CITY AND COUNTY
OF SAN FRANCISCO

SEA LEVEL RISE VULNERABILITY AND CONSEQUENCES ASSESSMENT

FINAL REPORT FEBRUARY 2020

CITY AND COUNTY
OF SAN FRANCISCO

SEA LEVEL RISE VULNERABILITY AND CONSEQUENCES ASSESSMENT

Contact
Adam Varat,
San Francisco Planning Department
adam.varat@sfgov.org
https://sfplanning.org/sea-level-rise-action-plan

February 2020

TABLE OF CONTENTS

TABLE OF CONTENTS

SEA LEVEL RISE VULNERABILITY AND CONSEQUENCES ASSESSMENT

EXECUTIVE SUMMARY

CITY AND COUNTY OF SAN FRANCISCO

The earth and its inhabitants are facing a climate emergency. Global heating creates extreme hazards that cause significant harm to people, homes, infrastructure, and the environment. In California, we are already facing many climate-related impacts: prolonged drought, extreme heat, massive wildfires, hazardous air quality, flooding, and severe weather.

As the earth heats, polar and glacial ice is melting much faster than predicted,[1] causing sea levels to rise worldwide and reducing the earth's defenses against further warming. Combined with new, more severe weather patterns like coastal storms, sea level rise (SLR) presents a daunting challenge for waterfront cities such as San Francisco.

San Francisco already experiences flooding and erosion in our low-lying coastal areas during times of high tides and severe weather. As the century progresses, sea levels will continue to rise, and flooding and related hazards will become more frequent and intense, affecting ever-greater areas of the City.

This Sea Level Rise Vulnerability and Consequence Assessment (Assessment) describes the vulnerability of public buildings and infrastructure to SLR and coastal flooding and the consequences of SLR-related flooding on people, the economy, and the environment. The Assessment will be used to inform how the City develops, prioritizes, invests, and implements adaptation strategies to enhance San Francisco's resilience to SLR and coastal flooding.

Approximately four square miles of San Francisco (not including Treasure Island or San Francisco International Airport [SFO]) are located within the City's Sea Level Rise Vulnerability Zone.[2] This area could be flooded by a 100-year coastal flood event[3] coupled with 66 inches[4] of SLR, an upper-range scenario by end of century. These low-lying areas are home to approximately 37,200 residents, approximately 17,100 businesses, approximately 167,300 jobs, new development, and a host of vital infrastructure. This infrastructure includes roadways, water and wastewater pipelines, power infrastructure, emergency services, transit lines, parks and open spaces, the Port of San Francisco (Port), and SFO.[5]

1 A recent study found that Arctic permafrost is thawing decades earlier than predicted: https://www.theguardian.com/environment/2019/jun/18/arctic-permafrost-canada-science-climate-crisis

2 The Sea Level Rise Vulnerability Zone equates to 108 inches (66 inches of SLR plus 42 inches of tidal and storm surge).

3 A 100-year event means there is a 1 percent annual chance of the flood event happening in any given year.

4 66 inches of SLR represents the upper-bound SLR projection for the end of the century (i.e., 2100) associated with the best available science (National Research Council, 2012) when the SLR Vulnerability Zone was adopted by the City in 2014. In 2017, three new reports were released that increased the upper-bound projections (USGCRP, 2017; Rising Seas, 2017; Sweet et al., 2017); however, a revised and expanded SLR Vulnerability Zone has not been adopted at this time.

5 San Francisco International Airport (SFO) is located south of the main City of San Francisco, within San Mateo County and directly adjacent to San Francisco Bay. However, SFO is part of the jurisdiction of the City and County of San Francisco.

Figure E.1 Sea Level Rise Vulnerability Zone

Sea Level Rise Vulnerability Zone

0 0.5 1.0 2.0
Miles

PLANNING FOR SEA LEVEL RISE

San Francisco has been considering SLR in its planning for many years. The City first approved SLR Capital Planning Guidance in 2014, which it updated in 2015 and 2019 (SLR checklist only).[6]

In March 2015, then-Mayor Ed Lee assembled the Sea Level Rise Coordinating Committee in response to the immediate and long-term threats from SLR and coastal flooding. The SLR Committee was tasked with developing a comprehensive understanding of the threat of SLR to San Francisco and to create a decisive plan of action.

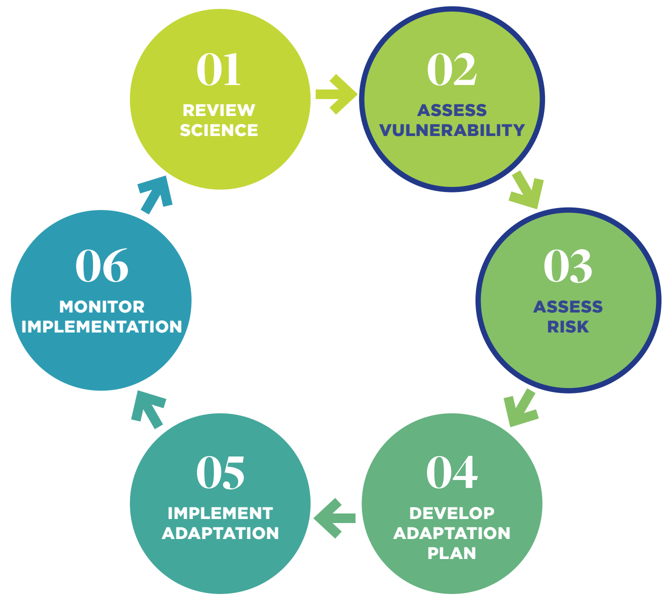
The SLR Committee created the Sea Level Rise Action Plan, released in March 2016. The Action Plan called on City departments to work together to understand the impacts of rising sea levels and to develop strategies to protect our shoreline, critical public assets and infrastructure, and public and private lands and structures from current and future coastal and SLR flooding.

The vision of the 2016 Sea Level Rise Action Plan Vision is:

Make San Francisco a more resilient city in the face of immediate and long-term threats of sea level rise by taking measures to protect and enhance public and private assets, the natural environment, and quality of life for all.

6 http://onesanfrancisco.org/sea-level-rise-guidance/

Figure E.2 Sea Level Rise Action Plan Framework



This report, the ***SLR Vulnerability and Consequences Assessment (Assessment)***, represents steps 2 and 3 in the process outlined in the SLR Action Plan: Assess Vulnerability and Assess Risk. These two steps have been combined into this Assessment.

The Assessment evaluates publicly owned infrastructure within the SLR Vulnerability Zone, identifies the infrastructure's vulnerability, and describes the consequences for people, the economy, and the environment. This information will inform capital planning, project design, and policy decisions for decision makers, City agencies, and public stakeholders so the City (in collaboration with San Francisco's communities) can develop, prioritize, and implement appropriate adaptation strategies to build San Francisco's resilience to SLR.

SEA LEVEL RISE EXPOSURE

The CPC Guidance and the 2016 Sea Level Rise Action Plan relied on the best available science at the time – the National Research Council's (NRC's) 2012 Report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present and Future*[7] to define a SLR Vulnerability Zone. This zone equates to 108 inches (66 inches of SLR plus 42 inches of tidal and storm surge),8 an upper-range scenario for the end of the century (Figure E.1).

Within the SLR Vulnerability Zone, the Assessment studied 10 scenarios within that range from 12 to 108 inches (Table E.1) to understand at what points infrastructure assets become vulnerable to intermittent or permanent flooding from SLR and tidal and storm surge.

Table E.2 calculates the number of homes, businesses, streets, and open spaces located within the SLR Vulnerability Zone if no action is taken to protect these areas.

The Assessment is based on best current available science. As climate science evolves, the City may need to assess higher water levels in the future and develop adaptation plans accordingly.

Table E.1
Sea Level Rise Scenario (Inches above MHHW)

Mapping Scenario	Reference Water Level
Scenario 1	MHHW + 12”
Scenario 2	MHHW + 24”
Scenario 3	MHHW + 36”
Scenario 4	MHHW + 48”
Scenario 5	MHHW + 52”
Scenario 6	MHHW + 66”
Scenario 7	MHHW + 77”
Scenario 8	MHHW + 84”
Scenario 9	MHHW + 96”
Scenario 10	MHHW + 108”

MHHW = Mean Higher High Water
” = inches

Table E.2 SLR Exposure

	Scenario 5	Scenario 6	Scenario 8	Scenario 10
Residents [9]	6,500	21,500	28,600	37,200
Businesses [10]	1,500	7,300	12,800	17,100
Jobs [11]	10,800	48,500	116.225	167,250
Streets [12]	18.5 miles	50 miles	71.1 miles	96.4 miles
Parks (Port and Parks and Rec) [13]	31 acres	55 acres	65 acres	74 acres

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

8 In response to updated national and regional reports, the State of California released updated Sea Level Rise Guidance (State Guidance) in 2018. This data results in an expanded area that is vulnerable to SLR. The additional area is not studied in this report.

9 2010 Census by block group

10 Business counts by Census Tract (2017 Dun & Bradstreet data set)

11 Job counts by Census Tract (2017 Dun & Bradstreet data set)

12 City and County of San Francisco Department of Public Works/Bureau of Street Use and Mapping (2018 San Francisco Basemap Street Centerlines data set)

13 DCP Open Space, DCP Trail Layer (2018 San Francisco data set)

SECTOR CHAPTERS

The Assessment identifies City-owned infrastructure within the SLR Vulnerability Zone by sector (Transportation, Water, Wastewater, Power, Public Safety, Open Space, and Port), describes each asset's vulnerability (sensitivity to flooding and capacity to adapt), and identifies consequences for people, the economy, and the environment. The project team collected and mapped information from agencies that own, operate, and maintain the buildings and infrastructure assets, and held in-depth meetings with key staff to determine how the asset would be affected by flooding. Based on this information, each asset was given a vulnerability rating.

Next, the Assessment describes the impact of each asset category (Figure E.2) if it were impaired or non-functional due to intermittent or permanent flooding, and describes the consequences on people, the economy, and the environment. The consequence assessment is high-level and is not a detailed multi-hazard risk assessment. More detailed assessments may be required at the project-level to support the implementation of adaptation strategies.

The sector-based vulnerability and consequence information forms the basis of the Sector Chapters (Chapters 5-11). See Figure E.3.

Figure E.3 Sector Asset Categories

Chapter 5. **TRANSPORTATION**	• Roadways • Bridges • Local and Regional Transit	• Bicycle and Pedestrian Facilities • Operations & Maintenance Facilities
Chapter 6. **WATER**	• Regional Water Distribution • Local Potable Water	
Chapter 7. **WASTEWATER**	• Treatment Plants • Pump Stations	• Buried Sewers • Combined Sewer Structures
Chapter 8. **POWER**	• Substations and Transformers • Streetlights	• PG&E facilities
Chapter 9. **PUBLIC SAFETY**	• Fire Department • Emergency Firefighting Water System	• Law Enforcement • Contaminated Lands
Chapter 10. **OPEN SPACE**	• Parks • Playgrounds • Recreational Areas	• Marinas • Trails
Chapter 11. **PORT FACILITIES**	• Piers • Seawall Lots	• Port Buildings • Rail Right-of-Way

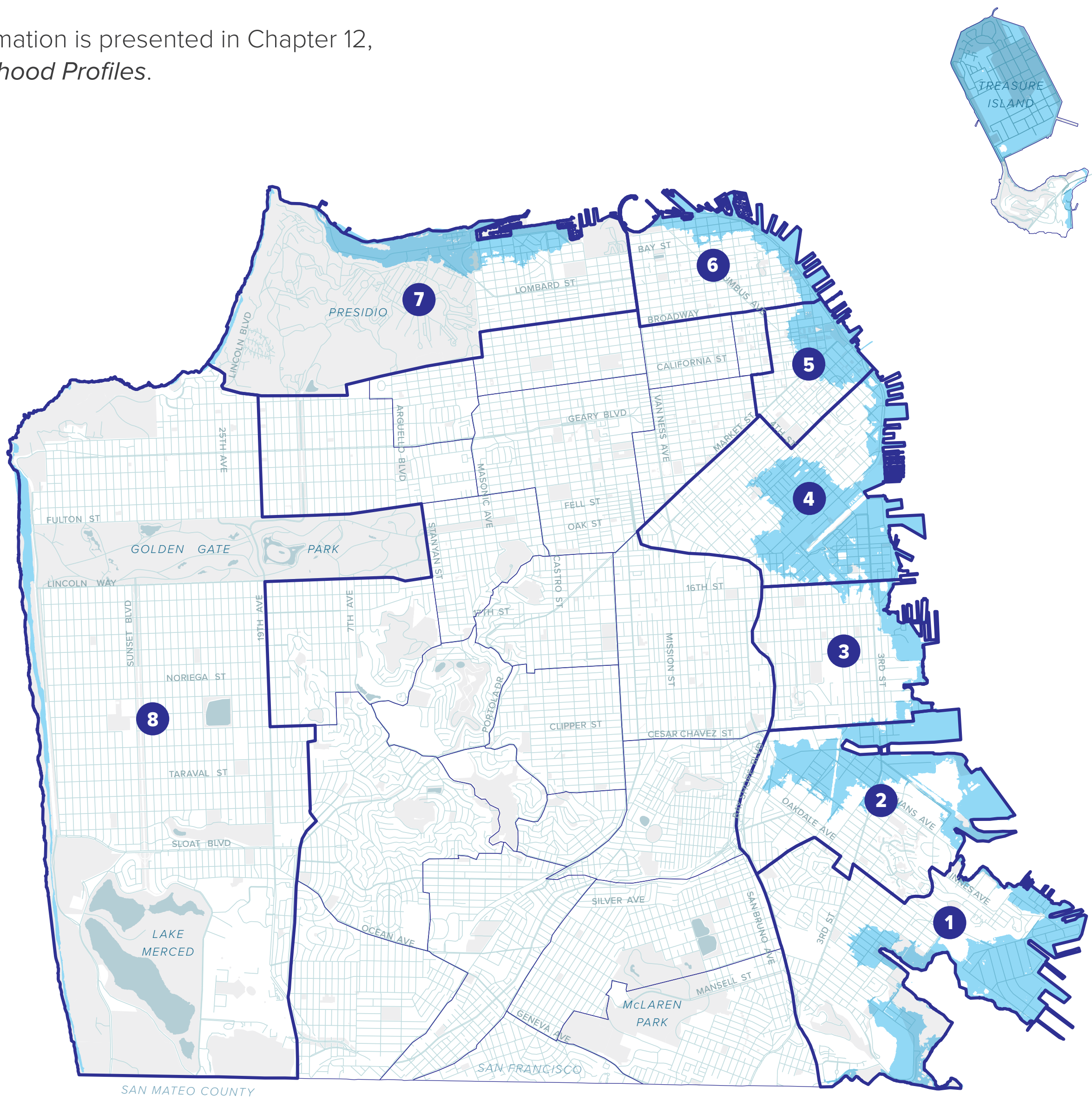
NEIGHBORHOOD PROFILES

For each shoreline neighborhood (Bay and Ocean) in San Francisco (Figure E.4), the Assessment includes a series of Neighborhood Profiles that describe potential consequences at the neighborhood scale. The Neighborhood Profiles consider how the different infrastructure sector categories would impact each other (the cascading consequences) at the neighborhood scale and how these interactions would affect the daily lives and well-being of people living and working in these neighborhoods, with a focus on how SLR impacts vulnerable populations.

This information is presented in Chapter 12, *Neighborhood Profiles*.

Figure E.4
Shoreline Neighborhoods

1. Bayview South / Hunters Point
2. Bayview North / Islais Creek
3. Potrero Hill / Central Waterfront
4. South of Market / Mission Bay
5. Financial District
6. North Beach / Fisherman's Wharf
7. Marina and Presidio
8. Westside / Ocean Beach



KEY FINDINGS

This section highlights key overall findings from the Assessment. Some of these findings are specific to one sector. Others are general and impact multiple sectors or suggest areas for further study. These findings reflect current conditions; the City is actively studying, planning for, and starting to address many of these issues.

Combined Precipitation and Coastal Flooding Risk

Although the assessment focuses on SLR, concern about the risk of combined precipitation and coastal flooding was raised throughout the process. How this combined risk will impact the City over time as sea levels rise and precipitation patterns change is not fully understood. The San Francisco Public Utilities Commission, with support from the Port of San Francisco and the Oakland International Airport, is leading a study to better understand changes in future precipitation intensity and frequency (see Chapter 4, Summary 5 for more information) to help better quantify this risk. Areas with precipitation flood risk, coastal flood risk, and drainage issues will be among the first and most severely affected neighborhoods in the City. Strategies to address flooding in these areas will need to keep coastal flooding out while allowing or improving drainage so that solutions to one type of flood risk do not exacerbate other types of flooding.

Portions of Mission Bay and Islais Creek are vulnerable today to flooding from both precipitation and coastal overtopping because they are at the downstream end of large watersheds, adjacent to the Bay, and historically these areas were tidal creeks and marshes (Figure E.5). Their current elevations are low and rain from the large upstream watersheds collects in these basins causing temporary flooding. This flooding typically occurs when Bay water levels are elevated due to storm-surge conditions concurrently with heavy rainfall. The temporary flooding subsides as the tides fall and drainage capacity is restored. Over time with higher SLR projections, the discharge outfalls will become submerged more frequently, preventing the outfalls from maintaining their function as currently designed, resulting in potential flooding that occurs more often across a wider area of the City.

Joint Impacts of Contamination and Liquefaction in Bay Fill Areas

Along San Francisco's Bay shoreline, historical fill (filling in former wetlands and areas of the Bay to create new land) and military and industrial land uses mean many neighborhoods are at risk of flooding, soil liquefaction and settlement during earthquakes, and environmental contamination. These concurrent hazards may exacerbate one another, such as when contaminated materials are mobilized during a flood event or when rising groundwater expands liquefaction areas. These physical hazards have potential public health and safety consequences. Neighborhoods like Bayview and Hunters Point, where many of these factors exist, already experience disproportionate contamination burdens among other health disparities.

Many sites undergoing remediation have plans for new housing development. Effective remediation and reuse of these sites will need to account for future flooding and groundwater changes due to SLR. Modeling and monitoring are required to fully understand interactions between sea level, groundwater, contamination, and soil stability.

Figure E.5 Historic Creeks and Sea Level Rise Vulnerability Zone

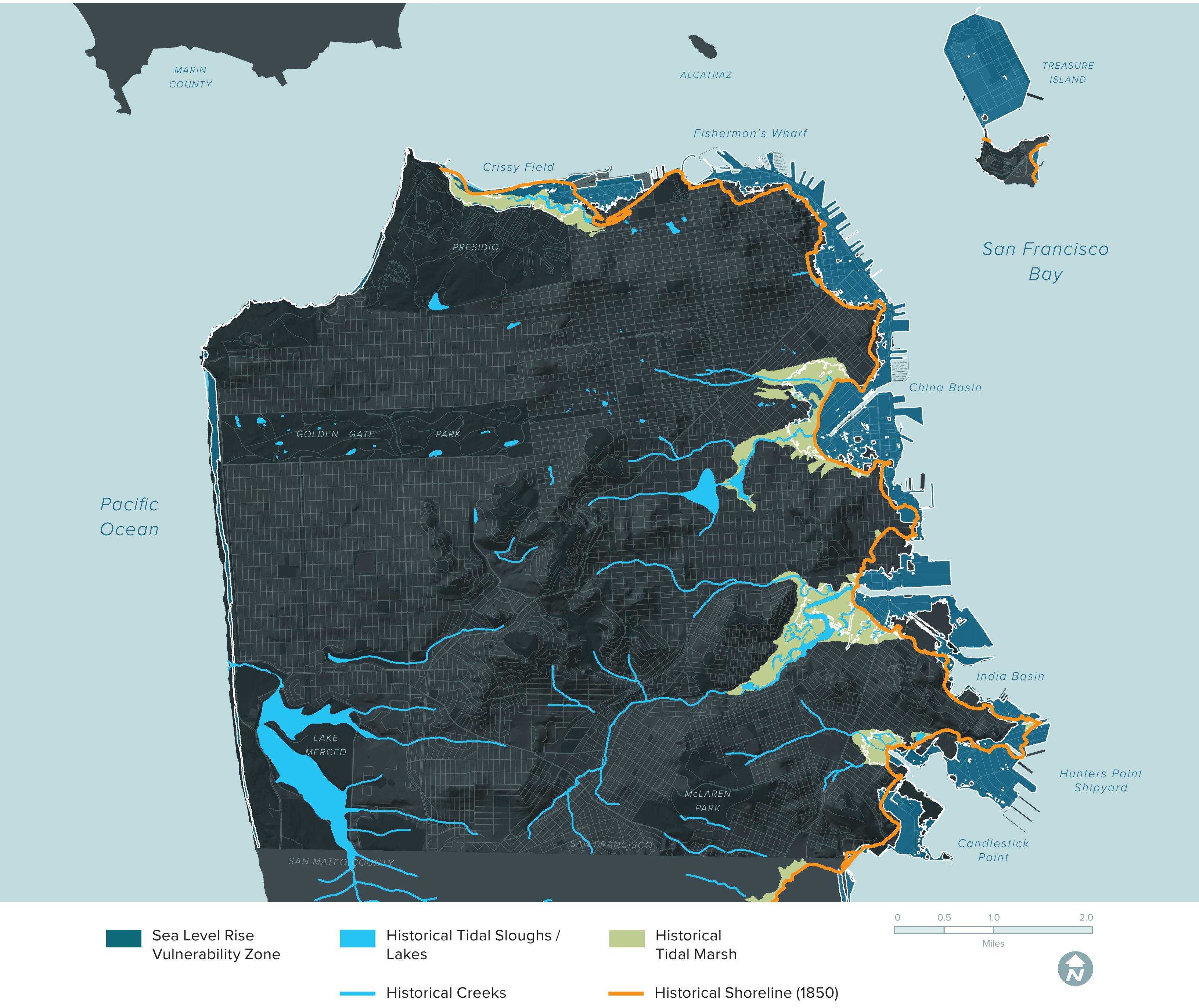


Photo E.1 Mission Rock Development

Source: Perkins&Will

Risks and Requirements for New Development in Waterfront Neighborhoods

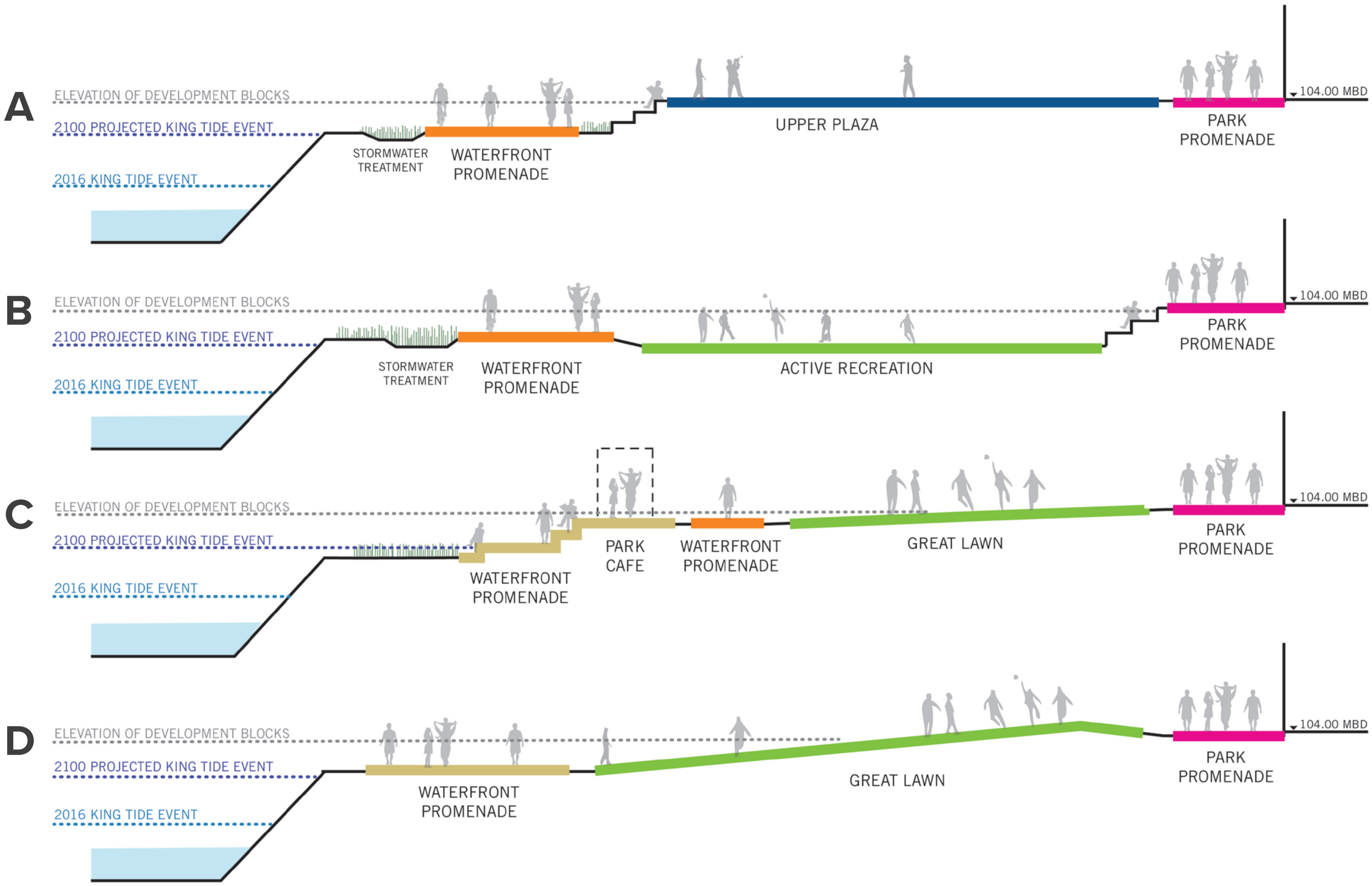
Many of San Francisco's large developable areas are along the southeastern shoreline in areas that are vulnerable to SLR. Many of these shoreline areas have planned or approved development plans. These shoreline developments would revitalize former military and industrial areas, providing significant amounts of new housing and job space. However, their location makes them potentially vulnerable to future flooding and SLR impacts (Figure E.7).

Current development plans account for expected SLR and identify adaptation measures like elevating building pads and designing open spaces to accommodate flooding. These strategies require developments to commit to a future water level elevation. If sea levels rise faster or higher than anticipated, these neighborhoods will need to pursue additional measures (Figure E.6).

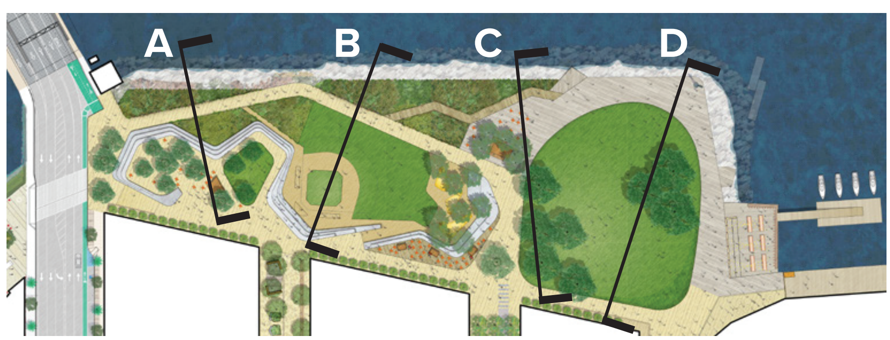
This effect is exacerbated by the long lead time for development approvals and construction. For example, the Treasure Island Redevelopment Authority secured its project approvals in 2011-2015 but buildout will not be complete until after 2035 and the housing and commercial buildings will persist past 2100. SLR science will continue to evolve and more protective measures may be necessary.

In addition to physical flood risks, these sites rely on existing transportation and utility networks that are not fully resilient to SLR and coastal flooding (Figure E.8). A residential and commercial development that becomes an island during flood events will still suffer from these impacts even if its own buildings stay dry. Site-specific adaptation strategies cannot fully protect the function and value of these new developments. They will need to engage in community adaptation planning to protect whole neighborhoods and the City.

Figure E.6 Mission Rock Development Elevations



This diagram illustrates the relationship of Mission Rock program areas to each other and to key sea level rise (SLR) elevations. The finish grade elevations will be based on 2100 king tide elevations (SLR + storm surge).



Source: Mission Rock Design Controls 2017

Photo E.2 Heron's Head Park

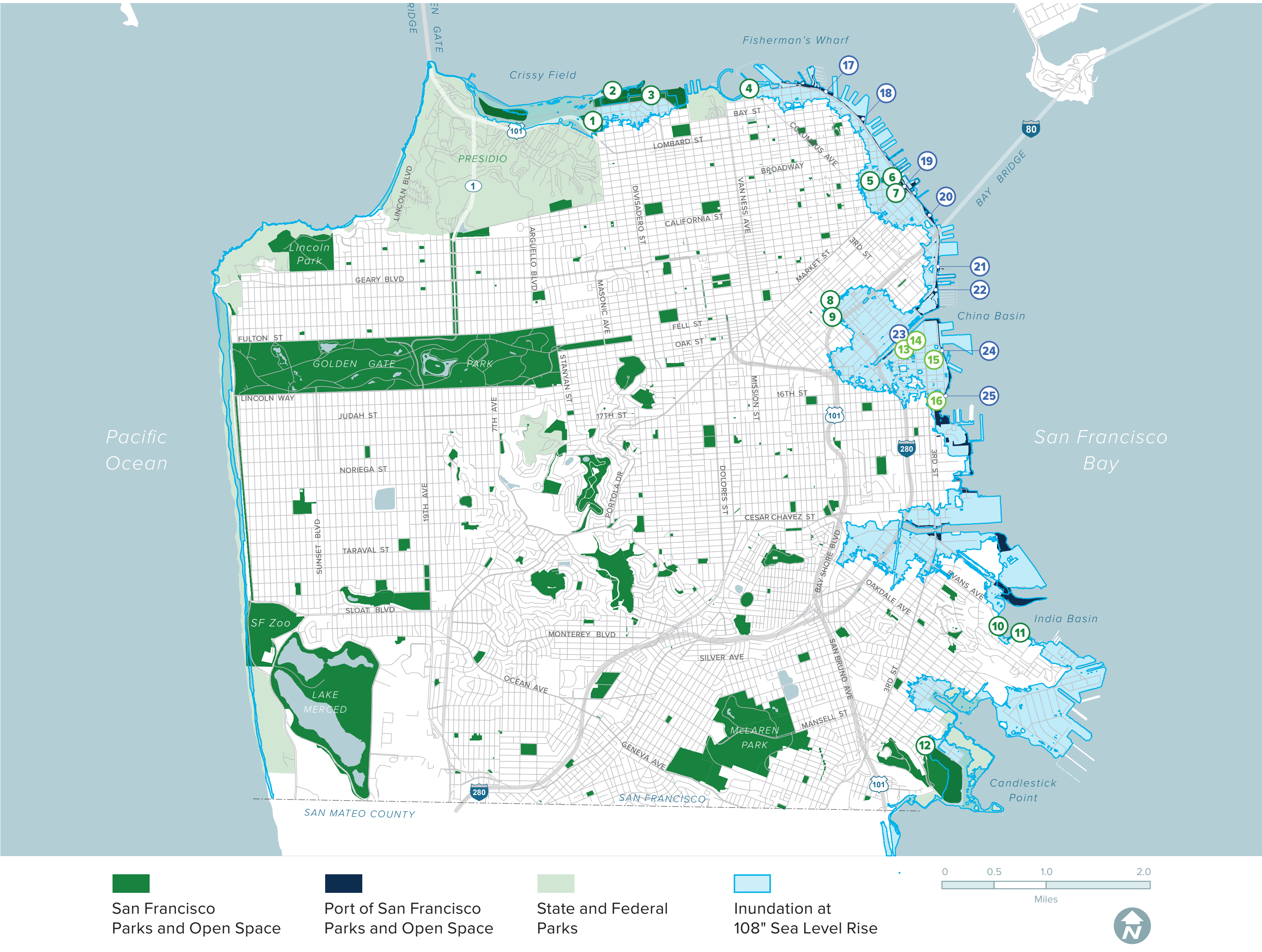
Source: Ed Brownson (CC BY-NC-ND 2.0)

Loss of Shoreline Open Space Through Flooding and Adaptation Efforts

Shoreline parks and open space add to San Francisco's quality of life and generate economic activity through tourism. Public access to the shoreline has been expanded and improved through the removal of the Embarcadero Freeway and shoreline redevelopment, but SLR may damage and eventually destroy these recreational facilities. Ocean Beach, Crissy Field, Marina Green, Fort Mason, Aquatic Park, the Embarcadero Promenade, and Heron's Head Park are iconic San Francisco destinations that are vulnerable to current flooding and future SLR impacts. Shoreline open space provides unique recreation such as swimming, small boat access, and wildlife viewing that cannot be replaced at other City open spaces.

