they are to inundation (vulnerability assessment, Figure 1 below).

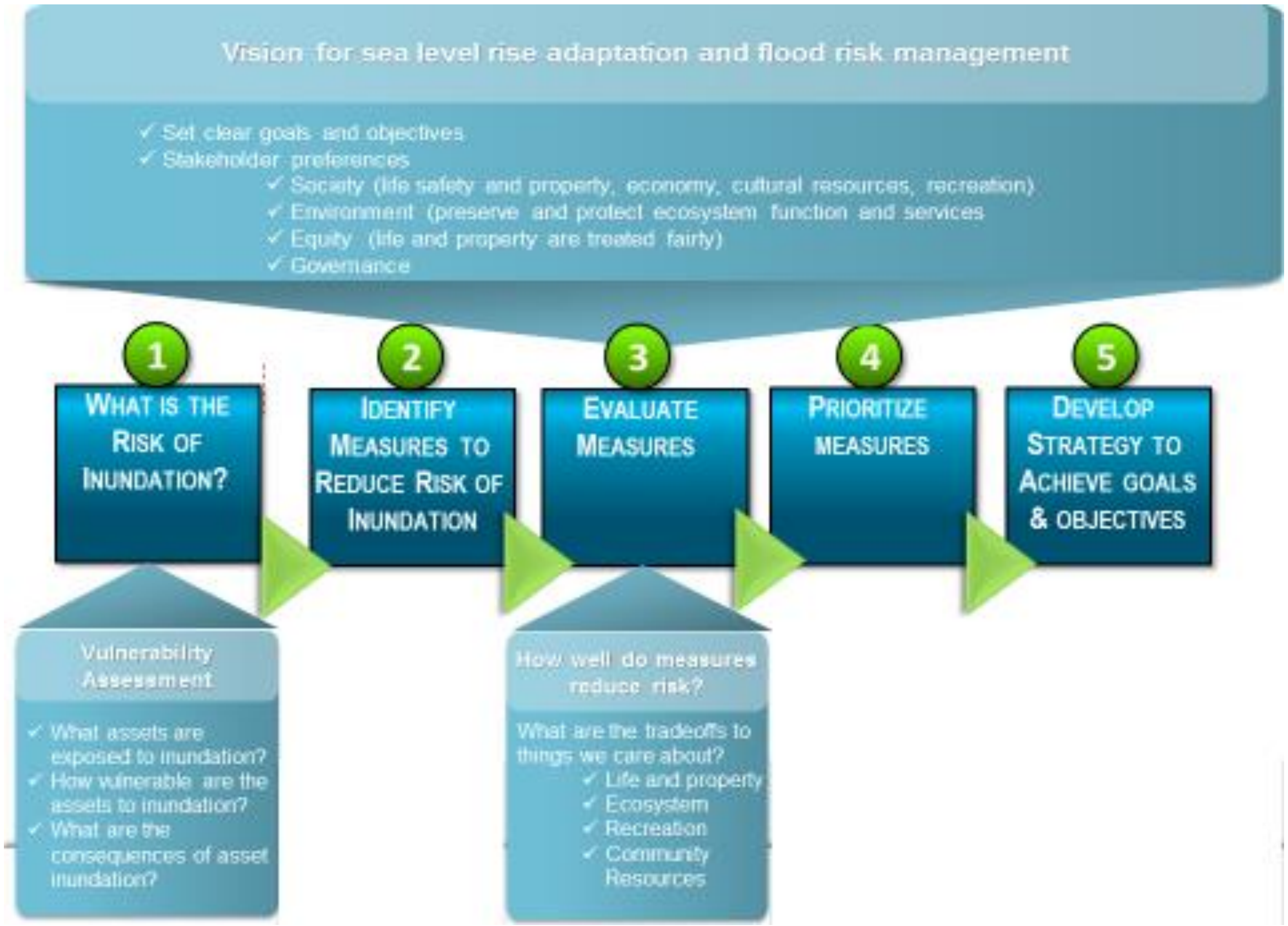
An *asset category* refers to a group of assets that are similar in function or service; for example, energy infrastructure and pipelines, ground transportation, hazardous materials, and natural areas.

An *asset class* refers to a group of assets that are organized based on risk and criticality for built assets, and based on habitat type or species for natural assets. Classifying assets is a critical part of understanding risk (part of Step 1 in Figure 1 below).

It is important to distinguish asset *classification* from asset *prioritization.* Asset classification is objective and transparent; it organizes built assets such as housing, transportation infrastructure, energy infrastructure, and critical infrastructure, according to their function and criticality as it relates to public health, safety, and welfare. Asset classification also objectively captures natural and human assets without a weight or preference that could influence investment decisions or the outcomes of future assessments; it is part of the Vulnerability Assessment in Step 1 of Figure 1 below.

Asset *prioritization,* on the other hand, is subjective; it comes later in the flood risk management process (Step 4 in Figure 1 below), and is part of an overall flood risk management and sea level rise adaptation strategy. Such a strategy would be developed based on the results of a full risk assessment (Step 1), the effectiveness of risk-reduction measures (Steps 2 and 3) including cost, and an overall vision with specific goals and objectives that incorporate stakeholder preferences.

Figure 1 Components of a flood risk management and adaptation strategy



2. Approach to Asset Categorization and Classification

For a vulnerability assessment to be useful regionally, the method should support, align with, or compliment other regional best practices. For a vulnerability assessment method to be credible, it should be transparent, defendable, and based on the best available science.

To that end, the San Francisco Bay Conservation Development Commission (BCDC) developed a methodology in the *Adapting to Rising Tides* (ART) project to guide vulnerability assessments in the San Francisco Bay area. This method is being adopted and used by many local jurisdictions as they begin to address SLR adaptation. The ART project specifically identifies and describes 12 asset categories into which assets should be organized for analysis[3]. This enables communities to assess vulnerabilities and risk to entire sectors. Therefore, to align with regional efforts, all natural and built assets in San Mateo County will be categorized in to the same 12 categories identified in the report and listed below.

Meanwhile, flood risk management under federal guidance (US Army Corps of Engineers) identifies life safety as paramount; federal funding for flood risk reduction and hazard mitigation is almost exclusively allocated to projects that reduce risk to life and property.[4] California state guidance on sea level rise preparedness[5] (Safeguarding California, California Coastal Commission Sea Level Rise Guidance) places an emphasis on nature-based solutions and protection of vulnerable populations. In addition, this project is funded through California State Coastal Conservancy Climate Ready grant funds, which require a focus on protection of natural resources. Therefore, it is critical to incorporate these elements into a vulnerability assessment since the vulnerability assessment is one of the first steps to developing a flood risk management and sea level rise adaptation strategy.

2.1 Built Assets

The American Society of Civil Engineers (ASCE) developed guidance on building standards in order to protect public health, safety, and welfare in the event of a hazard. In the guidance, titled *ASCE 24-14 Flood Resistant Design and Construction*[6] and *ASCE 7-10 Minimum Design*

[3] San Francisco Bay Conservation Development Commission (BCDC). (2012). Adapting to Rising Tides: Existing Conditions and Stressors

[4] California Department of Water Resources (DWR). (2013). Floodsafe California: California's Flood Future: Recommendations for Management the State's Flood Risk.

[6] American Society of Civil Engineers (ASCE). (2015). 24-14 Flood Resistant Design and Construction

Loads for Buildings and Other Structures[7], built assets are assigned a risk classification according to the assets' function or occupancy type, and the classes range from class 1—no or low risk to public safety and society (including economic disruption)—to class 4—highest risk to public safety and society. The guidance documents then provide construction and design guidelines for assets in each class in order to minimize risk to public safety, and society. The ASCE built asset classes are used by FEMA in its Hazard Mitigation Assistance programs[8], whereby flood mitigation measures must be designed for a flood elevation that is associated with each asset class. The ASCE asset classes have also been adopted by the International Building Code Council[9]and by the California Building Codes[10]; it is therefore appropriate to use them in this vulnerability assessment. This approach of asset classification is also consistent with the State of Florida Department of Emergency Managements' Public Facilities Flood Mitigation Initiative[11]

In addition to assigning each asset type to one of the 12 *Adapting to Rising Tides* (2012) categories referenced above, all built assets in San Mateo County will be herein classified according to the same criteria used to classify assets in *ASCE 24-14*. This approach is transparent and defendable; it also enables consideration of societal disruption, as well as issues of equity because all assets are classified objectively using the same criteria.

2.2 Natural Assets

To date, no guidance exists to assign *natural assets* to a risk class (low to high) as in the built asset method, and there is currently not consensus among the scientific community on which ecosystem types are more critical or valuable than others in a way that would support a risk classification for natural assets. If natural assets were assigned to the classes under *ASCE 24-14*, they would in most cases be assigned to the lowest risk class because inundation would not necessarily pose a threat to public health, safety, and welfare. As a result, a decision maker, unless he or she has time to do a detailed investigation into each of the classified assets, would

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[7] ASCE (2013). 7-10 Minimum Design Loads for Buildings and Other Structures

[8] FEMA (2015). Hazard Mitigation Assistance Guidance Addendum. Available from: http://ecodes.biz/ecodes_support/free_resources/2013California/13Building/PDFs/Chapter%2016%20-%20Structural%20Design.pdf

[9] International Code Council, see table 1604.5 Available from: http://publicecodes.cyberregs.com/icod/ibc/2012/icod_ibc_2012_16_par023.htm

[10] California Building Codes, 2013, see table 1604.5, available from http://ecodes.biz/ecodes_support/free_resources/2013California/13Building/PDFs/Chapter%2016%20-%20Structural%20Design.pdf

[11] Florida Division of Emergency Management (2015). Public Facilities Flood Hazard Mitigation Assessment Manual. Accessible: http://www.floridadisaster.org/Mitigation/SMF/Index.htm

not be aware of potentially critical habitat or natural asset. Therefore, it would be inappropriate to assign natural assets a risk-based classification.

However, natural assets such as wetlands, marshes, beaches, and endangered species are of great importance to San Mateo County, the State of California, and the federal government (see applicable State of California Coastal Act policies[12], Executive Order 11990 on the protection wetlands, Executive Orders 11988 and 13690 on the wise use of floodplains, and the Federal Endangered Species Act,). Not only do natural assets provide intrinsic value to San Mateo County and its residents, but natural assets are also recognized for the services they may provide, including biodiversity, flood and erosion control, water quality improvement, and carbon sequestration.[13] Therefore natural assets will be included in this vulnerability assessment. Natural assets will be classified as simply N, 'Natural,' with a descriptor partially based on the habitat types assessed in the *Climate Change Vulnerability Assessment for the North-Central California Coast and Ocean*[14], such as *N-beach*, or *N-wetlands*, *N-rocky intertidal,* or *N-species of concern* (Table 2). This provides an inventory of natural assets to support future flood risk analyses, and provides a baseline against which future adaptation strategies can be compared, in terms of how strategies may positively or negatively affect the county's natural assets.

2.3 Human Assets

The protection of human health and safety is often the priority of a flood risk management strategy, therefore the vulnerability assessment offers an opportunity to identify the number of people that are exposed to a flood hazard or will be exposed in the future (Methodology report, steps five, six, and seven). Further, some individuals and communities are less able to respond and adapt to natural hazards like flooding (and the risks posed by sea level rise); instead, they are more vulnerable than the general population at large and may experience disproportionate impacts from flooding. Strategies to reduce the risks from flooding to vulnerable populations may need to be considered explicitly. The factors that could affect an individual's or community's ability to respond include (but are not limited to), things like age, income, education, and mobility. It is therefore imperative in SLR planning that the County understand

[12] California Coastal Act Sections: 30230, 30231, 30240, and 30253

[13] BCDC. (2012). *Adapting to Rising Tides*. Chapter 4

[14] Hutto, S.V., K.D. Higgason, J.M. Kershner, W.A. Reynier, D.S. Gregg. (2015). Climate Change Vulnerability Assessment for the North-central California Coast and Ocean. Marine Sanctuaries Conservation Series ONMS-15-02. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD.

where socially vulnerable or disadvantaged communities are, and consider this in the risk reduction strategies.

Similar to natural assets, human assets will not be classified according to risk. Instead, human assets will be classified as an "H", *followed by a descriptor,* meaning *human asset.* The vulnerability assessment will inventory both the population at risk (*H-Population*), and in the identification of socially disadvantaged or vulnerable populations (*H-Disadvantaged Community*). The assessment may also identify the location of affordable housing units (*H-Affordable Housing Unit*).

3. Asset Categories and Classes

All assets in San Mateo County will be assigned to one of the following 12 categories:

- Airport
- Community land use, services, and facilities
- Contaminated lands
- Energy infrastructure and pipelines
- Ground transportation
- Hazardous materials
- Natural areas
- Parks and recreation areas
- Seaport
- Structural shorelines
- Storm water
- Wastewater

For a detailed description of each category, please refer to *Adapting to Rising Tides: Existing Conditions and Stressors* (2012).

Table 1 below, is adapted from *ASCE 24-14* and describes each asset *class* according to the function of the asset or the occupancy of the building. The description includes examples of asset types that belong to each asset class. There are a number of asset types present in San Mateo County that were not explicitly listed in ASCE's table; therefore, these asset types are identified in the far right column and are organized according to asset class based on the description provided. In the far right column, where an asset has a number with parentheses, e.g., (4.*X*), the *X* refers to the number in the column to the left, as justification for why an asset was placed in that class.