In addition to publicly owned recreation sites, many shoreline developments have identified shoreline open spaces as part of their adaptation strategies. This approach may protect buildings and infrastructure, but the open space will narrow and eventually disappear. These shrinking open spaces will limit recreation opportunities for residents and workers in those developments and for the City as a whole. This effect would be most severe in the Central and Southeastern Waterfront areas where private developments have agreed to provide extensive open space for a rapidly growing population as part of their development agreements.

Figure E.7 Shoreline Open Space at Risk



RECREATION & PARKS

1. Palace of Fine Arts
2. San Francisco Marina Small Craft Harbor
3. Marina Green
4. Dolphin Club/South End Rowing Club
5. Maritime Plaza
6. Sue Bierman Park
7. Embarcadero Plaza
8. Gene Friend Recreation Center
9. Victoria Manalo Draves Park
10. India Basin Shoreline Park
11. India Basin Natural Areas
12. Gilman Playground

OCII

13. Mission Bay Dog Park
14. Mission Bay Kids' Park
15. Mission Bay Commons Park
16. Mission Bay Parks 23 & 24

PORT OF SAN FRANCISCO

17. Public Park (near Pear 39)
18. Pier 27 (Cruise Ship Terminal)
19. Harry Bridges Plaza
20. Rincon Park
21. Brannan Street Wharf
22. South Beach Park
23. Mission Creek Park
24. Pier 52 Boat Launch
25. Agua Vista Park
16. Mission Bay Parks 23 & 24

Photo E.3 Embarcadero Station

Source: Travel Nevada (CC BY-NC-ND 2.0)

Local and Regional Transportation Impacts

San Francisco relies on local and regional transportation infrastructure to bring workers and tourists into the City and to connect San Francisco with the rest of the Bay Area. Caltrain, the Bay Area Rapid Transit (BART), and freeways are vulnerable to current and future flooding within and beyond San Francisco's boundaries and they will not function well in the future without local and regional action. For example, the Embarcadero BART and Muni station is vulnerable to near-term flood impacts. Even if San Francisco implements adaptation measures for the Embarcadero station, the station cannot function if the Transbay Tube is out of service or BART is unable to adapt other vulnerable stations. Similarly, flooding on U.S. Highway 101 in San Mateo County has severe impacts for SFO, although the flooding is outside of San Francisco's jurisdiction.

In addition to planning for current infrastructure, the Bay Area is planning and implementing major transportation investments like High Speed Rail, a potential second Bay BART crossing, and ferry network extensions. These projects will need to consider SLR and coastal flooding in their designs and coordinate with San Francisco shoreline projects like the Embarcadero Seawall Program. San Francisco cannot plan and implement effective regional transportation adaptation alone and will need to work with state, regional, and federal partners to protect and enhance transportation networks.

CONSIDERATIONS FOR SEA LEVEL RISE ADAPTATION PLANNING

As the City advances adaptation planning efforts, we have identified key considerations to guide adaptation planning and ensure that adaptation strategies are effective, efficient, equitable, and environmentally appropriate.

Successful adaptation planning should:

- Begin with robust community engagement to ensure strategies will meet local needs and build public and political support for action
- Prioritize and include vulnerable neighborhoods that already bear disproportionate environmental contamination burdens and will be most impacted by future flooding
- Include natural solutions where possible to improve the City's environment and provide open space recreation opportunities
- Create a decision-making framework for when and where to implement facility-specific floodproofing versus neighborhood-scale shoreline strategies
- Identify strategies that could be implemented by multiple actors, including individual agencies, private landowners, and the City as a whole
- Adopt adaptation policies for private development and public investment in addition to implementing physical strategies
- Identify potential funding sources and identify and empower appropriate lead agencies for adaptation projects that cross agency jurisdictions
- Balance uncertainty in long-term climate projections with the need for urgent action
- Integrate SLR and coastal flooding programs with other City resilience efforts

NEXT STEPS

San Francisco's efforts to adapt to SLR, coastal flooding, and other climate impacts will continue for decades. Major adaptation projects that involve significant changes to the City's shoreline infrastructure will take many years to plan, fund, and build. Some areas of the City are already affected by coastal flooding and require near-term solutions. Other areas may be affected within 10 years, while others may not be affected for decades.

The City is currently developing several plans, policies, and projects that help adapt the City to SLR, including:

1. **Updated SLR Capital Planning Guidance.** The City adopted Sea Level Rise Capital Planning Guidance in 2014 for infrastructure projects of $5 million or more. The SLR checklist (a portion of the guidance) was recently revised to reflect updated State SLR projections.
2. The **Hazards and Climate Resilience Plan** assesses Citywide vulnerability to a variety of climate and other hazards, such as earthquakes, heat, poor air quality, drought, and SLR, and develops strategies to mitigate risk and make the City more resilient to these hazards.
3. **Ocean Beach Master Plan implementation** involves multiple projects that will carry out improvements to Ocean Beach and the Great Highway to protect critical infrastructure such as the Westside Pump Station, reduce beach and cliffside erosion, and add recreational opportunities such as a new multi-use trail.
4. The **Embarcadero Seawall Program** is a Citywide effort, led by the Port, to seismically strengthen the Embarcadero Seawall and to address current and future flood and SLR risk due to climate change.

5. The **U.S. Army Corps of Engineers/Port Flood Study** will study flood risk along San Francisco's Bayside shoreline from Aquatic Park to Heron's Head Park, identify areas that are vulnerable to shoreline flooding, and develop strategies to reduce current and future flood risk.

6. The **Islais Creek Adaptation Strategy** will develop a long-range vision for the Islais Creek basin, with an emphasis on securing the area's critical transportation facilities.

7. The **SFO Shoreline Protection Project** will address potential flood risks resulting from both 100-year storm and SLR out to 2085 at SFO.

All nine counties that surround San Francisco Bay are vulnerable to SLR and coastal flooding and are engaged in assessing SLR vulnerabilities and risks or moving forward with SLR adaptation efforts. The City is participating in and coordinating with several regional efforts, including San Francisco Bay Conservation and Development Commission's (BCDC) Adapting to Rising Tides (ART) Program, The Bay Area Climate Adaptation Network (BayCAN), and the San Francisco Bay Regional Coastal Hazards Adaptation Resiliency Group (CHARG).

In addition, new planned developments and open spaces along the City's shoreline are being designed to adapt to SLR and provide funding for future SLR adaptation measures. See Chapter 13, *A Changing Shoreline*.

The plans and projects listed above are described in Chapter 14, *Next Steps*.

CONCLUSION

As the City continues to study, plan for, and address SLR impacts, we are considering climate resilience comprehensively – both how we continue the City's efforts to mitigate climate emissions and how we adapt our City to become more resilient to climate impacts, considering not only SLR but other climate-related hazards such as extreme precipitation, drought, poor air quality, extreme heat, and wildfire.

Next steps to adapt San Francisco to a changing climate include capital planning, code updates for new construction and renovations, and policy, funding, legislation, and governance strategies to implement climate policies and actions.

We are facing a climate emergency. San Francisco is one actor on a global scale. We can be a leader in working to address the climate crisis and adapt our City to the coming impacts of climate change to improve the lives of people who live and work in San Francisco.

This Assessment provides essential information to help us understand our vulnerabilities to SLR and coastal flooding. It lays the groundwork for the City to work with communities to develop strategies to adapt San Francisco to SLR.

Photo by Sergio Ruiz

CONTRIBUTORS

This report represents a collaborative effort among multiple City Departments, staff, and consultants. The information in this report was developed through working sessions with relevant agency staff to compile, understand, and describe asset-specific information, such as maps, asset descriptions, and asset vulnerabilities. Workshops were held with each asset-owning department to better characterize asset-specific vulnerabilities and consequences, and to begin the discussions of multi-sector consequences. A citywide consequences workshop was held to discuss how the sector- and asset-based vulnerabilities combine and interact with the other sectors to create cascading consequences at the neighborhood scale, including consequences to society and equity, the economy, governance, and the environment.

The SLR project team led the compilation of the asset information and vulnerability assessments, and prepared the individual report chapters with substantive involvement and review from the respective City departments. SLR Coordinating Committee members were provided with regular updates, and they provided feedback on the methodology, report outline, presentation of findings, and reviewed relevant chapters and complete drafts as the work progressed. This report represents the cumulative effort of all project staff and agencies to provide the best-known information about SLR vulnerabilities and consequences (with a focus on city-owned assets) in San Francisco as of this publication.

Thank you to all who contributed!

CONTRIBUTORS

Mayor

London N. Breed

Board of Supervisors

Norman Yee, *President*
Vallie Brown
Sandra Lee Fewer
Matt Haney
Rafael Mandelman
Gordon Mar
Aaron Peskin
Hillary Ronen
Ahsha Safai
Catherine Stefani
Shamann Walton

Department Heads

Naomi Kelly, City Administrator
John Rahaim, Planning Department
Elaine Forbes, Port of San Francisco
Tom Maguire, San Francisco Municipal Transportation Agency
Harlan Kelly, San Francisco Public Utilities Commission
Mohammed Nuru, SF Public Works
Phil Ginsburg, Recreation and Parks Department
Ivor Satero, San Francisco International Airport
Debbie Raphael, SF Environment
Nadia Sesay, Office of Community Investment and Infrastructure
Joaquin Torres, Office of Economic and Workforce Development
Grant Colfax, Department of Public Health

SLR Coordinating Committee Members

Co-Chair: AnMarie Rodgers, *Director of Citywide Planning*, Planning Department
Co-Chair: Brian Strong, *Chief Resilience Officer*, Office of Resilience and Capital Planning
Tyrone Jue, Mayor's Office
Adam Varat, Alesia Hsiao, Maggie Wenger, Diana Sokolove, Paul Maltzer, Planning Department
Melissa Higbee, Office of Resilience and Capital Planning
Byron Rhett, Brad Benson, Lindy Lowe, Steven Reel, Port of San Francisco
Tim Doherty, San Francisco Municipal Transportation Agency
David Behar, Anna M. Roche, San Francisco Public Utilities Commission
John Thomas, Boris Deunert, Public Works
Brian Stokle, Recreation and Parks Department
Joe Birrer, San Francisco International Airport
Cyndy Comerford, SF Environment
Sally Oerth, Office of Community Investment and Infrastructure
Leigh Lutenski, Office of Economic and Workforce Development
Matt Wolff, Department of Public Health

Primary Authors

Adam Varat, Alesia Hsiao, Maggie Wenger, Kris May, Karen Askeland

Other Contributors

Gary Chen, *Graphic Designer,* Planning Department
Mike Webster, *GIS Analyst*, Planning Department

Consultants

Laura Harnish, Armin Munevar, Karen Askeland CH2M/Jacobs
Kris May, Yanna Badet, Abigail Mohan, Silvestrum Climate Associates

● SLR Working Group member

ACRONYMS & ABBREVIATIONS

Current to April 4, 2019

°F	degrees Fahrenheit
ABAG	Association of Bay Area Governments
AC Transit	Alameda-Contra Costa Transit
ADA	Americans with Disabilities Act
ART	Adapting to Rising Tides
AST	aboveground storage tank
BARC	Bay Area Regional Collaborative
BART	Bay Area Rapid Transit
BAWSCA	Bay Area Water Supply and Conservation Agency
BCDC	Bay Conservation and Development Commission
Caltrans	California Department of Transportation
CC	City and County
CEQA	California Environmental Quality Act
City	City of San Francisco
CMGC	construction management-general contractor
CPC	Capital Planning Committee
CSD	combined sewer discharge
DB	design-build
DTSC	California Department of Toxic Substances Control
DTX	Downtown Rail Extension
DWL	dynamic water level
EFWS	Emergency Firefighting Water System
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FUDS	formally used defense site
GGNRA	Golden Gate National Recreation Area
GHG	greenhouse gas
GIS	geographic information system
gpm	gallons per minute
I-280	Interstate 280
I-80	Interstate 80
IPCC	Intergovernmental Panel on Climate Change
JPB	Joint Powers Board
LPFH	low-pressure fire hydrant
LRV	light rail vehicle
MARAD	Maritime Administration Ready Reserve
MG	million gallons
MHHW	mean higher high water
MMT	Muni Metro Turn-back Facility
MTC	Metropolitan Transportation Commission
Muni	Municipal Railway
NCAR	National Center for Atmospheric Research
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
O&M	operations and maintenance
OCII	Office of Community Investment and Infrastructure
PAH	polynuclear aromatic hydrocarbon
PCA	Priority Conservation Area
PCB	polychlorinated biphenyl
PDA	Priority Development Area
PG&E	Pacific Gas and Electric Company
PM	particulate matter
Port	Port of San Francisco
psi	pounds per square inch
Public Works	San Francisco Department of Public Works
RPD	Recreation and Park Department
RWS	Regional Water System
SamTrans	San Mateo County Transit District
SCADA	supervisory control and data acquisition
SFCD	San Francisco City Datum
SFCTA	San Francisco County Transportation Authority
SFDPH	San Francisco Department of Public Health
SFFD	San Francisco Fire Department
SFMTA	San Francisco Municipal Transportation Agency
SFO	San Francisco International Airport
SFPUC	San Francisco Public Utilities Commission
SLR	sea level rise
SOMA	South of Market area
SPP	Shoreline Protection Program
SR 1	California State Route 1
SSIP	Sewer System Improvement Program
TNC	Transportation Network Company
UCSF	University of California, San Francisco
US 101	U.S. Highway 101
USGS	United States Geological Survey
VTA	Santa Clara Valley Transportation Authority
WETA	Water Emergency Transportation Authority

GLOSSARY

Adaptation Toolkit
A suite of physical, operational, governance, and informational adaptation strategies that can be selected individually or in combination to mitigate or reduce sea level rise impacts and risks.

Adaptive capacity
The ability of an asset or system to adjust to sea level rise (including cyclic sea level variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Climate adaptation
Adjustment or preparation of natural, built or social systems to new or changing climate conditions and climate variability which moderate harm or exploit beneficial opportunities.

Climate change
A change in global or regional climate patterns, in particular a change apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.

Climate change impacts
The effects of climate variability and extreme events on built, natural, and human systems. Potential impacts are assessed in the absence of potential adaptation measures.

Consequence
The result or effect of the climate change impacts on society, equity, the economy, and the built and natural environment. Consequences can be quantitative or qualitative.

Criteria
Definitions used to map indicators to a qualitative rating scale for sensitivity and adaptive capacity.

Economic vulnerability
Economic variables that may be affected by climate impacts such infrastructure damage, repair or replacement costs and lost revenues during periods of recovery.

Environmental vulnerability
Environmental variables that may be affected by climate impacts such as species biodiversity, water quality, and ecosystem functions.

Exposure
The nature and degree to which natural, built, or social systems are subjected to sea level rise inundation and storm surge flooding.

Exposure assessment
An evaluation of the timing and degree of temporary flooding and/or permanent inundation of an asset.

Geospatial data
Information about assets and sea level rise that can be represented by numerical values in a geographic coordinate system and shared as maps and other visualizations.

Greenhouse effect
Trapping and build-up of heat in the atmosphere (troposphere) near the Earth's surface. Some of the heat flowing back toward space from the Earth's surface is absorbed by water vapor, carbon dioxide, ozone, and several other gases in the atmosphere and then reradiated back toward the Earth's surface. If the atmospheric concentrations of these greenhouse gases rise, the average temperature of the lower atmosphere will gradually increase.

Greenhouse gases
Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

Indicators
Characteristics of specific assets, asset types, or asset categories that are used to define the degree of sensitivity and adaptive capacity.

Inundation zone
The area temporarily or permanently inundated by a specific sea level rise and storm surge scenario.

King tide
While the term 'king tide' isn't a scientific term, it is used to describe an especially high tide event when there is an alignment of the gravitational pull between sun and moon.

Permanent inundation
Permanent inundation occurs if an area is exposed to regular daily tidal inundation. Maritime facilities, natural areas, shoreline protection features, and outfalls may be exposed to permanent inundation now.

Private asset
An asset that is owned, operated, and maintained by a private entity.

Public asset
An asset that is owned, operated, and maintained by a public agency or City department.

Ratings
A scale that is used to define a broad range of quantitative information in a qualitative manner for the purpose of comparison (e.g., sensitivity, adaptive capacity, vulnerability and each risk category each have a qualitative ratings scale).

Resilience
The capacity of a system and its component parts to cope with hazardous shocks and stresses in a timely and efficient manner by responding, adapting, and transforming in ways that restore, maintain, and even improve its essential functions, structures, and identity while retaining the capacity for growth and change.

Risk
The potential for temporarily and permanently losing something of value associated with the natural, built, or social environment (i.e., consequence). Values (such as level of service, economic health, physical health, social status, governance, etc.) can be gained or lost under a range of sea level rise and storm surge impacts. Risk can also be defined as the intentional interaction with uncertainty (i.e., likelihood). Risk is often framed as likelihood × consequence.

Risk assessment
Risk assessments describe (quantitatively or qualitatively) the potential consequences of the damage that could or will occur due to sea level rise and storm surge impacts.

Risk category
An over-arching values that can be used to define a specific type of risk to the natural, built, or social environment. Risk categories can be used individually or collectively to define risk ratings.

Risk metric
A standard of measurement to quantitively or qualitatively define the degree of risk associated with each risk category.

Sea level rise
As the temperature of the earth changes, so does sea level. Temperature and sea level are linked for two main reasons:

1. Changes in the volume of water and ice on land (namely glaciers and ice sheets) can increase or decrease the volume of water in the ocean
2. As water warms, it expands slightly—an effect that is cumulative over the entire depth of the oceans.

Sea level rise projections
Model-derived estimates of local and regional rates of sea level rise based on global climate models that consider a range of future greenhouse gas emission scenarios.

Sector
A distinct collection of assets that work together to comprise one complete system (e.g., water supply, wastewater, power, transportation).

Sensitivity
Characteristics of assets or asset systems that could lead to damage or disruption in the event of temporary flooding or permanent inundation. E.g., electronic equipment is sensitive to flooding and it more likely to be destroyed by a short-term flood event than a paved roadway that is less sensitive and may recover quickly once floodwater recede.

Social vulnerability
Characteristics of individuals and households that affect their ability to prepare for, respond to, and recover from a disaster.

Storm surge
The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The height of a storm surge event is the difference between the observed sea level and the sea level that is expected based on regular tidal variations.

Temporary flooding
Temporary flooding caused by storm events or extreme tides is generally short in duration (hours to days) but can have long lasting consequences.

Vulnerability
The degree to which an asset someone or something is susceptible to, or unable to cope with, a hazard. Vulnerability is a function of exposure, sensitivity, and adaptive capacity.

Vulnerability assessment
Vulnerability assessments describe the impacts that would be incurred by an asset or set of assets by temporary flooding or permanent inundation from coastal waters. This may include erosion, physical damage or functional disruption to structures or systems from temporary coastal floods, and/or land and asset loss through permanent inundation.

Photo by Sergio Ruiz

CHAPTER 1

INTRODUCTION

The earth and its inhabitants are facing a climate emergency.

Global heating creates extreme hazards that cause significant harm to people, homes, infrastructure, and the environment. In California, we are already facing many climate-related impacts: prolonged drought, extreme heat, massive wildfires, hazardous air quality, flooding, and severe weather.

As the earth heats, polar and glacial ice is melting much faster than predicted,[1] causing sea levels to rise world-wide and reducing the earth's defenses against further warming. Combined with new, more severe weather patterns like coastal storms, sea level rise (SLR) presents a daunting challenge for waterfront cities like San Francisco.

San Francisco already experiences flooding and erosion in our low-lying coastal areas during times of high tides and severe weather. As the century progresses, sea levels will continue to rise, and flooding and related hazards will become more frequent and intense, affecting ever-greater areas of the City. The City released the Sea Level Rise Action Plan in 2016, which called on City agencies to work together to address the impacts of SLR. We have already begun to tackle coastal erosion and flooding in the most urgent parts of the City and in new public and private projects.

1 A recent study found that Arctic permafrost is thawing decades earlier than predicted: https://www.theguardian.com/environment/2019/jun/18/arctic-permafrost-canada-science-climate-crisis

Flooding along the Embarcadero. Mike Filippoff

Existing seawall along the Embarcadero. Port of San Francisco

We must continue to plan for SLR in earnest. With no action, significant areas of Downtown San Francisco, SoMa, Mission Bay, and Bayview will become permanently inundated or regularly flood. All or portions of Ocean Beach, Crissy Field, Marina Green, Heron's Head Park, and other waterfront open spaces will disappear. Thousands of homes and jobs will be affected, and critical infrastructure will be damaged or destroyed.

Some areas of the City are already affected by coastal flooding and require near-term solutions. Other areas may be affected within 10 years. Infrastructure solutions and capital investments will take years or decades to plan, engineer, and fund.

We are not sitting idly by. San Francisco is already focusing on addressing near-term threats while developing plans for the future. The City is developing and implementing plans and projects to protect people, buildings, infrastructure, and open space. For example, we are addressing coastal erosion at Ocean Beach, seismic safety and flooding along the Embarcadero Seawall, and coastal and overland flooding along the southeastern shoreline.

But we must do more. This report is an early step towards developing a comprehensive strategy to address SLR and coastal flooding and adapt San Francisco so that our City can continue to thrive into the future as our physical environment changes.

1.1 SEA LEVEL RISE ADAPTATION PLANNING

Approximately four square miles of San Francisco are located within the City of San Francisco's (City's) SLR Vulnerability Zone.[2] This area could be flooded by a 100-year coastal flood event coupled with 66 inches of SLR, a high-end scenario by end of century.[3] These low-lying areas are home to approximately 37,200 residents, 17,100 businesses, 167,300 jobs, new development, and a host of vital infrastructure. This infrastructure includes roadways, water and waste-water pipelines, power infrastructure, emergency services, transit lines, parks and open spaces, the Port of San Francisco (Port), and San Francisco International Airport (SFO).[4]

2 Four square miles, not including Treasure Island or the San Francisco airport (SFO).

3 66 inches of SLR represents the upper-bound SLR projection for the end of the century (i.e., 2100) associated with the best available science (National Research Council, 2012) when the SLR Vulnerability Zone was adopted by the City in 2014. In 2017, three new reports were released that increased the upper-bound projections (USGCRP, 2017; Rising Seas, 2017; Sweet et al., 2017); however, a revised and expanded SLR Vulnerability Zone has not been adopted at this time.

4 San Francisco International Airport (SFO) is located south of San Francisco, within San Mateo County adjacent to San Francisco Bay. However, SFO is part of the jurisdiction of the City and County of San Francisco.

San Francisco has been considering SLR in its planning for many years. The Mission Bay development requirements from the 1990s required properties to raise their foundations by one to two feet in response to best known science at the time. The City approved SLR Capital Planning Guidance in 2014.[5]

In March 2015, then-Mayor Ed Lee assembled the Sea Level Rise Coordinating Committee in response to the immediate and long-term threats from SLR and coastal flooding. The SLR Committee was tasked with developing a comprehensive understanding of the threat of SLR to San Francisco and to create a decisive plan of action.

5 http://onesanfrancisco.org/sea-level-rise-guidance/

San Francisco waterfront and skyline. Sergio Ruiz, SPUR

1.1.1 Sea Level Rise Action Plan

The SLR Committee created the Sea Level Rise Action Plan, released in March 2016. The Action Plan called on Departments to work together to understand the impacts of rising sea levels and to develop strategies to protect our shoreline, critical public assets and infrastructure, and public and private lands and structures from current and future coastal and SLR flooding.

The Sea Level Rise Action Plan completes four strategic tasks:

- Establishes an overarching vision, goals, and a set of guiding principles for SLR planning;
- Summarizes current climate science, relevant policies and regulations, and vulnerability and risk assessments conducted to date;
- Identifies data gaps and establish a framework for further assessment, adaptation planning, and implementation; and
- Provides the foundation and guidance to develop a Citywide Sea Level Rise Adaptation Strategy

The Action Plan describes a series of steps to adapt San Francisco to SLR and coastal flooding.

1.1.2 Sea Level Rise Vulnerability and Consequences Assessment

This SLR Vulnerability and Consequences Assessment (Assessment) represents steps 2 and 3 in the process outlined in the SLR Action Plan: Assess Vulnerability and Assess Risk. These two steps have been combined into the Assessment.

The Assessment provides a deeper understanding of the vulnerabilities of public assets and infrastructure to SLR and the consequences of SLR-related flooding on people, the economy, and the environment. The Assessment identifies publicly owned infrastructure within the SLR Vulnerability Zone by sector (Transportation, Water, Wastewater, Power, Public Safety, Open Space, and Port) and evaluates the infrastructure's vulnerability to temporary coastal flooding and long-term permanent inundation by SLR. It identifies the potential consequences for society and equity, the economy, and the environment. The project team worked closely with City departments that own and operate infrastructure and facilities to identify vulnerabilities of existing assets.

Based on the sector-based assessments, the Assessment includes neighborhood profiles that describe how neighborhoods would be impacted by SLR and coastal flooding over time. Within each neighborhood, the project team analyzed where and how flooding would occur, how this would impact infrastructure, and what the consequences of flooding would be. The project team also analyzed how different infrastructure types interact and the cascading consequences of those interactions.

The neighborhood profiles also include a broad-brush analysis of impacts to the community, with a focus on low-income communities and vulnerable populations. The goal of the neighborhood profiles is to provide information to support implementable and innovative neighborhood-scale solutions to rising sea levels and enhance Citywide and cross-sector collaboration.

1.1.3 Sea Level Rise Adaptation Strategy

The information in this SLR Vulnerability and Consequences Assessment will be used to develop adaptation strategies and policies, identify priorities for investment, and build future projects to protect the City from SLR and coastal flooding to complete steps 4-6 from the SLR Action Plan. As every San Francisco neighborhood has unique characteristics and community-specific needs, substantive community engagement to tailor strategies to the unique characteristics of every San Francisco neighborhood will be required to develop and implement neighborhood-based SLR adaptation solutions.

See Chapter 14, *Next Steps* for more detail.

1.2 VISION

The SLR Action Plan contains the following Vision statement:

Make San Francisco a more resilient City in the face of immediate and long-term threats of SLR by taking measures to protect and enhance public and private assets, the natural environment, and quality of life for all.

1.3 GOALS

The Assessment works toward this vision by providing information to decision makers, City agencies, and public stakeholders about the vulnerabilities of public infrastructure and the consequences for people, the economy, and the environment. This information will help the City in collaboration with community stakeholders to develop, prioritize, and implement appropriate adaptation strategies to build San Francisco's resilience to SLR. This information will identify adaptation opportunities for infrastructure to provide multiple benefits, such as open space, waterfront access, and circulation.

The goals of this report are to:

- Identify vulnerabilities across sectors and the consequences of inaction in vulnerable areas
- Provide information to decision makers to help them develop, prioritize, fund, and implement adaptation actions
- Build City agency capacity to enable leadership and staff to implement timely and responsible solutions
- Provide information to support community dialogue on SLR adaptation strategies and actions
- Encourage interagency, state, regional, and federal collaboration

1.4 OBJECTIVES

To move San Francisco toward achieving the overarching Vision and Goals, the Sea Level Rise Working Group[6] has developed the following objectives to frame the Assessment. The Assessment is used to:

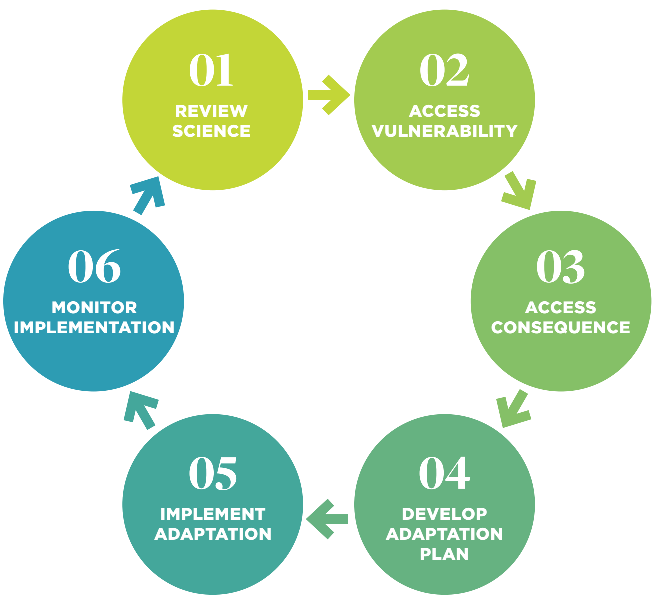
- Increase awareness of the potential threats and consequences to public assets and infrastructure from SLR and understanding of the shared Citywide responsibilities in SLR adaptation
- Support decision making under a range of SLR projections, over broad timespans, and across sectors
- Provide defensible and actionable information at the department, neighborhood, and Citywide scales regarding asset vulnerability to SLR
- Create shared baseline information and a framework for future investments
- Recognize interdependencies, promote collaboration, and incorporate lessons learned across City agencies and other Bay Area county-based SLR vulnerability assessments (e.g., Alameda, San Mateo, Marin)
- Contribute to interagency Citywide efforts to assess the City's vulnerabilities to multiple hazards (e.g., seismic, flooding, heat)
- Reduce overall costs associated with adaptation by providing holistic information about SLR vulnerabilities and how various infrastructure systems intersect

6 The Sea Level Rise Working Group is a sub-group of the Sea Level Rise Coordinating Committee that includes the project team and representatives from various City agencies and departments.

1.5 OUTCOMES

The overall Assessment approach was developed to provide detailed information to support effective and successful adaptation planning. By identifying the potential physical damages and consequences of the damage assets may incur when exposed to hazards, the Assessment considers risks and prioritizes strategies across four categories: capacity building within the City, external funding, sustainable growth, and Capital Planning. The Assessment approach is consistent with 2018 State of California Sea Level Rise Guidance.[7]

Figure 1.1 Adaptation Framework



1.5.1 Capacity Building

The Assessment approach and outcomes is intended to increase Citywide awareness of SLR vulnerabilities and consequences and increase interdepartmental coordination by:

- Developing a climate resilience working group to comprehensively support and implement climate mitigation and adaptation work across multiple climate hazards
- Developing a shared understanding of and consistent messaging about SLR vulnerabilities and consequences
- Enhancing Citywide coordination on SLR and coastal flooding hazards
- Building a centralized interagency database of public assets, vulnerabilities, consequences, and hot-spots of vulnerability
- Helping agencies understand their own assets' vulnerability and chronology of exposure, and identify opportunities to build resilience in current projects
- Helping agencies understand Citywide interagency vulnerabilities, chronology of exposure, and cascading consequences
- Building capacity to collaborate in the region and continue to lead on SLR planning

7 http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf.

1.5.2 External Funding

Implementing SLR adaptation strategies and solutions across San Francisco will take considerable time and funding. Much of the necessary funding is likely to come from external sources.

The Assessment approach and outcomes were developed to:

- Provide information for grant submissions for SLR-related capital projects, studies, and planning efforts
- Support the City as it applies for state and federal funding related to reducing SLR and flooding risks
- Help the City identify its internal strategic priorities for SLR adaptation so the City can collectively pursue funding for the highest priority projects

1.5.3 Resilient Investment and Growth

The Assessment approach and outcomes is intended to help guide investments and growth within San Francisco considering SLR and coastal flooding by:

- Informing new policies, guidelines, and code amendments to protect and adapt existing infrastructure and assets to SLR
- Providing information to support planning, design, California Environmental Quality Act (CEQA) review, and permitting
- Identifying potential partnerships (e.g., multiple departments, stakeholders) in hot-spot areas of vulnerability
- Inform future adaptation efforts to provide multiple benefits, such as open space, waterfront access, and circulation

1.5.4 Capital Planning / Internal City Funding

The Assessment approach and outcomes will better prepare departments developing their capital programs and seeking Capital Plan funding by providing asset-based and neighborhood-based information that can:

- Support Capital Planning SLR guidance process and provide information needed to complete the checklists and support prudent investments
- Inform future adaptation efforts to support the development of resilient infrastructure that considers multiple hazards such as SLR, flooding, heat, air quality, and earthquakes
- Identify projects that can increase the resilience of at-risk infrastructure for submission to the Capital Plan
- Help the City's Capital Planning Committee (CPC) make strategic choices about funding SLR adaptation projects
- Supporting repairs and/or retrofits to aging infrastructure that consider SLR risks

King Tide along the Embarcadero.
Photo by Dave Rauenbuehler (CC BY-NC 2.0)

CHAPTER 2

SEA LEVEL RISE CLIMATE SCIENCE AND SCENARIOS

In 2013, former San Francisco Mayor Ed Lee tasked a Sea Level Rise Technical Committee with reviewing the state-of-the-science and developing guidance for addressing SLR vulnerabilities. The committee produced a comprehensive summary of SLR science, as well as Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco (CPC Guidance), adopted in 2014 and revised in 2015.[1] The SLR capital planning checklist (a portion of the CPC Guidance) was updated in 2019 based on updated State science projections.

The CPC Guidance and the 2016 Sea Level Rise Action Plan relied on the best available science at the time – the National Research Council's (NRC's) 2012 Report, *Sea-Level Rise for the Coast of California, Oregon, and Washington: Past, Present and Future*.[2] The NRC report was also adopted as best available science by the State of California[3] and the California Coastal Commission.[4] However, the science related to understanding climate change and its projected trends and impacts is continually evolving. In response to updated national and regional reports,[5] [6] [7] the State of California released updated Sea-Level Rise Guidance [8] (State Guidance) in 2018.

This chapter discusses historical changes in local sea levels, presents updated SLR projections consistent with the current science and State Guidance, and describes the 10 mapped SLR and storm surge scenarios used in this Assessment.

1 http://onesanfrancisco.org/sea-level-rise-guidance/

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

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

4 California Coastal Commission. 2015. Sea Level Rise Policy Guidance: Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits.

5 Sweet, W.V., R. Horton, R.E. Kopp, A.N. LeGrande, and A. Romanou. 2017: Sea Level Rise. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 333-363, doi: 10.7930/J0VM49F2.

6 Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, C. Zervas. 2017. Global and Regional Sea Level Rise Scenarios for the United States. NOAA Technical Report NOS CO-OPS 083.

7 Griggs, G, J. Arvai, D. Cayan, R, DeConto, J. Fox, H.A. Fricker, R.E. Kopp, C. Tebaldi, E.A. Whiteman (California Ocean Protection Council Science Advisory Team Working Group). 2017. Rising Seas in California: An Update on Sea-Level Rise Science. California Ocean Science Trust.

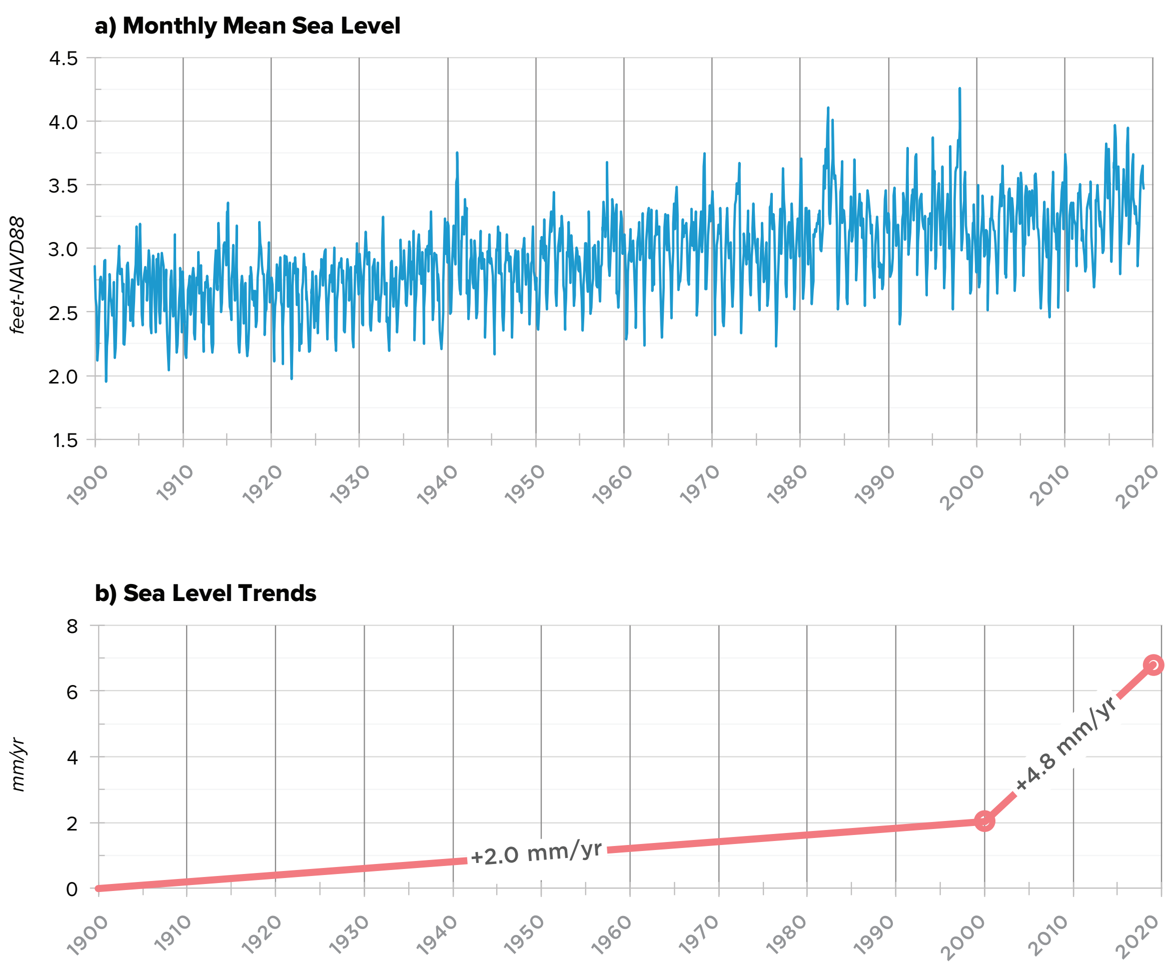
8 http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf

2.1 HISTORICAL SEA LEVEL RISE

The Presidio Tide Gauge located near Crissy Field along the San Francisco shoreline is one of the country's major scientific landmarks – the oldest continually operating tide gauge in the Western Hemisphere. The tide gauge has been collecting tidal observations since June 30, 1854, and has played a central role in understanding the impact of climate change on local and global sea levels. Sea levels have risen eight inches between 1900 and 2000, as measured at the Presidio Tide Gauge, and SLR has accelerated in the most recent decades (see Figure 2.1). SLR is projected to rise at a more accelerated rate over the next century (i.e., SLR is not anticipated to be linear and the rate of rise will continue to increase).

The modest historical rise in sea levels in the open Pacific Ocean and San Francisco Bay is already impacting San Francisco with periodic coastal flooding of low-lying shorelines and increased shoreline erosion. As sea levels rise further over the coming decades, the frequency and extent of coastal flooding will increase. Where shorelines are built on Bay fill, subsidence may further intensify flooding risks, and higher groundwater levels may increase liquefaction and seismic risks during earthquakes. Understanding how fast sea levels may rise over the coming decades is critical to understanding how the City should respond and adapt, where the City needs to focus adaptation efforts, and how quickly the City needs to implement adaptation solutions.

Figure 2.1 Sea Level Trends at the Presidio Tide Gauge



2.2 SEA LEVEL RISE PROJECTIONS

Over the next few decades, climate and SLR projections have a relatively high degree of certainty. After mid-century, the changes are harder to forecast and depend on the amount of greenhouse gases (GHGs) emitted globally and on the sensitivity of Earth's climate to those emissions.[9] In 2014, the Intergovernmental Panel on Climate Change (IPCC) adopted a set of four GHG concentration trajectories scenarios known as "Representative Concentration Pathways," or RCPs:

- RCP 8.5 assumes anthropogenic (human-caused) global GHG emissions continue to rise over the next century (i.e., there are no significant efforts to limit or reduce emissions)
- RCP 6.0 assumes anthropogenic global GHG emissions peak in 2080 and then decline
- RCP 4.5 assumes anthropogenic global GHG emissions peak in 2040 and then decline
- RCP 2.6 assumes strict emissions reductions, with anthropogenic global emissions declining by about 70 percent between 2015 and 2050, to zero by 2080, and below zero thereafter (i.e., humans would absorb more GHGs from the atmosphere than they emit).

Current State Guidance relies primarily on RCP 8.5 and RCP 2.6. RCP 8.5 was selected because, thus far, worldwide GHG emissions have continued to follow this trajectory; and RCP 2.6 was selected because, although it will be challenging to achieve at the global scale, it aligns with California's ambitious GHG reduction efforts. To date, the City of San Francisco has selected RCP 4.5 instead of RCP 2.6 as a more realistic potential lower bound for SLR planning for two reasons. First, voluntary GHG emissions controls agreed to by all nations participating in the Paris Climate Agreement ("nationally determined contributions"), if successfully implemented, will result in warming by 2100 roughly equal to the RCP 4.5 scenario. And second, RCP 2.6 assumes significant actions at a global scale that are neither underway nor under San Francisco's control.

The State Guidance also includes an extreme scenario (referred to as H++). This scenario represents a future with rapid Antarctic ice sheet mass loss, under the premise that the physics governing ice sheet mass loss will change after mid-century due to overall warmer global temperatures. The H++ scenario is, at present, highly uncertain and is a topic of ongoing scientific research.

Figure 2.2 presents the projected SLR curves for San Francisco for RCP 2.6, RCP 4.5, RCP 8.5, and H++. For the RCP curves, both the "Likely" value of SLR and the "1 in 200 Chance" SLR projections are presented.[10] The RCP curves for all three emission scenarios are virtually identical through 2050; however, the curves diverge after 2050, with the highest projected SLR associated with RCP 8.5. It should be noted that the three RCP scenarios still show good general agreement through 2150. The largest uncertainty associated with future SLR is related to the rate of Antarctic ice sheet loss; therefore, this uncertainty is considered separately with the H++ scenario.

The CPC Guidance recommends the NRC 2012 SLR projections for the "Likely" and "Upper Range" scenarios for guiding design and adaptation decisions, respectively. The 2018 State Guidance recommends a different suite of SLR projections. Although the NRC 2012 and State Guidance projections compare reasonably well, the State Guidance recommends slightly different projections in the latter half of the century. For example, the recommended upper range number for long-range (2100) adaptation planning increases from 66 inches (NRC 2012) to between 71 and 83 inches (State Guidance). In addition, the recommended likely value of SLR at 2100 changes from 36 inches (NRC 2012) to 33 to 41 inches (State Guidance).

9 USGCRP. 2017: Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 470 pp, doi:10.7930/J0J964J6.

10 The "Likely" and "1 in 200 Chance" SLR projections are adopted from Kopp et al 2014. These probabilities are "Bayesian probabilities" that consider the likelihood of the SLR projection occurring given a defined set of global circulation model inputs for a specific GHG concentration trajectory. Therefore, each GHG concentration trajectory (e.g., RCP4.5 or RCP8.5) has its own distinct set of Bayesian probabilities. These probabilities are not the same as the more commonly used statistical analyses of historic events, such as the FEMA 1-percent annual chance flood event (a one in 100 Chance event). Although the terminology is similar, historical probabilities of past events are generally well defined based on historical observations, while probabilities of a future event occurring reflect specific choices made in the analysis and modeling, and different approaches may create different probabilities. As a result, their use as "predictions," or in a simple risk assessment context (Risk = Consequence X Likelihood), is typically discouraged.

Figure 2.2 Relative Sea Level Rise in San Francisco, California

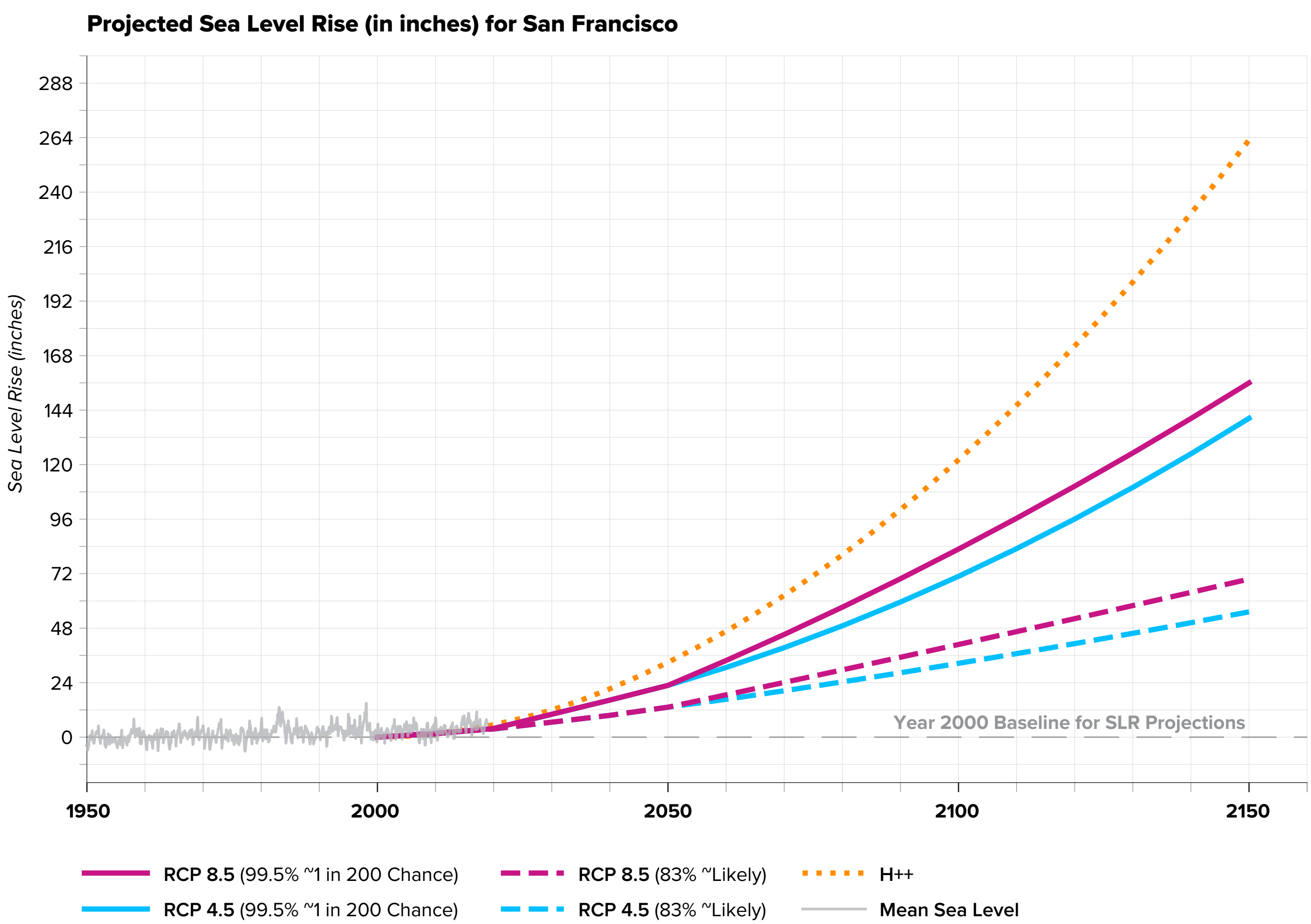


Table 2.1 San Francisco Sea Level Rise Projections (inches)

	NRC 2012		RCP 4.5 Rising Seas 2017		RCP 8.5 Rising Seas 2017	
Year	Likely	Upper Range	Likely	1 in 200 Chance	Likely	1 in 200 Chance
2030	6	12	6	10	6	10
2050	11	24	13	23	13	23
2070	20	38	20	39	24	45
2100	36	66	33	71	41	83
2150	--	--	55	140	70	156

2.3 SEA LEVEL RISE AND STORM SURGE SCENARIOS

This Assessment relies on a full range of SLR scenarios, from 12 to 108 inches, which provide compatibility with both the CPC Guidance and the State Guidance. This Assessment employs the "One Map, Many Futures" framework developed through the Adapting to Rising Tides (ART) program created by the San Francisco Bay Conservation and Development Commission (BCDC). The One Map, Many Futures approach defines 10 primary scenarios that represent a range of possible combinations of extreme tide levels and SLR.[11] Table 2.2 presents the 10 scenarios

11 For a complete discussion of the inundation scenarios and mapping, refer to Adapting to Rising Tides Bay Area Sea Level Rise Analyses and Mapping Project, Final Report, September 2017. Prepared by AECOM for the Bay Conservation and Development Commission, the Metropolitan Transportation Commission, and the Bay Area Tool Authority.

http://www.adaptingtorisingtides.org/project/regional-sea-level-rise-mapping-and-shoreline-analysis/.

Table 2.2
Sea Level Rise Scenario (Inches above MHHW)

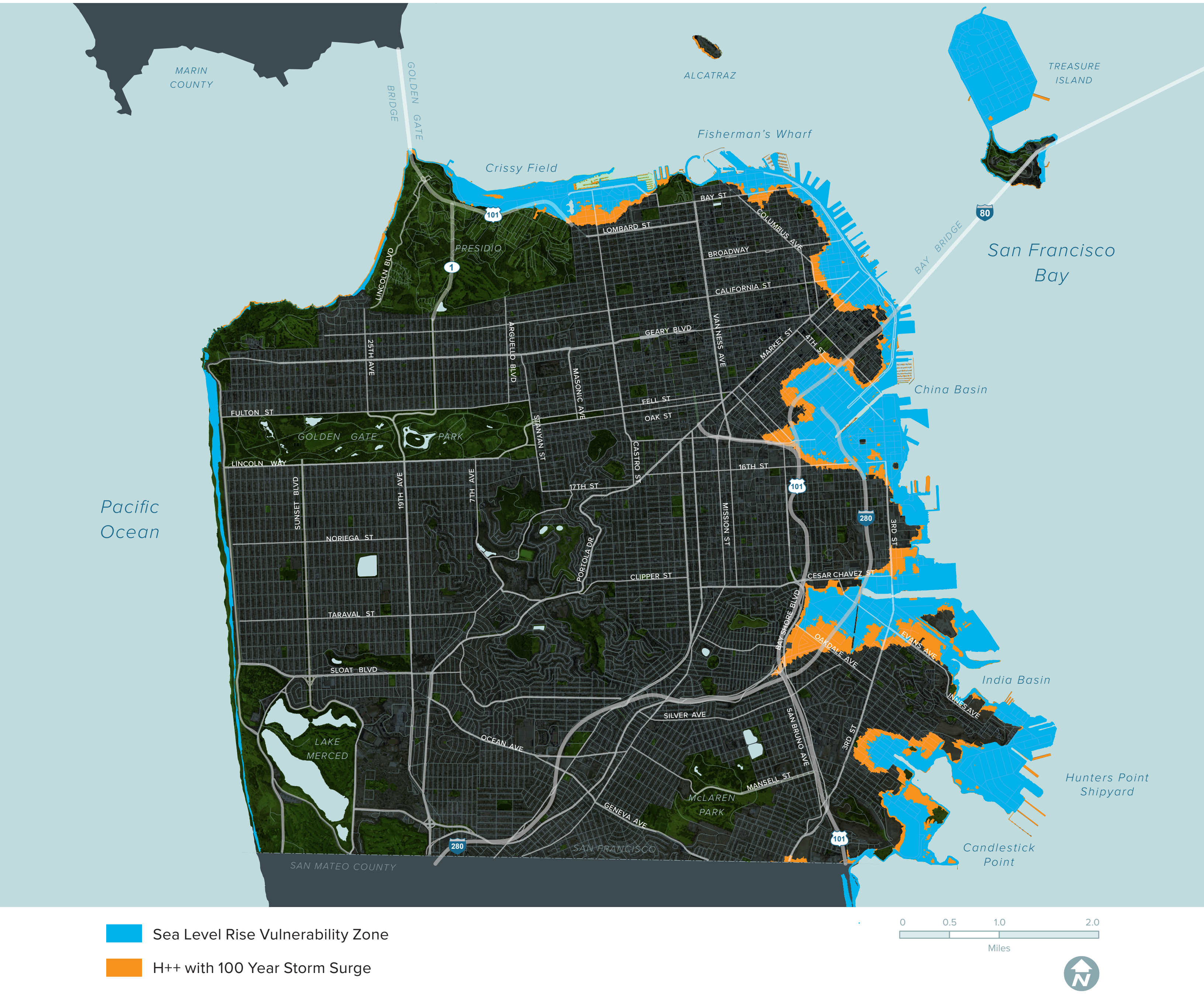
Mapping Scenario	Reference Water Level
Scenario 1	MHHW + 12"
Scenario 2	MHHW + 24"
Scenario 3	MHHW + 36"
Scenario 4	MHHW + 48"
Scenario 5	MHHW + 52"
Scenario 6	MHHW + 66"
Scenario 7	MHHW + 77"
Scenario 8	MHHW + 84"
Scenario 9	MHHW + 96"
Scenario 10	MHHW + 108"

MHHW = Mean Higher High Water
" = inches

Table 2.3 Sea Level Rise and Extreme Tide Matrix

Sea Level Rise Scenario	Daily Tide	Extreme Tide (Storm Surge)						
	+SLR (in)	1-year	2-year	5-year	10-year	25-year	50-year	100-year
	Water Level above MHHW (in)							
Existing Conditions	0	12	19	23	27	32	36	41
MHHW + 6"	6	18	25	29	33	38	42	47
MHHW + 12"	12	24	31	35	39	44	48	53
MHHW + 18"	18	30	37	41	45	50	54	59
MHHW + 24"	24	36	43	47	51	56	60	65
MHHW + 30"	30	42	49	53	57	62	66	71
MHHW + 36"	36	48	55	59	63	68	72	77
MHHW + 42"	42	54	61	65	69	74	78	83
MHHW + 48"	48	60	67	71	75	80	84	89
MHHW + 52"	52	64	71	75	79	84	88	93
MHHW + 54"	54	66	73	77	81	86	90	95
MHHW + 60"	60	72	79	83	87	92	96	101
MHHW + 66"	66	78	85	89	93	98	102	107

Figure 2.3 Comparison of the SLR Vulnerability Zone and H++ with 100-year Storm Surge



relative to SLR in inches above mean higher high water (MHHW). When expanded to consider extreme tides ranging from the 1-year to the 100-year recurrence frequency, these 10 scenarios can represent a matrix of over 50 possible combinations of SLR and extreme tides (see Table 2.3).

Table 2.3 presents the relationship between each scenario and different combinations of SLR and extreme tides. For example, Scenario 1 (MHHW + 12") can represent 12 inches of SLR (permanent inundation) or an annual extreme high tide with a 1-year recurrence interval (often correlated with a King Tide condition). Scenario 3 (MHHW + 36") could represent the area inundated with 36 inches of SLR (permanent inundation), or a temporary flood event today with a 50-year recurrence interval, or a range of SLR and extreme tide combinations in between the two bookends.

2.4 SEA LEVEL RISE VULNERABILITY ZONE VS. H++

In 2014, the City adopted a SLR Vulnerability Zone that represents an area that could be flooded by the end of the century by a 100-year coastal flood event coupled with 66 inches of SLR – a high-end scenario. Sixty-six inches of SLR represents the upper-bound SLR projection in NRC 2012. The SLR Vulnerability Zone was defined to identify potential public capital projects that must complete a Sea Level Rise Checklist as part of the submission to the Ten-Year Capital Plan. The CPC Guidance requires a completed checklist if a project falls within the SLR Vulnerability Zone.

Figure 2.3 presents a comparison of the area within the SLR Vulnerability Zone (108 inches) and the area that falls within H++ scenario coupled with a 100-year extreme tide (164 inches).[12]

12 It should be noted that the 100-year extreme tide (the Bay water level with a 1 percent annual chance of occurring in any even given year) would most likely change dramatically if the San Francisco Bay experiences 122 inches of SLR. However, in the absence of better information, the existing 100-year extreme tide was used for comparison purposes. The H++ plus 100-year extreme tide inundation boundary was provided by BCDC.

The H++ scenarios include a high degree of uncertainty and were developed for the Bay shoreline due to the differences in the water level and wave dynamics in the Bay and the open Pacific Ocean. The extent of inundation is largely controlled by the changes in topography. That is, inundation is limited to the low-lying areas along the shoreline and does not directly flood the steep hills and upland areas.

For comparison purposes, the area inundated by the SLR Vulnerability Zone in Figure 2.3 is 3.9 square miles, H++ is 4.4 square miles (not shown on map), and the H++ plus 100-year extreme tide scenario is 5.5 square miles. At this time, the H++ scenarios are not used for planning or adaptation purposes; however, they help illustrate the uncertainties that remain with respect to the longer-term SLR projections.

2.5 DECISION MAKING WITH EVOLVING CLIMATE SCIENCE

Climate change science and SLR projections are continually evolving. This Assessment includes analysis of a wide range of possible scenarios between now and 2100, but it does not include the most extreme emerging science. Depending on future global climate mitigation efforts and the behavior of Antarctic ice sheets, the City may need to assess higher water levels in the future.

This assessment provides actionable information for near- and mid-term adaptation, but the work to increase the City's resilience to SLR is not complete. Adapting to SLR and other climate hazards and impacts will require ongoing monitoring of the science and local impacts, as well as applying lessons from the implementation of adaptation solutions within San Francisco and the larger San Francisco Bay Area region.

Sunrise on Ferry Building in San Francisco
Photo by Thomas Hawk (CC BY-NC 2.0)

CHAPTER 3

ASSESSMENT APPROACH

3.1 OVERALL PROCESS

This Assessment is based on the adaptation framework outlined by San Francisco's Sea Level Rise Action Plan and guided by the ART planning process1 (see Figure 3.1). The overall framework relies on three primary factors for success:

- **Collaboration across City agencies and departments.** No single entity or agency can scope, plan, design, and implement solutions that address the challenges of SLR across the entire City. The challenges of SLR are cross-cutting, and the framework emphasizes close collaboration throughout the process to build strong relationships across the departments, and to develop a common understanding of the potential consequences that could occur in the absence of action.

- **Information sharing that builds a strong, actionable case for moving forward with SLR adaptation.** All the data, analysis, and decisions that inform this Assessment were developed using a collaborative interagency process.

- **Consideration of all aspects of sustainability throughout the Assessment,** using the ART program's four sustainability frames. The ART sustainability frames are Society and Equity, Economy, Environment, and Governance (see Figure 3.2)

The 2016 Sea Level Rise Action Plan completed the Scope and Organize phase of the ART planning process. The Scope and Organize phase includes defining the project area, assets, and climate impacts to be considered, convening a working group, and setting resilience goals.

1 The Adapting to Rising Tides planning process is presented in detail on the following website: http://www.adaptingtorisingtides.org/howto/art-approach/.

Figure 3.1 Adapting to Rising Tides Approach

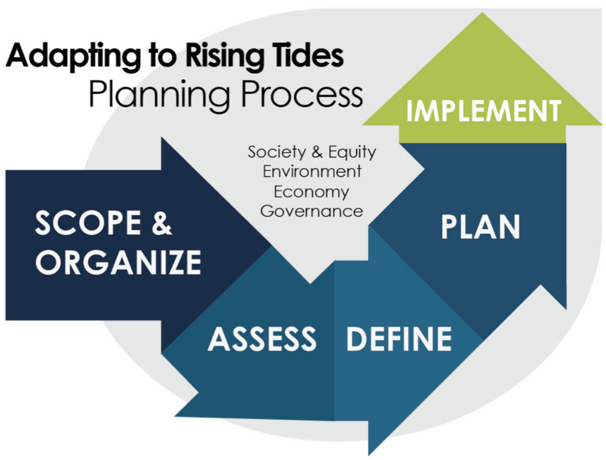


Figure 3.2 Adapting to Rising Tides Approach

SOCIETY & EQUITY Effects on communities and the services on which they rely, with a focus on disproportionate impacts due to existing inequalities	**ECONOMY** Economic values that may be affected such as costs of infrastructure damages or lost revenues during periods of recovery
ENVIRONMENT Environmental values that may be affected, such as air and water quality, natural systems, and ecosystem functions	**GOVERNANCE** Factors such as organizational structure, jurisdiction, and mechanisms of partnership that affect vulnerability to impacts

This report completes the Assess and Define phases. The Assess phase includes gathering information on the assets, completing the exposure assessment, identifying asset-based vulnerabilities and consequences, and refining the analysis based on working group and stakeholder input. The Define phase includes summarizing the analysis into clear, outcome-oriented vulnerability and consequence statements, reviewing cascading consequences across sectors and across neighborhoods, and defining key planning issues.

This chapter focuses on describing the City's process for completing the Assess and Define phases. Chapter 14, *Next Steps* outlines a process for the Plan and Implement phases.

3.2 VULNERABILITY ASSESSMENT

For this Assessment, the City team collected information on City-owned assets and infrastructure, completed exposure assessments for each of these assets, and identified each asset's vulnerability to SLR and coastal flooding based on conversations with agencies that own, operate, and maintain the assets.

3.2.1 Asset Inventory

The City team convened an Asset Inventory Working Group with representation across all asset-owning departments. The Working Group collected and organized the best available information on all City-owned assets (e.g., roadways, facilities, infrastructure, parks, etc.). This information forms the foundation of the exposure assessment.

The Working Group collected the City's best available geographic information system (GIS) data, and facilitated the completion of questionnaires[2] to gather information on each asset, including the existing condition of the asset, factors that may affect the asset's vulnerability, and information that informs the scale of the consequence that could occur if the asset is impacted.

2 Sample questionnaires and a description of the process are presented at: http://www.adaptingtorisingtides.org/wp-content/uploads/2015/10/ARI-H2G-Assessment-Questions-Guide_web-aligned_V3.pdf.

Figure 3.3 Sector Asset Categories

MOBILITY	• Roadways • Bridges • Local and Regional Transit	• Bicycle and Pedestrian Facilities • Operations and Maintenance Facilities
WATER	• Regional Water Distribution • Local Potable Water	
WASTEWATER	• Treatment Plants • Pump Stations	• Buried Sewers • Combined Sewer Discharges
POWER	• Substations and Transformers • Streetlights	• PG&E facilities
PUBLIC SAFETY	• Fire Department • Emergency Firefighting Water System	• Law Enforcement • Contaminated Lands
OPEN SPACE	• Parks • Playgrounds • Recreational Areas	• Marinas • Trails
PORT FACILITIES	• Piers • Seawall Lots	• Port Buildings • Rail Right-of-Way

The assets are grouped by sector based on the service the assets provide for the City: Transportation, Water, Wastewater, Power[3], Public Safety, Open Space, and Port Facilities (see Figure 3.3).[4] Chapters 5 through 11 present a description of each sector as a whole, asset-based descriptions, and assessment findings.

3.2.2 Exposure Assessment

The exposure assessment was completed in GIS by overlaying the sector-based GIS geodatabases with the ten SLR scenarios described in Chapter 2. For the most part, assets outside of the SLR Vulnerability Zone (Scenario 10, 108 inches, or a 100-year coastal flood event coupled with 66 inches of SLR) are not exposed and not included in the assessment.

3 Power is largely provided by Pacific Gas and Electric Company (PG&E). This Assessment does not include a detailed vulnerability assessment of PG&E's assets. However, Chapter 8, Power includes an exposure assessment for major PG&E facilities. PG&E is completing a Bay Area-wide vulnerability assessment of its assets and the City will use this information as it becomes available.

4 Sector-based GIS geodatabases were developed to inform the Assessment.

However, certain assets that impact public safety, such as fire stations, that are located outside the SLR Vulnerability Zone but within the zone inundated by the H++ scenario are included within the assessment.

Within the GIS geodatabases, each asset is represented as a point, line, or polygon. The exposure assessment was based on how each asset is represented. For point assets (e.g., small facilities, bus stops, fire hydrants), the assessment evaluated whether each asset was within the SLR inundation zone for each of the ten SLR scenarios. For linear assets (e.g., roadways, pipelines), the length and percentage of the asset within the SLR inundation zones were calculated. For polygon assets (e.g., parks, large facilities, piers), the area and the percentage of the asset within the SLR inundation zones were calculated. The exposure information was added to the GIS geodatabases to allow asset managers to identify when (and by how much) each asset would be inundated by SLR and coastal flooding for each scenario.