Table 1 Classification for built assets in San Mateo County (Adapted from ASCE 24-14, Table 1-1)

Risk Classification	Description of Category	Asset type or function	San Mateo County assets not previously identified in ASCE list
1	Buildings and structures that normally are unoccupied and pose minimal risk to the public or minimal disruption to the community should they be damaged or fail due to flooding.	(1) temporary structures that are in place for less than 180 days (2) accessory storage buildings and minor storage facilities (does not include commercial storage facilities) (3) small structures used for parking of vehicles (4) certain agricultural structures.	Transit Maintenance Yard Trails and trailheads Beach access points
2	Buildings and structures that pose a moderate risk to the public or moderate disruption to the community should they be damaged or fail due to flooding, except those listed as Flood Design Classes 1, 3, and 4.	The vast majority of buildings and structures that are not specifically assigned another risk class, including most residential, commercial, and industrial buildings.	Marinas Job Centers Dept. of Defense Infrastructure (subset) Historic and Cultural Places/Resources Gas Fields Hotels/Hostels (subset) Parks
3	Buildings and structures that pose a high risk to the public or significant disruption to the community should they be damaged, be unable to perform their intended functions after flooding, or fail due to flooding.	(1) buildings and structures in which a large number of persons may assemble in one place, such as theaters, lecture halls, concert halls, and religious institutions with large areas used for worship (2) museums (3) community centers and other recreational facilities (4) athletic facilities with seating for spectators (5) elementary schools, secondary schools, and buildings with college or adult education classrooms (6) jails, correctional facilities, and detention facilities (7) healthcare facilities not having surgery or emergency treatment capabilities (8) care facilities where residents have limited mobility or ability, including nursing homes but not including care facilities for five or fewer persons (9) preschool and child care facilities not located in one- and two-family dwellings (10) buildings and structures associated with power generating stations, water and sewage treatment plants, telecommunication facilities, and other utilities which, if their operations were interrupted by a flood, would cause significant disruption in day-to-day life or significant economic losses in a community (11) buildings and other structures not included in Flood Design Class 4 (including but not limited to facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing toxic or explosive substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.	Confined Animal Facilities Water Sources, Canals, Intakes, and Outfalls Hazardous/Contaminated Sites (subset, 3.11) DoD Infrastructure (subset, 3.1, 3.11) Sports Facilities (3.1) Gas storage (subset, 3.11) Gas wells Nat. Gas Pipelines & Stations (3.11) Oil Pipelines (3.10, 3.11) Hotels/Hostels (subset, 3.1) Mines (subset, 3.11) Railroads Non-Federal Roads/Highways (3.10) Ports Transit Hubs Lighthouses
4	Buildings and structures that contain essential facilities and services necessary for emergency response and recovery, or that pose a substantial risk to the community at large in the event of failure, disruption of function, or damage by flooding.	(1) hospitals and health care facilities having surgery or emergency treatment facilities (2) fire, rescue, ambulance, and police stations and emergency vehicle garages (3) designated emergency shelters (4) designated emergency preparedness, communication, and operation centers, other facilities required for emergency response (5) power generating stations and other public utility facilities required in emergencies (6) critical aviation facilities such as control towers, air traffic control centers, and hangars for aircraft used in emergency response (7) ancillary structures such as communication towers, electrical substations, fuel or water storage tanks, or other structures necessary to allow continued functioning of a Flood Design Class 4 facility during and after an emergency (8) buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.	Hazardous/Contaminated Sites (subset, 3.11) Flood Control Infrastructure Fire Hydrants Evacuation Routes Gas Storage (subset, 4.8) Oil Pipelines (4.8) Bridges/Tunnels Mines (4.8) Federal Highways

Table 2 below identifies the classes that will be used to account for natural assets in San Mateo County. To date, they account for all natural assets in the dataset. Developing risk classes for natural assets may be a useful exercise in the future so that flood risk reduction measures can be evaluated for their effectiveness at reducing risk to critical ecosystems (as in Figure 1 above), or to those ecosystems and habitats most important to the region; however, this would require considerable scientific input, debate, and consensus. In the interim, as previously mentioned, existing legislation discourages building in floodplains, wetlands, or environmentally sensitive habitat areas, and the take of threatened species[15], so the suggested classification scheme for natural assets in San Mateo County should be appropriate. Details on the vulnerability of these natural assets and the services they provide will be assessed in the Asset Vulnerability Profiles if a natural asset is selected for a profile.

Table 2 Classification for natural assets in San Mateo County

Class	Natural Asset Descriptor	Natural asset type and examples
N-W	Natural Assets – Wetlands/ Estuaries	Wetlands, marshes, etc.
N-B	Natural Assets – Beaches/ Dunes	Beaches
N- R	Natural Assets – Rocky Intertidal	Rocky intertidal
N-S	Natural Assets – Species of concern	Federally or State-listed, threatened, or endangered species, or other species of concern, including those identified in the Climate Change Vulnerability Assessment for the North-central California Coast and Ocean, or elsewhere.
N-G	Natural Assets – Groundwater	Groundwater basin or source
N-O	Natural Assets – Other	Natural assets not listed in any other category

As mentioned, human assets will be accounted for and organized/classified in terms of the sheer number of the persons that are or could be exposed to current and future flooding posed by sea level rise, and in terms of communities that have been identified as socially vulnerable or disadvantaged.

[15] Coastal Act Sections: 30230, 30231, 30240, and 30253

3.1.1.1 Table 3 Classification of human assets

Class	Human Asset Description
H-P	Population exposed to current or future flooding (in number of individuals)
H-DC	Disadvantaged community
H-H	Affordable housing unit

4. Next steps: inundation mapping and asset inventory

As described in the Methodology report, after all assets for which data are available have been both categorized and classified, those assets that are exposed to current flooding or future sea level rise (step four in the methodology) will be displayed on a map according to asset class (steps five and six). This will provide county, city, and asset managers a clear sense of what types of assets are at risk, and where they are located. Asset inventories and spreadsheets (step seven) that correspond with the assets on the inundation maps will then be developed. The inventories will identify the number and types of assets at risk in each area according to asset category and asset class. A sample asset inventory spreadsheet is included in the Methodology report.

APPENDIX G

Appendix G: Selection of Inundation Scenarios for San Mateo County Sea Level Rise Vulnerability Assessment Memo

MEMO

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Copies:
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From:
Peter Wijsman

Date:
September 15, 2015

ARCADIS Project No.:
LA00SCC.0000

Subject:
Memo Regarding the Selection of Inundation Scenarios for San Mateo County Sea Level Rise Vulnerability Assessment

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Introduction

This memo describes the selection of three inundation scenarios that will be used to carry out the sea level rise risk and vulnerability assessment. These three inundation scenarios are based on the guidance in the California Coastal Commission's August 2015 Sea Level Rise Guidance Document Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits, which is consistent with many of the local sea level rise planning efforts in California. With the selection of inundation scenarios, the Project Management Team (PMT) aims to provide an understanding of today's flood risk as well as realistic future scenarios that account for sea level rise.

Why Scenarios

The use of scenarios is important to better understand the impact of flooding on local San Mateo County communities under different circumstances. While higher sea level rise scenarios are less likely to occur or will happen later in time, looking at these scenarios provides valuable input for zoning and risk reduction decisions. For example, flood protection features along the shoreline could be designed in such a way that they can be adapted later to withstand higher flood levels as there is more confidence in the rate of sea level rise, land use could shift over time to those that are more compatible with temporary or permanent inundation or, with capital improvements decisions on critical infrastructure taking a 100-year planning horizon into account might lead to a different designs or locations of assets.

Another important aspect of the selection of these scenarios is to understand the relationship between current day flood risk and future flood risk. The past few decades have shown that large parts of San Mateo County are vulnerable to flooding and erosion even today. Both on the bayshore and Pacific Ocean side, storm events have led to flooding and loss of assets in storm events well below the 1%-annual chance flood (also called the 1% chance flood, 1% annual exceedance probability), the event most commonly referenced storm event in FEMA flood hazard maps. The challenge and disruption posed by flooding will be exacerbated by sea level rise and future development, and risks of inundation will increase. Rather than presenting sea level rise as solely a problem of the future, tying flood risk to present the day will allow for near term action to reduce inundation risks to San Mateo County communities.

Coastal Commission and Other State Guidance

The Coastal Commission Sea Level Rise Guidance document Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits (2015) uses the 2012 National Research Council's (NRC) report *'Sea-Level Rise in California, Oregon and Washington that released the report, Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future'* as the most up to date and best available science for the California coast regarding sea level rise projection. This report provides an examination of global and regional sea level rise trends and projections of future sea level. The table below is an interpretation of this guidance used by the City of San Francisco for the San Francisco shoreline. This table provides an overview of potential sea level rise projections and ranges:

Year	Projections	Ranges
2030	6 +/- 2 inches	2 to 12 inches
2050	11 +/- 4 inches	5 to 24 inches
2100	36 +/- 10 inches	17 to 66 inches

Table 1: Sea Level Rise Projection for San Francisco (based on NRC 2012 from guidance for incorporating sea level rise into capital planning in San Francisco: assessing vulnerability and risk to support adaptation (September 2014))

The table presents the local projections which represent the *likely* sea level rise values (11 inches for 2050 and 36 inches for 2100) based on a moderate level of greenhouse gas emissions and extrapolation of continued accelerating land ice melt patterns with a certain deviation. The extreme limits of the ranges (17 and 66 inches for 2100 as an example) represent unlikely but possible levels of sea level rise utilizing both very low and very high emissions scenarios.

Furthermore, the Coastal Commission poses two key questions to help in establishing scenarios:

- What are the impacts from the worst-case scenario of the highest possible sea level rise plus elevated water levels from high tide, El Nino, and a 100-year storm (described in this study as the 1% annual event)?

- What is the minimum amount of sea level rise that causes inundation, flooding, or erosion concerns?

Other state guidance that is used to determine appropriate sea level rise scenarios comes from former Governor Schwarzenegger's Executive Order S-13-08 and the California Ocean and Climate Action Team (CO-CAT). This includes the following, partially overlapping recommendations:

- Executive Order S-13-08 details that planning should consider a range of sea level rise scenarios for the years 2050 and 2100 and sites the NRC 2012 scenarios.
- CO-CAT March 2013 Sea Level Rise Guidance Document recommends:
    1. Use of NRC 2012 ranges as a starting point and select sea level rise values based on agency and context-specific considerations of risk tolerance and adaptive capacity.
    2. Consider timeframes, adaptive capacity, risk tolerance when selecting estimates of sea level rise.
    3. Consider storms and other extreme events, including giving consideration to scenarios that combine extreme oceanographic conditions on top of the highest water levels projected to result from sea level rise over the expected life of a project.
    4. Coordinate with other state agencies when selecting values of sea level rise and, where appropriate and feasible, use the same projections of sea level rise.
    5. Future SLR projections should not be based on linear extrapolation of historic SLR observations.
    6. Consider changing shorelines as California has a very dynamic coast which will evolve under rising sea level. Assessments of impacts from sea level rise to shoreline projects must address local shoreline changes.
    7. Consider predictions in tectonic activity (not applicable for San Mateo County).
    8. Consider trends in relative local mean sea level. Predictions of future sea levels at specific locations will be improved if relative trends in sea level from changes in land elevation are factored into the analysis.

Our Coast Our Future Tool

The sea level rise vulnerability assessment will rely on the Our Coast Our Future (OCOF) tool. This is an online tool developed by National Oceanic and Atmospheric Administration (NOAA) and others, and fueled by the United States Geological Survey (USGS) hydrodynamic model called CoSMoS (Coastal Storm Modeling System) (http://data.prbo.org/apps/ocof/). The tool allows users to view different inundation scenarios for San Francisco Bay and parts of the Pacific Coast. In total, a combination of 41 different sea level rise and storm scenarios, including a King Tide scenario, can be selected. The output of the model is an interactive flood map in which flood extent, depth, duration, and minimum and maximum flood potential, wave height, and current velocity can be displayed. As this is a relatively new tool, there are some portions of the OCOF tool in San Mateo County that may not accurately reflect the shoreline elevation and could over or underestimate the risk from sea level rise.

Since the project is relying on an existing tool with existing data, there are limitations in terms of which storm and which sea level rise scenario is selected for further analysis. The storm scenarios available in the tool are: none, annual, 20-year and 100-year storms. There are 10 sea level rise scenarios available for analysis. These are summarized in the table below, in centimeters and inches above Mean Higher High Water (MHHW).

OCOF Tool Available Scenarios					
Sea Level Rise				Storms	
No.	Cm	Inches		No.	
1	0	0		1	None
2	25	9.8		2	Annual
3	50	19.7		3	20-year
4	75	29.5		4	100-year
5	100	39.4			
6	125	49.2			
7	150	59.1			
8	175	68.9			
9	200	78.7			
10	500	196.9			

Table 2: OCOF Tool Available Scenarios

Considering combinations that can be made from ten sea level rise scenarios and four storm scenarios, there are 40 possible alternative scenarios. Separately there is also one King Tide scenario (based on January 2014 King Tide) available, leading to 41 scenarios that are available to choose from for this study.

Peer Comparison

Appendix A provides an overview of San Mateo County, San Francisco Bay Area and other California sea level rise vulnerability studies that are currently underway and the inundation scenarios that are being used in those studies. From this overview, it is clear that there is a wide variety in approaches as to which scenarios could be used, however most of these studies are following the state's guidance and using the NRC best available science, yet they have not examined a common set of scenarios when comparing one to another. It should also be noted that while scenarios are presented for many different time horizons and different storm scenarios, the vulnerability and risk assessments themselves often use a subset of scenarios to describe the vulnerabilities in detail.

Proposed Inundation Scenarios

The table below presents the three proposed inundation scenarios for the vulnerability assessment and a rationale why these 3 scenarios were selected. These scenarios provide a broad range of water levels using approximately 0, 3 and 6 feet of sea level rise scenario (0, 100, 200 cm), plus the 1% annual chance storm. The 1% annual chance or 100-year storm is added as this is commonly used as input for the design height of a shoreline protection feature.