Sensitivity describes the degree to which an asset is affected. For example, temporary flooding could cause minimal impact, or it could result in a complete loss of an asset or shutdown of operation.

Table 3.1 Sensitivity Ratings

LOW	MODERATE / LOW	MODERATE	MODERATE / HIGH	HIGH

SLR and/or coastal storm surge inundation have little or no impact on the asset physically or functionally.

SLR and/or coastal storm surge inundation have an influence on the asset physically or functionally, but the asset would recover quickly once the floodwaters subside or would retain partial function when permanently inundated.

SLR and/or storm surge inundation have a significant influence on the asset physically or functionally. The asset would not recover quickly once floodwaters subside, or the asset would lose major function when permanently inundated.

Adaptive capacity describes the ability of an asset (or system) to adjust to climate change hazards, to moderate potential damages, to take advantage of opportunities, or cope with the consequences.

Table 3.2 Adaptive Capacity Ratings

LOW	MODERATE / LOW	MODERATE	MODERATE / HIGH	HIGH

Asset has little inherent ability to adapt to SLR inundation or coastal storm surge flooding without capital investments.

Asset has some inherent ability to adapt to SLR inundation or coastal storm surge flooding without capital investments (e.g., a reasonable alternate route is available).

Asset has substantial capacity to adapt to SLR inundation or coastal storm surge flooding without capital investments (e.g., flood barriers on doorways can mitigate flood impacts).

Table 3.3 Vulnerability Ratings

		SENSITIVITY				
		Low	Mod/Low	Moderate	Mod/High	High
ADAPTIVE CAPACITY	Low	L	M	H	H	H
	Moderate/Low	L	M/L	M/H	H	H
	Moderate	L	L	M	M	H
	Moderate/High	L	L	L	M/L	M
	High	L	L	L	L	M/L

3.2.3 Vulnerability Assessment

For this Assessment, "vulnerability" is defined as a function of an asset's sensitivity and adaptive capacity (its inherent ability to adapt). Using the information provided during the asset inventory process, the City team reviewed the functional, physical, and operational characteristics of each asset or asset category. Based on this information, the team assigned each asset sensitivity and adaptive capacity ratings that considered both temporary flooding (flooding associated with a coastal storm surge or tidal event) and permanent inundation (inundation associated with daily high tides with SLR) (Table 3.1 and Table 3.2).

The team presented this information in matrix form, resulting in a vulnerability rating for each asset or asset category (see Table 3.3), relying on quantitative information such as the presence of wet- or dry-floodproofing, location of potential flood pathways, and location of mechanical or electrical components and qualitative information such as previous or expected performance and professional judgment.

For each sector, the City team vetted the sensitivity, adaptive capacity, and vulnerability ratings with staff from each asset-owning department. The team mapped these ratings to identify potential areas of high vulnerability (geographic areas where multiple vulnerable assets, across multiple sectors, are located in close proximity). The sector-based chapters highlight vulnerability assessment findings for that sector's assets.

3.3 CONSEQUENCE ASSESSMENT

Following the vulnerability assessment, the consequence assessment considers the impact that could occur across the four sustainability frames (society & equity, the economy, the environment, and governance) if an asset is temporarily flooded or permanently inundated. The consequence assessment also considers the scale of the potential impact: local (immediate impact is largely localized to the individual asset), neighborhood (impact expands beyond the asset, but is largely limited to the surrounding inundated area), Citywide (impact extends beyond the inundated area and could have Citywide implications), and regional (impact could have regional consequences).

The consequence assessment relied on both quantitative information from the exposure assessment, such as how many miles of roadway or transit routes are inundated under each scenario, and qualitative information such as the scale of a potential impact. The assessment first focused on sector-based consequences (i.e., the impacts within the transportation sector were considered in isolation from the other sectors). These findings were then used to support how consequences in one sector could affect other sectors as well.

The team convened asset-owning agencies for a multi-agency cascading consequences workshop focused at the neighborhood scale. At the workshop, participants linked the projected impacts of key assets in each neighborhood to a range of consequences and discussed the potential chain of events that could occur across the four sustainability frames. For example, the disruption of a regional transportation link could have cascading consequences on the regional economy (e.g., commuters could be delayed or prevented from reaching their workplace, impacting personal incomes, business revenues, and transit revenues), the environment (e.g., transit riders could shift to driving vehicles, increasing congestion and GHG emissions and impacting local air quality), and society & equity (e.g., transit-dependent households would be the most impacted).

The consequence assessment is high-level and is not a detailed multi-hazard risk assessment. More detailed assessments may be required at the project-level to support the implementation of adaptation strategies. Consequence assessment findings are presented within each sector-based chapter. Multi-sector and cascading consequences are presented in Chapter 12 in the neighborhood profiles.

CHAPTER 4

SUPPORTING ASSESSMENTS

The City of San Francisco has been working to address the challenges of climate change for more than a decade. The City has also partnered and coordinated with regional agencies on climate change-related planning efforts. This chapter includes summaries of the latest and most relevant studies and programs that support the Citywide Assessment. This is not an exhaustive list of the climate-related efforts that have been completed to date. These efforts were reviewed for pertinent information regarding the vulnerability to, and effects of climate change, including SLR, coastal flooding, precipitation, and in some cases, seismic hazards. This information is summarized in the “summary sheets” that follow.

The documents and underlying data that were reviewed and summarized are organized in three categories: work that has been completed by the City, work that is currently in progress by the City, and work that is ongoing by regional agencies.

Completed Studies

The completed studies were generally undertaken by a single department for a specific purpose and were not necessarily developed with a goal of supporting a multi-sector assessment; however, the insights from these studies help inform this Citywide, multi-sector assessment. This chapter summarizes the following completed studies:

1. **Lifelines Council Interdependency Study** (2014)
2. **San Francisco’s Climate and Health Adaptation Framework** (2017) with excerpts from Climate and Health: Understanding the Risk: An Assessment of San Francisco’s Vulnerability to Flooding & Extreme Storms (2016)
3. San Francisco Public Utilities Commission (SFPUC) **Flood Resilience Report** (2017)
4. SFPUC **Climate Vulnerability and Adaptation Assessment** (work completed; report in progress)

Studies in Progress

City agencies are currently working on several related assessments. Many of the efforts underway by the City are assessments of climate change impacts, and other hazards beyond SLR, or are undertaking more detailed assessments in specific geographies or specific sectors. These in-progress studies can inform and be informed by this Citywide SLR Assessment,. In-progress studies reviewed and summarized include:

5 SFPUC, Port of San Francisco (Port), and San Francisco International Airport's (SFO's) **Extreme Precipitation Study**

6 SFPUC's **Long-term Vulnerability Assessment and Adaptation Plan for the Water Enterprise**

7 San Francisco Office of Resilience and Capital Planning's **Hazards and Climate Resilience Plan**

8 Port's **Seawall Earthquake Safety and Disaster Prevention Program**

9 SFO's **Shoreline Protection Program**

Regional Programs

BCDC leads the regional Adapting to Rising Tides (ART) Program, which has conducted a region-wide high-level SLR assessment. San Francisco has collaborated with BCDC in developing this assessment and ensuring inclusion of the City's information and the relevance of any and all findings and outcomes, so that ART can support the City's ongoing climate resilience efforts. The regional studies reviewed and summarized include:

10 BCDC's **Adapting to Rising Tides Program**

This chapter includes a summary sheet for each study or program to highlight the most relevant information to this report. The summaries emphasize relevant elements for this report, and include the following sections:

1. Title, authors, date published or timeline for completion, key words, and cover image;
2. Summary highlighting each study or program's relationship to this Assessment, project timeline, project area, study focus, and target audience;
3. Relevant hazards (e.g. heat, drought, SLR, coastal flooding, extreme precipitation, seismic hazards) and insights for this Assessment;
4. Consequences and potential interdependencies organized by ART sustainability frames:

   a. Society and Equity (i.e., effects on communities and services on which they rely, with a focus on disproportionate impacts due to existing inequalities)

   b. Economics (i.e., economic values that maybe affected such as infrastructure damage, disruptions in service, and recovery considerations)

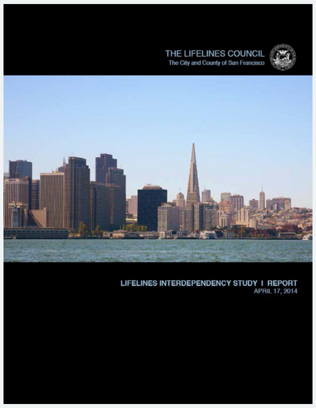
   c. Environment (i.e., environmental values that may be affected, such as water quality, species biodiversity, and ecosystem function and services)

   d. Governance (i.e., factors such as organizational structure, jurisdictions, policies, and mechanisms of participation that affect vulnerability to impacts)

5. A list of outcomes that the summarized report or program resulted or will result in, such as policy changes, additional studies, building code changes, and new projects.

1 LIFELINES COUNCIL INTERDEPENDENCY STUDY

The Lifelines Council of the City and County of San Francisco
April 2014



SUMMARY

The City's Lifelines Council completed a study of the interdependencies between different lifeline systems operating within the City limits. It considers normal functioning as well as restoration of systems following a major magnitude 7.9 earthquake on the San Andreas Fault. Eleven lifeline operators managing 12 types of lifeline systems participated in a structured interview process, detailing lifeline system impacts and consequences, response and restoration schemes, and dependencies upon other lifeline systems. The participating lifeline systems included regional roads and City streets, electric power, natural gas, telecommunications, water, auxiliary water for fire suppression, wastewater, transit, ports, airports, and fuel. The study found that the expected levels of system damage are not as severe as they might have been without the major retrofits and upgrades that have been made to many of the City's and region's lifeline systems over the past several decades. Nonetheless, most lifeline systems are still vulnerable to moderate damage that could substantially affect system functioning and delay restoration. The study also found that restoration of some lifeline systems is closely coupled and interdependent with the performance and restoration of other lifeline systems. This coupling varies with time—in the first hours, days, weeks, and months—following a major disaster. While some lifeline systems may only experience moderate damage, their restoration could be significantly delayed because of their dependence of other lifelines for operation. The study does not explicitly consider aftershocks, which could be substantial following an earthquake of such magnitude, which could cause additional damage to lifeline systems and also further delay restoration.

TIMELINE OR STATUS
Completed in Spring 2014

AREA
San Francisco, CA

FOCUS
Disaster preparedness

TARGET AUDIENCE
San Francisco City agencies

Relevant Hazards

HAZARD	INSIGHTS
General Climate Change (extreme heat, drought, or other)	In terms of system restoration (until system upgrades currently planned or underway are completed), power disruptions lasting more than 72 hours and particularly affecting those systems with a heavy power dependency and limited back-up power supplies, notably the wastewater, municipal transit, and telecommunication systems will be heavily affected (p. vi). This may be exacerbated if a major earthquake happens during a heatwave, resulting in less ability to keep work areas, living spaces, and perishable foods cool.
Sea Level Rise	A significant level of damage to the San Francisco bayside waterfront seawall from a major earthquake could impact all lifeline systems running along or crossing the waterfront seawall area. This is considered one of the most critical interdependency issues that could impact emergency response efforts and the safety of people and property (p.v). Seawall conditions have degraded with time and are also now threatened by rising sea levels (p.33). Such damage may be exacerbated by high tides in the short term and by SLR in the longer term following a major earthquake. Strengthening the seawall could be quite costly but the cost of post-disaster reconstruction and the potential economic consequences of a major waterfront closure could be far greater (p.33).
Coastal Flooding	The study calls for a multi-hazard risk assessment of the seawall vulnerabilities along San Francisco's waterfront due to liquefaction, SLR, and flooding (p.vi). More details are provided in Chapter 4.1 under the heading "San Francisco waterfront seawall multi-hazard risk assessment" (p.32).

Extreme Precipitation	Suggested key areas for enhanced coordination include planning for public emergency drinking water and sanitation services until services are restored (p.vii). Heavy precipitation could exacerbate issues with drinking water and sanitation services after a major earthquake.
Seismic Hazards	In addition to strong shaking, areas of unconsolidated soils and artificial fills near the San Francisco Bay are likely to experience ground failure-related damage due to liquefaction. Landslides could also be generated in hillside areas where soils are very susceptible to failure (p.3). Rising groundwater levels and extreme precipitation could exacerbate the effects. Infrastructure "hubs" or "choke points" with potentially significant ground failures, such as the Financial District, the seawall along San Francisco's waterfront, and the southeastern reaches of the City around Mission and Islais Creeks, could significantly impede system restoration and recovery (p.vi). It is estimated that there could be 0.5 to 2 feet of ground settlement and lateral spreading through a major earthquake, potentially making these areas more susceptible to flooding after an earthquake.

Consequences and Potential Interdependencies

ART SUSTAINABILITY FRAMES	
Society and Equity	Outside of the study scope.
Economics	Considering all loss components, the total price tag for a repeat of the 1906 earthquake could reach $150 billion (2006 dollars). This includes damage to both public and private buildings, as well as infrastructure and business interruption losses. Damage to utilities and transportation systems was estimated to increase losses by an additional 5 to 15 percent. This does not include the potentially significant and long-term losses that might be caused by widespread economic disruption, such as potential decreases in property values and property tax revenue, loss of tourism revenues, and other key income generators for the region (p.4).
Environment	Outside of the study scope.
Governance	Chapter 3.2, Setting lifeline system response and restoration priorities (p.28), describes the organizational structures that the operator organizations plan to use to coordinate post-disaster. It also describes business-as-usual coordination pathways.

Outcomes

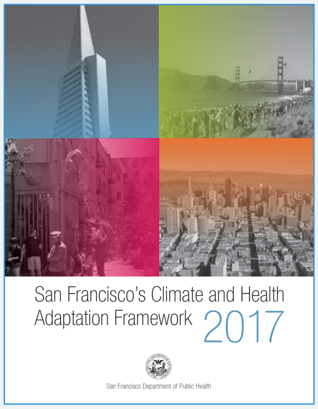
- The Port's multi-hazard risk assessment of the seawall is moving forward under the Seawall Earthquake Safety and Disaster Prevention Program (assessed in Section 8). The multi-hazard risk assessment will analyze vulnerabilities along a 3-mile section of the seawall due to seismic activity, liquefaction, SLR, and flooding.
- The Lifelines Council launched a Lifelines Restoration Performance Project in 2017 that will assess current and target restoration times for the 12 major lifeline systems following a scenario M7.9 San Andreas or M7.0 Hayward fault earthquake. The project aims to identify actions needed to reduce restoration times and meet performance goals.

References

The Lifelines Council of the City and County of San Francisco. 2014. Lifelines Interdependency Study. Report. April. Available at https://sfgov.org/orr/sites/default/files/documents/Lifelines%20Council%20Interdependency%20Study.pdf.

2 SAN FRANCISCO'S CLIMATE AND HEALTH ADAPTATION FRAMEWORK

San Francisco Department of Public Health (SFDPH)
2017



TIMELINE OR STATUS
Completed 2017

AREA
San Francisco, CA

FOCUS
Health impacts of climate change

TARGET AUDIENCE
San Francisco City agencies, San Francisco communities

SUMMARY

This framework is a compendium of the City's Climate and Health Program's work over the last several years. It is intended as a starting point to engage San Francisco's diverse City and community stakeholders in conversations about how best to adapt to the health impacts of climate change. As part of the effort, a screening matrix tool was developed to systematically prioritize adaptations and interventions and identified climate risk health indicators that measure health impacts and community resiliency associated with climate change-related hazard events. An important result of this work is the identification of San Francisco's most vulnerable populations by census group. A 2016 SFDPH Report, *Climate and Health: Understanding the Risk: An Assessment of San Francisco's Vulnerability to Flooding & Extreme Storms*, was included in this framework and provides a detailed view of San Francisco through a Flood Health Vulnerability Index. The Flood Health Vulnerability Index examines socioeconomic, demographic, health, exposure, and infrastructure characteristics that comprise vulnerability specifically for the health impacts of flooding and extreme storms. A comparative analysis was used to create an overall index by both block group and neighborhood. The final indicators used in the flood vulnerability assessment fall into four general categories:

1. Socioeconomic and demographic indicators, often based on systemic inequalities, that may impact a person's ability to prepare for or recover from hazard events;
2. Exposure indicators that identify areas most likely to experience flood inundation;
3. Pre-existing health conditions that may be especially impacted by a hazard events and interruption in government or community services during and after hazard events; and
4. The quality of housing and living conditions.

Relevant Hazards

HAZARD	INSIGHTS
General Climate Change (extreme heat, drought, or other)	Heat waves, defined for San Francisco as three sequential days surpassing 85 degrees Fahrenheit (°F), are expected to increase due to climate change (p.8). Increases in extreme heat, such as heat waves, may increase the number of premature deaths. Additionally, climate change is expected to impact local air quality with small increases in ground-level ozone levels and increased levels of particulate matter (PM2.5) due to wildfires and stagnant weather patterns (p.9). Direct impacts to human health include heat stroke, dehydration, and other heat-related mortality, as well as worsening of pre-existing conditions such as diabetes and renal disease, respiratory illnesses, asthma, and allergies.
Sea Level Rise, Coastal Flooding	Direct effects from SLR on human health include fatal and non-fatal injuries and waterborne disease. Standing water or failure of sewage, wastewater, or drinking water infrastructure may cause waterborne illnesses, such as bacteria, viruses, and parasites to flourish. Flooding may cause release of household toxic materials into the soil and waterways. Household dampness after inundation can increase mold growth, leading to respiratory illness, asthma, and allergies.

Extreme Precipitation	As extreme storms become more frequent and severe, heavy precipitation events may cause municipal storm drains to overflow or residential stormwater management systems to malfunction. Populations that are particularly vulnerable to illnesses from contact with contaminated water include children, elderly residents, populations with pre-existing health conditions, populations in high-risk sewer overflow zones, and those without adequate housing or in homes with poor plumbing. Direct impacts from extreme precipitation include lacerations and non-fatal injuries from extreme storms, increases in vector-borne diseases such as West Nile Virus, and increases in asthma and respiratory illness (pp.9-11).
Seismic Hazards	Seismic impacts were not addressed in this framework.

Consequences and Potential Interdependencies

ART SUSTAINABILITY FRAMES	
Society and Equity	Climate change will impact all San Franciscans but will have the largest health impact on vulnerable populations. This framework addresses the “Climate Gap,” or the degree to which a person is sensitive to climate exposures depending largely on established social, political, or environmental inequalities and existing vulnerabilities. Disruptions to certain sectors may impact populations differently. Any transit service disruption may have cascading health impacts on transportation-dependent populations. Power outages may impact vulnerable populations dependent on electronic medical devices and elevators.
Economics	Economics are discussed only in a socioeconomic context. Economic inequalities and vulnerabilities are contributing factors to poor health and increased vulnerability to climate change events (p.11).
Environment	The framework highlights how rising ocean temperatures can lead to an increase in the frequency of naturally occurring pathogens and lead to an increased uptake of contaminants in fish and mammals, resulting in serious health effects (p.24). Similarly, an increase of vector-borne and zoonotic illnesses (i.e., diseases transmitted through animal vectors, including mosquitos, ticks, fleas, and host populations such as rats and mice) is addressed (p.25).
Governance	The Climate and Health Program has started to inventory adaptive improvements in SFDPH-owned and operated buildings, including hospitals, health clinics, and administrative offices (p.40).

Outcomes

- A primary outcome of this framework is the inclusion of vulnerable populations in the 2019 Hazards and Climate Resilience Plan.

References

San Francisco Department of Public Health (SFDPH). 2016. *Climate and Health: Understanding the Risk: An Assessment of San Francisco’s Vulnerability to Flooding and Extreme Storms*. Winter. Available at https://sfclimatehealth.org/wp-content/uploads/2018/12/FloodVulnerabilityReport_v5.pdf.

San Francisco Department of Public Health (SFDPH). 2017. *San Francisco’s Climate Health and Adaptation Framework*. Available at https://sfclimatehealth.org/wp-content/uploads/2018/12/SFDPH_ClimateHealthAdaptFramework2017a.pdf.

3 FLOOD RESILIENCE REPORT

San Francisco Public Utilities Commission (SFPUC)
2016

SUMMARY

SFPUC initiated the Flood Resilience Report in response to several large rain events over the last decade. This report characterizes the economic impacts of flooding and identifies and evaluates flood resilience-driven capital projects and programmatic measures as options for reducing those impacts. The purpose of the report is twofold:

1. Provide a transparent framework for evaluating the economic impacts of flooding and the benefits of new capital projects. This framework is used to develop a benefit-cost comparison between various levels of flood protection. A suite of policy options was developed. Each policy option is an assessment of what it would take to address flooding in incrementally larger design storms, including the current design storm (5-year return period storm) and four more severe storms (10-, 25-, 50-, and 100-year return period storms). For each policy option evaluated, infrastructure needs, costs, benefits, and ratepayer impacts are presented.

2. Provide recommendations for and advance the development of programmatic flood risk reduction measures to build City-wide flood resilience, including options to ratepayers and property owners to help manage stormwater and reduce the risk of flooding damage when a storm exceeds the chosen level of flood protection. Examples include future modifications to the building code, grant funding for property owners to flood-proof their properties, clarification/outreach around affordable, and federally backed flood insurance.

TIMELINE OR STATUS
Published 2016

AREA
San Francisco, CA

FOCUS
Flooding reduction, economic cost-benefit analysis

TARGET AUDIENCE
SFPUC, San Francisco City agencies, San Francisco residents

Relevant Hazards

HAZARD	INSIGHTS
General Climate Change (extreme heat, drought, or other)	Outside of the report scope.
Sea Level Rise, Coastal Flooding	SLR may limit the hydraulic capacity of the collection system to discharge through combined sewer discharge (CSD) outfalls to the Pacific Ocean and San Francisco Bay (p.77-80).
Extreme Precipitation	Flooding from extreme precipitation is the focus of this report. Flooding represents any water that is on the land surface because the amount of rainfall or runoff is greater than that which the drainage infrastructure can accommodate. When flooding occurs, there is a risk to property and public safety.
Seismic Hazards	Outside of the report scope.

Consequences and Potential Interdependencies

ART SUSTAINABILITY FRAMES

Society and Equity

Environmental justice is not included as a specific issue area, but the principles of environmental justice were carefully considered in the development of the economic methods. This was done by excluding property value from flood impacts to the extent possible to avoid prioritizing projects in neighborhoods of higher socioeconomic status. SFPUC has done comprehensive work identifying the neighborhoods in San Francisco with the greatest flood risk and identifying which priority projects are needed first to upgrade the collection system. While no sewer system can be designed to handle storms of all strengths and sizes, the agency will be proposing more than $700 million of flooding work to be included in the Sewer System Improvement Program (SSIP) over the next 15 years. Subsequently, the City will continue to implement additional flood projects over time. The study discusses that any policy decisions must also consider ratepayer affordability. Ultimately, the funding of projects to manage stormwater and minimize flooding in any storm will come from rates.

Economics

This report focuses on the economic impact from flooding. The 13 issue areas used in the study are grouped into three main categories:

Damages: economic impacts borne by people and property as a direct result of flooding;

- First-order losses: economic impacts caused by interruptions to activities and services such as business, transit, and utilities; and

- Indirect effects: economic impacts that are not a direct result of flooding but are caused by damages and first-order losses.

Environment

Environmental consequences, especially regarding their economic cost, were not included as they are hard to quantify. Examples of these consequences include damage to natural assets and the impact on the environment from natural resources required to rebuild damaged assets.

Governance

The report provides recommendations for programmatic flood risk reduction measures to build City-wide flood resilience. This includes options to ratepayers and property owners to help manage stormwater and reduce the risk of flooding damage when a storm exceeds the chosen level of flood protection.

Outcomes

- In August 2012, as part of SSIP validation, SFPUC affirmed a specific goal to integrate green and grey infrastructure to manage stormwater and minimize flooding, and a corresponding level of service to control and manage flows from a storm of a 3-hour duration that delivers 1.3 inches of rain, corresponding to the 5-year storm. In March 2016, SFPUC reaffirmed the levels of service through the SSIP baseline of scope, schedule, and budget of specific SSIP projects.

- In addition to capital projects, SFPUC coordinates with a variety of City agencies to prepare for storms. Throughout the year, City crews clean pipes and clear catch basins, perform targeted tree trimming, and sweep streets across the City. And before, during, and after a major storm, SFPUC increases staffing and prioritizes locations in low-lying neighborhoods to respond to SF311 calls reporting things like clogged storm drains. SFPUC installs temporary plastic barriers at 17th and Folsom prior to heavy rains to help minimize floodwater intrusion into properties that are at risk of especially deep flooding.

- SFPUC and San Francisco Public Works jointly provide free sandbags every year. Residents and businesses can receive up to 10 free sandbags at the SFPUC Operations Yard. Public Works also prunes street trees to help prevent potentially dangerous limbs from breaking off during storms. Crews also are on the ground before and during storms to clean storm drains.

- To help make it easier for residents and business owners to get involved, the City has developed new, innovative programs with distinct measures that community members can take. These strategies will not change the capacity of the collection system but are intended to complement longer-term capital improvement projects because there is no single solution that fits all circumstances. They include Adopt-A-Drain—SFPUC provides residents training and equipment to keep storm drains clear of debris. Volunteers have adopted more than 1,700 drains across the City since the program launched in 2016; Flood Insurance—Connecting to experts on how to buy flood insurance. Over the past 2 years, the number of flood insurance policies in San Francisco has tripled; Floodwater Grant—the SFPUC reimburses improvements made by property owners to help protect against flooding.

  Based on community feedback and suggestions, SFPUC is proposing a major overhaul of the program to:

  - Increase funding –the SFPUC approved a $2 million program funding increase on October 24, 2017;
  - Expand the list of flood-proofing project concepts;
  - Significantly streamline the grant application process;
  - Provide more technical and administrative assistance for grant applicants;
  - Include special assistance for low-income applicants through partial upfront payments of grant funds; and
  - Make it easier for applicants to identify a suitable contractor.

- In addition to these voluntary programs, SFPUC also wants to develop requirements to incorporate flood resilience into San Francisco neighborhoods over time, such as:

  - Better flood maps so property owners are aware of potential flood risks;
  - New construction standards in flood areas; and
  - Flood-protection requirements for property sales and renovations.

- SFPUC has already targeted outreach to those residents who are directly impacted by flooding in low-lying areas. That community engagement will continue over the next several months to ensure residents and businesses are educated on how they can become “RainReady.”

References

San Francisco Public Utilities Commission (SFPUC). 2017. *Flood Resilience Report*. Available at https://sfwater.org/Modules/ShowDocument.aspx?documentid=9127

4 SFPUC CLIMATE VULNERABILITY AND ADAPTATION ASSESSMENT

San Francisco Public Utilities Commission (SFPUC)
In Development

SUMMARY

SFPUC's SSIP is upgrading San Francisco's aging sewer infrastructure to improve the sustainability and performance of San Francisco's sewer system, now and into the future. One of the key challenges in achieving this goal is understanding the potential impacts of climate change on SFPUC's combined wastewater and stormwater system assets. The SFPUC assessment began early in the program and has provided a continuous stream of design criteria, modeling data, and climate science support and guidance to SSIP projects and studies. Two key companion studies that provide additional information are the Collection System Capital Improvement Strategy, which focuses on the operational needs, condition assessments, and overall goals of the sewer system, and the Flood Resiliency Study (Summary 3), which focuses on localized flooding concerns. The SFPUC assessment focuses primarily on the integrity of the system by identifying the assets potentially at risk of climate change-related impacts over the next century; the timing of potential future impacts as climate change-driven overland flooding occurs; and recommending a suite of flood resiliency (e.g., flood barriers, raising electrical equipment, etc.) and adaptation options that can reduce or mitigate the impacts to individual assets and protect the sewer system infrastructure, the environment, and public health.

TIMELINE OR STATUS

In development; 2013 - present

AREA

San Francisco, CA

FOCUS

Climate vulnerability and risk assessment for wastewater assets

TARGET AUDIENCE

SFPUC, San Francisco City agencies

Relevant Hazards

HAZARD	INSIGHTS
General Climate Change (extreme heat, drought, or other)	Rising groundwater due to SLR or increases in precipitation could result in increased infiltration into the current system or may flood belowground structures that are not flood resistant. Current shallow groundwater locations in San Francisco are considered in the SFPUC assessment as a secondary climate hazard. The SFPUC assessment identified wastewater assets located in the shallow groundwater zone.
Sea Level Rise, Coastal Flooding	SLR and storm surge are considered as primary climate hazards in the SFPUC assessment. SLR was identified as a hazard that could potentially exacerbate the effects of other hazards such as coastal erosion and increasing groundwater levels (and subsequently landslides and liquefaction hazards). The timing of exposure to SLR and storm surge scenarios were identified for all wastewater asset types. The assessment identified assets located within the City's SLR Vulnerability Zone.
Extreme Precipitation	Precipitation flooding was considered in the SFPUC assessment because extreme events may damage structures and electrical equipment. The SFPUC assessment identified wastewater assets located in a stormwater flooding vulnerability zone (the area potentially flooded during a 100-year 3-hour rainfall event). Future changes in precipitation patterns and intensity was not addressed in this study — sufficient projections of future precipitation for San Francisco were not available.
Seismic Hazards	Landslide and liquefaction hazards were considered in the assessment because rapid land movement can physically damage structures that are not seismically resilient. A rise in sea level and an associated rise in groundwater can result in soil instability and increase the potential for land movement, in both liquefaction and landslide zones. An increase in the severity of rain events can also affect the frequency and magnitude of landslides occurring in steeper topography. Current liquefaction and landslide locations in San Francisco are considered a secondary climate hazard in the SFPUC assessment. It also identified wastewater assets located in a seismic hazard zone.

Consequences and Potential Interdependencies

ART SUSTAINABILITY FRAMES	
Society and Equity	Impacts to communities resulting from climate impacts were quantified using the total population and number of critical facilities affected within identified asset-based service areas. Consequences identified also included localized street flooding within an asset's service area. The likelihood of an impact associated with a specific climate change scenario was not considered.
Economics	Outside of assessment scope.
Environment	Potential water quality impacts to San Francisco Bay and the Pacific Ocean were identifed as potential consequences of assets that fail (e.g., discharge of untreated water).
Governance	Factors such as organizational structure, jurisdictions, policies, and mechanisms of participation that affect vulnerability to impacts were not quantified.

Interdependencies between wastewater asset types (e.g., pump stations and treatment plants) are discussed in the SFPUC assessment as a function of overall system consequences.

Outcomes

The SFPUC assessment, and the tools and approaches developed for it by SFPUC, are guiding multiple resiliency efforts both within SFPUC and the City and County of San Francisco. The benefits to SFPUC include design criteria for new infrastructure, asset-based adaptation strategies, operational strategies, and the preliminary identification of neighborhoods where regional adaptation solutions can provide greater City benefit.

The products from the SFPUC assessment have informed SFPUC project design, parallel studies, and City-wide planning efforts, which include:

- San Francisco SLR and storm surge inundation mapping (2014)
  - Updated to include Port of San Francisco piers and wharves (2016)
  - Compiled within the Regional Bay Area Sea Level Rise Analysis and Mapping (2017)
- Guidance for Incorporating Sea Level Rise into Capital Planning (2014; 2015)
- Sea Level Rise Scenario Selection and Design Tide Calculation (2015)
- San Francisco Sea Level Rise Action Plan (2016)
- Resilient SF: Stronger Today, Stronger Tomorrow (2016)
- Flood Resilience Study (Draft) (2016 - ongoing)
- Local Coastal Plan Amendment / Western Shoreline Area Plan (2017)

For system upgrades, including rehabilitating structures to enhance and extend their functional lifespan, the SFPUC assessment informs design criteria and adaptation strategy selection. The vulnerabilities and risks of the existing wastewater system assets are described and catalogued in a series of asset profiles. As projects and needs are identified, the relevant climate risk and adaptation information can be readily incorporated. The asset profiles can also inform maintenance activities (i.e., installing conduit seals, flood-proof access hatches, relocating electrical control panels) and emergency planning (i.e., identifying known vulnerabilities that can be addressed in advance of an anticipated extreme event).

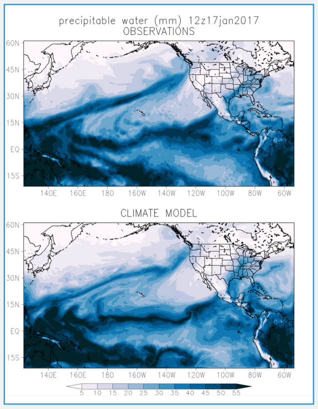
The SFPUC assessment also informs the design of new infrastructure and facilities. The SLR and storm surge inundation mapping informs site selection and helps set critical elevations related to earthwork and grading, first floor elevations, elevations of electrical equipment and control panels, as well as methods, materials, and techniques for dry- and wet-flood proofing to achieve greater flood resilience.

References

San Francisco Public Utilities Commission (SFPUC). 2018. *SFPUC Climate Vulnerability and Adaptation Assessment*.

5 SFPUC, PORT OF SAN FRANCISCO, AND SFO'S EXTREME PRECIPITATION STUDY

SFPUC, Lawrence Berkeley National Laboratory,
Silvestrum Climate Associates
Project work expected 2018-2019



TIMELINE OR STATUS
2019

AREA
San Francisco, CA; South San Francisco (Bayside)

FOCUS
Extreme precipitation

TARGET AUDIENCE
San Francisco City agencies, SFPUC, Port, SFO

SUMMARY

This study seeks to fill a critical gap in our regional understanding of how precipitation may change over the coming century, with an emphasis on extreme events and storms commonly used as design criteria. While SLR is fairly well understood and there is local agreement on the best available SLR science, understanding how precipitation may change over the coming century in the San Francisco Bay Area remains a key uncertainty. Unfortunately, if SLR adaptation projects are planned and constructed without a robust understanding of how extreme precipitation may change, these projects may underestimate future flood hazards, and may contribute to increased watershed-driven flood risks. The objectives of this project are to:

1. Design and perform climate model simulations of anthropogenic influences on extreme precipitation events impacting the San Francisco Bay Area; and

2. Engage with stakeholders to translate the climate model output into actionable science.

An "extreme precipitation event," or "storm event," is defined as a period of heavy precipitation lasting up to 10 days. Climate model simulations are being developed for four storm events as they occurred in the recent past (i.e., between 1980 and 2017) and as they could occur in future warmer climates (e.g., in 2050 or 2100). One of the key deliverables will be a "Guidebook" to inform and support stakeholders in understanding how precipitation across an array of storm events is likely to change in and around the San Francisco Bay Area. The Guidebook will include how the model results and products can be used to support sensitivity analyses, long-range planning, project-based planning, and design.

The scope of work is based on a SFPUC white paper from July 2017, which highlighted the need to consider the joint impact of future major storms and SLR on the Bay Area, versus considering them in isolation – together, they can combine to create the Bay Area's "perfect storm" – a storm event for which much of the Bay Area is not prepared, as previous storms have shown.

Relevant Hazards

HAZARD	INSIGHTS
General Climate Change (extreme heat, drought, or other)	Outside of the report scope.
Sea Level Rise, Coastal Flooding	Although the focus of this study is on extreme precipitation, the large atmospheric river and extra-tropical storm events that bring extreme rainfall often also bring high winds and elevated Bay water levels. The study will include a preliminary analysis comparing historic winds for up to two of the selected storm events with the projected future winds, at a model grid cell closest to the Port of San Francisco (Port) shoreline. Using FEMA one-dimensional wave runup analysis methods, the estimated increase in wave runup (with increased windspeeds and SLR) will be calculated at up to two locations along the Port shoreline.
Extreme Precipitation	The study's future precipitation information can be used to support hydrologic modeling, hydraulic modeling, and floodplain mapping. These analyses can help identify areas where flooding could be problematic if storm intensities increase so that capital improvement needs can be identified. The analyses can also help appropriately size new facilities, so they are capable of meeting future demands within the projects planned functional lifespan. Ideally, two agency-specific examples will be identified by the stakeholder working group for presentation within the Guidebook in a step-by-step "how to" guide format.
Seismic Hazards	Outside of study scope.

Consequences and Potential Interdependencies

Consequences or potential interdependencies between particular ART Sustainability Frames (Society/Equity, economics, Environment, Governance) are not called out in the scope; however, the study is designed to address the known consequences of storm-induced precipitation and elevated coastal water levels.

The data that this study will develop are intended to bring more knowledge and certainty to planning efforts that look at the consequences and interdependencies.

Outcomes

The results of the study will be used to develop a Guidebook that can be used by regional stakeholders to inform their understanding of future precipitation conditions. The Guidebook will present the results of the modeling study in an easy-to-understand and highly graphical format. The intent of the Guidebook is to explain how precipitation across a large array of extreme scenarios is likely to change throughout the larger Bay Area, and to inform the selection of future precipitation criteria for a wide range of Bay Area stakeholders and projects.

6 LONG-TERM VULNERABILITY ASSESSMENT AND ADAPTATION PLAN FOR THE SFPUC WATER ENTERPRISE

SFPUC
In progress

SUMMARY

Climate change and other changing conditions may jeopardize the future ability of the Hetch Hetchy Regional Water System's (RWS's) ability to meet SFPUC's desired level of service. Current planning will benefit from early identification of potential vulnerabilities and evaluation of possible adaptations to address them. This proposed effort will provide the insights needed to plan for an uncertain future by conducting a comprehensive vulnerability assessment of climate and other drivers for change and an adaptation planning process. A tailored methodology was designed to complete the following:

1. identify vulnerabilities through a systematic exploration of uncertainty ranges for a variety of future conditions (e.g., climate, regulatory changes, financial conditions); and
2. assess the risks associated with these vulnerabilities singly and in combination.

In addition, SFPUC will convene a small workshop featuring top climate scientists tasked with helping discern which climate futures might be more likely than others. The next phase of this project will utilize an "adaptation pathways" approach to develop an adaptation plan consisting of a portfolio of options that together are flexible and robust to a wide range of possible futures. The study is designed to provide a comprehensive understanding of system performance over a wide range of possible futures, and in doing so, clearly define the conditions that cause failure and identify priorities for adaptation planning. To support adaptation planning, the same approach is employed to evaluate the performance of alternative adaptation options and combinations of options. The computational engine of analysis is a multi-dimensional, algorithmic sensitivity analysis, called a "stress test," that explores ranges of uncertain variables, including both climate and non-climate uncertainties, and creates a database of system responses that are mined to identify vulnerabilities. A simulation platform will be developed that can reproduce system operation and performance and allow exploration of alternative futures, including climate change and other factors such as changes in demand, regulatory requirements, and other factors.

TIMELINE OR STATUS
In progress;
2016-present

AREA
SFPUC Regional Water System

FOCUS
Water supply and reliability

TARGET AUDIENCE
SFPUC, San Francisco City agencies

Relevant Hazards

HAZARD	INSIGHTS
General Climate Change (extreme heat, drought, or other)	The risk of drought is being examined in the future climate scenarios applied in the modeling effort. A 2012 SFPUC report, *Sensitivity of Upper Tuolumne River Flow to Climate Change Scenarios*, which preceded this study, evaluated the impacts on runoff into the Hetch Hetchy Reservoir and the San Francisco Water Supply System under a range of climate -driven changes in temperature and precipitation using best available climate science in 2012. The following insights were derived from that study: • In critically dry years, reductions in annual runoff at Hetch Hetchy would be significantly greater, with runoff decreasing up to 46.5 percent from present-day conditions by 2100 using the same climate change scenarios.

General Climate Change (extreme heat, drought, or other)	• In addition to the total change in runoff, there will be a shift in the annual distribution of runoff. Winter and early spring runoff would increase, and late spring and summer runoff would decrease. • Under all scenarios, snow accumulation would be reduced, and snow would melt earlier in the spring, with significant reductions in maximum peak snow water equivalent under most scenarios).
Sea Level Rise, Coastal Flooding	Outside of the study scope.
Extreme Precipitation	Climate extremes will be included as part of the climate data mining.
Seismic Hazards	Outside of the study scope.

Consequences and Potential Interdependencies

The study will result in a robust adaptation plan to guide future water supply decisions. Actions will be evaluated using modeling tools and performance metrics to reassess vulnerabilities and risks with the actions in place. The actions that provide the most benefit will be assembled into a sequence of actions for implementation over time. Appropriate triggers and thresholds will be identified, and the results monitored to support implementing actions, including identification of climate trends that require adjustments in intended actions ("pathways"). The adaptation plan will allow decision makers to identify opportunities, no-regret actions, and the timing of any given action while avoiding locking in measures that prove ineffective as conditions change. The adaptation plan, and the underlying vulnerabilities and risks, should be revisited on a 5- to 10-year cycle as uncertainties are reduced and advancements in climate science are made.

Outcomes

Outcomes will be documented in technical memorandums and presented to SFPUC either in person or through a webinar presentation. The following is a list of deliverables for this project.

- Technical Memorandum No. 1: Summary of weather generator and climate background information (including the National Center for Atmospheric Research's [NCAR's] climate-forcing data and report summarizing the CMIP-5 projections for SFPUC study domain and the nature of the climate indicators under current and future conditions)
- Technical Memorandum No. 2: Hydrologic and System Modeling Report
- Technical Memorandum No. 3: Vulnerability assessment (including NCAR's whitepaper on regional climate data sets for impact assessment and regional climate data sets with report on methods and data products)
- Hydrologic models and R modeling platform for use by SFPUC
- Technical Memorandum No. 4: Summary of findings of Piloting Adaptation Pathways (by Deltares) and stylized integrated assessment model
- Final Report 1: Summary of Methods and Findings

References

San Francisco Public Utilities Commission (SFPUC). 2012. *Sensitivity of Upper Tuolumne River Flow to Climate Change Scenarios*.

7 HAZARDS AND CLIMATE RESILIENCE PLAN

San Francisco Office of Resilience and Capital Planning
In Progress, expected to be submitted to FEMA in 2019

SUMMARY
The Hazards and Climate Resilience Plan is a combined hazard mitigation and climate adaptation plan that serves as the City's 2019 update to the Hazard Mitigation Plan and underpins the next update to the Safety Element and Climate Action Strategy. The plan profiles the wide range of hazards facing the City, including seismic hazards, climate hazards, and human-made hazards. The plan incorporates information on how climate hazards, such as flooding, drought, and extreme heat, may increase in frequency and severity in the future due to climate change. The plan includes near-term actions to be implemented in the next five years and mid- to long-term actions to manage risk and build resilience for current and future hazards.

This plan leverages the information collected for this Assessment and presents findings at a higher level for this multi-hazard and Citywide effort.

TIMELINE OR STATUS
Submit to FEMA in 2019
Anticipated adoption in 2020

AREA
San Francisco, CA

FOCUS
Multi-hazard, seismic hazards, climate hazards

TARGET AUDIENCE
San Francisco City agencies, decision makers

Relevant Hazards

HAZARD	INSIGHTS
General Climate Change (extreme heat, drought, or other)	The plan takes into consideration how hazards in San Francisco are influenced by climate change, including flooding, drought, extreme heat, wildfire, and landslides. The plan will include strategies to adapt to hazards that are projected to become more frequent or severe due to climate change.
Sea Level Rise, Coastal Flooding	The coastal flooding hazard profile includes a discussion of how SLR influences future coastal flooding frequency, extent, and severity. Coastal flooding is profiled as a hazard, including how it is influenced by SLR.
Extreme Precipitation	The plan discusses how changes in precipitation patterns due to climate change may influence several hazards, including flooding, drought, landslides, and wildfires.
Seismic Hazards	The plan assesses vulnerability to seismic hazards, including ground shaking, liquefaction, and tsunami. It also includes discussion of fire following earthquake (urban conflagration) and flood following earthquake.

Consequences and Potential Interdependencies

The plan will assess social, environmental, and economic consequences per the Association of Bay Area Governments (ABAG) Risk Assessment Handbook.

Outcomes

- Compliance with the Disaster Management Act of 2000, SB 379, and San Francisco's commitment to C40 to develop a Paris Agreement-compliant Climate Action Strategy
- Direction setting for future capital planning, area planning, and policy and program development
- Greater alignment of departmental hazard mitigation and climate adaptation work.

8 EMBARCADERO SEAWALL PROGRAM

Port of San Francisco
2018-2100

SUMMARY

The Port of San Francisco is leading the Embarcadero Seawall Program, a Citywide effort to create a more sustainable and resilient waterfront. Part of the Port's Waterfront Resilience Program, the Seawall Program will provide the tools to address current and future risks over time. There are three elements to the Program—Strengthen, Adapt and Envision—which allow the Port to respond to risks and conditions. Planning for all three elements is occurring now, implementation for each element will depend upon findings, public input, regulatory input, cost/benefit analysis, and availability of funding and financing.

San Francisco voters passed a $425 million General Obligation Bond for the Program in the November 2018 election. The Port is currently pursuing local, state, federal, and private funding sources to fully fund infrastructure improvements anticipated to cost up to $5 billion.

Immediate seismic and flood protection upgrades are targeted for completion by 2026. The Program is currently in the early stages of planning, following an extensive Vulnerability Study.

The Embarcadero Seawall Program is part of the Port of San Francisco's Waterfront Resilience Program. The Port developed a Waterfront Resilience Framework to address immediate hazards including seismic and flooding, as well as longer term hazards like SLR. This adaptive planning framework allows the Port to act now to address risks to life safety and emergency response, while planning for mid- and long-term risks. It also allows the Port to be responsive to community priorities, changes in science, and funding and partnership opportunities.

The Framework consists of the following elements:

1. **Strengthen** (2018-2026): Immediately implement highest-priority disaster response and life safety projects.
2. **Adapt** (2020-2050): Identify policies and projects that will result in a Port that is resilient to seismic and increasing flood risks and that can respond to changing priorities.
3. **Envision** (2050-2100): Develop visions that can respond to remaining seismic risk and increasing flood risks and long-term SLR and have an ongoing public conversation about the trade-offs of different options.

TIMELINE OR STATUS

Planning: 2018-2021
Design and Construction: 2021- 2026

AREA

Port property and surrounding areas along the Embarcadero Seawall

FOCUS

Immediate seismic risks and emerging flood risks

TARGET AUDIENCE

San Francisco communities, San Francisco City agencies, regional and State agencies and organizations, and regional community members

The Strengthen Element is currently underway and involves a multi-hazard risk assessment to evaluate the combined risks of earthquakes and flooding to the seawall and the assets, services, and neighborhoods it protects. The results of the multi-hazard risk assessment will be combined with a prioritization process and input from stakeholders, including the City, community, and regional partners. Projects will undergo review for prioritization to ensure that the projects constructed focus on the most critical life-safety and flood risk locations along the seawall. Based on these assessments, projects options will be developed, evaluated, and advanced into design and construction. Construction completion of Strengthen Element projects is targeted for 2026.

Subsequent phases of the Seawall Program will be advanced through the Adapt Element, which will be updated every five years. The Adapt Plan will include the framework for advancing the planning and constructing projects designed to address additional seismic risk and current flood risk and adapt to SLR, while considering and prioritizing action based on Port and City goals and initiatives. An extensive public outreach and educational effort is occurring throughout the City and includes Seawall Community meetings, focused briefings, a Seawall Program Roadshow presented to Citywide community, neighborhood, interest area, and political groups. Additionally, the program includes a Resource Agency Working Group, a Policy and Technical Advisory Committee, and a Citywide Seawall Executive Committee Meeting.

Relevant Hazards

HAZARD	INSIGHTS
General Climate Change (extreme heat, drought, or other)	Outside of program scope.
Sea Level Rise, Coastal Flooding	The Seawall Program will identify threshold water levels for the seawall to support the Port and the City's efforts in planning for SLR and coastal flooding. These thresholds will allow the Seawall Program to identify the water levels and types of events that will create flooding along the seawall and the water levels that increase that flooding. Both temporary and permanent flooding will be evaluated along with their risks and consequences. By evaluating the overtopping potential along the seawall, the program will also identify the most effective ways to address that flooding. For example, is the flooding localized and coming from a low spot along the seawall that can be addressed through a site-specific strategy or is it extensive and overtopping a large segment of the seawall and in need of a landscape scale strategy? The program will also be conducting a wind wave, wave run-up, and overtopping assessment with new bathymetry and additional analysis, as well as using SFPUC data to better understand the combined flood risk of coastal and overland flooding.
Precipitation	The impact of the increase of extreme precipitation events will be considered in the program.
Seismic Hazards	The Embarcadero Seawall was built before modern engineering and understanding of seismic risks in the area. Most of the Embarcadero Seawall was built over Young Bay Mud, which can amplify earthquake shaking and is subject to earthquake-induced lateral spreading and settlement. Land behind the seawall was created using fill and is susceptible to liquefaction during seismic events. In the event of a large earthquake, the seawall will slide outward to the Bay by as much as five feet. This will likely result in extensive damage to the bulkhead wharfs, piers, utilities, transportation system (including ferry terminals, MUNI lines, and BART Embarcadero Station), roadways, and structures adjacent to the seawall. Additionally, this damage may impede the ability to evacuate and respond to the disaster.

Consequences and Potential Interdependencies

ART SUSTAINABILITY FRAMES	
Society and Equity	The Seawall Program will increase the resilience of this critical shoreline to seismic and flood risk. The Embarcadero Seawall segment of the Port's jurisdiction is home to transportation and utilities that serve the entire City, as well as the region. Past hazard events have demonstrated that some of our community members will be more at risk than others, including the elderly, the young, those with access to fewer resources, and those with mobility challenges. That is why equity is a big priority for the Seawall Program. Protecting the seawall will protect a significant number of existing jobs and small businesses that currently lease Port property or rely on the transportation and utilities that are protected by the seawall. The multi-hazard risk assessment includes a number of metrics to identify the demographics of the people that live, work, and recreate along the Embarcadero Seawall, the jobs that may be lost, and the disruptions to transportation and utilities if the seawall fails. Additionally, the strategies developed by the program to address the seismic and flood risks will be evaluated for the

Society and Equity	potential impacts on community members and will provide an opportunity to ensure that no one is disproportionately impacted. The Port also provides many unique societal assets such as the Embarcadero Historic District, several museums, an extensive pedestrian and bicycle network, and critical Citywide and regional open spaces.
Economics	The seawall protects over $100 billion of assets and economic activity. The economic value of the assets at risk from seawall failure is 10-40 times greater than the $2 billion to $5 billion cost to strengthen the seawall and address SLR. The Port is also home to a number of industries and uses that would not be possible without the Port, such as maritime and water-dependent uses and small and local businesses from restaurants to agriculture to local artisans. These uses draw millions of people to the waterfront, as well as help the San Francisco economy stay diverse.
Environment	The Seawall Program projects may result in environmental benefits such as enhanced open space, elevated parks, low-impact development such as stormwater gardens, and may include mitigation measures consisting of nearshore habitat enhancements adjacent to the seawall or in other parts of the Bay.
Governance	Overall, the Seawall Program will involve extensive collaboration between the Port and City departments, communities, regulatory agencies, and regional partners. The Adapt Element will include governance measures such as modifications to organizational structures, jurisdictions, policies, and mechanisms of participation to improve resilience as conditions along the seawall evolve over time.

Outcomes

The program will have several outcomes over the next two or three decades. The following outcomes are expected by the end of 2021:

- A multi-hazard Risk Assessment that will provide detailed information regarding the risks and consequences of seismic and flood events along the Embarcadero Seawall. This information will be used by this Assessment to provide vulnerability and consequence information for this segment of the City's shoreline;
- A robust public communication and engagement process that can be built upon and leveraged by, this Assessment;
- An approach to adaptation planning and implementation that could be built upon and leveraged by this Assessment;
- A comprehensive understanding of the potential financing mechanisms that can be employed to fund adaptation efforts;
- Implementation of adaptation projects and policies in a highly visible part of the City's shoreline, providing an opportunity for public engagement and education on the issue;
- Strengthen projects focused on addressing current seismic and near-term flood risk to improve performance on life safety and emergency response;
- An Adapt Plan and Envision Element that lay out the adaptation planning and implementation approach, including a policy framework, to ensure a Port that can adapt and thrive until 2070 and that identifies landscape scale changes that may be necessary in 2100 and beyond; and
- Goals, objectives and principles that guide the Port's work on the Seawall Program and build off the existing goals, which are to:

  1. Act quickly to improve disaster preparedness
  2. Reduce earthquake damage
  3. Improve flood resilience
  4. Enhance the City and the Bay
  5. Preserve historic resources
  6. Engage the community

References

Port of San Francisco (Port). 2019. *San Francisco Seawall Earthquake Safety and Disaster Prevention Program*. Available at https://www.sfportresilience.com/seawall-program.

9 SFO SHORELINE PROTECTION PROGRAM

San Francisco International Airport (SFO)
2013 -2085

SUMMARY

San Francisco International Airport (SFO) is classified as a large hub airport by the Federal Aviation Administration (FAA) and was the seventh busiest airport in the United States in 2017 serving over 55.8 million annual passengers (6.6 percent of U.S. traffic demand). SFO is an important West Coast gateway airport and operates as a prominent link between North American cities as well as being a major gateway for traffic from the United States to and from Europe and Asia. Annually, about 70 percent of the Bay Area's air traffic demand is served through SFO, including over 90 percent of international air traffic demand.

The SFO Shoreline Protection Program (SPP) is a multi-year program to address SFO's risk of flooding, both storm-related and from longer-term SLR. The SPP requires a multi-step implementation process. The first phase was a feasibility study, which consisted of an assessment of SFO's existing shoreline protection, a deficiencies analysis, a seismic analysis, a bathymetry and wave modeling study, and proposed possible flood protection solutions for consideration.

The second phase produced the Shoreline Protection Program - Conceptual Design Study, which took the findings and recommendations in the feasibility study and developed the recommendations to a conceptual design level and developed a ranking matrix to establish a uniform and consistent process to select preferred flood protection alternatives for development of CEQA and National Environmental Policy Act (NEPA) documentation. The Shoreline Protection Program - Conceptual Design Study also developed budget estimates and program schedules for inclusion in SFO capital planning.

The next steps include submission of CEQA documentation to the San Francisco Planning Department, NEPA documentation to the FAA, and application for project construction permits.

Given SFO's 8 miles of Bayfront shoreline and its operational requirements, the project will be constructed in very tightly planned and controlled phases. It is anticipated that the construction of this program will be implemented through an alternate contract delivery method, e.g., design-build (DB), or construction management – general contractor (CMGC) methodology.

SFO's SPP will require a quantifiable amount of Bay fill. SFO staff is working with other local agencies, nonprofit organizations, and state and federal regulatory agencies to develop and implement an advanced mitigation program. SFO believes if successful, this program could be a model for other entities around the Bay implementing flood and SLR programs.

TIMELINE OR STATUS

2013 –2015 Shoreline Protection Feasibility Study

2015-2018/2019 Shoreline Protection Program - Conceptual Design Study

2018 – 2019 Pre CEQA/NEPA documentation preparation

AREA

SFO

FOCUS

Flood protection from storm events and sea level rise

TARGET AUDIENCE

SFO Executive Management; SFO Commission; Board of Supervisors; local, State and Federal Agencies, the general public

Proposed SPP Schedule:

1. Program Studies	2013-2019
2. Environemntal Review	Start 2020
3. Contract Procurement/ Programming	2024
4. Construction	Start 2025

Relevant Hazards

HAZARD	INSIGHTS
General Climate Change (extreme heat, drought, or other)	Outside of program scope.
Sea Level Rise, Coastal Flooding	SFO is currently vulnerable to flooding from a 1 percent annual chance flood as mapped by FEMA's 2015 Preliminary Flood Insurance Rate Map (FIRM). SLR will only exacerbate that problem over time.

Extreme Precipitation	SFO, the Port, and SFPUC are partnering with Lawrence Berkeley National Laboratory and Silvestrum Climate Associates to study the effects of extreme precipitation near SFO (see Summary 5) and will use the study results to further inform future storm drainage system requirements and future infrastructure improvements.
Seismic Hazards	The feasibility study examined the seismic stability of SFO's existing shoreline protection system and identified the reaches with the greatest risk of failure in a seismic event. The solution(s) to address the seismic deficiencies will be determined during the design phase of the SPP.

Consequences and Potential Interdependencies

ART SUSTAINABILITY FRAMES	
Society and Equity	Outside of program scope.
Economics	**Business Activity** • SFO directly accounted for $8.4 billion in on-airport business activity supporting nearly 43,000 airport jobs. • Offsite business activities that depend directly on local air service raise the direct airport economic contribution to the Bay Area to $35.7 billion in business sales with over 165,000 jobs. • When including spin-off activities in the region associated with suppliers of goods and services to the directly affected businesses, and the re-spending of additional worker income on consumer goods and services, the total economic footprint of SFO in the Bay Area increases to over $62.5 billion in business sales, including $20.9 billion in total payroll, and over 300,000 jobs in the region. **Tax Revenue** • State and local tax revenues linked to operations at SFO totaled nearly $2.9 billion in FY 2015/16: • $1.6 billion from direct activities and close to $1.3 billion from purchases of supplier goods and services, and subsequent spending of worker income in the Bay Area. • Aviation operations at SFO generated $1.2 billion in federal taxes and $791 million in U.S. Customs revenue from international air freight shipments.[1]
Environment	The SPP will require quantifiable amounts of Bay fill but will be offset by 3:1 to 5:1 habitat restoring mitigation.
Governance	The SPP will involve extensive collaboration between SFO, City departments, San Mateo County, surrounding cities and their communities, regulatory agencies, and regional partners. Adaptation to SLR may include governance measures such as modifications to organizational structures, jurisdictions, policies, and mechanisms of participation to improve resilience as SLR and flood risk evolve over time.

Outcomes

When complete, the SPP will provide protection for SFO's 8 miles of Bayfront shoreline to allow continued operation of the airport as the climate changes. SFO is an important regional transportation and economic hub for the City and the entire Bay Area. Resilience efforts implemented by SFO will directly or indirectly benefit all sectors, communities, and employers. This program could be a model for other entities around the Bay implementing flood and SLR programs.

1 Note that these tax revenues are remitted to the U.S. Department of the Treasury and do not directly benefit the Bay Area or the State of California.

10 ADAPTING TO RISING TIDES BAY AREA

Bay Conservation and Development Commission (BCDC), the Metropolitan Transportation Commission (MTC), and the Bay Area Regional Collaborative (BARC)

SUMMARY

The San Francisco Bay Area is the fourth-largest metropolitan area in the country, with a population of 7.4 million people and growing. The region, made up of nine counties (Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma), is diverse in every way – from its people to its economy to its environment.

A significant proportion of the region's communities, job centers, and transportation infrastructure, among other critical assets, are located along the San Francisco Bay shoreline with some locations at the risk of flooding today and others at risk of future flooding due to the changing climate.

The project will increase the resilience of the Bay Area's transportation system to current and future flooding, while also improving the safety and sustainability of communities, particularly those that are most vulnerable and disadvantaged. The project includes a regional vulnerability assessment of the Bay Area's transportation infrastructure, Priority Development Areas (PDAs) and Priority Conservation Areas (PCAs) as identified in the Sustainable Communities Strategy (Plan Bay Area), and vulnerable and disadvantaged communities. The project also includes the development of a suite of adaptation strategies to improve the resilience of Bay Area transportation assets and communities for inclusion in Plan Bay Area as well as other appropriate local and regional planning documents.

TIMELINE OR STATUS
2017 - 2019

AREA
The 9-County
San Francisco Bay Area

FOCUS
Sea level rise

TARGET AUDIENCE
Governmental agencies, planners, decision makers, and stakeholders

Relevant Hazards

HAZARD	INSIGHTS
General Climate Change (extreme heat, drought, or other)	The regional impacts of other general climate change-related hazards are not considered in the Bay Area-wide regional vulnerability assessment. However, several smaller-scale assessments completed as part of the overall ART program have considered these impacts if data are readily available. The impacts of these climate hazards on vulnerable populations are particularly important to consider.
Sea Level Rise, Coastal Flooding	The ART program considers the impacts that could occur from temporary or permanent coastal flooding, riverine, localized nuisance flooding including: 1. areas that currently flood may flood more frequently; 2. flooding may be more extensive, have a longer-duration, or occur in new areas; 3. permanent inundation may happen in areas currently not exposed to regular tides; 4. shoreline erosion may increase; and 5. groundwater may rise, and salinity intrusion may increase. The ART program produced the SLR, extreme tide, and shoreline analysis maps for the nine-county region to encourage regional consistency in SLR planning.

Extreme Precipitation	Sufficient regional data are not available to address the combined impacts of extreme precipitation and SLR. The program is using FEMA's flood insurance rate maps to approximate areas that are prone to riverine flooding, recognizing that this underestimates the combined threat and does not consider future riverine flooding potential with climate change.
Seismic Hazards	The program references the Association of Bay Area Governments (ABAG) and BCDC *Stronger Housing, Safer Communities - Strategies for Seismic & Flood Risks Report* (March 2015) to highlight vulnerabilities to seismic hazards, liquefaction, and flooding risks for fragile housing. The program recognizes that the region is slowly addressing the current challenge of upgrading and seismically retrofitting aging infrastructure, and that much of this infrastructure was not designed to be resilient to changes in precipitation, temperature, and increasing flooding due to SLR and rising groundwater levels.

Consequences and Potential Interdependencies

The City of San Francisco coordinated with the ART Bay Area assessment area in San Francisco, which addresses the Bay shoreline and includes the areas around Islais Creek, Mission Bay, and the Embarcadero. The ART Bay Area assessment focuses largely on the regional transportation assets (Highway 101 and Interstates 80 and 280), and vulnerable communities within the City's PDAs. The assessment also considers impacts to the SFMTA light rail and bus transit system.

Outcomes

This Assessment is using the ART framework to enhance consistency with the regional ART Bay Area program. The findings from both assessments should, therefore, complement and enhance each other and allow San Francisco to better understand how the City-wide vulnerabilities and consequences may impact the overall Bay Area region across the four sustainability frames (Society & Equity, Environment, Economy, and Governance), and conversely, how regional vulnerabilities and consequences may impact the City of San Francisco.

References

Association of Bay Area Governments (ABAG) and San Francisco Bay Conservation and Development Commission (BCDC). 2015. *Stronger Housing, Safer Communities - Strategies for Seismic & Flood Risks Report. Summary Report*. Principal authors D. Brechwald, C. Kroll, W. Goodfriend, and L. Lowe. March. Available at http://resilience.abag.ca.gov/wp-content/documents/housing/Final%20Report/StrongerHousingSaferCommunities_SummaryReport.pdf.

San Francisco Bay Conservation and Development Commission (BCDC). 2019. *Adapting to Rising Tides*. Available at http://www.adaptingtorisingtides.org/.

Photo by Jeremy Menzies, SFMTA

CHAPTER 5

TRANSPORTATION

Transportation, including all the ways people travel within San Francisco, supports economic activity and quality of life.

Residents, commuters, and visitors all use the road network, transit systems, and bicycle and pedestrian infrastructure to get around. People make over four million trips per day on a typical weekday to, from, and within San Francisco by various means – walking, cycling, taking transit, driving, and other travel modes.

San Francisco's local transportation network is overseen primarily by the San Francisco Municipal Transportation Agency (SFMTA), with some overlapping responsibility by San Francisco Public Works (Public Works), the San Francisco County Transportation Authority (SFCTA) and the Port. Regional transportation providers also provide service to, from, and within San Francisco, including AC Transit, BART, CalTrain, Golden Gate Transit, Water Emergency Transportation Authority (WETA), and Sam Trans. The Transbay Joint Powers Authority (TJPA) operates and maintains the Salesforce Transit Center and the Downtown Rail Extension. Each of these agencies has its own capital improvement program. In addition, numerous private mobility services operate on City streets and sidewalks.

The overall transportation network consists of roadways, local and regional transit infrastructure, maintenance and storage facilities, parking, bicycle and pedestrian networks, and an increasing diverse suite of emerging mobility services. The following sections describe the various components of the City's multimodal transportation system and provide information about how key elements of the system may be vulnerable to SLR and coastal flooding.

5.1 ROADWAYS

San Francisco's roadways are a networked system of freeways, and major and minor streets that provide the main pathway for vehicle traffic throughout the City. The transportation network links people with community facilities and services, jobs, family and friends, recreation, and other destinations within the City and throughout the Bay Area region. The City's public ground transportation system (Section 5.3 - 5.5) relies on the roadway network for its safe and reliable operations. The roadways support pedestrian use, bicycling, public transit, vehicle traffic (both commercial and private), and parking. Many roadways within the City are routinely closed to vehicle traffic to support parades, demonstrations, and other recreational uses.