No.	Proposed Short Name	Water Level Input	Rationale
1	Present Day Flood Risk	MHHW + 1%-annual chance storm	The 100–year storm (1% annual chance) provides insight in present day flood risk without sea level rise. This is a water level that is high enough, compared to the other nearest lower OCOF flood levels (King Tide and 20-year storm), to show significant inundation in the county.
2	2100 Scenario (or 3 feet scenario + 100 year storm)	MHHW + 39 inches SLR + 1%-annual chance storm	Sea level rise scenario available in OCOF closest to NRC 'likely' 2100 scenario (36 inches), plus 1% annual chance storm. This is significantly different from water level from present day flood risk compared to a 2050 11 inch most likely scenario. Also used in Half Moon Bay, Marin County and San Francisco.
3	Extreme Scenario (or 6 feet scenario + 100 year storm)	MHHW + 79 inches SLR + 1%-annual chance storm	In line with Coastal Commission's Guidance Document recommendation to use an extreme scenario that presents a potential 'worst case', plus 1% annual chance storm. Also used in Marin.

Table 3: Recommended Inundation Scenarios for San Mateo County

Appendix A: Sea Level Rise Scenarios Used in San Mateo County Projects and Other California Sea Level Rise Vulnerability Assessments

City of Foster City Levee Protection Planning Study

- Based on CCAMP and NRC Report
- 2030: 0.5 feet
- 2050: 1 foot
- 2100: 2 feet

San Francisco International Airport Shoreline Protection Feasibility Study Evaluation and Recommendations Report

- Based on NRC Report
- 2050: Max SLR of 2 feet
- Two SLR scenarios
  - 2 feet
  - Greater than 2 feet

Climate Change Vulnerability Assessment for the North-Central California Coast and Ocean

- Based on NRC Report and Climate Change Impact Report from Cordell Bank and Gulf of the Farallons National Marine Sanctuary Advisory Councils
- 2050: 5 to 24 inches
- 2100: 17 to 66 inches

San Mateo County Climate Action Plan

- Based on NRC Report
- 2030: 7 inches
- 2050: 14 inches
- 2100 Low GHG: 40 inches
- 2100 High GHG: 55 inches

San Mateo County General Plan: Energy and Climate Change Element

- Based on NRC
- 2050: 5 to 24 inches
- 2100: 17 to 66 inches

SAFER Bay Project

- Based on FEMA preliminary FIRM, LIDAR, and parcel data
- 3 feet

San Bruno and Colma Creek Resilience Study

- Based on NRC Report
- Between 2030 and 2080: 1 foot
- Between 2050 and 2125: 2 feet
- Between 2065 and 2155: 3 feet

City of Half Moon Bay Local Coastal Program Update

- Scenarios include conditions in the near-term (next decade), General Plan/LCP horizon (2040-2050), as well as a longer view (approaching 2100)
- 0 centimeters with King Tide
- 25 centimeters with 100-yr storm event
- 50 centimeters with 100-yr storm event
- 3 feet with 100-yr storm event

Humboldt County

- Relative sea level rise rates, the high projections (due to tectonic subsidence)
- Based on NRC
- 2015, 2030, 2050 and 2011
- *for some critical assets, looking at 2070 too

Marin County

- Annual storm + 25 cm (0.82 ft)
- 5% annual chance (20-year) storm + 25 cm (0.82 ft)
- 5% annual chance storm + 50 cm (1.64 ft)
- 1%-annual chance (100 year) storm + 100 cm (3.28 ft)
- 1%-annual chance storm + 200 cm (6.56 ft)

City of Benicia

- 12 inches (1 foot)
- 24 inches (2 feet)
- 60 inches (5 feet)
- *also took into account the effect on storms

City of Oakland Oakland/Alameda County Adapting to Rising Tides Study

- *SLR projections range from 12-96 inches. Range selected based on:
  - Best available science (based on CO-CAT March 2013 report, which presents ranges in 3 time periods, based on the NRC 2012 report:
    - 2030: 2 inches (low), 12 inches (high)
    - 2050: 5 inches (low), 24 inches (high)
    - 2100: 17 inches (low), 66 inches (high)
  - Range of elevations of the Alameda County shoreline
  - Water levels that are most likely to overtop the current shoreline

- *Total of 6 future climate scenarios; based on 2 SLR projections + 3 bay water levels
    - 16 inches + MHHW
    - 16 inches + 1%-annual chance Stillwater (SWEL)
    - 16 inches + 1%-annual chance Stillwater (SWEL) + wind driven waves
    - 55 inches + MHHW
    - 55 inches + 1%-annual chance Stillwater (SWEL)
    - 55 inches + 1%-annual chance Stillwater (SWEL) + wind driven waves
- **uses "one map, many futures" approach that shows, for example that a future bay water level of 36 inches above MHHW can represent:*
    - the new "daily" high tide with 36 inches of SLR,
    - and can also represent the existing 2% annual chance high tide level with no SLR,
    - An annual high tide level (e.g. King tide) with 24 in SLR, and
    - Or a 2 year tide level with 18 inches SLR.

City of San Francisco Mission Creek Adaptation Study

- Uses maps derived from San Francisco Public Utilities Commission Sewer System Improvement Program. Similar approach to Alameda County ART study
- Uses 2 scenarios for 2050 and 2100 based on NRC 'most likely' scenarios
    - 2050: 11 inches of SLR + 1%-annual chance -year storm
    - 2100: 36 inches of SLR + 1%-annual chance storm

APPENDIX H

INTRODUCTION

Sea level rise inundation and extreme high tide[1] (a.k.a., storm tide) flooding maps for the San Francisco Bay Area are available from multiple sources. The two most prominent sources are the Adapting to Rising Tides (ART) and Our Coast, Our Future (OCOF) projects. While the mapping products from ART and OCOF are similar, there are several underlying differences in the methods and data used to develop each product. This document highlights some of the key over-arching technical differences between the ART and OCOF analysis methods and mapping products:

- The purpose of the mapping products (i.e., what considerations drove their development);
- The scenarios mapped;
- The terrain used;
- The model components and considerations;
- The storm definitions (i.e., how the 100-year storm is defined); and
- A brief overview of the inundation mapping approach.

PURPOSE

Adapting to Rising Tides

The Adapting to Rising Tides (ART) Program, led by the San Francisco Bay Conservation and Development Commission (BCDC), provides support, guidance, tools, and information to help agencies and organizations understand, communicate, and begin to address complex climate change issues. The ART sea level rise and storm surge flooding maps use a "one map equals many futures" approach, which allows each map to represent multiple potential future combinations of sea level rise and extreme water levels. The maps show the inland areas that are at risk of inundation or flooding, and the companion products -- the shoreline delineation, shoreline type, and overtopping potential maps -- identify the pathways of inundation

Our Coast, Our Future

Our Coast, Our Future (OCOF) is a collaborative, user-driven project focused on providing San Francisco Bay Area coastal resource managers and planners locally-relevant, online maps and tools to help them understand, visualize, and anticipate vulnerabilities to sea level rise, storm surge, and wave hazards.

The project included a collaborative product-development process that was designed to: meet stakeholders' information needs; map infrastructure and ecosystem vulnerabilities at scales relevant to planning and management;

[1] Extreme tides (a.k.a., storm tides) are relatively infrequent water level events that are a result of relatively high astronomical tides coupled with a storm surge event. The absolute elevations reached during these events are due to short-term meteorological processes (such as low atmospheric pressure due to storms) and large-scale oceanographic conditions (such as King Tides or El Niño conditions).

or flooding from the Bay. Together, the products support robust, local scale vulnerability assessments and the development of both near-term and long-term adaptation strategies.

Through a collaborative effort with local and state agencies, the ART mapping is currently available for Alameda, Contra Costa, San Francisco, and San Mateo Counties. With funding from the Bay Area Toll Authority and the Metropolitan Transportation Commission, the ART maps will be completed for all nine Bay Area counties by early 2017. Technical reports, maps, case studies, and additional information, including ART Program staff Help Desk support, are available at: www.adaptingtorisingtides.org.

develop products in accessible, user-friendly formats; and provide training and technical assistance on the use of the products and tools.

The OCOF maps are available for all nine Bay Area counties, as well as additional areas along the open Pacific coast. The maps are presented within an online viewer, and the data can also be downloaded and used offline, depending on the project need. The online viewer and additional information on the OCOF project are available at: www.ourcoastourfuture.org/

An additional online viewer that translates the flood extents in socioeconomic exposure is available at https://www.usgs.gov/apps/hera/.

SCENARIOS

Adapting to Rising Tides

The ART maps depict the inland extent of inundation or flooding associated with ten scenarios ranging from 12 inches to 108 inches above mean higher high water (MHHW). Using the one map equals many futures approach, the ten scenarios can represent over 50 combinations of sea level rise (i.e., from 0 to 66 inches) and extreme water level (i.e., from 1- to 100-year tide) scenarios. The scenarios range from an existing conditions King Tide (i.e., MHHW + 12 inches) to a 100-year storm surge condition coupled with 66 inches of sea level rise (equivalent to MHHW + 108 inches). The ten mapped scenarios are intended to be used in tandem with a county-specific matrix (i.e., reference table) of sea level rise and extreme water level elevations that identify the equivalent scenarios that can be represented by each of the ten maps.

Our Coast Our Future

The OCOF maps depict inland extents of flooding associated with astronomic tides in combination with a range of sea level rise values and extreme coastal storms that are user-selected within the online viewer. The user can select the amount of sea level rise from 0 to 200 cm (in 25 cm increments), as well as 500 cm. These scenarios correspond approximately to 0-, 10-, 20-, 30-, 39-, 49-, 59-, 69-, 79-, and 197-inches of sea level rise. The user can pair the selected sea level rise scenario with a King or spring tide and everyday atmospheric conditions, or spring tides in conjunction with a 1-year, 20-year, or 100-year coastal storm event. This range of scenarios represents 50 possible combinations of sea level rise and extreme storm-driven water levels in San Francisco Bay.

TERRAIN

Adapting to Rising Tides

The ART maps use a 1-meter digital elevation model (DEM) developed from the 2010/2011 LiDAR collected by the USGS and NOAA as part of the

Our Coast Our Future

The OCOF maps use a 2-meter bare-earth DEM developed from the 2010/2011 LiDAR collected by USGS and NOAA as the base topographic information. The DEM is of sufficient resolution and detail to capture the majority of shoreline

California Coastal Mapping Program[2]. The DEM is of sufficient resolution and detail to capture the majority of shoreline levees and flood protection assets, but structures narrower than the 1-meter LiDAR resolution may not be adequately represented in the LiDAR or the resulting DEM.

The ART approach relied on stakeholder review and feedback to verify if features such as flood walls and tide gates were accurately captured in the DEM. If areas are shown as inundated with less than 24 inches of sea level rise above MHHW, and these areas have never been inundated during a King Tide condition or storm event, the local topography is reviewed. Stakeholders submit as-built drawings or infrastructure, or higher-resolution survey data, to improve the DEM. Potential levee or shoreline improvement projects (i.e., projects that are not yet constructed) are not incorporated within the DEM. Future shoreline erosion and geomorphic change are not considered, and the base DEM does not change over time.

levees and flood protection assets, but structures narrower than the 1-meter LiDAR point spacing or the 2-meter DEM resolution may not be adequately represented in the DEM.

As part of the DEM development process, levees were hand-digitized as needed to better represent these features. However, some local features may not be adequately represented. The OCOF team maintains a "known issues" database to capture areas where the DEM may need refinement to better represent local flood protection structures or other features.

Future shoreline erosion and geomorphic change are not considered, and the base DEM does not change over time for areas inside San Francisco Bay.

MODEL COMPONENTS

Adapting to Rising Tides

The ART maps use water level output from the Federal Emergency Management Agency (FEMA) San Francisco Bay Area Coastal (SFBAC) Study[3]. The FEMA modeling relied on regional hydrodynamic and wave modeling using MIKE21 developed by DHI. The following sections describe the model simulation timeframe, general model setup, and input and boundary conditions.

Our Coast Our Future

The OCOF maps are created using the Coastal Storm Modeling System (CoSMoS) developed by the USGS. A coupled 2-way Delft3D hydrodynamic and wave model is primarily used within the CoSMoS structure to simulate flow and flooding projections within the San Francisco Bay. The following sections describe the model simulation timeframe, general model setup, and input and boundary conditions.

[2] http://www.opc.ca.gov/2010/01/mapping-californias-coastal-areas/
[3] http://www.r9map.org/Pages/San-Francisco-Coastal-Bay-Study.aspx

Model Simulation Timeframe

The FEMA MIKE21 model is calibrated and validated for existing conditions. In the Central and North Bay, the hindcast[4] period spans January 1973 through December 2003[5]. In the South Bay, the hindcast period spans January 1956 thru December 2009[6]. The models were calibrated to two storm events (January and December 1983), and validated against 11 large storm events that occurred during the model hindcast period. Although the model is well calibrated to water levels, limited wave data was available for model calibration and validation, therefore a higher uncertainty is associated with the modeled wave conditions. Model output is saved at 15-minute time steps for water levels, and 1-hour time steps for waves, over the entire 31- or 54-year hindcast period. The model is driven by observed data (e.g., water levels, winds, atmospheric pressure) and modeled data (e.g., Delta inflows, offshore waves, and tributary discharges).

Model Simulation Timeframe

CoSMoS simulates potential future conditions during 21st century storm events. Storm events (1-year, 20-year, 100-year, and average conditions) and associated atmospheric/environmental conditions were identified and derived from one CMIP5 (Coupled Model Intercomparison Project Phase 5) Global Circulation Model (GCM): the Geophysical Fluid Dynamics Laboratory (GFDL) Earth System Model (ESM2M). For each discrete 21st century event, CoSMoS' Delft3D models were driven by projections of water levels, offshore ocean swell, winds, atmospheric pressure, and riverine discharges for the storm's conditions. Models were run for more than 1 tide cycle (17+ hours to include the higher-high tide); time-steps varied on location and resolution of the particular model (see 'Model Domain').

Model Domain

The MIKE21 model uses a rectangular grid with 100-meter grid cell sizing for the entire model domain. The model domain spans the entire San Francisco Bay and into the Delta, with an eastern boundary just upstream of the City of Antioch. The western model boundary lies outside of the Golden Gate to capture the penetration of ocean-driven swell through the Golden Gate and into the Central Bay.