San Francisco's roadway network includes 1,088 miles of roadways and 447 miles of bicycle streets, of which 121 miles are considered the "high-quality bike network."[1]

When roadways are flooded, all transportation modes are affected (e.g., motor vehicles, public transit, bicycles, etc.) and traffic congestion is more likely to occur as traffic is rerouted onto alternate streets, where possible. The roadway surface and subsurface materials can degrade, particularly with repeated inundation by saltwater. As the frequency of flooding increases with SLR, roadways are likely to erode and subside. Electrical components such as traffic signals, lighting, and control systems are particularly sensitive to any inundation. Flooding along roadways can

1 San Francisco Municipal Transportation Agency (SFMTA). https://www.sfmta.com/sites/default/files/reports-and-documents/2019/05/sfmta_2019_bike_program_report.pdf. "High-quality Bike Network" includes bike paths, protected bikeways, neighborways, and buffered bike lanes.

Photo 5.1 San Francisco street. Jeremy Menzies, SFMTA

also provide a conduit for floodwaters to enter utility access holes, vents, underground tunnels, and other low-lying or subsurface infrastructure.

This section describes the roadways that intersect or lie within the SLR Vulnerability Zone, describes their vulnerabilities, and highlights the consequences that could occur if roadway segments are flooded.

5.1.1 Potentially Vulnerable Assets

San Francisco's roadways are classified by their functional use, as described in Table 5.1 and shown in Figure 5.1. The functional use affects the City and roadway users in the event the roadway, or a portion of the roadway, is flooded.

Table 5.1 Functional Transportation Classifications[2]

CLASSIFICATION	DEFINITION
Freeways	Very high-capacity facilities with limited access; primary function is to carry intercity traffic; they may, because of route location, also serve the secondary function of providing for travel between distant sections in the City.
Major Arterials	Cross-town thoroughfares whose primary function is to link districts within the City and to distribute traffic from and to the freeways; these are routes generally of citywide significance; of varying capacity depending on the travel demand for the specific direction and adjacent land uses.
Transit Preferential Streets[3]	Streets with a primary transit function that are not classified as major arterials but experience significant conflicts with automobile traffic.
Secondary Arterials	Primarily intra-district routes of varying capacity serving as collectors for the major thoroughfares; in some cases, supplemental to the major arterial system.
Recreational Streets	A special category of street whose major function is to provide for slow, pleasure drives and cyclist and pedestrian use; more highly valued for recreational use than for traffic movement. The order of priority for these streets should be to accommodate: pedestrians, hiking trails, or wilderness routes, as appropriate; cyclists; equestrians; and automobile scenic driving. Speeds should be slow and consistent with the topography and nature of the area, and there should be adequate parking outside of natural areas.
Collector and Local Streets	**Collector Streets:** Relatively low-capacity streets serving local distribution functions primarily in large, low-density areas, connecting to major and secondary arterials. Also includes streets intended for access to abutting residential and other land uses, rather than for through traffic. **Local Streets:** All other streets intended for access to abutting residential and other land uses, rather than for through traffic; generally, of lowest capacity.
Truck Routes	Designated routes through the City that have, or can accommodate, significant truck traffic for goods movement.

2 These classifications are based on those set by the Federal Highway Administration and adopted by the State of California and the city of San Francisco as documented in the Transportation Element of the General Plan. Source: City of San Francisco Planning Department. San Francisco General Plan, "Table 1: Classification of Elements in Vehicle Circulation Plan." Available at http://generalplan.sfplanning.org/I4_Transportation.htm.

3 Referred to as "Transit Conflict Streets" in the Transportation Element of the San Francisco General Plan

Figure 5.1 Overview of Roadways

Inundation at 108" Sea Level Rise

Freeways

Major Arterials

Transit Preferential Streets

Secondary Arterials

Recreational Streets

Collector and Local Streets

Truck Routes

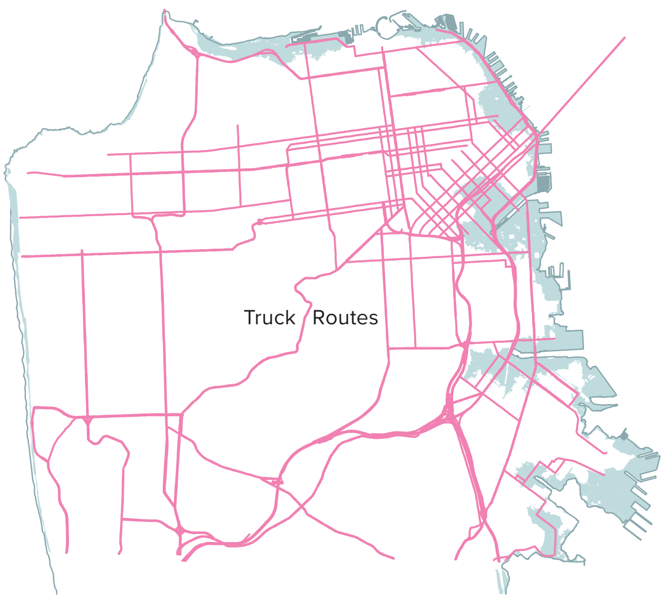


Photo 5.2 **Freeway approach to Bay Bridge.** Thomas Hawk (CC BY-NC 2.0)

Photo 5.3 **Geary Blvd - a major arterial.** Flickcr user eng1ne (CC BY 2.0)

5.1.1.1 Freeways

San Francisco has an urbanized roadway network with a limited number of freeways. Interstate 80 (I-80) enters San Francisco at the western terminus of the San Francisco – Oakland Bay Bridge (Bay Bridge) and continues for four miles until connecting with U.S. Highway 101 (US 101) (see Photo 5.2). I-80 is the only direct roadway link to the East Bay. It connects San Francisco to Oakland and other East Bay cities, and then continues to Sacramento, Reno, and across the country to New Jersey. US 101 operates as a freeway as it enters San Francisco at the San Francisco – San Mateo County line. At the Mission Street / Van Ness Avenue off-ramps, US 101 switches to using arterial streets to connect to the Golden Gate Bridge. US 101 and the Golden Gate Bridge are the only direct roadway link to Marin County and the North Bay. US 101 is also a core connection for commuters between San Francisco and Silicon Valley.

Interstate 280 (I-280) begins south of the Bay Bridge in the South of Market neighborhood, continuing south along the eastern edge of the City, and connecting with US 101 at the Alemany Maze. I-280 extends inland, connecting with California State Route 1 (SR 1) near John Daily Boulevard in Daly City, just south of the San Francisco – Daly City border. I-280 is also a core connection for commuters between San Francisco and Silicon Valley.

I-80 and I-280 are both elevated in areas of potential SLR exposure and, thus, less vulnerable to flooding. However, the footings of the elevated structures may be impacted by temporary flooding by saltwater (e.g., concrete structures may experience enhanced degradation and/or scour). In addition, the on- and off-ramps that connect with surface streets could be impacted through surface flooding. The I-280 on- and off-ramps at 6th and Brannon Street and 5th and King Street are within the SLR Vulnerability Zone. Along I-80, the on-and off-ramps at Fourth, Fifth, Harrison, and Bryant Streets are also within the SLR Vulnerability Zone. Portions of SR 1 are also within the SLR Vulnerability Zone.

Although alternative on- and off-ramps can be used to access the freeways, rerouting traffic increases traffic congestion on City streets. Local and regional public transit also uses the freeways, which would cause additional impacts to the transit system. Regional impacts associated with the freeways are being assessed through the Bay Area Adapting to Rising Tides regional assessment (see Chapter 4, *Supporting Assessments*).

5.1.1.2 Major Arterials

San Francisco is one of the few Bay Area cities with arterial thoroughfares instead of having numerous interstates and highways within the City, due largely to the City's unique geography and the strong public opposition to new freeway construction in the 1960s and 1970s. The arterials are classified as major (i.e., cross-town thoroughfares whose primary function is to link districts within the City and to distribute traffic from and to the freeways), and secondary (i.e., intra-district routes that also serve as collectors for

Photo 5.4 **Market Street - a transit preferential street.** Sergio Ruiz

Photo 5.5 **Jefferson Street, a recreational street in Fisherman's Wharf.** Flickr user Ray_LAC (CC BY 2.0)

the major arterials). Other major east-west arterials include Geary Boulevard, Lincoln Way / Fell Street, and Market Street / Portola Drive (see Photo 5.3). The major arterials are concentrated near the financial district and south of Market Street, and fan out to connect to other neighborhoods.

There is some redundancy and alternatives for primary arterials if impacted by flooding. Traffic could be rerouted onto other streets designed to carry lesser traffic loads; however, this also impacts cross-town traffic.

5.1.1.3 Transit Preferential Streets

Transit Preferential Streets are designed to expedite transit services and specifically the movement of transit vehicles. The red lanes and peak-hour transit lane restrictions associated with the City's Transit Preferential Streets serve to reduce congestion and parking movement-related delays within the designated transit lanes.

Transit preferential streets have limited redundancy, particularly for transit streets with tracks, because track-based transit cannot be rerouted. If vehicle traffic is rerouted onto transit preferential streets during a flood event, significant traffic and congestion impacts could occur.

Transit conflict streets in the SLR Vulnerability Zone include Market Street and Mission Street. These streets exhibit many of the same characteristics as major arterials and carry a significant volume of traffic in addition to significant numbers of transit vehicles. Market Street is a key multimodal transit corridor through core financial and commercial districts with multiple transportation stations (Bay Area Rapid Transit [BART] and Municipal Railway [Muni]) along the route, coupled with automobile and bicycle routes (see Photo 5.4). Market Street is also a key connector between the Ferry Terminal and other modes of transportation.

5.1.1.4 Secondary Arterials

Secondary arterials primarily consist of intra-district routes with varying capacity serving as collectors for the major thoroughfares; in some cases, supplemental to the major arterial system.

There is some redundancy and alternatives for secondary arterials if impacted by flooding. Traffic could be rerouted onto other streets designed to carry lesser traffic loads; however, this also impacts cross-town traffic.

5.1.1.5 Recreational Streets

Recreational streets provide multiple amenities, including park-like atmospheres and scenic views, while also accommodating automobile throughput. The streets tend to have lower speed limits, with a preference for cyclists, pedestrians, and, in some instances, equestrian use.

Although traffic on recreational streets can be rerouted if a portion of the street is flooded, the same user experience would not be provided. Recreational

Photo 5.6 A local city street.

streets provide a place-based use with automobile traffic providing the lowest value of use. Recreational streets in San Francisco include Jefferson and Beach Streets in the Fisherman's Wharf area (see Photo 5.5) and portions of Mason and Lincoln Streets in the Presidio area of San Francisco.

5.1.1.6 Collector and Local Streets

Collector and local streets include all other public roadways for vehicle traffic within the City. This includes collector streets that provide access throughput for low-density urban and residential areas and connect traffic flow with major and secondary arterials. This also includes local streets that are intended for residential access rather than for through traffic. Collector and local streets are typically low capacity and provide short-distance mobility (see Photo 5.6).

There is some redundancy for streets that serve a collector function; adjacent streets outside of flooded areas can provide this function with minor disruption and inconvenience, if they are not transit preferential streets. Rerouting motor vehicle traffic onto streets served by public transit (or by transit vehicles in non-revenue service) will likely increase transit delays and reduce service levels in areas beyond the immediate flooded zone. In addition, for businesses and residents located on impacted local streets, alternative routes would not provide direct access.

5.1.1.7 Truck Routes

Truck routes are a secondary roadway classification that is applied to designate the primary pathway through San Francisco for heavy truck traffic for delivering goods to and from San Francisco. The roadways are usually major arterials and key secondary arterials but can also include all roadway types from freeways to City streets, except for transit priority streets, as truck traffic is generally prohibited on these streets (see Sections 5.1.1.3 and 5.1.1.4).

5.1.1.8 Sidewalks and Pedestrian Facilities

San Francisco sidewalks allow pedestrian travel across the City and provide access to buildings, open spaces, roadways, and public transit. San Francisco sidewalks are typically six to 12 feet wide and have distinct zones that divide the sidewalk space into the pedestrian throughway, street curb, building frontage, and if space allows, street furnishings, planting strips, and lighting. Sidewalks also typically have subsurface utilities with access points for maintenance. Most sidewalks are elevated six to eight inches above the roadway surface and have curb ramps that provide disability access in compliance with the Americans with Disabilities Act (ADA).There are approximately 2,000 miles of sidewalk curb in San Francisco.[4]

In general, new roadways are designed to carry the 100-year flood event within the curb line (i.e., the roadway is intended to carry the floodwaters without flooding the adjacent sidewalk and structures). However, many roadways in San Francisco were constructed before this design criteria became standard practice. Many roadways and sidewalks have subsided and impacted their drainage potential, and in some areas roadways repairs and re-grading efforts have reduced flood capacity of the street.

Sidewalks are generally not sensitive to flooding and can resume their function once floodwaters recede; however, during flood events, accessibility and safety are issues. Traffic and pedestrian signals have conduits below grade and control boxes at grade that may be sensitive to flooding. Sidewalks have minimal adaptive capacity for flooding because they cannot be easily raised and need to consider ADA accessibility and maximum slope restrictions when meeting the roadway.

4 Based on a GIS analysis performed for the Citywide Infrastructure Level of Service Study, by Hatch Economics, 2019. Counting both sides of the street (but not accounting for breaks in the sidewalk where intersections may be), equals 2,267 linear miles of sidewalk curb, discounted by 10% to account for intersections.

5.1.1.9 Bicycle Facilities

San Francisco has 447 miles of streets on the bike network[5], of which 121 miles are counted as part of the "High-Quality Bike Network."[6] San Francisco bikeways are classified using the Caltrans classification system, as shown in Table 5.2. Bikeway designations are not a hierarchy. Each class of roadway has its appropriate application.

Bicycle lanes and bikeways can experience flooding without significant damage; however, there are impacts to accessibility and safety until floodwaters recede. During flood events, alternative bikeways and shared roadways can be used for bike mobility if needed; however, disruptions will occur. Similar to roadways, bicycle lanes have minimal adaptive capacity to adapt to flood events (Photo 5.7).

5 https://www.sfmta.com/sites/default/files/reports-and-documents/2019/05/sfmta_2019_bike_program_report.pdf; Mileage counts for bike network are directional: a 1-way street is counted as one mile, a two-way street is counted as two miles

6 "High-quality Bike Network" includes bike paths, protected bikeways, neighborways, and buffered bike lanes.

Photo 5.7 A protected bicycle lane on the Embarcadero. Sergio Ruiz

Table 5.2 California Department of Transportation Bikeway Classifications

CLASSIFICATION	DEFINITION
Shared Roadway (No Bikeway Designation)	Bicycle travel in the State occurring on streets and highways without bikeway designations. Street systems considered adequate for safe and efficient bicycle travel.
Bike Path (Class I Bikeway)	Bike paths providing mobility corridor that is not served by streets and highways or where a wide right-of-way exists to allow a bike path to be constructed away from the influence of parallel streets. Bike paths also offer recreational opportunities or serve as direct high-speed commute routes if cross-flow by motor vehicles and pedestrian conflicts is minimized. Commonly located along waterways, abandoned railroad rights-of-way, or within and between parks.
Bike Lane (Class II Bikeway)	Bike lanes are established along streets in corridors where there is significant bicycle demand. Bike lanes delineate the right-of-way assigned to bicyclists and motorists to provide for more predictable movements by each.
Bike Route (Class III Bikeway)	Bike routes are shared facilities which serve either to provide continuity to other bicycle facilities (usually Class II bikeways); or designate preferred routes through high-demand corridors. Bike routes are shared with motor vehicles; the routes are maintained consistent with the needs of bicyclists.
Separated Bikeways (Class IV Bikeway)	Separated bikeways are intended for the exclusive use of bicycles and require a separation between the bikeway and the through vehicle traffic. The separation may include, but is not limited to, grade separation, flexible posts, inflexible posts, inflexible barriers, or on-street parking.

Source: Caltrans. 2015. California Highway Design Manual. Available at http://www.dot.ca.gov/design/ manuals/hdm/chp1000.pdf.

Since 2006, bicycling has increased 184 percent with approximately 82,000 bicycle trips occurring around San Francisco daily.[7] In 2015, biking comprised 4.3 percent of all commute trips.[8] To accommodate the rapid growth in bicycling across San Francisco, SFMTA has focused on improvements to bicycle infrastructure through protected bikeways (bicycle lanes), neighborways, and streetscape projects. Protected bicycle lanes are physically separated from vehicle traffic using flexible posts, concrete barriers, or parking lanes. Neighborways are residential streets redesigned to promote increased foot and bicycle traffic. Streetscape projects are large-scale street plans that make streets safer through upgraded utilities, transit amenities, and lighting.

7 San Francisco Municipal Transportation Agency (SFMTA). 2016. 2015 Transportation Fact Sheet. Available at https://www.sfmta.com/reports/2015-transportation-fact-sheet.

8 San Francisco County Transportation Authority (SFCTA). 2017. San Francisco Transportation Plan 2040. Available at https://www.sfcta.org/san-francisco-transportation-plan-2040-plan-details.

As of 2017, San Francisco has 5,200 bicycle racks and 70 bicycle corrals dispersed throughout the City. By 2021, an additional 2,500 bicycle racks and 50 corrals are planned. Bicycle parking infrastructure that allows bikes to be secured is primarily made of durable metal structures with no mechanical or electrical equipment required for operation. Therefore, bicycle parking infrastructure has low sensitivity to flooding. Bicycle-share stations are discussed in Section 5.6.

5.1.2 Exposure Assessment

The exposure of each roadway and roadway right-of-way type was evaluated relative to the 10 SLR scenarios (see Chapter 2). The mileage of roadway type that could be inundated under each scenario was calculated and is presented in Table 5.3. The mileage of inundated roadway right-of-way access is presented in Table 5.4.

Table 5.3 Roadway Exposure Summary (Miles Inundated)

Roadway Type	Miles of Roadway within Each Sea Level Rise Scenario									
	1	2	3	4	5	6	7	8	9	10
Freeways[9]	-	-	-	0.1	0.4	1.6	2.4	2.8	3.9	5.0
Major Arterials	-	-	0.1	0.8	1.1	6.4	7.6	8.2	9.6	10.9
Transit Preferential Streets	-	-	-	0.1	0.2	0.6	0.7	0.8	0.9	1.0
Secondary Arterials	-	-	-	-	0.1	0.7	1.0	1.4	2.2	3.3
Recreational Streets	-	-	0.2	0.3	0.7	1.8	2.4	2.5	2.5	2.6
Collector and Local Streets	-	0.2	4.7	8.7	14.1	32.2	41.0	46.1	53.1	60.1
Truck Routes	-	-	0.1	0.9	1.9	6.7	8.5	9.3	11.3	13.5

Table 5.4 Bicycle Facility Asset Exposure Summary (Miles Inundated)

Bicycle Facility	Miles of Bicycle Facility within Each Sea Level Rise Scenario									
	1	2	3	4	5	6	7	8	9	10
Bike Path (Class I)	0.1	0.1	0.4	1.8	3.2	11.5	16.6	17.4	17.9	18.3
Bike Lane (Class II)	-	-	0.1	1.2	3.6	9.9	13.6	14.9	16.9	18.8
Bike Route (Class III)	-	-	0.9	1.4	2.2	7.3	8.6	9.7	12.0	13.7
Separated Bikeway (Class IV)	-	-	-	-	-	0.2	0.4	0.6	0.9	1.2

9 As noted in text, freeways are generally elevated, but freeway supports and ramps may be affected by SLR. This number represents all freeway miles within the SLR Vulnerability Zone.

5.1.3 Consequence Summary

This report evaluates key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: Flooded roadways affect all transportation modes (i.e., motor vehicles, public transit, bicycles, etc.) and can cause traffic congestion on alternate streets. Critical access in neighborhoods and through traffic in large areas of the City would be impeded, affecting the ability to respond to emergencies, and everyday life. Degradation of the roadway surface and subsurface materials from repeated inundation by saltwater further stress an already stressed system and can cause additional road closures due to repairs. As the frequency of flooding increases with SLR, roadways are likely to erode and subside. Electrical components such as traffic signals, lighting, and control systems are particularly sensitive to any inundation. Flooding along roadways can also provide a conduit for floodwaters to enter utility access holes, vents, underground tunnels, and other low-lying or subsurface infrastructure. Permanent inundation would make roadways and the neighborhoods and destinations to which they provide access inaccessible.

Society and Equity: The number of vehicles using a roadway provides a good proxy for magnitude of impact. Freeway disruption impacts commuter traffic (person vehicles, car shares, public transportation, etc.), resulting in more dangerous road conditions, longer commute times, missed work days, and regional economic impacts on the labor force. I-80 and I-280 are also designated lifeline routes[10] and access is critical both before and after an emergency event.

Disruption along major and secondary arterials will impact commuters, cross-town traffic, local businesses, and residents. It could also result in longer transit times for emergency access vehicles, resulting in delays in lifesaving healthcare, fire suppression, and police support. Flooded roadways could also impair the City's ability to clear roadways after an earthquake. Clearing roadways is generally the first step to bring back other essential functions, such as power and water supply.[11]

Along transit preferential streets, such as Market Street, and other streets with fixed transit lines inaccessible portions of the roadway could cause major delays of critical public transportation routes and affect connections with regional transit links.

Disruption along City streets can impact residential access to home, school, work, local services, and parks, and can impact emergency vehicle access to residents. Inaccessible City streets in disadvantaged neighborhoods will be particularly impactful on community mobility, including access to public transportation, paratransit, schools, healthcare, and access to services and jobs. Flooding will likely require rerouting local buses and transit, impacting residents and causing delays in commute times.

Disruption to roadways could prevent or inhibit access to healthcare services (at a facility or in-home care); this may disproportionately impact disadvantaged communities, the elderly, young children, and those with pre-existing medical conditions. Disruption to roadways will also increase congestion on alternative routes, impacting traffic, travel times, and increasing the likelihood for accidents as well as exposing neighborhoods adjacent to alternate routes to more air pollution and associated health problems. Restrictions to sidewalk access during flood events can adversely impact pedestrian safety.

10 The criteria for state lifeline route designation include providing emergency relief access through or across a potentially impacted region, connecting major population centers within the region; for areas with more than one route providing interregional access, the route provides the most effective emergency relief access; providing direct or nearby access to and from major emergency response and recovery supply centers and staging areas; and providing access to an airport (military or civilian), seaport, major rail facility, or a major distribution center that would be involved in immediate relief activities. Source: Caltrans. Purpose and Need for Project, "Lifeline Structure." Available at http://www.dot.ca.gov/dist4/sfobb/PurposeandNeed.html.

11 The Lifelines Council of the City and County of San Francisco. 2014. Lifelines Interdependency Study. Report. April. Available at https://sfgov.org/orr/sites/default/files/documents/Lifelines%20Council%20Interdependency%20Study.pdf.

Limited alternate bike routes are available, and some routes may shift to shared roadways with vehicles. Alternate routes would have increased congestion and limited bike facilities, leading to potentially unsafe conditions for bicyclists. Bicycle commuters may shift to other transportation means, such as public transportation or personal vehicles.

Moped and e-bicycle charging stations would be inaccessible in flooded areas. Although moped and e-bicycles can be returned to charging stations in non-impacted areas, charging spaces could be limited. Mopeds and e-bicycles in the flooded areas would be inaccessible (and may be permanently damaged by floodwaters) for check out by local commuters and tourists. Safety issues could arise if commuters and tourists attempt to access charging stations in flooded areas.

Economy: If short- or long-term flooding occurs and causes freeway disruption, this can impact the movement of goods. This can also impact public transportation revenue (due to less workers flowing in/out) or shift revenue between agencies (e.g., from bus to BART). Disruption along transit preferential streets can cause delays and a reduction in transit agency revenue (i.e., decreased fares or ridership).

Disruption to truck routes can result in the delay or prevention of goods distribution and deliveries of commercial facilities, grocery stores, medical facilities, etc. Trucks are not as easily rerouted as other vehicles due to weight restrictions on potential alternate routes.

Disruptions along major and secondary arterials can impact patronage and access to local businesses adjacent to impacted routes. The flow of people in and out of the City will be impacted. Damage to the multimodal system will also require additional capital and operating funds to both protect and repair damage from flood events.

Environment: Flooded roadways may be contaminated by oil, gas, and other spilled substances. These contaminants will be mobilized and may drain to the sewer system, open space, wetland habitats, or directly to the ocean and Bay. Neighborhoods adjacent to alternate routes could be exposed to more air pollution from additional vehicles and associated congestion.

Governance: Managing and identifying alternate routes for vehicle traffic, public transportation, and truck routes may be a challenge during an extreme event. Identifying funds for the planning and repairs to damaged infrastructure will also require working with local, regional, state and federal partners.

5.2 BRIDGES

San Francisco's bridges provide vehicular, railroad, public transit, and bicycle/pedestrian access across waterways and/or above other City streets or parkways to connect adjacent areas. San Francisco bridges include four drawbridges, the Bay Bridge, and the Golden Gate Bridge (Photo 5.8). Although bridges are generally elevated structures, and vehicle traffic flow on the bridges may be above the floodwaters, the bridge supports (e.g., pilings, steel trusses), abutments, and bridge on- and off-ramps may be impacted by flooding at ground level or by an elevated water surface within the waterway itself.

The four drawbridges are vulnerable to SLR and coastal flooding, and the elevated approach to the Bay Bridge is also vulnerable. The Golden Gate Bridge abutment in San Francisco is elevated on a hill and located outside of the SLR Vulnerability Zone. The vulnerability of the Golden Gate Bridge's supporting structures to SLR was not evaluated as part of this Assessment.

This section describes the bridges that intersect or lie within the SLR Vulnerability Zone, describes their vulnerabilities, and highlights the consequences that could occur if these assets or their companion roadway segments (Section 5.1) are temporary flooded or permanently inundated.

5.2.1 Potentially Vulnerable Assets

The City of San Francisco has four drawbridges, including three historic drawbridges that were constructed in the early- to mid-19th century. Two drawbridges (Lefty O'Doul Third Street Bridge and Peter R. Maloney Fourth Street Bridge) cross the Mission Creek Chanel, and two drawbridges (Illinois Creek Bridge and the Third Street Bridge) cross the Islais Creek channel. Historically, these waterways extended farther inland and supported ship traffic, earning them a designation of a "navigable waterway." Over time, the upstream portions of both waterways were filled in and culverted (i.e., constrained in pipes below ground) and only the downstream tidal portions of both channels remain.

Photo 5.8 Bay Bridge approach. Todd Lappin (CC BY-NC-ND 2.0)

Because the designation of a navigable waterway remains, the U.S. Coast Guard regulates drawbridge operations and requires the drawbridges to remain in operational condition.

5.2.1.1 Lefty O' Doul Bridge

Lefty O'Doul Bridge on Third Street is a moveable bridge (i.e., drawbridge) that crosses Mission Creek Channel and connects the Mission Bay and China Basin neighborhoods (see Photo 5.9). It was completed in 1933 and is a registered San Francisco landmark (#194). The drawbridge allowed for cargo ship traffic to access the north bank of Mission Creek where bananas were offloaded and processed through the 1950s. In the 1960s, a community of about 35 boats and 20 houseboats was relocated from Islais Creek to Mission Creek; since the 1960s, the primary ship traffic through Mission Creek is recreational boaters. Currently, the drawbridge is undergoing mechanical and structural rehabilitation and is closed to navigation.

The bridge has five lanes that provide vehicular and shared bicycle mobility in addition to separated pedestrian walkways. There are three northbound lanes and two southbound lanes with no left turn onto Terry Francois Street. Future plans include a two-way cycle track on the easternmost lane. Lefty O'Doul Bridge has a single-level deck with structural components (support piles, steel trusses), mechanical components (counterweights, motors), and electrical components that allow the bridge to open for ship navigation in Mission Creek. Inundation of the mechanical or electrical components could impact bridge operations, although they are located at a higher elevation than the bridge deck.

The area surrounding Mission Creek is built on fill, and subsidence of the bridge approach slabs could increase with repeated flooding and increased high tides. Total and differential settlement due to subsidence of fill could adversely impact operation of the bridge. The lower portion of the bridge span already experiences submergence during present-day high tides; during very high tides, bearing plates and anchor bolts at the bridge pier become submerged and can reach the bottom flange of the main bridge stringers. Some high tides also overtop the concrete pier.

There is limited redundancy for bridges. Inland roadways can provide alternative routes for street traffic. However, Third Street is one of the primary north-south corridors on the southeast side of the City. Closures along Third Street would increase traffic and congestion. If drawbridge operations are impacted and the bridge cannot open for navigation, the primary impact would be to the houseboat community. Bridge operations may resume after floodwaters recede and inspections are completed.

Lefty O'Doul bridge will be inundated on the south side at Scenario 2 (24 inches of SLR or 12 inches of SLR and an annual extreme high tide with a 1-year recurrence interval) and on both sides at Scenario 4 (48 inches of SLR or six inches of SLR and a 100-year extreme tide).

5.2.1.2 Peter R. Maloney Fourth Street Bridge

Peter R. Maloney Bridge on Fourth Street is a drawbridge that crosses the Mission Creek Channel to connect the Mission Bay and China Basin neighborhoods. The bridge was completed in 1917 and is a registered historical landmark. Bridge rehabilitation work was completed in 2007; the rehabilitation included earthquake retrofitting, replacing mechanical and electrical operating equipment, and the addition of trackwork and an overheard catenary and traction electrification system to support the San Francisco Municipal Railway (Muni) T-Line public transportation route. Fourth Street Bridge is located inland (i.e., upstream or west) of Third Street Bridge (see Section 5.2.1.4).

This bridge has multiple vehicular lanes, supports the Muni T-Line, and has separated pedestrian and bicycle access. Fourth Street Bridge has a single-level deck and structural components (support piles, steel trusses), mechanical components (counterweights, motors), and electrical components that allow the bridge to open for ship navigation through the Mission Creek channel. Inundation of the mechanical or electrical components could impact bridge operations.

Similar to Lefty O'Doul Bridge, the drawbridge no longer supports cargo ship traffic within the channel. The primary ship traffic within the Mission Creek

Photo 5.9 **Lefty O'Doul Bridge.** Don Barrett (CC BY-NC-ND 2.0)

Photo 5.10 **Fourth Street Bridge.** Jim Maurer (CC BY-NC-ND 2.0)

channel is related to the sail boats docked near the houseboat community. In addition, houseboats may be moved out of the channel under the drawbridges for repair and/or maintenance (i.e., houseboats can be hauled out of the water at a shipyard for significant rehabilitation or repair).

The area surrounding Mission Creek is built on fill, and subsidence of the bridge approach slabs could increase with repeated flooding and increased high tides. There is limited redundancy for bridges. Inland roadways can provide alternative routes for street traffic.

Fourth Street is one of the primary north-south corridors on the southeast side of the City (Photo 5.10). Closures along Fourth Street would increase traffic and congestion. The Muni T-Line is track-based and could not be rerouted. If drawbridge operations are impacted and the bridge cannot open for navigation, the primary impact would be to the houseboat community.

Fourth Street bridge will be inundated on the south side at Scenario 2 (24 inches of SLR or 12 inches of SLR and an annual extreme high tide with a 1-year recurrence interval) and on both sides at Scenario 3 (36 inches of SLR or 12 inches of SLR and an annual extreme high tide with a 5-year recurrence interval).

5.2.1.3 Illinois Street Bridge

Illinois Street Bridge is a drawbridge that crosses the Islais Creek channel and connects the Hunter's Point/Bayview and Central Waterfront/Dogpatch neighborhoods. Illinois Street Bridge is the City's newest drawbridge. It was completed in 2006 and primarily serves to provide railroad and heavy truck access to Piers 90-96 (see Chapter 11, *Port of San Francisco*), while also relieving congestion on Third Street. The bridge includes two vehicle traffic lanes, a shared centerline railroad track, and separate bicycle/pedestrian lanes.

Unlike the historic truss design drawbridges, Illinois Street Bridge has a modern and low-profile design. It is operated by hydraulic cylinders that raise the bascule (i.e., bridge "leaf") 84 degrees to provide a navigable channel for boat traffic. This bridge is rarely opened and requires 72 hours advance notice for it to open. Historically, Islais Creek served as a docking area for World War II ocean-going vessels, and hosted cargo ships for transporting coconuts to a nearby coconut processing plant and sardines to support the local sardine canning industry. Today, Islais Creek channel does not support any commercial shipping industries inland of the drawbridges.

The lower portion of the bridge could experience submergence during present-day high tides. There is limited redundancy for bridges. Although inland roadways can provide alternative routes for light vehicle traffic, there are limited routes for heavy truck traffic, and no alternate routes for the railroad corridors or routes that could provide redundancy for street traffic, including Islais Creek Bridge. Closures along Illinois Street would increase traffic and congestion for the remaining transit network.

Photo 5.11 Islais Creek/Third Street Bridge. Craig Philpott

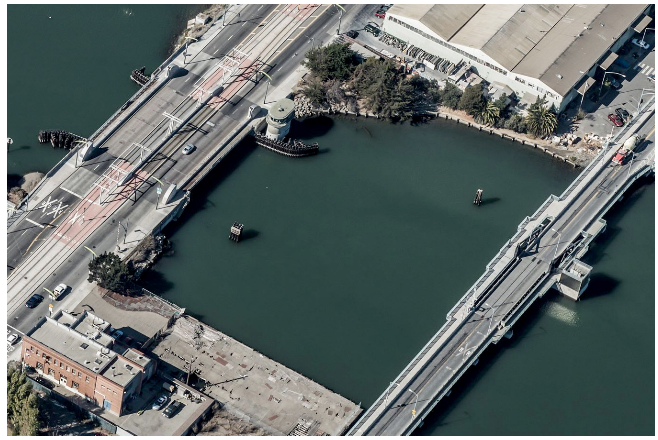


Photo 5.12 Aerial view of the Islais Creek/Third Street Bridge (left) and the Illinois Street Bridge (right). Bing Maps

This bridge access will be partially inundated at Scenario 4 (48 inches of SLR or six inches of SLR and a 100-year extreme tide) and completely inundated at Scenario 5 (52 inches of SLR or 12 inches of SLR and a 100-year extreme tide).

5.2.1.4 Islais Creek Third Street Bridge

Islais Creek Bridge on Third Street (a.k.a., the Levon Hagop Nishkian Bridge, and more commonly known as Third Street Bridge) is a drawbridge crossing the Islais Creek channel directly west of Illinois Street Bridge (Photos 5.11 and 5.12). This bridge also connects the Hunter's Point/Bayview and Central Waterfront/Dogpatch neighborhoods. This drawbridge was completed in 1945 to replace a previous drawbridge at the same location. Unlike the other three bridges that have a single bascule, Third Street Bridge is a double-bascule bridge (i.e., it has two bridge leafs that open, one on each side). Similar to Illinois Street Bridge, there is rarely a need to open Third Street Bridge to support boat traffic.

The bridge supports four lanes of vehicle traffic (two lanes in each direction) with the track-based Muni T-Line in the center. The bridge has separated lanes for bicycle/pedestrian access. Islais Creek Bridge has a single-level deck with structural components (support piles, steel trusses), mechanical components (counterweights, motors), and electrical components that allow the bridge to open for ship traffic. Flooding of underground tunnels and equipment rooms can occur if access openings are not floodproofed.

There is limited redundancy for bridges. Inland roadways could provide alternative routes for street traffic. However, Third Street is one of the primary north-south corridors on the southeast side of the City. Closures along Third street would increase traffic and congestion. This bridge also carries the Muni T-Line, which is track-based public transit and cannot be rerouted.

This bridge is partially inundated with flooding on the road leading to it at Scenario 5 (52 inches of SLR or 12 inches of SLR and a 100-year extreme tide) and completely inundated at Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide).

5.2.1.5 Bay Bridge Approach

The Bay Bridge is the primary connector between San Francisco and the East Bay. Within the City, the approach to the Bay Bridge includes elevated structures that are within the SLR Vulnerability Zone. Like the smaller City drawbridges, the support pilings and other structural members could be impacted by flooding at ground level.

The Bay Bridge approach is a 1-mile stretch of I-80 that leads to the Bay Bridge, carrying approximately 270,000 vehicles daily[12] between San Francisco and the East Bay, and supporting commuter and goods movement for the region. The approach begins as two single-level concrete decks in parallel starting at Fifth Street and transitions into a double-deck design,

12 Caltrans. 2019. The San Francisco/Oakland Bay Bridge. Available at http://www.dot.ca.gov/hq/esc/tollbridge/SFOBB/Sfobbfacts.html. Accessed July 2018.

Table 5.5 Bridge Exposure Summary

Bridge	Approach Inundated (Y/N) within Each Sea Level Rise Scenario 1	2	3	4	5	6	7	8	9	10
Lefty O'Doul	-	●	●	●	●	●	●	●	●	●
Peter R. Maloney Fourth Street Bridge	-	●	●	●	●	●	●	●	●	●
Illinois Street Bridge	-	-	-	●	●	●	●	●	●	●
Islais Creek/Third Street Bridge	-	-	-	-	●	●	●	●	●	●
Bay Bridge Approach	-	-	-	-	-	●	●	●	●	●

each with their own independent column and foundation support systems. Although most of the approach infrastructure is not sensitive to flooding, the concrete foundations and supports could be impacted by prolonged exposure to saltwater.[13]

The approach to the Bay Bridge from Fremont Street is not exposed in any scenario. The approach on Fifth Street between Bryant and Harrison is inundated under Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide).

There are no good alternative routes for the Bay Bridge approach if street-level sections are flooded. If motorists want to avoid the congestion that would stem from only having one functioning access ramp available (at Fremont Street), they would have to drive around the Bay via San Jose or access San Francisco via other major bridges, such as San Mateo Bridge to the south, or Richmond-San Rafael Bridge and Golden Gate Bridge to the north, further increasing existing traffic on those roadways. Drivers could also convert to using public transit that is not dependent on the Bay Bridge, such as BART or ferry services, if those services remain functional.

5.2.2 Exposure Assessment

The exposure of the bridges was evaluated qualitatively relative to the 10 SLR scenarios (see Chapter 2). The assessment evaluated if the bridge approach (i.e., the roadway leading up to each bridge) was inundated, under the assumption that if the bridge approach is inundated, the bridge would be out of service until floodwater recedes. Table 5.5 presents the bridge exposure summary. A more detailed assessment of bridge exposure would consider the elevation of the lowest structural member over open water, as well as the elevation of mechanical or electrical controls. This information was not available at the time of the assessment.

5.2.3 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE 1: Reduced access to the Bay Bridge approach would cause cascading consequences that could extend far beyond the localized approach and cause congestion and reduced mobility in other cities as vehicles would likely be rerouted across the Golden Gate and San Mateo bridges. Regional transit would be severely impacted if access to the Bay Bridge is reduced and it could cause overcrowding on alternative roadways or on public transit such as BART, Caltrain, and the ferry system.

KEY ISSUE 2: Flooding would cause increased congestion and impaired people and goods movement, particularly around the Oracle Park, King Street Station, and the Mission Bay area, affecting the drawbridges. San Francisco public transit options that run across the drawbridges are on

13 The portions of concrete foundations discussed here are made from uncoated concrete. They are not currently adapted to saltwater submergence.

fixed rail and unable to be rerouted; buses would be needed to replace light rail cars. These buses would need to be rerouted to alternative streets, meaning that some stops would no longer be served.

KEY ISSUE 3: The drawbridges are built on fill, and subsidence of the bridge approach slabs could increase with repeating flooding and increased high tides. Total and differential settlement due to subsidence of fill could adversely impact operation of the bridges. Flooding could also impact the electrical controls of the bridges, which would be of most consequence for any boaters relying on the drawbridges to remain functional.

Society and Equity: Disruption or blocked access to the Bay Bridge approach would impact commuter traffic (e.g., personal vehicles, car shares, and public transportation, etc.), resulting in longer commute times, missed work days, and would have regional economic impacts on the labor force.

Bridge closures of the drawbridges on the major arterials, Third and Fourth Streets, due to flooding or subsidence repair work, would impair person and goods movement and increase traffic and congestion on alternative routes. Congestion impacts would also increase if both Mission Bay bridges and/or if both Islais Creek bridges are closed. Fourth Street carries the Muni T-Line (track-based rail) which cannot be rerouted. It serves several already vulnerable communities that would have to contend with reduced and rerouted public transit, which may result in missed work time and other mobility limitations for the local residents.

Treasure Island residents dependent on Muni's 25 Treasure Island Service would be directly impacted by inundated streets and reduced Bay Bridge Access.

The local houseboat community in Mission Bay would also be impacted if the drawbridges were no longer in operation. The sail boats would not be able to leave the channel, and the houseboats themselves could not be moved out of the channel for service or repairs.

Economy: Reduced Bay Bridge access would impact the ability of commuters to reach their jobs and impair regional labor economies.

Goods movement would be impacted for truck traffic and rail traffic if the local bridges are closed to through traffic. As Fourth Street serves as a truck route with significant truck traffic, bridge closures would impair goods movement and increase traffic and congestion on alternative routes. Truck traffic may be more difficult to reroute because there are weight limitations on some of the potential alternate routes.

Illinois Street is a City street, and a truck route for providing heavy truck access to Piers 90-96. The bridge also has rail tracks for cargo traffic from Piers 90-96, and the rail line connects with the regional Union Pacific Railroad to the South Bay. Bridge closure would increase traffic and congestion on alternative routes (although not as much as a Third Street Bridge closure). The rail line cannot be rerouted, creating economic impacts to dependent industries. Congestion impacts would increase if both Islais Creek bridges are closed, causing time delays and higher transportation costs. Damage to the bridges will also require additional capital and operating funds to both protect and repair damage from flood events.

Environment: Increased traffic due to rerouted bridge access, congestion, or conversion to private or shared vehicles from public transit would lead to higher greenhouse gas emissions.

Governance: The bridges and associated infrastructure are overseen by different agencies, including the Port, Public Works, SFMTA, and CalTrans. There is also jurisdictional oversight of the drawbridges and navigable waterways by the United States Coast Guard. Interagency coordination will be imperative for drawbridge closures or financing of repairs.

5.3 LOCAL PUBLIC TRANSPORTATION

San Francisco's network of Muni buses, light rail trains, historic streetcars, and cable cars covers all corners of the City. SFMTA has one of the most diverse transit fleets in the world and is also the most environmentally sustainable multimodal fleet in California. The network consists of 54 bus lines, 17 electric trolley bus lines, six light rail lines that operate above and below ground, three cable car lines, and two historic streetcar lines. SFMTA's daily transit ridership is approximately 700,000 passengers.

The network also relies on increasingly data-driven communication infrastructure, which allows users to stay informed in real time about next-bus arrivals, transit delays, and traffic interruptions, for example through the website 511.org. This system relies on technology, power, and the telecommunication system to work, which may be a vulnerability. The transit system relies heavily on the energy grid which can be impacted by flood events. Disruptions to the power system would lead to disruptions to transit service as well.

If they stay operational, these communications systems can be very useful in warning of traffic disruptions and providing alternate routes for motorists and public transit users. San Francisco's network connects with regional transportation services, such as BART, Caltrain, SamTrans, Golden Gate Transit, Alameda-Contra Costa Transit (AC Transit), Amtrak, Greyhound, and the ferry systems operating at Pier 41, the Ferry Building, and Oracle Park by Golden Gate Ferry and the San Francisco Bay Ferry (see Section 5.5, *Regional Transit*).

5.3.1 Potentially Vulnerable Assets

5.3.1.1 Buses

SFMTA is replacing aging vehicles with low-floor biodiesel-electric hybrid buses. The new hybrids run on B20, a blend of diesel and biodiesel, which is made from recycled oil and fat. The 30-foot, 40-foot,

Photo 5.13 Passengers boarding a Muni bus on Market Street. Jeremy Menzies, SFMTA

Photo 5.14 **Electric trolley buses.** Jeremy Menzies, SFMTA

and 60-foot biodiesel and biodiesel-hybrid buses help connect surrounding communities with central San Francisco. This bus fleet includes 477 vehicles from various manufacturers and is the backbone of SFMTA's Muni service (see Photo 5.13), carrying over 40 percent of the public transportation system's riders.

Although some bus lines also operate on US 101 and I-280, the bus lines generally operate on local streets, which can be impacted by localized flooding (see Section 5.1, *Roadways*). Buses can be moved out of the inundation zone to safety during temporary flood events and bus routes can be rerouted to avoid areas of flooding. This would impact specific bus routes and all bus stops within flooded areas.

Buses can also be used to provide adaptive capacity for other types of public transit during a flood event. For example, if BART or the light rail is taken out of service during a flood event, additional buses can be brought into service to provide temporary alternative transportation for passengers. Because San Francisco has a limited diesel bus reserve fleet with spare buses (per federal rules associated with capital funding), any buses used to replace Muni or BART rail service will likely be pulled from other bus routes, reducing service on those lines. Finding enough drivers to operate additional buses is also critical and may be challenging during a flood event.

5.3.1.2 Electric Trolley Buses

Electric trolley buses operate citywide on a fixed overhead line network that provides the electricity to power the trolley buses (see Photo 5.14). These zero-emission vehicles carry about 30 percent of the public transportation system's riders and operate on local streets that can be impacted by localized flooding (see Section 5.1, *Roadways*).

Electric trolley bus routes have been disrupted during temporary precipitation-driven flood events, and additional routes along the waterfront are projected to be inundated as sea levels rise. Although the trolley buses themselves can be moved to safety during a flood event, unlike standard buses, electric trolley buses are not as easy to reroute along adjacent streets as a connection to the overhead line is required to maintain service.[14] If a portion of the route is impacted by flooding, the service along a much larger portion of the route may be impacted.

14 Trolley buses can use battery power to operate off the overhead lines. However, this range is limited. When off the wires, trolley coach operation depletes both electricity and air reserves. Braking, doors, and wheelchair ramps use air. In congested traffic and down hills, trolleys will be forced to brake often, quickly depleting air reserves. Driving up hills will require more electricity usage than driving on flat ground. The manufacture claims the new trolleys can go up to six miles on battery power, but that is based on flat terrain without braking much, if at all, reducing the off-grid radius in San Francisco.

Photo 5.15 **Cable car.** Matthew Black (CC BY-SA 2.0)

Photo 5.16 **Historic streetcar on the Embarcadero.** Dennis Jarvis (CC BY-SA 2.0)

To provide traction power to the OCS (Overhead Contact System) as well as electricity to traffic signals, SFMTA operates and maintains major duct banks which consist of a series of concrete-encased electrical ducts. A duct bank is an assembly of conduits or ducts installed between structures or buildings to protect electrical wiring. The duct bank is used for traction power and communications infrastructure. In general, duct banks can withstand rain driven flood events. However further study is warranted to better understand their sensitivity and performance under projected sea level rise scenarios.

Service may also be disrupted during power outages as they rely on the energy grid. Buses can provide service along alternate routes during disruptions if sufficient buses are readily available; however, this likely requires pulling buses from other routes, reducing service on those lines. Finding enough drivers to operate additional buses is also critical and may be challenging during a flood event.

5.3.1.3 Cable Cars

Cable cars operate on fixed routes on select lines along Market, Powell, Hyde, California, and other Streets. Cable cars were invented in San Francisco nearly 150 years ago and were named a historic landmark in 1964 (see Photo 5.15). The cars are hauled by a continuously moving cable running at a constant speed located just below street level. Individual cars stop and start by releasing and gripping the cable. The cable car lines are all powered from the Washington-Mason Powerhouse at 1201 Mason Street. Each cable has its own drive machinery at the powerhouse.

Two cable car lines are within the SLR Vulnerability Zone: the California Street line terminus near California and Drumm Streets and the Powell/Mason Street line terminus at Bay and Taylor Streets. Exposure to saltwater would likely increase the corrosion rate of the cables, resulting in an increased need for inspection and maintenance. The cable car terminals include underground pits which are designed for minimal water intrusion. The pits contain sump pumps that become overburdened easily and are not designed to pump saltwater, only freshwater or rain runoff. Cable cars can continue to operate during minimal flooding[15]; however, operation would likely cease until floodwaters recede for safety reasons. Cable cars are currently not used during severe weather.

Buses can provide alternative service during disruptions if enough buses are available and conditions allow; however, buses would not provide the same user experience. If the California and Drumm Street terminus is impacted, it may not have systemwide disruptions on the cable car system because cars can reverse direction prior to the impacted area. Although there is a switchback on California between Montgomery and Kearny, it is rarely used. During parades or other events that make the California Street/Drumm terminal unusable, cable cars are usually temporarily replaced with buses.

5.3.1.4 Historic Streetcars

Historic streetcars operate on Market Street (F Line) and the Embarcadero (E Line) (see Photo 5.16). The

15 The standard used in San Francisco is whether the operator can see the top of the rails.

Photo 5.17 **Muni light rail.** Jeremy Menzies, SFMTA

Photo 5.18 **Embarcadero Station.** BrokenSphere (CC BY-SA 3.0)

streetcars operate on tracks along the roadway, with some track sections separated from the regular auto traffic on dedicated streetcar right-of-way.

Service on the historic streetcar lines has been disrupted due to precipitation-based flooding in the past. Historic streetcar routes are projected to be inundated by SLR along the Embarcadero waterfront, Don Chee Way, Steuart Street, and Market Street. If a portion of the route is flooded, the entire streetcar line would not operate until after the floodwaters recede. There is limited redundancy or alternatives for the historic streetcar lines. Buses could provide alternative service during disruptions; however, if the historic streetcar routes are inundated by floodwaters, bus operations would be impacted similarly, and service would be reduced on other lines as buses are redeployed. Like other rail vehicles, service can continue to operate during minimal flooding. More severe flooding would trigger a disruption in service.

5.3.1.5 Muni Metro Light Rail / Subway / BART

The Muni Metro light rail system includes 71.5 miles of standard-gauge track, seven light rail lines (six regular lines and one peak-hour shuttle), three tunnels, nine subway stations, 24 surface stations, and 87 surface stops (see Photo 5.17). The fleet will include 219 light rail vehicles (LRV) by the end of 2019[16], with an average weekly ridership of 173,500 passengers. Muni Metro operates below ground in the subway along Market Street, sharing four of the nine subway stations with BART. BART is generally operated at the lowest level underground, with Muni Metro located between BART and the surface streets. LRV service also operates along the Embarcadero and King Street at surface grades, with long portions of track and stations located in the SLR Vulnerability Zone.

Muni Metro LRVs enter the Market Street tunnel along the Embarcadero between Howard and Folsom Streets (Photo 5.18). The Embarcadero Muni portal is vulnerable to SLR at 48 inches (Scenario 4). If the Embarcadero Muni portal were flooded, water could enter the Embarcadero Station and the BART/Muni tunnel, causing significant service disruptions for the City and region.

As of this publication, BART is conducting a SLR Assessment to understand the impact of SLR on the BART system. This study will provide more detailed information on flood pathways into Embarcadero Station and the BART/Muni tunnel system.

Muni Metro is currently under expansion through the Central Subway Project, which will expand subway service through the South of Market Neighborhood, Union Square, and Chinatown, increasing public transportation to and from some of the City's busiest, most densely populated areas and connecting to the CalTrain and BART systems. Central Subway portal is on Fourth Street between Harrison and Bryant Streetsin the SLR Vulnerability Zone. The lowest point within the Central Subway is under Market Street, below the existing Market Street subway. The Central Subway Project is planned to be completed in 2020.

16 https://www.sfmta.com/projects/expansion-and-upgrade-muni-light-rail-vehicle-fleet

The Embarcadero Station

The Embarcadero BART/Muni Station,located at the intersection of Market Street and the Embarcadero, is the most vulnerable subway station to SLR and to coastal flooding in San Francisco (Photo 5.19).

As part of the U.S. Army Corps of Engineers San Francisco Waterfront Continuing Authorities Program, potential impacts to Muni and BART service related to coastal flooding are currently being evaluated to support the need for flood protection for the entire San Francisco Waterfront. BART is conducting a SLR Assessment to understand the impact of SLR on the BART system. This study will provide more detailed information on flood pathways into Embarcadero Station and the BART/Muni tunnel system.

Photo 5.19 **Embarcadero Station.** Franco Folini (CC BY-SA 2.0)

Floodwaters could enter the underground station through multiple pathways, such as manholes, vents, access hatches, and the Embarcadero Muni portal. Muni Metro LRVs enter the Market Street tunnel along the Embarcadero between Howard and Folsom Streets. The Embarcadero Muni portal is vulnerable to SLR at 48 inches (Scenario 4). The first pedestrian entrances to the underground Embarcadero Muni/BART Station would be impacted in Scenario 5 (52" of SLR or 12" of SLR and a 100-year extreme tide). The BART vent located on Ferry Plaza would be affected by SLR at 60 inches, or Scenario 6.The BART rail tracks (whether above or below ground) are fixed electric third-rail routes that are sensitive to inundation. Exposure to saltwater would accelerate corrosion risks and damage sensitive electrical equipment. There are other less visible components that are vital to maintaining operations including tunnels, ventilation tubes, street vents, and control equipment.

If floodwaters enter the station, flooding can impact communication equipment, electrical systems, fuel supplies, station operations, and BART service connecting San Francisco with the East Bay, and southbound service including service to SFO. Depending on the scope and the duration of the flood event, the Muni light rail system might be able to continue to operate west of Van Ness Station.

Any impacts here would ripple throughout the entire system. The length of repairs and the amount of disruption would depend on the duration and extent of the flooding and the corresponding damage.

Impacts to the Embarcadero Station would cause significant citywide and regional impacts to transportation. The Embarcadero station is the last San Francisco BART stop before connecting to Oakland via the Transbay Tube. Impacts to the Embarcadero BART station would cause significant delays and impact the ability for commuters to reach San Francisco from the East Bay. BART service is a key remaining link to the East Bay for hundreds of thousands of riders when there are traffic closures or heavy traffic affecting the Bay Bridge.

Muni service going to the Southern Waterfront or to other parts of San Francisco would also be impacted. Disruption of the Embarcadero Station would lead to congestion of other modes of transportation such as buses, personal vehicles, and ferries, and would impact people's ability to get to work, school, or to or from the East Bay. Alternate modes of mobility can be used by certain passengers if the impact is short term; however, there is minimal redundancy within the transit network to alleviate long-term impacts to BART rail or stations.

Light rail tracks (above and below ground) are sensitive to inundation. LRVs can continue to operate during minimal flooding. However, rail service would be suspended if inundation exceeds a minimum safe depth. Exposure to saltwater would accelerate corrosion risks and damage sensitive electrical equipment of tracks along the shoreline. LRVs can be moved out of potentially inundated areas prior to a storm event with enough notice, but finding adequate and safe storage for the fleet is a challenge. The rail system would require inspection by regulators before placing the system back in service.

Underground subway stations are sensitive to projected flooding and inundation, as numerous flood pathways are available for floodwater to enter the stations (portals, utility access holes, conduits, vents, grates, stairs, etc.). Portions of the light rail system may continue to operate if inundation impacts are localized. However, impacts to the subway portions and the electrical systems could cause systemwide disruptions and impacts to stations that are outside of inundated areas.[17] Buses can provide limited alternative service during disruptions and maintenance. Buses are placed into service to provide alternate transportation during construction and/or long-term repairs to portions of the system. However, short-term replacements would require pulling buses from other routes, impacting residents on those revenue lines.

5.3.2 Exposure Assessment

The exposure of the local public transportation network (Muni only, see Regional Transit for other transit providers) was evaluated relative to the 10 SLR scenarios (see Chapter 2). Table 5.6 shows the mileage of each type of transit that would be inundated under each scenario. Table 5.7 describes the number of riders impacted by transit type. Table 5.8 shows the number of stops impacted.

17 If the Muni Metro Turn-back Facility (MMT) or Embarcadero Muni/BART Station are flooded, there will likely be no Muni Metro service to downtown. Inbound trains will likely be switched back at Van Ness Station. N-Judah service would not be able to access its terminus point at the Caltrain Station. LRVs would not be able to pull out from, or pull into, the Muni Metro East Yard. Green and Cameron Beach Yards are already at capacity in terms of storage. Other than parking trains overnight on the mainlines in the subway or on public streets (which is difficult to do for operational and security reasons), there is nowhere to store LRVs that are currently stored at MMT. The Mint Yard at Church and Duboce Streets can only store four to six cars.

5.3.3 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: Disruptions to any sector of public transit will have cascading consequences throughout the City and the region. If public transit routes are impacted by flooding and cannot operate as usual, transit that does not operate on fixed rail can be rerouted; however, this would impact residents and businesses on alternate routes through increased traffic congestion and environmental pollution from increased auto trips. Transit that operates on fixed rail often relies on bus service during periods of disruption. The Federal Transit Authority only allows SFMTA to have a 20% reserve bus fleet, which is not large enough to substitute rail or trolley service without pulling buses from other revenue lines, diminishing service on those lines. Driver availability in flood events may also be a limiting factor.

Vulnerable communities, such as the transit-dependent, elderly, or impaired, would be left with reduced mobility if there were no alternative transit options that were easy to access. The impacts could also reach a regional level if BART or Caltrain are affected. If commuters are unable to get to their workplace, there is a potential for missed work days and increased reliance on the already limited parking resources from a transition to personal vehicles, adding to congestion issues.

Society and Equity: Impacts and downtime at the Embarcadero Muni/BART Station would significantly impact travelers between San Francisco and the East Bay. If impacts to the electrical system occur, systemwide outages or disruptions are possible. Disruption and delays in public transit could result in more individuals driving personal vehicles or using ride-hailing services, leading to more congestion and time delays. This option may be cost-prohibitive for some transit-dependent persons in vulnerable communities.

Table 5.6 Public Transit Route Exposure Summary (Miles Inundated)

Transit Type	Miles of Public Transit within Each Scenario									
	1	2	3	4	5	6	7	8	9	10
Bus	-	-	0.7	1.3	3.6	14.2	20.3	24.0	31.0	37.2
Electric Trolley Bus	-	-	-	0.7	2.6	10.1	13.4	15.4	18.4	21.1
Cable Car	-	-	-	-	-	0.2	0.3	0.4	0.4	0.5
Historic Streetcar	-	-	-	0.4	1.5	7.1	10.5	10.8	11.1	11.5
Muni Metro	-	-	-	1.1	3.0	11.1	13.5	15.0	16.3	18.0
Total	**-**	**-**	**0.7**	**3.5**	**10.7**	**42.7**	**58.0**	**65.6**	**77.2**	**88.3**

Table 5.7 Total Weekday Passenger Trips Potentially Impacted by Each Scenario

Transit Type	Trips[1] Impacted within Each Scenario									
	1	2	3	4	5	6	7	8	9	10
Bus	-	-	-	17,000	68,000	182,000	190,000	207,000	221,000	221,000
Electric Trolley Bus	-	-	-	74,000	112,000	172,000	172,000	172,000	172,000	172,000
Cable Car	-	-	-	-	-	5,000	5,000	5,000	5,000	11,107
Historic Streetcar	-	-	-	23,000	23,000	23,000	23,000	23,000	23,000	23,000
Muni Metro	-	-	-	83,000	83,000	158,000	158,000	158,000	158,000	158,000
Total Ridership Impacted	**-**	**-**	**-**	**197,000**	**287,000**	**540,000**	**548,000**	**565,000**	**579,000**	**586,000**

Table 5.8 Public Transit Stops Exposure Summary

Transit Type	Number of Transit Stops Impacted within Each Scenario									
	1	2	3	4	5	6	7	8	9	10
Bus	-	-	8	15	22	82	98	119	165	208
Electric Trolley Bus	-	-	-	2	15	47	62	70	86	104
Cable Car	-	-	-	-	1	4	6	7	8	9
Historic Streetcar	-	-	-	-	1	39	49	49	53	53
Muni Metro	-	-	-	-	-	32	33	36	44	44
Total	**-**	**-**	**8**	**17**	**39**	**204**	**248**	**281**	**356**	**418**

1 Impacted riders were estimated based on total ridership values in 2015. If a bus route is impacted under a specific SLR scenario, the total ridership along that route was included in the totals presented in Table 5.7.

Flooding of mostly fixed transit systems, such as electric trolley buses (which require a connection to the overhead powerline), and fixed transit systems, such as light rail, historic streetcars, and cable cars, can lead to widespread outages and delays because even if only a portion of a route is impassable, a larger service area may be disrupted. Buses may provide replacement service; however, sufficient buses and/or operators may not be available to meet demands, which means that some areas will remain without service.

Although buses can be rerouted around flooded areas, individuals living or working in flooded areas would need to be able to walk farther and potentially through a flooded area to reach a serviced bus stop. People in affected vulnerable neighborhoods, in particular transit-dependent, elderly, and infirm persons would be the most impacted and could be left without access to mobility services, rendering them unable to go about their daily lives, get to work on time, or access health services.

Economy: Disruptions to public transit can have major impacts on the economy, affecting the ability of millions of commuters to access their workplaces, shopping, etc. Transit disruptions would impact local travelers by increasing commute times, reducing work hours, and requiring potentially more costly mobility solutions. Transit disruptions would also negatively impact tourism industry revenue. Cable cars and the historic streetcars are popular tourist attractions in and of themselves, in addition to providing transportation to tourist attractions and local San Francisco businesses. Transit disruptions would also impact local businesses and the transit agencies due to lost revenue and worker productivity. Damage to the multimodal system will also require additional capital and operating funds to both protect and repair damage from flood events.

Environment: Reduced access to public transit could shift riders to using standard buses or private vehicles that have higher greenhouse gas emissions. Additional vehicle traffic would increase vehicle miles traveled and greenhouse gas emissions.

Governance: If fixed transit lines are affected, there may not be enough alternate means of public transportation options available to meet demand. Muni, BART, and the ferries all note buses as a possible alternative mode during construction or during short- or long-term downtime; however, there are only a limited number of buses, and bus yards. Maintenance facilities may also be affected (see Section 5.5). Relationships and mutual aid agreements with private transportation firms or other municipalities may be required. Identifying funds for the planning and repairs to damage infrastructure will also require working with local, regional, state and federal partners.

Mitigating these effects and adapting the public transit system will require concerted and coordinated efforts across agencies because ownership and rights-of-way for each component of the public transportation infrastructure (e.g., rail, roads, stations, and maintenance facilities) vary.

5.4 TRANSIT OPERATIONS AND MAINTENANCE FACILITIES

The City's public ground transportation system relies on a variety of operations and maintenance facilities where vehicles and equipment are stored, serviced, assembled, repaired, tested, painted, and fueled (see Figure 5.2). These facilities are required for continued safe and reliable operation of the public transit system. Many of these facilities are in low-lying areas within the SLR Vulnerability Zone and vulnerable to both temporary and permanent flooding as sea levels rise. The facilities within the SLR Vulnerability Zone were evaluated individually.

5.4.1 Potentially Vulnerable Assets

5.4.1.1 Muni Metro East

Muni Metro East is a 13-acre storage and operations and maintenance facility located east of Illinois Street, between 25th Street and Cesar Chavez Street (Photo 5.20). This is currently the main facility where LRVs are repaired and maintained. The facility includes an 180,000-square-foot maintenance building, an electric substation, a diesel back-up generator, and paved outdoor track and storage space. Large portions of the parcel are low-lying and have experienced precipitation-driven flooding.

SFMTA plans to expand the facility eastward. The Muni Metro East Expansion Project would develop an empty 4-acre lot east of the existing 17-acre Facility. Improvements will include paving the site, installation of light rail storage track for up to 36 light rail vehicles, and construction of a maintenance building for light rail vehicles. Increasing the capacity of the site will provide vehicle storage capacity for future expansion of both the bus and light rail fleets. This site is also subject to future flooding as sea levels rise.

There is limited redundancy for Muni Metro East and systemwide impacts to the Muni transit lines would occur if this facility is out of service for an extended period. Vehicles could be moved offsite prior to a storm event with enough notice; however, options are limited.