Model Domain

The Delft3D model uses a grid with ~100 meter grid cell sizing, with higher resolution of 10 to 20 meters in select focus areas including: Coyote Creek/Alviso, Foster City, Corte Madera, Highway 37, Petaluma River, Napa River estuary, Richardson Bay, Oakland Airport, Embarcadero (Pier 54/Mission Bay), and East Palo Alto, among others. Focus areas were identified as locations where hydrologic and shoreline complexity necessitated finer resolution, and with further input from the OCOF Advisory Committee. The model domain spans the entire San Francisco Bay and into the Delta, with an eastern boundary just upstream of the City of Antioch. The western boundary lies outside of the Golden Gate and offshore of the continental shelf to capture the penetration of ocean-driven swell through the Golden Gate and into the Central Bay.

[4] A hindcast is a simulation of historical conditions using a model driven by historical observations of certain environmental parameters such as wind or water level.
[5] Regional Coastal Hazard Modeling Study for North and Central San Francisco Bay, 2011. Prepared by DHI Water and Environment for FEMA Region IX.
[6] Regional Coastal Hazard Modeling Study for South San Francisco Bay, 2013. Prepared by DHI Water and Environment for FEMA Region IX.

Offshore Water Levels

The offshore open boundary was driven by water levels recorded by the National Oceanic and Atmospheric Administration (NOAA) at the San Francisco Presidio (Presidio) tide station. The observed sea level rise trend was removed from the recorded water levels to raise the historical water levels to present day (i.e., 2009 for Central and North Bay; 2011 for South Bay) mean sea level conditions.

Offshore Ocean Swell

The offshore ocean swell boundary condition relies on a 31-year hindcast of 3-hourly deep ocean wave conditions produced by Oceanweather, Inc. (OWI). OWI developed the hindcast using their Global Reanalysis of Waves (GROW) model which relies on deep water and nearshore wave measurements from the National Data Buoy Center and the Coastal Data Information Program for model calibration and validation.

Offshore Water Levels

Offshore and regional water levels rely on tidal constituents from the Oregon State University TOPEX/Poseidon model. Modeled water levels inside San Francisco Bay are highly correlated ($r^2 > 0.97$)[7] with observed water levels for most water level stations inside San Francisco Bay.

Offshore Ocean Swell

Offshore ocean swell conditions were modeled using a combination of the global and nested Eastern North Pacific grids of the NOAA WAVEWATCH III (WWIII) model. Swell conditions were originally modeled as part of OCOF projections for the outer coast[8]. To capture the variability in global-scale projections for the 21st century, the WWIII model was driven by wind fields generated from two different climate scenarios (Representative Concentration Pathways (RCP) 4.5 and 8.5) and four CMIP5 GCMs. Ocean swell simulated with the RCP4.5 scenario and winds from NOAA's GFDL-ESM2M GCM was selected as boundary conditions to the Bay's coupled Delft3D and Simulating Waves Nearshore (SWAN) models. The RCP4.5 scenario was selected based on analysis of the WWIII results which show higher storm waves offshore of the Central California coast compared to the RCP8.5 scenario. The GFDL-ESM2M GCM was selected because the resulting wave time-series compare well with the observed wave climatology spanning 1976-2005 from the regional wave buoy network (i.e., from the National Data Buoy Center and the Coastal Data Information Program), and additionally, spatially downscaled GFDL-ESM2M wind data through the year 2100 available for the San Francisco Bay area at the time of the modeling effort (see section on winds and wind-driven waves below).

[7] r^2 (r-squared) is a statistical measure of the goodness-of-fit of model data to observed data. A higher r^2 value (closest to 1), usually indicates a better fit.

River Discharge

The open Delta riverine boundary condition is represented by discharge from the Sacramento River (just upstream of the City of Antioch). Delta inflows are based on daily mean streamflow throughout the model hindcast period. Daily mean streamflow was generated using the California's Interagency Ecological Program (IEP) Dayflow daily discharge model. Smaller freshwater tributary inflows are input at a constant rate, represented by mean annual discharge.

River Discharge

River discharge rates for principal tributaries in the Bay (Napa, Sonoma, Petaluma, San Francisquito, Guadalupe, Coyote, Old Mill, and Corte Madera, and the Delta) were included in the CoSMoS framework. Using 21st century precipitation patterns depicted in the GCM (GFDL-ESM2M) and similar patterns from the GFDL-ESM2M-derived Delta discharge from the CASCaDE project (Computational Assessments of Scenarios of Change for the Delta Ecosystem), appropriate Delta discharges were identified for CoSMoS storm events. Historical relationships between the tributaries and the Delta were then used to calculate river discharge rates for each 21st century coastal storm event.

Winds and Wind-Driven Waves

Wind-driven waves are not considered in the ART mapping because increases in wave heights do not scale linearly with increases in mean sea level due to sea level rise. The ART mapping process only incorporates processes that can scale linearly with sea level rise (e.g., MHHW). However, wind-driven wave information is available from the FEMA SFBAC study. The wind fields for the SFBAC study were developed from hourly observations of wind speed and direction from the San Francisco International Airport, the Oakland International Airport, and the Travis Airforce Base. The wind fields were used as forcing for MIKE21 simulations to appropriately simulate waves and surge. Wind-driven waves were modeled using the MIKE21 SW (Spectral Wave) model.

Winds and Wind-Driven Waves

Wind fields were derived from a downscaled version of the GFDL ESM2M GCM. The downscaled wind projections come from the University of Idaho Multivariate Adaptive Constructed Analogs[9] (MACA) statistically-downscaled GCM data. The MACA method downscales GCM output to 1/24 degree (~4 km) spatial resolution at a daily time step. The temporal resolution of the wind fields were increased to 3-hour time steps to support the wind-wave modeling within Delft3D using the coupled SWAN (i.e., wave) model. Wind fields for identified storm events were used as forcing for Delft3D simulations to appropriately simulate waves and surge. Data from the single GCM was used due to time constraints and to maintain consistency with other single GCM-derived storm conditions (i.e. river discharge and swell).

STORM DEFINITION

Adapting to Rising Tides

Our Coast Our Future

[8] Barnard, P. L., O. van Maarten, L.H. Erikson, J. Eshleman, C. Hapke, P. Ruggiero, P. Adams, and A. Foxgrover (2014), Development of the Coastal Storm Modeling System (CoSMoS) for predicting the impact of storms on high-energy, active-margin coasts, Nat. Hazards, 74(2), 1095-1125, doi:/10.1007/s11069-014-1236-y.

[6] Abatzoglou J. T. and Brown T.J. 2011. A comparison of statistical downscaling methods suited for wildfire applications. International Journal of Climatology.

[9] Abatzoglou J. T. and Brown T.J. 2011. A comparison of statistical downscaling methods suited for wildfire applications. International Journal of Climatology.

The ART maps use a response-based[10] statistical approach to define local extreme tide recurrence intervals (e.g., 1-year, 10-year, 100-year, etc.) based on historical conditions at 900 points along the Bay shoreline[11]. This approach assumes that no single storm "event" will simultaneously produce the 100-year (or other recurrence internal) flood extent along the entire Bay shoreline. Instead, multiple storm events with varying storm directions and intensities are analyzed to produce a composite map that represents the 100-year flood hazard[12] (the extent and depth of inland inundation that has a 1-percent-annual-chance of occurring at any given location along the shoreline). This approach is consistent with the FEMA guidelines for analyzing and mapping coastal hazards along the Pacific coast[13]. The 100-year extreme high tide levels are consistent with the values used for the FEMA SFBAC study; however, these values do not include the addition of waves or wave runup at the shoreline.

The OCOF maps rely on an event-based approach, which includes defining discrete storm events (i.e., 1-year, 20-year, and 100-year) based on detailed analysis of the storm climatology from the downscaled GFDL ECM2M GCM output over the 21st century. The analysis considers storm direction and orientation, as well as the geometry and orientation of the Bay shoreline, to define a storm event that has a 1-percent-annual-chance (or other recurrence interval) of occurring in any given year. As the complex topography of the Bay affects exposure to storms and wind direction, and in turn resulting storm waves and related flooding, multiple events for major storms (20-year and 100-year) were identified and simulated. Storm events were identified for predominant wave and wind directions in each region of the Bay. Thus, the resultant hazard projections are a composite of all contributing storm simulations for the event. Orientation differences between storm events may yield flood extents that are larger for less-intense storms (i.e. 20-year vs. 100-year) in some locations.

FLOOD MAPPING

Adapting to Rising Tides

The ART inundation mapping uses an approach developed by the NOAA Coastal Services Center[14]. San Francisco Bay water levels are projected landward on a 1-meter DEM to assess the inland extent and depth of flooding, and low-lying areas that are protected from flooding by levees or other topographic features are removed from the direct flood zone and highlighted

Our Coast Our Future

For each storm event (1-year, 20-year, 100-year), a coupled (hydrodynamic-wave) Delft3D model with inclusive storm conditions (e.g., discharge, wind, atmospheric pressure) is run over more than 1 tide cycle (17+ hours to include higher-high tide). Resulting water levels are projected onto a 2-meter DEM to create OCOF flooding maps and corresponding depth of flooding. This

[10] Response-based analysis refers to a coastal analysis technique in which long time series of environmental parameters, such as astronomical tides, atmospheric pressure, and winds, are combined and simulated to derive an estimate of storm water level conditions at the shoreline. This is in contrast to an event-based analysis technique in which a short time period considered to be representative of a desired storm magnitude (such as a 100-year event) is simulated. The response-based analysis is considered to be more robust than an event-based analysis, especially in the Bay where extreme tide levels can be realized through many different combinations of astronomical tides and storm surge conditions.

[11] San Francisco Bay Tidal Datums and Extreme Tides Study, 2016. Produced by AECOM for FEMA.

[12] Extreme Storms in San Francisco Bay – Past to Present. 2016. Produced by AECOM for FEMA.

[13] Guidelines for Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States. 2005. FEMA.

[14] Marcy, D., B. William, K. Dragonoz, B. Hadley, C. Haynes, N. Herold, J. McCombs, M. Pendleton, S. Ryan, K. Schmid, M. Sutherland, and K. Waters. 2011. "New Mapping Tool and Techniques for Visualizing Sea Level Rise and Coastal Flooding Impacts." In: *Proceedings of the 2011 Solutions to Coastal Disasters Conference*. June 2011.

in green. The extent and depth of flooding is controlled by the difference between the water and ground surface elevations.

The flood mapping uses a base water level of existing MHHW, which is spatially variable along the San Francisco Bay shoreline. Discrete amounts of sea level rise are added to MHHW to create the ten mapped scenarios. This approach does not account for the complex physics of overland flow, dissipation, levee wave overtopping, storm duration, or the potential for shoreline erosion and levee failure that can occur during storm events. To account for these processes, a more sophisticated modeling effort would be required. However, given the uncertainties associated with climate change and sea level rise, as well as potential future land use changes, development, and geomorphic changes that will occur throughout the 21st century, a more sophisticated approach may not necessarily provide more accurate results.

The ART maps include an analysis of the type and elevation of the shoreline that produces an overtopping potential map that illustrates not only where overtopping may occur, but how deep the water may be, on average, over the shoreline. Overtopping potential maps help identify locations that pose the largest risk to shoreline communities and infrastructure. This is a powerful tool that is unique to the ART maps. Coupled with the inundation and storm surge maps, the overtopping potential maps help users quickly and efficiently identify the shoreline locations and flowpaths that could lead to inland flooding so that additional investigation (e.g., field verification or more sophisticated modeling) can be targeted at these locations.

approach and inclusion of overland high-resolution grids captures the physics of overland flow; therefore the inland extent of flooding accounts for the volume of Bay water available during the simulated event that may overtop the shoreline and flood low-lying areas during a discrete storm event. Each storm simulation is repeated for the range of sea level rise scenarios considered and the resulting depth and extent of flooding is mapped.

Acknowledgements

Prepared by: Kris May, Michael Mak, Justin Vandever (AECOM), Patrick Barnard, Andy O'Neill, Li Erikson (USGS), Wendy Goodfriend (BCDC)

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APPENDIX I

Appendix I: Groundwater Resources Evaluation

Groundwater in San Mateo County is present in alluvial groundwater basins. These include the more populated Westside and San Mateo Plain Basins on the San Francisco Bay side of San Mateo County and San Pedro Valley (Pacifica), Half Moon Bay Terrace, San Gregorio Valley, and Pescadero Valley on the less populated Pacific Ocean side of San Mateo County. The beneficial uses of groundwater is summarized below.

San Mateo County Groundwater Uses

The Westside Groundwater Basin is approximately two miles wide by 11 miles long, ranging in depth from approximately 500 feet in Golden Gate Park to about 3,500 feet near Daly City (San Francisco Bay Regional Water Quality Control Board, 1996). The Basin is bounded to the north by a northwest trending bedrock ridge northeast of Golden Gate Park in San Francisco, to the east by a bedrock ridge that includes San Bruno Mountain, and to the west by the San Andreas Fault. The southern boundary is estimated to end south of the City of San Bruno. The water bearing zones in this Basin include the Merced and Colma formations. Groundwater is unconfined in the shallow Colma Formation and confined in the Merced formation. The deeper Merced formation is used for municipal groundwater supply because groundwater in the shallower Colma formation is inferior and subject to points of contamination from anthropogenic sources.

As of 2013, groundwater pumping in the Westside Basin was primarily for municipal water supply to Daly City, San Bruno, and South San Francisco, as well as for irrigation and other non-potable uses by the San Francisco Zoo, Golden Gate Park, golf courses, and cemeteries (San Francisco Public Utilities Commission 2014). Production wells in the San Mateo County portion of the Westside Basin are present near the Lake Merced Golf Club, the California Golf Club, and Cal Water wells near San Bruno and South San Francisco. In the Town of Colma, groundwater is primarily used for irrigation at the cemeteries. No municipal pumping is currently ongoing within the Town of Colma. Other groundwater pumping within the Westside Basin (e.g., private homeowner wells, groundwater remediation extraction wells, and construction dewatering wells) is estimated to be negligible compared to the municipal and large-scale irrigation uses.

The San Mateo Plain Basin begins south of the West Side Basin and extends approximately from the city of San Mateo south to the Santa Clara County line. Groundwater is used for irrigation, public drinking water, and private drinking water (San Francisco Bay Regional Water Quality Control Board, 2007). The San Mateo Plain is a northern extension of the Santa Clara Basin located to the south. The majority of pumping for irrigation occurs in the South San Mateo Plain Sub-basin, where approximately 90% of the irrigation wells are located. Of the wells in the South San Mateo Plain Sub-basin, approximately 65% are located in Atherton. The majority of the wells in Atherton and Menlo Park are screened in the deeper aquifer making them unlikely to be affected by sea level rise, while the majority of the irrigation wells in other cities in the South San Mateo Plain Sub-basin are screened in the shallower aquifer making them potentially vulnerable to sea level rise.

Public drinking water wells in the San Mateo Plain Basin are located in East Palo Alto (Palo Alto Park Mutual Water Company), Menlo Park (O'Connor Tract Corporation and Menlo College), and in the City of San Mateo (San Mateo High School). While Menlo College and San Mateo High School are small water systems that provide water for their campuses, O'Connor Tract Corporation and Palo Alto Park Mutual Water Company provide drinking water for the population of East Palo Alto and to the East Menlo neighborhood in Menlo Park. All public drinking water wells are screened in the deeper aquifer. Public drinking water wells are discussed in more detail in the following section.

A few private drinking water wells are located in East Palo Alto. These wells were installed in the 1980s when Palo Alto Park Mutual Water Company had a moratorium in place on new water connections. Most of the houses developed in the 1980s have since been connected to public drinking water, and their wells have either been destroyed or are currently used for irrigation only. These drinking water wells are screened in the shallow water-bearing zone, making them potentially vulnerable to sea level rise, however there are not estimated to be many private drinking water wells currently in use. Of the known wells in the San Mateo Plain, 74% are monitoring wells related to current site remediation activities. The majority of the monitoring wells, about 72%, are located in the South San Mateo Plain Sub-basin. There are no known plans for significantly expanding groundwater uses in the San Mateo Plain (California Regional Water Quality Control Board San Francisco Bay Region, 2003).

Assessment of Municipal Groundwater Use in San Mateo County

An evaluation of the primary sources of potable municipal water supply in each of the following Water Districts of San Mateo County was performed to assess potential vulnerability to current potable water resources from sea level rise: Brisbane, Burlingame, Daly City/Colma, East Palo Alto, Hillsborough, Millbrae, Redwood City, San Bruno, Coastside County Water District (Half Moon Bay), Estero Municipal Improvement District (Foster City), Guadalupe Valley Municipal Improvement District (Brisbane), Mid-Peninsula Water District (Atherton, Belmont, Hillsborough, Portola Valley, Woodside), North Coast County Water District (Pacifica), Westborough Water District (South San Francisco), California Water Service Company (Cal Water) (Los Altos, Menlo Park, San Mateo, and San Carlos).

Information was obtained from the following sources:

- The Bay Area Water Supply and Conservation Agency http://bawsca.org/members/map
- Annual Consumer Confidence Reports for each of the water districts: http://www.greenenvironmentnews.com/State/California/WaterQualityReports

As reported by the sources above, the San Francisco Regional Water System provides water to San Francisco, Santa Clara, Alameda and San Mateo counties. Approximately 85% of the water provided to these counties comes from Sierra Nevada snowmelt stored in the Hetch Hetchy reservoir situated on the Tuolumne River in Yosemite National Park. Hetch Hetchy water flows 160 miles from Yosemite to the San Francisco Bay Area. The remaining water comes from runoff in the Alameda and Peninsula watersheds and is captured in reservoirs located in San Mateo and Alameda counties. Groundwater is not a resource for the majority of the Water Districts in San Mateo County, and where it is used it represents a small portion of current water supply. Districts in San Mateo County where groundwater is a reported resource include San Bruno, South San Francisco, Daly City, East Palo Alto, the Coastside County Water District, and less populated areas on the Pacific Ocean side of San Mateo County (e.g., Pescadero and San Gregorio). The potential vulnerability of these potable groundwater resources to sea level rise is discussed below.

Estimated Vulnerability of Groundwater to Sea Level Rise

Municipal groundwater extraction wells are reported to be in use in the cities of San Bruno, South San Francisco, and Daly City. All wells are reported to be screened in the deeper, confined Merced aquifer where the water quality is better than shallow groundwater. In March 2003, a drinking water source assessment was completed for the Daly City supply wells, and the assessment showed that five of Daly City's six municipal production wells are highly protected from potential pathways of contamination with one well identified as moderately protected. The moderately protected well was scheduled for replacement in 2015 (City of Burlingame, 2011).

An aquifer susceptibility assessment for the Santa Clara and San Mateo County groundwater basins was performed by Lawrence Livermore National Laboratory in (LLNL, 2004) and included collection of tritium samples to estimate groundwater age. In two areas of San Mateo County on the western side of the San Francisco Bay, the Westside Basin (includes the northern portion of San Mateo County) and San Mateo Plain (includes the southern portion San Mateo County) many of the public supply wells produce old, entirely pre-modern groundwater, indicating that recharge has not occurred for the last 50 years or more. Groundwater that is this old is unlikely to be adversely affected by sea level rise in the near-term.

A relatively large number (8 of 14) of Westside Basin wells do not contain detectable tritium (less than 1 picocuries per liter [pCi/L]), and another two Daly City wells have tritium values between 1 and 2 pCi/L, for a total of 10 wells with groundwater ages that indicate that the groundwater recharge occurred more than 50 years ago. Three wells in

South San Francisco and two in Daly City also produce water that is also largely greater than 50 years old. Supply wells with deeper screens (greater than 200 feet below ground surface) draw an older groundwater component and are free of volatile organic compounds (VOCs) (sourced from modern anthropogenic activities). In this basin, supply wells that tap deeper aquifers appear to be protected from the widespread contamination present at the surface. The age and low detections of VOCs in the supply wells of the Westside Basin suggests that that these wells would likely be protected from future sea level rise.

In East Palo Alto, groundwater is also identified as a potable water resource. The City of East Palo Alto overlies a portion of the San Francisquito Cone Sub-basin, an area that overlaps the San Mateo Plain and Santa Clara sub-basins of the Santa Clara Valley Groundwater Basin (City of East Palo Alto, 2015). The principal groundwater aquifers of the basin and sub-basins are composed of interbedded coarse- and fine-grained alluvial fan deposits of San Francisquito Creek, extending from the Santa Cruz Mountains north and under San Francisco Bay, and distal alluvial fan deposits of the Niles Cone, extending from the Diablo Range. Overlying most of the alluvial sediments beneath the City are thick, laterally-extensive fine-grained materials, deposited when the area was below sea level. These Bay Mud sediments form a continuous aquitard or confining layer. The USGS characterized the groundwater aquifers and aquitards as a generalized three-layer system: an upper unconfined to a confined shallow aquifer zone, a fine-grained Bay Mud unit near the Bay, and a deep principal aquifer beneath the confining layer (Metzger 2002). Most large production wells in East Palo Alto derive their water from the deep aquifer zone, at depths ranging from 200 to over 800 feet below ground surface (ft-bgs). Nine wells in Palo Alto and East Palo Alto, considered to be part of the San Mateo Plain Basin, produce mostly pre-modern groundwater (older than 50 years). In general, the groundwater produced from deep-screened wells in this part of the basin is tens to hundreds of thousands of years old, and likely has a very deep source (LLNL 2004). Therefore, the potential for an adverse impact by sea level rise is estimated to be very limited.

The Coast Side Water District derives approximately 28% of the its water supply from local wells and surface water, the remaining 72% is from the San Francisco Regional Water System with water derived from Hetch Hetchy (Coastside County Water District, 2016). The Pilarcitos Well Field and the Denniston Project supply ground water. Water from the Pilarcitos Well Field is limited to pumping between November and March. In the California aquifer susceptibility assessment for the Santa Clara and San Mateo County groundwater basins performed by LLNL (LLNL, 2004), it was noted that on the Pacific Coast in San Mateo County, a small number of wells provide the sole source of drinking water for coastal communities. Many of these supply wells are estimated to draw groundwater from a shallow, unconfined aquifer in the Coastside Basin and have a mean groundwater age of only 4 years (based on tritium age dating data). The young age of the water pumped from these wells indicates that there is rapid recharge of surface water into the aquifer. This shall0ow, rapid recharge makes these wells highly vulnerable to near-surface contamination sources, and these wells may also be susceptible to impairment from sea level rise.

Bay Mud Aquitard Influence on Potable Groundwater Protection

The Bay Mud aquitard occurs beneath San Francisco Bay and extends south-southwest under the entirety of East Palo Alto. There is a clear increase in aquitard thickness (up to 300 ft-bgs) in the northeast closer to the San Francisco Bay. The unit does not extend to the foothills in the southwest resulting in an unconfined aquifer system. The southwestern extent of the Bay Mud aquitard has been mapped by USGS and others, and demarcates the unconfined and confined aquifer zones. In the vicinity of East Palo Alto (El Camino Real and Sand Hill Road) the Bay Mud is generally present four or more miles from the San Francisco Bay forming a confining unit. This would presumably prevent sea level rise from the San Francisco Bay from impairing the unconfined aquifer generally east of El Camino Real in the future. A more detailed evaluation of the western San Francisco Bay groundwater elevations in comparison to groundwater levels at the estimated western limits of the Bay Mud aquitard would provide more information to estimate how high sea level rise would need to occur to potentially migrate beneath the Bay Mud Aquitard and affect high quality deep aquifer groundwater.

Groundwater Susceptibility to Impacts from Hazardous Materials Sites

As previously described, the presence of land or facilities containing hazardous materials in areas at risk of inundation increases the risk of exposure to toxic chemicals for nearby residents and ecosystems.

Summary of Findings

Reported information suggests that there is generally a limited risk posed by sea level rise to municipal supply wells due to the great depths that they are screened across, the presence of shallow confining layers such as the Bay Mud above these deep supply wells, and the distances of supply wells from the San Francisco Bay on the eastern portion of San Mateo County. In addition, most of the population of San Mateo County receives potable water from the State Water Project (Hetch Hetchy), so groundwater is not a primary resource for potable water supply. A potential exception that warrants further review pertains to any municipal supply wells adjacent to the Pacific Ocean, which are reported to be screened much shallower and contain much younger groundwater indicating a higher potential for adverse impacts from sea level rise. In addition, some private domestic drinking water wells are reported to be in use in southern San Mateo County that may be screened in the shallow aquifer and vulnerable to sea level rise. Beneficial use of groundwater may also be affected by sea level rise with many irrigation wells reported to be screened in the shallow aquifer that is much more vulnerable to anthropogenic contaminants, flooding, and potentially sea level rise.

APPENDIX J

Appendix J: Pacific Gas & Electric - Sea Level Rise in San Mateo County

This section was written by Pacific Gas and Electric.

Company Overview

PG&E is one of the largest combined natural gas and electric utilities in the United States. Based in San Francisco, with more than 23,000 employees, the company delivers some of the nation's cleanest energy to nearly 16 million people throughout a 70,000-square-mile service area in Northern and Central California.

PG&E's Approach to Climate Change Resilience

PG&E understands that there is no single approach to building climate change resilience. It involves taking a holistic approach to better understand, plan for and respond to climate change risks—and doing so in partnership with others.

There are four key aspects to PG&E's approach to addressing changing climate conditions:

Near-term planning: Robust emergency response plans and procedures to address near-term risks, including extreme storms, heat waves and wildfires.

Risk assessment and operational planning: A multi-year, comprehensive risk assessment process to prioritize infrastructure investments for longer-term risks associated with climate change.

Staying abreast of the latest science: An in-house science team that regularly reviews the most relevant climate-change science and integrates that research into PG&E's risk assessment process.

External engagement: Active engagement and partnerships at the federal, state and local level on climate change adaptation and resilience.

PG&E's *Climate Change Vulnerability Assessment* highlights many of the physical risks the company faces from climate change and PG&E's progress in understanding and addressing them on behalf of its customers. The report is available at http://www.pgecurrents.com/wpcontent/uploads/2016/02/PGE_climate_resilience.pdf.

PG&E's Risk Assessment and Operational Planning

PG&E has undertaken a multi-year, comprehensive risk assessment to gain a better understanding of how the company's critical assets would perform under different natural hazard scenarios. The overarching goal of the assessment, known as PG&E's Natural Hazard Asset Performance (NHAP) initiative, is to identify potential risks resulting from natural hazards and enable PG&E's business units to evaluate those risks and develop response plans.

The assessment, which covers PG&E's electric and gas infrastructure, includes scenarios for both flooding and sea level rise. The flooding scenario assesses PG&E's assets against Federal Emergency Management Agency (FEMA) 100- and 500-year flood zones. The sea level rise scenario assesses the potential impact on PG&E's assets of 24 inches—or two feet—of sea level rise above the Mean Higher High Water by 2050, per California Coastal Commission Sea Level Rise Guidance issued in August 2015.

PG&E is conducting the NHAP process in several phases. To date, PG&E has completed an assessment and identified the risk exposure of the company's assets, calculated as the percentage of assets in the hazard zone. As a next step, PG&E is assessing the ability of those assets to withstand the natural hazards.

The results of the NHAP assessment will be integrated into PG&E's enterprise-wide integrated planning process. The results will also inform PG&E's emergency planning and response activities so the company can continuously improve and make its system more resilient to catastrophic events. PG&E is also piloting a more robust coastal flood risk analysis of at-risk assets using additional scenarios of sea level rise.

Potential Risk Exposure to PG&E's Substations and Gas Infrastructure

As part of the NHAP assessment, PG&E found that two of its substations in San Mateo County are located within areas modeled for two feet of sea level rise and six are located in FEMA's 100-year flood zones. PG&E also found that about 3% of its gas transmission pipelines in San Mateo County are located within areas modeled for two feet of sea level rise and about 14% are located in FEMA's 100-year flood zones.

Compared to sea level rise, FEMA's flood zones put a larger number of PG&E's assets at risk given the streams and tributaries within a watershed that eventually flow into the Bay or ocean. Similar to earthquake zones, it is not expected that all of the FEMA flood zones would be affected by a flooding incident at the same time.

Actions Taken

Substations and Electric Infrastructure

When making repairs or modifications to facilities, PG&E takes into account any additional modifications necessary to protect structures within the 100- and 500-year flood zones. For example, PG&E has elevated structures at several of its substations to reduce the risk of flooding, including the San Mateo 115kV GIS Building. In some cases, the company also looks to reinforce identified substations; in other cases, in the event of a flood, the reliability of the electric grid can allow the flexibility to serve customer load through other parts of the system.

PG&E also uses a model developed by PG&E meteorologists to predict the number and timing of sustained power outages each PG&E geographic region can expect during adverse weather conditions. The model is run on a daily basis, with more frequent updates issued as storms approach. The model outage forecast information is a key tool that PG&E uses to determine the number and type of resources needed to restore operations and power delivery back to normal.

Gas Infrastructure

From a planning perspective, PG&E's Gas Emergency Response Plan prescribes immediate actions to be taken to ensure safety and reliability in major flooding events. PG&E has prioritized areas of exposed pipeline and pipeline spans in flood zones and coordinated on response plans for assets with higher-risk exposure to flood zones. PG&E is also developing long-term plans to address areas of gas transmission pipeline at risk of erosion and landslides.

From an operational perspective, PG&E continues to identify and mitigate potential impacts from flooding through scheduled air and ground patrols, leak surveys and routine maintenance. PG&E has also automated notifications for areas at risk of landslides due to heavy rain events. In addition, PG&E has identified and is monitoring pre-determined gas transmission pipeline locations susceptible to erosion and landslides through use of Light Detection and Ranging (LiDAR) to monitor and track potential land movement, accompanied by field verification.

Additionally, PG&E's meteorological department forecasts where and when storms are likely to arrive and progress through PG&E's service area, including identifying potential areas of greatest rainfall intensity. A PG&E-developed model enables the company's gas operations to identify high risk areas susceptible to rainfall-induced landslides. Together, the rainfall forecasts and associated models help PG&E to better understand the potential impact to its gas system infrastructure from storms.

APPENDIX K

Appendix K: Baylands Ecosystem Habitat Goals Science Update 2015: The Baylands and Climate Change: What Can We Do: Application in San Mateo County

This section was written by Kelly Malinowski from the California State Coastal Conservancy and explains how the Goals Project (Conservancy 2015) applies in San Mateo County.

Introduction

Baylands Ecosystem Habitat Goals Science Update 2015: The Baylands and Climate Change: What We Can Do (Conservancy 2015) is an update to the 1999 Baylands Ecosystem Habitat Goals, which for the first time set comprehensive restoration goals for the San Francisco Bay estuary, produced by a collaborative of 21 management agencies working with a multi-disciplinary team of over 100 scientists. The 2015 science update synthesizes the latest science, and incorporates an understanding of climate change and sediment supply, and projected change through 2100 to generate new recommendations in achieving healthy baylands ecosystems. Recommended actions offer opportunities for multi-benefit projects to enhance ecological function, which can also provide benefits to the built and human communities and help enhance resilience to sea level rise. Summaries of segments are included below. For a full list of the opportunities, segment features and setting, implications of drivers of change, recommended actions and considerations for implementation of the actions, and challenges, please visit: http://baylandsgoals.org/

Segment J

Overview

Segment J covers the section of bayshore in San Mateo County north of Coyote Point to the northern boundary of San Mateo County.

Opportunities

Opportunities for this segment include restoration of tidal wetlands, beaches, sand dunes, intertidal rocky areas, subtidal habitats, and demonstration projects to educate the public and raise awareness about climate change impacts, and promote solutions. Ongoing creek work in the segment could be leveraged to integrate climate-change-adaptation techniques. Though highly urbanized, Segment J offers the opportunity for multi-benefit projects that incorporate small-scale restoration and the protection of existing infrastructure, shorelines, and baylands. This segment also presents the opportunities for innovative and experimental approaches, such as sediment placement, the use of uncontaminated on-site fill-in restorations, and integrated multi-habitat designs.

Sea Level Rise Adaptation Recommendations

Near-Term (Now to midcentury, prior to sea level rise curve acceleration)

Near-term actions to enhance the existing baylands and provide immediate ecological benefits will maximize shoreline resilience. One action to preserve and enhance native eelgrass and oyster beds is to create living breakwaters around fringing marshes and partner with industrial and shoreline communities to create habitat bayward of flood protection levees. For infrastructure remaining in current configurations, living seawalls could enhance habitat value, and improving tide gate management can also enhance habitats. Additional habitat can also be created along flood-control channels.

Long-Term (Letter half of the century, after sea level rise curve acceleration)

In the long-term, it is likely sea-level rates will outpace vertical accretion rates for marshes in this segment. Prior to this, plans for restoring or relocating functions within existing tidal marshes should be implemented. The creation of wetlands bayward of flood protection levees could provide this landward migration space. If managed retreat opportunities become available, options to restore areas to baylands or to connect bay habitats should be pursued.

Segment M

Overview

Segment M covers the San Mateo County bayshore between Coyote Point and Steinberger Slough.

Opportunities

Opportunities in Segment M are limited, but include opportunities to protect and enhance remaining tidal marshes and other wetlands, subtidal habitat, creating breakwaters to protect fringing marshes or artificial rock groins to form small beaches. Horizontal levees can be built along the shoreline as residential communities invest in flood protection against sea level rise.

Sea Level Rise Adaptation Recommendations

Near-Term

Near term actions to enhance the baylands will provide immediate ecological benefits and maximize their resilience. Breakwaters around fringing marshes can be used to preserve shell mounds, and marsh recharge can increase vertical accretion rates for marshes. Native oyster and eelgrass beds can also be restored in this segment, and there are opportunities for horizontal levees bayward of flood protection levees. There is also a unique opportunity to restore the transition zone along the Foster City shoreline at the mouth of Belmont Slough.

Long-Term

Since sea level rise rates will likely outpace vertical accretion rates, a plan for restoring or relocating functions of existing marshes should be implemented prior to sea level rise acceleration. Creating wetlands bayward of the flood-protection levees could provide this landward migration space. If managed retreat opportunities arise, there will be opportunity for restored marshes along this segment.

Segment N

Overview

Segment N covers the San Mateo County bayshore from Steinberger Slough to the Dumbarton Bridge and includes both the Bair Island restoration and Ravenswood pond complex.

Opportunities

There are opportunities in Segment N for tidal marsh restoration and the enhancement of seasonal wetlands and ponds, Bedwell Bayfront Park allows for some marsh migration as sea levels rise, and local sediment and water supplies could be used for habitat creation.

Sea Level Rise Adaptation Recommendations

Near-Term

In this segment, near-term opportunities are significant in restoring tidal marsh in managed ponds. Other measures, such as levees, may be needed in protecting Highway 101 on the western side of Inner Bair and to prevent flooding of Highway 84 next to the Ravenswood pond complex.

Long-Term

If sea level rise accelerates and sediment supply decreases in the long-term, marsh plains could become fringing marshes and tidal marshes may be unable to keep up with sea level rise. Gently sloping levees bayward of existing levees would facilitate anticipated landward migration of marshes.

Segment O

Overview

Segment O covers the San Mateo County bayshore from the Dumbarton Bridge to the southern boundary of San Mateo County.

Opportunities

Segment O provides opportunities to enlarge existing marshes and to link the eastern and western parts of the South Bay for tidal-marsh-dependent species. There are also opportunities to enhance tributary streams such as San Francisquito Creek and the Guadalupe River.

Sea Level Rise Adaptation Recommendations

Near-Term

In the near-term, restoring tidal marsh in managed ponds can help create a continuous corridor of tidal marsh, and managed ponds could continue to be managed for shorebirds and waterfowl while rates of sea-level rise are low.

Long-Term

As sea level rise accelerates, marsh plains will convert to narrower fringing marshes and tidal marshes may be unable to keep up with rising seas. A gently sloping transition zone bayward of the levee would facilitate marsh migration in the long-term.

APPENDIX L

Appendix L: Stakeholder Group List

The project team engaged local experts through public meetings, workshops, guided discussions, personal interviews, and site visits. The team also worked with asset managers, civic leaders, elected officials, and representatives from agencies and special interest groups to collect information and feedback. This information augmented scientific and archival information to provide a more comprehensive perspective on sea level rise vulnerability in San Mateo County. The stakeholders involved to-date are in the following list.

Stakeholder Group List
Alain Pinel Realtors
Association of Bay Area Governments (ABAG)
Bay Area Rapid Transit (BART)
Bay Area Regional Collaborative (BARC)
Bay Localize
Bay Planning Coalition
Bayshore Sanitary District
California Coastal Commission
California Department of Fish and Wildlife
California Department of Transportation (Caltrans) District 4
California State Coastal Conservancy
California State Lands Commission
California State Office of Assemblyman Gordon
California State Office of Assemblyman Mullin
California State Office of Congresswoman Speier
California State Office of Senator Hill
Caltrain
Cargill, Inc.
City of Belmont
City of Brisbane
City of Burlingame
City of Daly City
City of East Palo Alto
City of Foster City
City of Half Moon Bay
City of Menlo Park
City of Millbrae
City of Mountain View
City of Pacifica
City of Redwood City
City of San Bruno
City of San Carlos
City of San Mateo
City of South San Francisco

City of South San Francisco - San Bruno Water Quality Control Plant
City/County Association of Governments of San Mateo County (C/CAG)
Committee for Green Foothills
Coravai, LLC.
County of Marin
County of San Mateo Office of Education
County of San Mateo Office of Emergency Services
County of San Mateo Office of Supervisor Horsley
County of San Mateo Office of Supervisor Pine
County of San Mateo Office of Sustainability
County of San Mateo Office of the County Counsel
County of San Mateo Parks Department
County of San Mateo Public Works Department
County of San Mateo Resource Conservation District
County Santa Clara Office of Sustainability
East Palo Alto Sanitary District
Environmental Risk & Financial Solutions (ER&FS)
Facebook
Federal Emergency Management Agency (FEMA) Region IX
Foster City Chamber of Commerce
Genentech, Inc.
Gilead Sciences, Inc.
Google
Granada Community Services District (GCSD)
Greater Farallones National Marine Sanctuary (GFNMS)
Kaiser Permanente
League of Women Voters
Life Moves Maple Street Shelter
Metropolitan Transportation Commission (MTC)
Midcoast Community Council
Midpeninsula Regional Open Space District
Mid-Peninsula Water District
Montara Water & Sanitary District
National Oceanic and Atmospheric Administration (NOAA)
North Coast County Water District (NCCWD)
Oracle
Pacific Gas and Electric Company (PG&E)
Pacifica Care Center, Inc.
Point Blue
Port of Redwood City
San Carlos Airport

San Francisco Bay Area Planning and Urban Research Association (SPUR)
San Francisco Bay Conservation and Development Commission (BCDC)
San Francisco Estuary Institute (SFEI)
San Francisco International Airport (SFO)
San Francisco Public Golf Alliance
San Francisco Public Utilities Commission (SFPUC)
San Francisquito Creek Joint Powers Authority (SFCJPA)
San Mateo - Foster City School District
San Mateo County Department of Public Works
San Mateo County Economic Development Association (SAMCEDA)
San Mateo County Harbor District
San Mateo County Transit (SamTrans)
San Mateo County Transportation Authority (SMCTA)
San Mateo County Union Community Alliance
Sewer Authority Mid-Coastside
Shore Up Marin
Sierra Club, Loma Prieta Chapter
Silicon Valley Clean Water (SVCW)
Silicon Valley Community Foundation
Silicon Valley Joint Venture
South Bay Salt Pond Restoration Project
Sustainable San Mateo County
Sustainable Silicon Valley
Town of Atherton
Town of Colma
Town of Hillsborough
Town of Portola Valley
Town of Woodside
United States Army Corps of Engineers (USACE)
United States Fish & Wildlife Service (FWS)
United States Geological Survey (USGS)
West Bay Sanitary District
Westborough Water District
Youth United for Community Action (YUCA)

APPENDIX M

Appendix M: Summary of Local Sea Level Rise Planning Efforts

Summary of Local Sea Level Rise Planning Efforts

Half Moon Bay SLR Planning Efforts

The City of Half Moon Bay is currently updating their General Plan and Local Coastal Program (LCP) in order to account for sea level rise. The City has completed a sea level rise vulnerability assessment, which has informed the development of the General Plan/ LCP update, and will support the development of adaptation projects. In February 2017, the City completed a site-specific erosion study of the California Coastal Trail between Kelly Avenue and Seymour Street (City of Half Moon Bay 2017). The City will continue to include erosion and other sea level rise-related studies and projects in the City's Capital Improvement Plan. To date, areas of concern include Surfer's Beach due to its low elevation, as well as multiple bluff areas that are prone to erosion.

City of Foster City Levee Protection Planning Study

Foster City's levees are no longer accredited under the National Flood Insurance Program administered by the Federal Emergency Management Agency (FEMA), resulting in 17,000 properties being placed in the Special Flood Hazard Area (SFHA) and subject to the mandatory flood insurance requirement if the levees are not improved. FEMA has given Foster City "Seclusion Mapping" designation, keeping properties out of the flood zone as long as progress to the levee improvement project is being made. At any time, FEMA can remove this designation if they feel that progress is not being made. As a result, Foster City initiated the Foster City Levee Protection Planning Study to review and better assess the current state of its levee system, and to propose alternatives to improve the levees to meet FEMA accreditation standards. The study was recently completed and the city is progressing with the design process.

The study compared current survey data (elevations) of the levee system to storm surge levels and wave run up elevations from the California Coastal Analysis and Mapping Program (CCAMP) that were prepared in July 2014. The study found 85% of the city's levees do not meet the required freeboard elevation to retain FEMA accreditation by an average of approximately two feet and a maximum of four feet. These numbers do not consider sea level rise (SLR) or land settlement, which could add another 1.5 feet to the freeboard requirement. Approximately 17,000 properties are at risk in Foster City and the City of San Mateo if levees are insufficient to protect against flooding. Widening of levees would be on the landward side due to the sensitive habitats and endangered species on the bay side of the levee.

Concerning SLR, the report references the 2012 National Research Council Report "Sea-Level Rise for the Coasts of CA, OR, and WA: Past Present Future" (NRC Report) as the best available science and is supported by both the City and County of San Francisco (CCSF) and the California Coastal Commission (CCC). The NRC Report provides a range of SLR estimates for years 2030, 2050, and 2100. CCSF and Foster City recommend using the mean of each range: 0.5 foot for 2030, 1 foot for 2050, and 3 feet for 2100. Levee improvements should be built to last until at least 2050, meaning they should have an extra foot of freeboard to accommodate for SLR. Design decisions, particularly with respect to long-term adaptability to rising sea levels, continue to be informed by ongoing work in the field, including the April 2017 "Rising Seas in California" report prepared by the California Ocean Protection Council Science Advisory Team (OPC-SAT).

Data used in this work that may be relevant to San Mateo County include Light Detection and Ranging (LIDAR) surveys and levee profiles for the region. Foster City's work is confirmation that the San Mateo County Sea Level Rise Vulnerability Assessment is relevant and necessary. The SLR component provides a good baseline of an approach and assumptions that can be built upon, and levee designs may be useful in the Adaptation Planning phase of the San Mateo Vulnerability Assessment. Coordination of efforts between the San Mateo County study and the Foster City assessment is encouraged.

The permit applications with the Environmental Regulatory agencies will be submitted in Fall 2017, with permits anticipated to be received during Spring 2018. Construction is anticipated to occur from Summer 2019 through Summer 2021, approximately 2 years.

San Francisco International Airport Shoreline Protection Feasibility Study Evaluation and Recommendations

The City and County of San Francisco entered into the FEMA National Flood Insurance Program in 2010, and the FEMA preliminary flood insurance rate map (FIRM), dated November 2016, mapped the majority of the San Francisco International Airport (Airport) property within Special Flood Hazard Areas. The majority of the Airport is mapped within the 1% annual chance flood hazard zone with flood elevation of approximately Elevation 10 feet NAVD. The Airport undertook a shoreline protection feasibility study completed in 2015 to evaluate flood risks from the 100 year storm and sea level rise and recommend mitigation against flood hazards.

The 2015 study identified current deficiencies in the existing shoreline protection system against flooding, and provided recommendations to correct deficiencies for flooding in the near term and to address sea level rise through longer term climate change. Data from this study that may be potentially useful in San Mateo County's work includes results from modeling of storm surge within San Francisco Bay. Coordination of efforts between the San Mateo County and the airport is encouraged.

With respect to the sea level rise basis for design, the Airport defers to the City and County of San Francisco's recommendation of relying on the National Research Council (NRC) Report. The NRC Report stipulates up to 2 feet of sea level rise by 2050. The next steps for the airport include continued development of a comprehensive shoreline protection plan and construction schedule to address flood protection and sea level rise. The first phase of the program would begin in 2020 pending completion of CEQA environmental review beginning in 2018 and receipt of the necessary approvals.

San Bruno Creek and Colma Creek Resiliency Study

The purpose of the study was to assess the vulnerability of SFO and its neighbors to flooding from sea level rise and storms along the Bay shoreline directly northwest of the airport where San Bruno Creek and Colma Creek meet the Bay. The scope of the study includes establishing an interagency working group, data collection, surveying, hydrologic and hydraulic modeling, and identifying vulnerable reaches and potential adaptation measures for the project area.

The study considers three scenarios for sea level rise: one foot (expected to occur between 2030 and 2080), two feet (expected to occur between 2050 and 2125), and three feet (expected to occur between 2065 and 2155). These estimates are taken from the NRC Report.

This study is an example of a smaller scale assessment and provides a good baseline of approach and valuable insight into that region of the County. Potential data from this study that may be useful in San Mateo County's work include LIDAR data for the project area, locations of flood control and other drainage infrastructure, and hydrologic and hydraulic modeling results from HEC-HMS and HEC-RAS models. Adaptation measures recommended may also be considered in the adaptation planning phase of the San Mateo County Sea Level Rise Vulnerability Assessment.

Climate Change Vulnerability Assessment for the North-central California Coast and Ocean (Farallones)

This vulnerability assessment aims to identify how habitats, species, and ecosystem services are likely to be affected by future climate conditions. The goal is to provide an assessment for marine resource managers to use to plan, manage, and respond to impacts of climate change. The study area included coast and ocean ranging from the southern edge of San Mateo County up to Alder Creek in Mendocino County. The study reviewed adaptive capacity, degree of exposure, and sensitivity for eight habitat types, 31 species, and 5 ecosystem services. Vulnerability was equated with decreased adaptive capacity, and increased exposure and sensitivity of the resource.

In addition, 32 stressors were listed and scored according to the degree of sensitivity the resources exhibited to that stressor. The number of resources impacted by each stressor was also recorded. The most vulnerable habitats, species, and ecosystems were those existing at the land-sea interface. Climate information referenced in the study was from Climate Change Impacts Report from the Cordell Bank and Gulf of the Farallones National Marine Sanctuary Advisory Councils. The study also included the NRC Report's estimates of 5-24 inches of SLR by 2050 and 17-66 inches of SLR by 2100.

We are currently waiting to hear what data sources may be available from this study. This work may be useful to San Mateo's current vulnerability assessment and future work by providing insight into relevant ecosystem vulnerabilities and impacts from SLR inundation.

SMC Climate Action Plan

The report describes a vulnerability assessment that focused on six distinct types of county assets: agriculture, built infrastructure in coastal zone, coastal ecosystems, property and safety threats due to wildfire, public health threats from increased temperatures, and impacts on water supply. The four major hazards analyzed were increased temperature, increased variability in precipitation, sea level rise, and increased chance of wildfire. Key findings and recommendations include a variety of 'warnings' regarding erosion risk along the coastline. Specifically, bluffs, low-lying beaches and trails, major roads including Highway 1, and coastal wetlands all are at risk of being eroded or destroyed. More irregular precipitation cycles will affect the water table, which will affect flooding patterns.

The SLR portion references the NRC report and establishes sea level rise averages for 2030 (7"), 2050 (14"), 2100 Low greenhouse gas scenario (GHG) (40"), and 2100 High GHG scenario (55"). Next steps include transitioning from the key vulnerability areas identified in the report to developing adaptation actions to address these areas.

The report lays out the various changes that will increase vulnerability across the region and lays out the need for a more focused sea level rise vulnerability assessment for the County.

Energy Efficient Climate Action Plan (EECAP)

EECAP intends to illustrate the County's continued commitment to reducing GHG emissions. The purpose of the report is to inventory GHG emissions, provide reduction strategies, discuss adaptation measures to future climate change impacts, and provide implementation strategies for reducing GHG emissions. The adaptation section summarizes the analysis provided in the SMC Climate Action Plan. The section recognized special vulnerabilities to increased temperature, increased variability in precipitation, increased wildfire risk, decreased supply of fresh water, and increased sea level rise. It also identifies adaptation measures such as updating the Local Hazard Mitigation

Plan, updating the resource management plans, updating emergency operations plan, and developing programs to educate residents and businesses of anticipated changes.

This report lays out the expected changes that will increase vulnerability across the region and emphasizes the need for further vulnerability assessment for the County.

San Mateo County General Plan: Energy and Climate Change Element

The purpose of the Energy and Climate Change Element of the General Plan is to demonstrate the County's commitment to energy efficiency and mitigate impact on climate change by reducing GHG consistent with state legislation (Assembly Bill AB32 – The Global Warming Solutions Act of 2006). The section on Potential Impacts of Climate Change references the NRC Report, which estimates 5-24 inches of SLR by 2050 and 17-66 inches of SLR by 2100. A series of adaptation goals were detailed as well, the first of which is to identify and prepare for climate change impacts by tracking and funding climate change assessments, integrate the assessments into the planning process, and develop a county-wide adaptation strategy. The second goal is to enhance the adaptive capacity of natural and man-made systems by encouraging future construction to consider climate change risks, as well as implementing generic monitoring and adaptation strategies and programs.

This report is relevant as it makes clear the need for further vulnerability assessment for the County. The report lays out the various changes that will increase vulnerability across the region.

Climate Snapshot San Mateo County

The Snapshot lists programs across the County that are addressing climate impacts and building community resiliency. It identifies Bay Area cities that have Climate Action Plans. Finally, a summary is provided of input from San Mateo stakeholders regarding forms of resources and assistance that would be useful for the community and these programs. Common themes from stakeholders include praise for the Regionally Integrated Climate Action Planning Suite (RICAPS), requests for planning guidelines or mandates from the state, desire to build political support for adaptation and resilience initiatives, requests for accessible and sustainable funding streams for local agencies, getting insurance industry more involved in adaptation, need for assistance with energy projects, and a push to focus outreach to the most vulnerable communities.

This report does not contain specific data relevant to use in the vulnerability assessment, but it is useful and relevant for the public outreach section of the County's vulnerability assessment and to identify vulnerable communities. The Snapshot can be used as a summary or glimpse into the local stakeholders' interests and viewpoints.

SAFER Bay Project

Motivated by the National Flood Insurance Program (NFIP) maps which cause a large number of properties in the Special Flood Hazards Area (SFHA) adjacent San Francisco Bay shoreline and San Francisquito Creek, and following projections for substantial sea level rise (SLR), the San Francisquito Creek Joint Powers of Authority (SFCJPA) initiated the Strategy to Advance Flood protection, Ecosystems, and Recreation along the Bay (SAFER Bay) for eleven miles of shoreline. The SAFER Bay project would reduce both the risks and the requirement for flood insurance associated with tidal flooding for thousands of properties in the cities of East Palo Alto, Menlo Park (and Palo Alto in Santa Clara County); create or restore marshes; and improve trail access along the shoreline. The study area includes East Palo Alto and Menlo Park, and covers roughly nine miles of bay shoreline. Design criteria for the shoreline project include water surface elevations for the 1% annual chance flood (base flood) with two feet of additional freeboard and three more feet to account for SLR over the project lifespan, which, taken together is about nine feet above today's daily high tide. The results from SAFER's feasibility study may be used in the adaptation planning phase of the San Mateo County Sea Level Rise Vulnerability Assessment to ensure regional coordination, and will be used to begin design and environmental documentation in early 2018.

The current schedule for the San Mateo County portion of the SAFER Bay project anticipates completing design and an Environmental Impact Report (EIR) in 2019. During 2017 and 2018, the SFCJPA intends to work with state and federal environmental regulatory agencies, and with landowners, to ensure that the project that is developed can be permitted and built. BY 2020, the SFCJPA intends to apply for permits and finalize project financing.

Silicon Valley 2.0

The Silicon Valley 2.0 project was developed to address regional climate adaptation planning for Santa Clara County. The purpose of the project was to identify the region's climate vulnerabilities (including flood but also other hazards), catalogue assets, map climate impacts, analyze the gaps in climate preparedness, and create a decision-support tool that maps assets with impact zones to assess the potential risk and cost of losing those assets. The Project does not provide any coverage outside of Santa Clara County.

The Project involved nine sectors from across the county: transportation, water, energy, telecom, shoreline assets, waste and waste treatment, super fund sites, state fund sites, and public health. Rather than using discrete SLR scenarios, the tool provides a sliding scale for storm surge and SLR. The tool aimed to address a number of uncertainties associated with SLR estimates such as: the estimates are too speculative, the existing data are too uncertain, the impacts are too far in the future to address now, resiliency projects cost too much, and we can rely on federal organizations to step in and protect the region. The online tool is expected to go live within the next few months.

Summary Table of Local Sea Level Rise Planning Studies or Efforts

Study or Project	Year	Sponsor	Geographic Area	Participants	Goals	Major Findings	Recommendations (Where applicable)	SLR Projections	Data source	Data date	How will the study be used?
City of Half Moon Bay Local Coastal Program Update	2015/2016	California Coastal Conservancy	City of Half Moon Bay	City of HMB, Coastal Conservancy, Consulting team	Not yet developed	Not Applicable	Not applicable	Preliminary/NA	NA	NA	It will be used to update the General Plan, Local Coastal Program, and to inform SLR adaptation.
City of Foster City Levee Protection Planning Study	2015	Foster City	Foster City	Schaaf and Wheeler	Review levee system to Regain FEMA accreditation	85% of levees do not meet required elevation by average of 2ft.	Large improvement of levee system is required to regain FEMA accreditation	2030: 0.5ft 2050: 1ft 2100: 2ft	CCAMP NRC Report	July 2014 2012	Design phase for updating levee system is beginning now.
San Francisco International Airport Shoreline Protection Feasibility Study Evaluation and Recommendations Report	2015	SFO	SFO	Moffatt and Nichol + AGS Inc.	Removing the Special Flood Hazard Area (SFHA) FEMA designation for the airport property	The current flood protection system was assessed for deficiencies and corrections to those deficiencies were proposed.	Address deficiencies in flood protection system so that SFO can apply for A99 certification.	Based on max SLR of 2ft by 2050, 2 scenarios were proposed: 2ft SLR and >2ft SLR	NRC Report	2012	The study will be used to update SFO's flood protection system to remove the SFHA designation from the project area.

Study or Project	Year	Sponsor	Geographic Area	Participants	Goals	Major Findings	Recommendations (Where applicable)	SLR Projections	Data source	Data date	How will the study be used?
Climate Change Vulnerability Assessment for the North-central California Coast and Ocean	2015	Gulf of the Farallones National Marine Sanctuary California Landscape Conservation Cooperative	North- central California coast and ocean	NPS, Point Reyes National Seashore, EcoAdapt, California Landscape Conservation Cooperative, Bay Area Ecosystems Climate Change Consortium, Golden Gate National Recreation Area, Point Blue Conservation Science	The goal is to provide an assessment for marine resource managers to use to plan, manage, and Respond to Impacts of climate change.	The most vulnerable habitats, species, and ecosystems were those existing at the land-sea interface.	Managers should focus on addressing stressors that impact high vulnerability areas at the land-sea interface	References range of estimates from NRC Report	Climate Change Impact Report NRC Report	2010 2012	Marine resource managers will use the report as a guide for addressing impacts of climate change.
San Mateo County Climate Action Plan	2011	County of San Mateo	County of San Mateo	ICLEI	Identify key areas that the County can focus on to increase resilience to climate change.	Erosion along the coastline is not well understood and can lead to major losses for multiple different areas	Nothing specific	again references NRC Report	NRC Report	2012	Adaptation actions need to be Developed to address key areas of vulnerability identified in the report

Study or Project	Year	Sponsor	Geographic Area	Participants	Goals	Major Findings	Recommendations (Where applicable)	SLR Projections	Data source	Data date	How will the study be used?
Energy Efficient Climate Action Plan	2013	County of San Mateo	County of San Mateo	DOE PMC DNV KEMA Fehr and Peers ICLEI	The purpose of the report is to inventory GHG emissions, provide reduction strategies, discuss adaptation measures to future climate change, and provide implementation strategies for reducing GHG emissions	Relevant sections repeat the analysis provided in the SMC Climate Action Plan.	Action items proposed as response to SMC Climate Action Plan include updating the County's hazard mitigation plans as well as public outreach to educate residents and Businesses on anticipated changes.	again references NRC Report	NRC Report	2012	Primarily the study will be used to continue to reduce GHG emissions across the County.
SMC General Plan. Energy and Climate Change Element	2013	County of San Mateo	County of San Mateo	PMC	Demonstrate commitment to energy efficiency and mitigate impact on climate change by reducing GHG consistent with state legislation.	Same list of potential impacts of climate change as the other reports.	First, ID and prepare for climate change impacts. Second, enhance adaptive capacity of natural and man-made systems	again references NRC Report	NRC Report	2012	Primarily the study will be used to continue to reduce GHG emissions across the County.

Study or Project	Year	Sponsor	Geographic Area	Participants	Goals	Major Findings	Recommendations (Where applicable)	SLR Projections	Data source	Data date	How will the study be used?
SAFER Bay Project	2014-ongoing	San Francisquito Creek JPA	Shoreline, San Francisquito Creek Watershed, including East Palo Alto and Menlo Park	City of Palo Alto, City of East Palo Alto, Menlo Park	Remove properties from SFHA, reduce flood risk, restore marshes, enhance restoration	List of alternatives for shoreline protection to protect entire area	Alternatives (report not yet available, but proposed alignment is)	3 feet of sea level rise	Lidar data, parcel data, FEMA preliminary FIRM data		After feasibility analysis complete, project will begin construction.
San Bruno and Colma Creek Resilience Study	2015	SFO	San Bruno and Colma Creeks	SFO and interagency groups	Assess vulnerability of SFO and its neighbors to Flooding from sea level rise and storms along the Bay shoreline directly northwest of the airport where San Bruno Creek and Colma Creek meet the Bay	Shoreline vulnerabilities and deficiencies	List of alternatives, including regional tide gate	**1** foot **2** feet **3** feet	Lidar, modeling data results, flood and drainage infrastructure		May use relevant data, and will consider adaptation strategies from Study in the adaptation planning phase of our vulnerability assessment

APPENDIX N

Appendix N: Recommendations for Next Steps from Stakeholders

This list is based on feedback from the Technical Working Group, Policy Advisory Committee, and Community Task Force at the July 2016 Sea Change SMC stakeholder meeting, the April 2016 Technical Working Group Meeting, and the October 2015 Policy Advisory Committee meeting. At these meetings, County staff solicited input on what needs cities, agencies, businesses, and others have with regard to sea level rise, and what outcomes they would like to see from the Sea Change SMC Initiative.

- Prioritize assets. Prioritize assets that are at risk now and with future sea level rise based on the most critical to the least critical.
- Develop Countywide sea level rise standards. Establish Countywide standards for sea level rise science, sources, scenarios, and assessment methodology and produce guidance on how to consistently address sea level rise in General Plans and Local Coastal Programs. This process includes identifying the key components of a rigorous sea level rise analysis and developing a standardization of information, assessments, and approach to limit a piecemeal or inconsistent way of looking at the problem. The guidance should be a two- to nine-page document tailored for San Mateo County city staff and elected officials.
- Understand adaptation options. Conduct a more detailed shoreline analysis to understand where levees are needed and what shoreline adaptation options would work in specific locations and incorporate flooding from the upper watershed. Evaluate ways to reduce greenhouse gas emissions during adaptation, prioritize green infrastructure options, and better understand the regulatory constraints and legal liability moving forward.
- Collaborate across sectors. Integrate adaptation into the Climate Action Plan process and work to collaborate between planning efforts, emergency preparedness efforts, and facility operations efforts. Use the Local Hazard Mitigation Plan as an avenue to accomplish this goal.
- Provide mapping products and accessible data. Provide a map viewer that all stakeholders could use. Cities, CalTrans, and wetland managers requested data in multiple formats: GIS files, PDFs, and online interactive viewers. Each of these would serve a different purpose. Google Earth/KMZ files would also be useful. Develop a system for sharing data across entities.
- Refine sea level rise modeling. Develop local wave run-up models. Understand watershed-scale flooding impacts, including combination of riverine and bay flooding.
- Evaluate governance options. Evaluate governance options, including formation of a Countywide joint powers authority. Consider establishing a Countywide independent review committee that would complete review of projects to ensure they adequately prepare for sea level rise. It may be helpful to consider different governance models.
- Investigate funding opportunities. Understand how to approach coordinated funding across cities.
- Raise public awareness of sea level rise. Understand what the current level of public understanding of sea level rise is, and develop a targeted outreach program to raise awareness of the issue among community members.

APPENDIX O

Appendix O: Additional Resource

The following reports can be found on the Sea Change SMC website and are relevant to the issues discussed in this report. Please refer to them for more information.

BCDC. 2012. Addressing Social Vulnerability and Equity in Climate Change Adaptation Planning. Prepared by the Baldwin Group. Accessible from: http://www.adaptingtorisingtides.org/wp-content/uploads/2015/04/ART_Equity_WhitePaper.pdf

PG&E's *Climate Change Vulnerability Assessment* (2016) is available from: http://www.pgecurrents.com/wp-content/uploads/2016/02/PGE_climate_resilience.pdf

San Francisco International Airport. (2015). San Bruno Creek/Colma Creek Resiliency Study Final Report. Prepared by Moffat and Nichol and AGS. Accessible from: http://seachangesmc.com/wp-content/uploads/2015/08/SanBruno_Colma-Resiliency-FINAL_Rpt_150820.pdf

San Mateo County, BCDC, the Conservancy, and AECOM. 2016. *Sea Level Rise & Overtopping Analysis for San Mateo County's Bayshore.* Accessible from: http://seachangesmc.com/wp-content/uploads/2015/08/SanMateoCo_Bayshore_Final_Report_w_Appendices.20160523_web.pdf.

APPENDIX P

Appendix P: Glossary

Glossary

Adaptation - The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. [7]

Adaptation strategies - A general plan of action for addressing the impacts of climate change, including climate variability and extremes. It may include a mix of policies and measures, selected to meet the overarching objective of reducing the country's vulnerability. [9,10]

Adaptive capacity - The ability of a system to respond to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences. [3]

Artificial reef - manmade structure that may mimic some of the characteristics of a natural reef. [13]

Asset - a resource that provides an economic, social, or environmental functions or services.

Asset sensitivity (also sensitivity) - Degree to which a resource, asset, or process is or could be affected, either adversely or beneficially, by climate variability or change. [2]

Beach nourishment - Placement of sand and/or sediment (e.g., beneficial re-use of dredged sediment) on a beach to provide protection from storms and erosion, to create or maintain a wide(r) beach, and/or to aid shoreline dynamics throughout the littoral cell. The project may include dunes and/or hard structures as part of the design. [3]

Berm - A commonly occurring, low, impermanent, nearly horizontal ledge or narrow terrace on the backshore of a beach, formed of material thrown up and deposited by storm waves. [5]

Bluff - A high bank or bold headland with a broad, precipitous, sometimes rounded cliff face overlooking a plain or body of water. [5]

Climate Change - Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. [1]

Effluent - Treated or partially treated wastewater that is discharged into the environment from a treatment plant, sewer, or industrial facility. [15]

Embankment - An artificial BANK, mound, DIKE, or the like, built to hold back water or to carry a roadway. [20]

Erosion - The wearing a way of land by natural forces; on a beach, the carrying away of beach material by wave action, currents, or the wind. Development and other non-natural forces (e.g., water leaking from pipes or scour caused by wave action against a seawall) may create or worse erosion problems. [3]

Exposure - The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and setting that could be adversely affected. [7]

Flap gates - a flow control device that, in principle, functions as a check valve, allowing water to flow through it in only one direction. [21]

Flood - A condition of partial or complete inundation of normally dry land areas from: (1) the overflow of inland or tidal waters, (2) the unusual and rapid accumulation or runoff of surface waters from any source, or (3) Mudslides. [6]

Flood proof - Any combination of structural and nonstructural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures and their contents. [6]

Force Main - A pressurized pipe installed to accommodate the pump discharge from a wastewater pumping station. [17]

Green infrastructure - Refers to the use of vegetative planting, dune management, beach nourishment or other methods that mimic natural systems to capitalize on the ability of these systems to provide flood and erosion protection, stormwater management, and other ecosystem services while also contributing to the enhancement or creation of natural habitat areas. [3]

Groundwater recharge (groundwater seepage) - Inflow of water to a ground-water reservoir from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. [5]

Hazard - The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts. [7]

Horizontal levee (also hybrid levee) - a type of natural infrastructure (also known as green infrastructure) restoration strategy to help reduce shoreline flooding caused by sea level rise [19]

Influent - the flow of untreated wastewater into a treatment process [16]

Inundation - The process of dry land becoming permanently drowned or submerged, such as from dam construction or from sea level rise. [3]

King tides - The highest predicted high tide of the year at a coastal location. [4]

Levee - A man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection from temporary flooding. While levees can help reduce the risk of flooding, they do not eliminate the risk. [6]

Living reef (also coral reefs) - a wave-resistant structure resulting from cementation processes and the skeletal construction of hermatypic corals, calcareous algae, and other calcium carbonate-secreting organisms [12]

Managed realignment (also managed retreat) - Reduces coastal flooding and erosion by setting back the flood defenses to allow flooding of a presently defended area [11]

Mean higher high water (MHHW) - The average of the higher high water height of each tidal day observed over the national tidal datum epoch [5]

Mitigation - Human intervention to reduce the human impact on the climate system [3]

Nature Based Solutions- features that mimic characteristics of natural features but are created by human design, engineering, and construction to provide specific se vices such as coastal risk reduction [2]

North American Vertical Datum 88 (NAVD 88) - The vertical control datum established in 1991 by the minimum-constraint adjustment of the Canadian-Mexican United States leveling observations [14]

Overtop - Water carried over the top of a coastal defense due to wave run-up or surge action exceeding the crest height. [20]

Resilience - The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation. [7]

Revetments - A sloped retaining wall; a facing of stone, concrete, blocks, rip-rap, etc. built to protect an embankment, bluff, or development against erosion by wave action and currents. [3]

Riprap - Loose boulders placed on or along the shoreline as a form of armoring. [5]

Risk - The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard (see Figure SPM.1). In this report, the term risk is used primarily to refer to the risks of climate-change impacts. [7]

Saltwater intrusion - Displacement of fresh or ground water by the advance of salt water due to its greater density, usually in coastal and estuarine areas. [5]

Sea level rise - Changes in the shape of the ocean basins, changes in the total mass of water and changes in water density. Factors leading to sea level rise under global warming include both increases in the total mass of water from the melting of land-based snow and ice, and changes in water density from an increase in ocean water temperatures and salinity changes. [3]

Seawall (also floodwall) - structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. It is usually a vertical wood or concrete wall as opposed to a sloped revetment. [3]

Sensitivity - The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., climatic or non-climatic stressors may cause people to be more sensitive to additional extreme conditions from climate change than they would be in the absence of these stressors). [7]

Slurry walls - a technique used to build reinforced concrete walls in areas of soft earth close to open water or with a high groundwater table. [8]

Storm surge - A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes the rise in water level due to atmospheric pressure reduction as well as that due to wind stress [3]

Tidal barrier- A large dam, gate, or lock — or a series of them — that manages tidal flows. [18]

Tidal floodplain - Any land area susceptible to being inundated by water from a tide event. [6]

Vulnerability - The extent to which a species, habitat, ecosystem, or human system is susceptible to harm from climate change impacts. More specifically, the degree to which a system is exposed to, susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, as well as of non-climatic characteristics of the system, including its sensitivity, and its coping and adaptive capacity. [3]

Water Table (groundwater table) - The depth at which the ground is saturated with water. [5]

Weir - A wall or plate placed in an open channel and used to measure the flow of water. The depth of the flow over the weir can be used to calculate the flow rate. [5]

Wetland - Areas that are frequently inundated or saturated with water for periods of time long enough to support vegetation suited for survival in saturated soils. Wetlands may include bogs, swamps, marshes, etc. [15]

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