Photo 5.20 Muni Metro East facility. Flickr user mliu92 (CC BY-SA 2.0)

Figure 5.2 Transit Maintenance Facilities

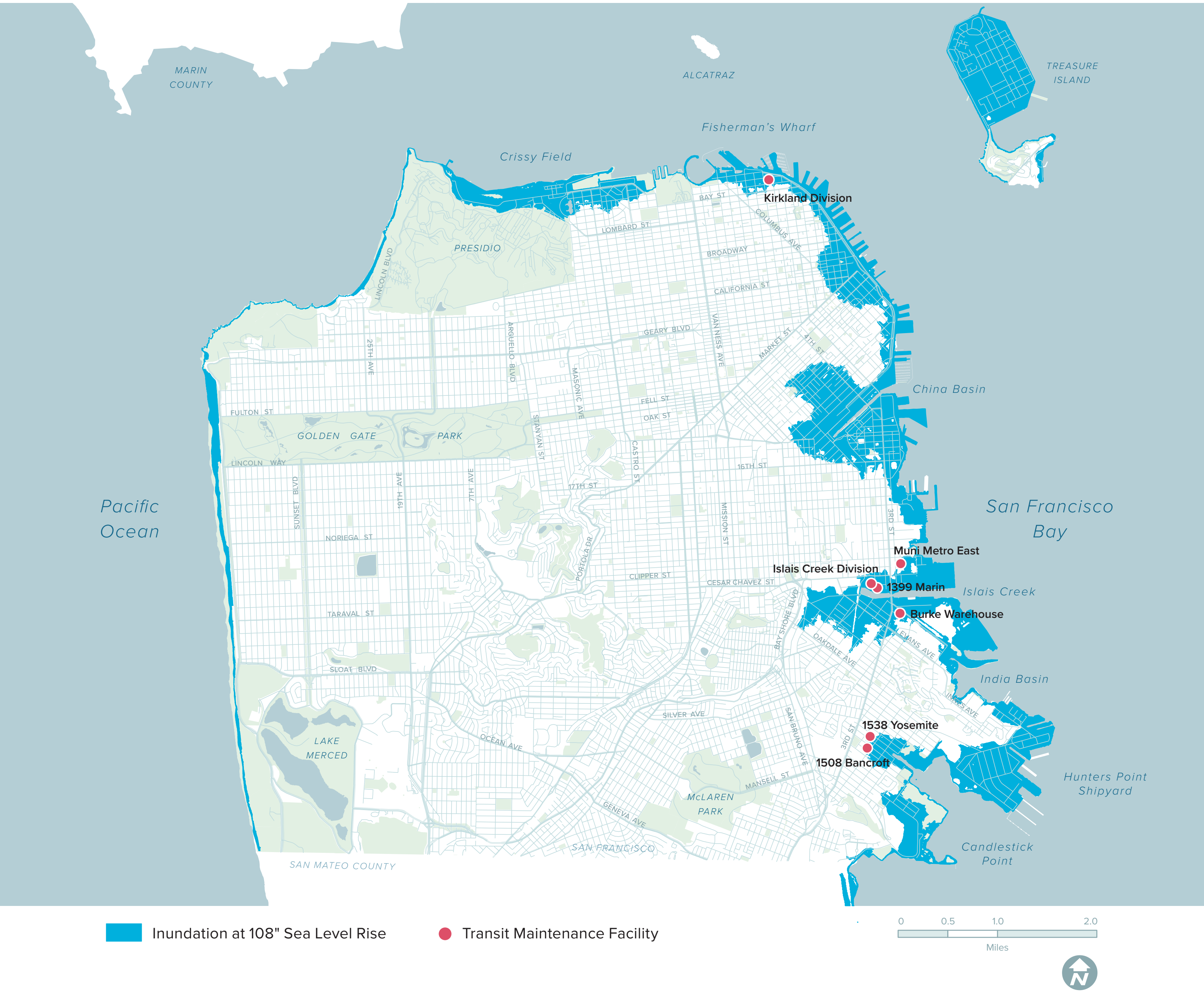


Photo 5.21 **Muni Metro East facility.** Jim Maurer (CC BY-NC-ND 2.0)

Photo 5.22 **Maintenance facility at 1399 Marin.** Todd Lappin (CC BY-NC 2.0)

SFMTA operates one other yard, Green Yard, that services and maintains LRVs, which has capacity to service 12 LRVs. However, no other facility can accept the same volume of vehicles and equipment. Additionally, vehicles would not be able to access Muni Metro East if Mission Creek or Islais Creek bridges were flooded (Photo 5.21). This current facility is not anticipated to be subjected to future flooding until Scenario 10 (108 incher of SLR, or 66 inches of SLR and a 100-year extreme tide).

5.4.1.2 Burke Warehouse

The Burke Warehouse is located between Burke Avenue and Cargo Way, just east of Third Street. This facility is SFMTA's central warehouse and the new home of Muni's Overhead Lines Maintenance Division (2017 capital project). The facility includes approximately 100,000 square feet of warehouse space that stores Muni parts and equipment and is the primary location for overhead line repairs. The existing warehouse has at-grade entrances and flooding currently occurs during high tides coupled with heavy rains.

Sand bags are the primary measure used to mitigate flood damage and disruption. Warehouse operations are disrupted until flooding subsides. There are no pumps located onsite and storm drains are the primary mechanism for removing floodwaters. Although there is some redundancy in the system with respect to warehouse storage, this is the only facility where overhead lines are repaired. Vehicles could be moved offsite prior to a storm event with sufficient notice.

This facility is first exposed to inundation from SLR with Scenario 5 (54 inches of SLR or 12 inches of SLR and a 100-year extreme tide).

5.4.1.3 1399 Marin

This facility is located between Tennessee and Indiana Streets, west of Third Street, just north of Islais Creek Channel (Photo 5.22). 1399 Marin is under the jurisdiction of the Port of San Francisco, and the SFMTA has a Memorandum of Understanding (MOU) with the Port to use the property. The primary structure is a metal-clad 27,000-square-foot warehouse located on a 3.2-acre site with an asphalt and concrete paved yard. This facility is used to accept, store, maintain, repair, and refuel Muni buses. The existing warehouse has at-grade entrances and flooding currently occurs during high tides coupled with heavy rains.

Sand bags are the primary measure used to mitigate flood damage and disruption. There are no pumps located onsite and storm drains are the primary mechanism for removing floodwaters. The electrical lifts are at or below grade and cannot be used when flooded, and the disruption lasts until flooding subsides and equipment is inspected and ready for operation.

The primary uses of this facility are storage and bus acceptance. Storage could be relocated, though current storage inventory is low. Bus acceptance could be completed at a lower efficiency at an alternate bus division; however, it is possible that an alternative facility outside of the SLR Vulnerability Zone could handle bus acceptance needs, such as

Photo 5.23 **Islais Creek Division transit facility.** Jeremy Menzies, SFMTA

Photo 5.24 **Kirkland Division facility.** Wayne Hsieh (CC BY-NC 2.0)

Woods, Flynn, Potrero, or Presidio. However, some locations have limitations on the size of vehicle they can accept (e.g., Woods could accept 40-foot coaches, but not 60-foot buses). Additionally, bus acceptance needs will likely decrease by 2020-2025 based on anticipated procurement trends. However, the SFMTA plans to use this facility to service and maintain the fleet as other facilities are rehabilitated such as the Potrero facility. Therefore, its important role in providing daily transit service will increase.

This facility is first exposed to SLR inundation with Scenario 5 (54 inches of SLR or 12 inches of SLR and a 100-year extreme tide). This facility already experiences flooding during rain events and high tide conditions.

5.4.1.4 1508 Bancroft

This facility is located on a 1-acre site located between Bancroft, Armstrong, Jennings, and Keith Streets just east of Third Street. The primary structure is a metal clad, two-story, 90,000-square-foot warehouse for street signage, temporary signage, and parking meter shops. The structure has at-grade entrances and below-grade loading docks within the building footprint, and no stormwater infrastructure or flood protection measures located onsite. There is no redundancy for the sign and meter shop within SFMTA's system. Fleet parking is also located at this location; however, fleet parking could be temporarily relocated if required.

This facility is not anticipated to be subjected to future flooding until Scenario 10 (108 inches of SLR or 66 inches of SLR and a 100-year extreme tide).

5.4.1.5 1538 Yosemite

This facility is located between Yosemite, Wallace, Jennings, and Keith Streets just east of Third Street. This site includes 40,000 square feet of leased warehouse space used primarily as a paint shop that operates in association with the field operations at 1508 Bancroft. SFMTA's Non-Revenue Vehicles (NRVs) are parking inside the leased areas. Paint shop operations include installation and maintenance of lane lines, crosswalks, bicycle lanes, and bus-only lanes, as well as all pavement messages and color curb zones. The shop holds paint materials, operational supplies, equipment, and vehicles. There is no redundancy for the paint shop within SFMTA's system. Fleet parking could be temporarily relocated if required.

This facility is not anticipated to be subjected to future flooding until Scenario 10 (108 inches of SLR or 66 inches of SLR and a 100-year extreme tide).

5.4.1.6 Islais Creek Division

The Islais Creek Division is a major transit facility located between Indiana Street and I-280, just north of Islais Creek Channel. 1301 Cesar Chavez at Islais Creek is a 395,356 square foot, (9.08 acre site) that is under the jurisdiction of the SFMTA and/or leased from Caltrans. This facility functions primarily as a bus operations and maintenance facility with the capacity to serve and house 164 buses. This facility includes one fuel and vehicle wash building (approximately 18,000 square feet), one operations and maintenance building (approximately 65,000 square feet), bus parking, public open space, and a bicycle path on Islais Creek.

Table 5.9 Transit Facility Exposure Summary

Facility	Transit Facility Exposure within Each Scenario (Y/-)									
	1	2	3	4	5	6	7	8	9	10
Muni Metro East (current boundary)	-	-	-	-	-	-	-	-	-	Y
Burke	-	-	-	-	Y	Y	Y	Y	Y	Y
1399 Marin	-	-	-	-	Y	Y	Y	Y	Y	Y
1508 Bancroft	-	-	-	-	-	-	-	-	-	Y
1538 Yosemite	-	-	-	-	-	-	-	-	-	Y
Islais Creek Division	-	-	-	-	Y	Y	Y	Y	Y	Y
Kirkland Division	-	-	-	-	-	Y	Y	Y	Y	Y

Although some redundancy for this facility may be provided at other locations (e.g., 1399 Marin and Kirkland Division - if those facilities remain functional), the Islais Creek Division is the largest bus operations and maintenance facility. SFMTA's bus system would be severely impacted if this facility is not operational. It should be assessed whether fouling of the underground fuel storage tank could occur from flooding events or rising groundwater.

This facility is first exposed to SLR inundation with Scenario 5 (52 inches of SLR or 12 inches of SLR and a 100-year extreme tide). This facility already experiences flooding during rain events and high tide conditions.

5.4.1.7 Kirkland Division

This facility is located on a 2.6-acre site between North Point, Beach, Stockton, and Powell Streets (Photo 5.24). This facility provides bus storage, operations, and limited maintenance for 135 40-foot hybrid buses. The site includes mostly flat, paved surfaces with small operations and maintenance structures and underground storage tanks. An underground fuel storage tank and fueling station is also located onsite, and this facility provides back up fuel for the City's emergency response in the event of an emergency. If this facility is flooded, water can enter the underground storage tank through openings such as fill pipes, vent pipes, gaskets, loose fittings, covers, and sumps. Water will settle on the bottom of the tank, allowing the fuel to float on top until it exits the tank and is released into the environment. The underground storage tank and fueling system will require inspection and servicing before it can be safely used. Rising groundwater levels can also cause additional problems for underground storage tanks.

Although this location has not experienced flooding issues yet, it has experienced power outages during extreme weather conditions. Disruption lasts until power is restored. No stormwater infrastructure or flood protection measures are located onsite.

This facility is first exposed to SLR inundation with Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide).

5.4.2 Exposure Assessment

The exposure of the transit facilities was evaluated relative to the 10 SLR scenarios (see Chapter 2) and is presented in Table 5.9.

5.4.3 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: Day to day transit service is reliant on the functioning of the facilities. If facilities are inundated and unable to function or operate at a reduced capacity, it would reduce the ability to provide transit service. It would also reduce the ability of the City to respond to a flooding event. For example, without sign making shops to inform the public of rerouted bus and transit route alternatives the public access and use of transit will be diminished. The maintenance and fueling facilities are imperative to keeping the largest number of buses running as buses are the first line of defense to respond to impacts on fixed transit lines.

Society and Equity: The majority of these facilities (Muni Metro East, Islais Creek, Burke Warehouse, 1508 Bancroft, 1538 Yosemite, and the Kirkland Division) all play a critical role in maintaining the transit system, vehicle maintenance, and storage. If these facilities are inaccessible and/or not operational due to flooding, this would have systemwide consequences, limiting the number of substitute buses available and the ability to store, repair, and maintain vehicles.

Closure of these sites could also directly impact the workers, causing missed work time and potentially lost income. As discussed above, public transit outages would particularly impact transit-dependent persons and vulnerable communities throughout the City.

- Repair and service of LRV and historic streetcars would be delayed until Muni Metro East facility is re-opened. Systemwide impacts could occur if this facility is out of service for an extended period.
- This Islais Creek Facility is the primary facility for maintaining buses. Although some redundancy is available at other facilities, overall operation and maintenance of the City's bus fleet would be impacted if this facility is not operational.
- Repair of overhead lines for electric trolley buses could not occur while the Burke Warehouse is impacted. Substantial disruption in electric trolley bus service could occur if this facility is out of service for an extended period.
- If 1508 Bancroft is impacted, delays and disruptions to field operations and access to appropriate signage could result in safety issues and concerns in flooded areas throughout the City. This facility operates in coordination with 1538 Yosemite. Both facilities are likely to be impacted by the same flood event or SLR scenario.
- The Kirkland Division facility provides back-up fuel for the City's emergency response services in the event of an emergency. The back-up fuel would not be accessible if this facility is impacted. This is a smaller, back-up facility for maintaining buses. The redundancy this facility can provide in the event larger facilities are impacted would be lost if this facility is also impacted.

Economy: As facilities are impacted, the repair, fueling, and maintenance of vehicles might have to be outsourced to alternative locations, causing increased fees and reducing labor needs, potentially affecting the existing workforce. In addition, if the loss of a facility results in a reduced capacity of the system (less buses or ability to reroute), there could be lost revenue and tremendous indirect economic costs in lost work time and limited service to some San Francisco neighborhoods.

Environment: Hazardous materials and/or waste stored at the Kirkland Division, Islais Creek Division, 1538 Yosemite, 1399 Marin, Burke Warehouse, and Muni Metro East facilities could be mobilized by floodwaters (particularly the Kirkland Division, which includes underground fuel storage tanks and a fueling station) and transported into the groundwater and/or Bay.

Governance: Managing flood response for mobility requires coordination across SFMTA, Public Works, and multiple regional transit agencies. Impacts to transit facilities will require an emergency operations and contingency plan for accommodating potential downtime at any one facility. Relationships and emergency response plans in coordination with neighboring jurisdictions could help SFMTA and other transportation agencies backfill some services while facilities are brought back online. SFMTA may be able to backfill some services for other jurisdictions if SFMTA's facilities remain online while neighboring jurisdictions are impacted.

Impacts to transit facilities will require an emergency operations and contingency plan for accommodating potential downtime at any one facility. Relationships and emergency response plans in coordination with neighboring jurisdictions could help SFMTA and other transportation agencies backfill some services while facilities are brought back online.

5.5 REGIONAL PUBLIC TRANSPORTATION

The City coordinates closely with the Metropolitan Transportation Commission (MTC) to ensure that critical regional and local priorities are incorporated into the Regional Transportation Plan and Plan Bay Area. Key projects include the Downtown Rail Extension, Caltrain Electrification, second Transbay rail crossing, and Muni and BART core capacity projects.

Like many counties in California, San Francisco is a “self-help” county where local revenues make up the majority of transportation funding. As a major regional employment hub, San Francisco depends on various regional public transportation systems to transport riders to and from the City daily. These include regionally operating trains, buses, and ferries (see Figure 5.3). Regional transportation lines that operate in San Francisco are discussed below (only assets within San Francisco are included in this assessment).

5.5.1 Potentially Vulnerable Assets

5.5.1.1 Bay Area Rapid Transit (BART)

BART provides regional transit service across five lines connecting Alameda, Contra Costa, San Mateo, and San Francisco counties, including direct service to SFO (Photo 5.25). BART is operated by the San Francisco Bay Area Rapid Transit District, with headquarters in Oakland. BART is the fifth-busiest heavy rail rapid transit system in the United States and carries more than 440,000 daily passengers to access many of the region’s prime destinations for work, school, and recreation. The total transit network provides service across 121 route miles: 28 miles in subways and tunnels, 32 miles on elevated structures, and 61 miles at ground level.[18] The service network includes the 3.6-mile Transbay Tube, which connects the East Bay with San Francisco and serves half of BART’s daily ridership.

18 https://www.bart.gov/about/history/facts

Photo 5.25 **BART train.** Christian Ramiro González Verón

Figure 5.3 Regional Transit Map

Inundation at 108" Sea Level Rise

0 0.5 1.0 2.0
Miles

- Bart / Stations
- Caltrain
- AC Transit
- Golden Gate Transit
- Sam Trans
- Ferry Lines / Terminals

Photo 5.26 **Caltrain terminal at Mission Bay/China Basin area.** Jim Maurer (CC BY-NC-ND 2.0)

Of the 44 regional BART stations, eight BART stations are in San Francisco. Of these eight, only one station, the Embarcadero Station, is located within the SLR Vulnerability Zone. Because all trains connecting the San Francisco Peninsula and the East Bay pass through the Embarcadero Station, its functionality is critical for the system. When there are traffic closures or heavy traffic affecting the Bay Bridge, BART service is a key remaining link to the East Bay for hundreds of thousands of riders.

The Embarcadero Station is one of the two most heavily used BART stations in the system and shares facilities with San Francisco's Muni Metro Light Rail system (see Section 5.3.1.5).

5.5.1.2 Caltrain

Caltrain is a commuter rail line that provides regional transit services along a single line connecting San Francisco, San Mateo, and Santa Clara counties (Photo 5.26). Caltrain is owned and operated by the Peninsula Corridor Joint Powers Board, which is composed of the City and County of San Francisco, the San Mateo County Transit District (SamTrans), and the Santa Clara Valley Transportation Authority.

Caltrain carries over 60,000 daily passengers, along San Francisco, the Peninsula, and Santa Clara Valley, for work, school, and recreation. Caltrain provides service across 51 route miles from 31 stations, two of which are within San Francisco. Caltrain has a fleet of 215 rail cars that provide daily service. Currently, Caltrain uses electricity for lighting, equipment, and amenities at its stations, Centralized Equipment Maintenance and Operations Facility, and for signals along the right-of-way.

Caltrain tracks are within the SLR Vulnerability Zone along the San Francisco shoreline in the low-lying area around Islais Creek and approaching the terminal at Fourth and King Streets. Of its stations, only the current terminal is located in the SLR Vulnerability Zone. The station is in the Mission Bay/China Basin area, bordered by Townsend Street to the north, Third Street to the east, Fourth Street to the west, and King Street to the south. The station is primarily located at street level, including pedestrian access, rail infrastructure, and equipment; there is no public parking available. It has building structures, fare vending equipment, waiting areas, and bicycle facilities, as well as bus and shuttle loading areas. It experiences the highest average weekday boarding volume of all Caltrain stations.

Downtown Rail Extension (DTX)

The City, in coordination with CalTrain, the Transbay Joint Powers Authority, and California High Speed Rail, is currently studying how to bring Caltrain and High Speed Rail to the Salesforce Transit Center while connecting San Francisco's fastest-growing neighborhoods on the east side of the City. The Rail Alternatives and Benefits Study (RAB) studied various underground rail alignments to connect rail to the Salesforce Transit Center from the County line to the Salesforce Transit Center. The Pennsylvania Avenue Extension, which includes a modified DTX and would extend underground rail south under Pennsylvania Avenue to the 22nd Street CalTrain Station area, is the City's preferred alignment. Both the DTX and the Pennsylvania Avenue extension would pass through the SLR Vulnerability Zone and include an underground station at 4th and Townsend Streets.

The Transit Center has two belowground levels with a Lower Concourse and Train Platform. The Lower Concourse houses retail space, fare equipment, and passenger waiting areas. The Transit Center will also accommodate future High-Speed Rail service that will connect to the greater regions of California (see discussion of Salesforce Transit Center).[20]

20 Transbay Program. Downtown Rail Extension. Available at http://tjpa.org/project/downtown-rail-extension.

Photo 5.27 Rendering of the RAB.

Photo 5.28 Cross section rendering of the Salesforce Transit Center.
Steelblue

Caltrain rail tracks (whether above or below ground) are not currently electrified. However, CalTrain is currently in the process of electrifying the CalTrain system, which would involve electrified tracks, foundations, poles, and overhead wires. Phase I of CalTrain electrification is expected to be complete by 2022.[19] For current non-electrified tracks, exposure to saltwater would accelerate corrosion risks. Caltrain stations also have sensitive electrical equipment at ground level. Within Caltrain stations and structures, there are other less-visible components that maintain operations, including tunnels, ventilation tubes, street vents, and control equipment.

If floodwaters enter a station, flooding could impact communication equipment, electrical systems, fuel supplies, and station operations. If the impacts are localized to a single station, the remaining stations could continue to operate; however, there would be severe disruption to the trip schedules. The length of repairs needed for a station and the amount of disruption would depend on the duration and extent of the flooding and the corresponding damage.

19 CalTrain is. See: https://calmod.org/

Figure 5.4 Ferry Connections

Photo 5.29 A Golden Gate ferry docked at the Ferry Building terminal. Melinda Young (CC BY-NC-ND 2.0)

5.5.1.3 Ferries

Ferries provide commute and leisure transportation for passengers to connect to communities along the San Francisco Bay shoreline (see Figure 5.4). There are three main operators that service the network of ferry routes that provide access to and from three designated San Francisco terminals.

San Francisco Bay Ferry (operated by the San Francisco Bay Area Water Emergency Transportation Authority [WETA]) provides ferry service to communities throughout the Bay Area from ferry terminals in San Francisco, Alameda, Oakland, South San Francisco, and Vallejo (see Photo 5.29). Annual ridership exceeds 2.8 million across 14 high-speed ferries.[21] San Francisco Bay Ferry is also responsible for coordinating and managing emergency ferry service after a catastrophic incident that severely disrupts normal regional transportation systems, such as during temporary Bay Bridge closures. San Francisco Bay Ferry also operates service from SF to Richmond as of Jan 2019 and serves an average of 10,000-11,000 passengers per weekday.

The Golden Gate Ferry is owned by the Golden Gate Bridge, Highway, and Transportation District. Ferry service is provided between San Francisco (San Francisco Ferry Building) and the communities of Larkspur, Sausalito, and Tiburon in Marin County. Limited service is also provided between Oracle Park and Larkspur for San Francisco Giants baseball games. The Golden Gate Ferry has seven vessels and an annual ridership of 2.5 million, with an average daily ridership of 8,000 on weekdays across all routes.

San Francisco Bay Ferry facilities (float, piles, and gangways) are designed to be resilient to SLR as it pertains to rising tides. Facilities may be impacted by debris from increased storm frequency and intensity. Surrounding supportive shoreside facilities (i.e. vehicle, pedestrian, bicycle access) may also be impacted (see Chapter 11, *Port of San Francisco*).

The Blue and Gold Fleet provides bay cruise and excursion services in San Francisco Bay as well as ferry services to Angel Island, Tiburon, Sausalito, and Pier 41 with a total of 19 vessels.[22]

In addition, Tideline Ferry, an official small-scale ferry and on-demand service owned by the Port of San Francisco, serves Transbay commuters primarily

21 Water Emergency Transportation Authority (WETA). Available at https://weta.sanfranciscobayferry.com/. Accessed September 2018.

22 Port of San Francisco. Ferries. Available at https://sfport.com/ferries. Accessed September 2018.

between Berkeley and Pier 1½ in San Francisco during weekday hours. The Tideline Ferry operates two small vessels, each with a 40-passenger capacity.

All of the San Francisco ferry terminals are located within the SLR Vulnerability Zone, including the San Francisco Ferry Building, Pier 41/Fisherman's Wharf, and Oracle Park. The Port of San Francisco is leading a project to build a new ferry terminal at Mission Bay, which will be designed to accommodate expected SLR.

Ferry vessels are designed to operate in saltwater and are not directly impacted by rising tides. However, they may be damaged from debris impacts during storm events. During severe storm events and high wind conditions, ferries may suspend operations until hazardous wave conditions in the Bay subside. During route closures, passengers are directed to use alternative public transportation methods, leading to added delays and disruptions of the operating transit network. Increasing storm intensities in the Bay may create increased disruption in service, particularly during the winter months.

Mooring locations (standard steel floating facilities) at the terminals may be impacted by debris and wave impacts during storms, reducing the operational capacity of the ferry network. Additionally, piers and ferry terminals will require adaptation to operate during permanently higher tide levels, resulting in loss of service while terminals are retrofitted.

Ferries can be used to provide adaptive capacity for other types of public transit during a flood event. For example, if regional buses or BART service is impacted, ferries can be used to provide temporary alternative transportation for commuters and recreational passengers if the ferry terminals remain accessible.

5.5.1.4 Regional Buses and Transbay Terminal

Regional buses shuttle passengers to and from San Francisco to the greater San Francisco Bay Area and beyond. A significant number of regional bus lines terminate at the Salesforce Transit Center, including Golden Gate Transit, Amtrak, and Greyhound.

5.5.1.5 SamTrans

The San Mateo County Transit District (SamTrans) is a bus service that provides regional transit throughout San Mateo County and San Francisco. SamTrans also provides shuttle service to BART stations, other community shuttles, and service to SFO.

SamTrans has approximately 312 fixed-route vehicles and 67 paratransit vehicles in service. SamTrans provides several bus lines with direct service to San Francisco, terminating at the Salesforce Transit Center. Travelers living on the San Francisco Peninsula can reach destinations in San Francisco by taking SamTrans to a BART or Caltrain station or connect to SFMTA bus network.

SamTrans stops typically have minimal infrastructure, including stop signage and lighting. Some route sections may be inaccessible during flood events resulting in some disruption in service. Buses may use alternate routes to maintain a reduce level of service. A stop may still function as intended with minimal impact after floodwaters recede. During a flood event, buses could use an alternate drop off and pick up location, but this will be accompanied by a disruption in service. Travelers may be able to find alternate public transit modes to reach their destinations (e.g. BART or CalTrain).

5.5.1.6 AC Transit

AC Transit is a bus service that provides regional transit through portions of Alameda and Contra Costa counties (Photo 5.30). AC Transit also provides

Photo 5.30 AC Transit bus at Salesforce Transit Center. Sergio Ruiz

Salesforce Transit Center

The Salesforce Transit Center is a new facility that replaced the seismically-unstable Transbay Bus Terminal. The Transit Center opened in 2018 and currently houses operations for Transbay bus lines and Muni, with the ability to handle future CalTrain and California High Speed Rail trains in a lower train platform. The Transit Center is located within the SLR Vulnerability Zone and is exposed at 77 inches (Scenario 7).

Photo 5.31 Salesforce Transit Center. Sergio Ruiz

services to San Francisco and select areas of San Mateo and Santa Clara counties. There are 24 different bus routes for passengers to reach the Salesforce Transit Center from the East Bay. Transbay commutes to the Transit Center comprise approximately 60 percent of the total ridership across the network.

Most AC Transit buses travel directly from the Bay Bridge to elevated ramps into the Transit Center. They do not use surface roads in San Francisco. Line 800 which provides all-night service from the East Bay to San Francisco travels along surface streets, but does not intersect with the SLR Vulnerability Zone. Other impacts to AC Transit would be concentrated to impacts to the Bay Bridge (see Section 5.2.1.5) and the Salesforce Transit Center (see sidebar above). AC Transit may also provide redundant service if other transit modes (i.e. BART) are impacted by flooding.

5.5.1.7 Golden Gate Transit

Golden Gate Transit is a bus service that primarily provides regional transit for Marin and Sonoma counties but also extends service to San Francisco and Contra Costa counties. Golden Gate Transit is owned by the Golden Gate Bridge, Highway, and Transportation District. Average daily weekday ridership is approximately 10,800, of which 7,500 is transit across the Golden Gate Bridge.

Golden Gate Transit operates 150 buses (with an additional 27 owned by Marin Transit) in the active fleet across the four counties. Golden Gate Transit provides mobility to key City services, including the Kaiser Permanente Medical Center, financial areas, and other transit connections (e.g., Salesforce Transit Center and Ferry Building).

There is typically minimal infrastructure required for bus stops; however, some locations have covered structures with seating and minimal digital signage. In the event of flooding on some of the routes along the Embarcadero and northern waterfront, there are several alternate routes that provide mobility through San Francisco, primarily through the SOMA neighborhood, the Van Ness corridor, and areas north of Golden Gate Park. However, all are governed by traffic conditions and prone to lengthy delays from any traffic disruptions.

There is a bus layover lot located under I-80 between Third Street and Fourth Street. No maintenance is performed at this location. During a flood event, buses could use an alternate drop-off and pick-up location, but this will be accompanied by a disruption in service. Ferries may provide some redundancy to reach San Francisco from Marin County if there is major disruption in Golden Gate Transit service.

5.5.2 Exposure Assessment

The exposure of the regional transportation network was evaluated relative to the 10 SLR scenarios (see Chapter 2). The mileage of each transit route (within the San Francisco City limits) that could be inundated under each scenario was calculated and is presented in Table 5.10. The number of transit stops in each scenario was also evaluated, as shown in Table 5.11.

Many of these transit routes could also be exposed to floodwaters outside of San Francisco, and this would result in additional impacts to regional commuters. However, assessing the overall impacts to these transit routes outside of the City limits was beyond the scope of this assessment.

Table 5.10 Regional Transit Routes Exposure Summary [23]

Agency	Miles of Transit Route Impacted within Each Scenario [24]									
	1	2	3	4	5	6	7	8	9	10
BART	-	-	-	-	Y	Y	Y	Y	Y	Y
Caltrain Rail	-	-	-	-	4.1	5.6	6.2	6.3	6.7	7.1
Transit Center	-	-	-	-	-	-	Y	Y	Y	Y
SamTrans	-	-	-	-	-	1.0	1.6	2.1	3.1	4.3
AC Transit [25]	-	-	-	-	-	-	-	-	-	-
Golden Gate Transit [26]	-	-	-	-	0.6	23.8	36.6	44.5	56.6	66.1

Table 5.11 Regional Transit Stop Exposure Summary

Agency	Regional Transit Stop Exposure Summary									
	1	2	3	4	5	6	7	8	9	10
BART	-	-	-	-	1	1	1	1	1	1
Caltrain	-	-	-	-	-	1	1	1	1	1
Salesforce Transit Center	-	-	-	-	-	-	1	1	1	1
Ferry Terminals	-	-	-	-	-	3	4	4	4	4
SamTrans	-	-	-	-	-	-	-	-	-	2
AC Transit	-	-	-	-	-	-	-	-	-	-
Golden Gate Transit	-	-	-	-	-	4	5	7	11	24
Total	-	-	-	-	-	8	15	22	27	46

23 Table 5.10 shows grade level exposure; however, grade level exposure doesn't account for how much track would be flooded due to grade changes along the route. BART is shown as "Y" because once floodwaters enter the station, the water will run downhill and impact the entire line.

24 For all providers, miles of route were calculated by adding all segments of all routes together (that is, if two lines share the same street for one mile, it was counted as two miles of transit routes).

25 AC Transit operates primarily on elevated roadways including the Bay Bridge, and ramps connecting to and from the Salesforce Transit Center. Only surface portions of AC Transit routes are included in this calculation, none of which intersect with the SLR vulnerability zone.

26 Golden Gate Transit operates 21 separate bus routes (including express bus routes) that cross the Golden Gate Bridge into San Francisco. Many of these bus routes occupy the same (or similar) routes along the shoreline within the SLR Vulnerability Zone, thereby creating a high mileage total of transit routes inundated under each SLR scenario.

5.5.3 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: The regional transit network connects commuters from across the Bay Area with jobs in San Francisco. If these commuters are unable to get to local and regional jobs, there could be both economic and labor impacts in missed work days and reduced services.

Society and Equity: Impacts and downtime at the Embarcadero Muni/BART Station would significantly impact commuters between San Francisco and the East Bay, and southbound service including SFO. This could also lead to increased traffic congestion due to a mode-shift and more personal vehicles on the roadways, and mode shift to ferries.

Disruption and access issues to Caltrain tracks or stations in San Francisco would impact commuting between San Francisco, the Peninsula, and the South Bay; ridership may shift to SamTrans, BART, or personal vehicles.

Disruption at the Ferry Terminal, or limitations in access due to flooding, would impact local commuter access between San Francisco and Marin County/North Bay, South San Francisco, and East Bay, shifting ridership to BART, AC Transit, Golden Gate Transit, and personal vehicles.

Disruption to SamTrans service would impact commuters between San Francisco and San Mateo County; ridership may shift to Caltrain and BART (if available), or personal vehicles. However, bus service may offer the best alternative transportation because buses can use alternative routes outside of flooded areas.

Economy: Any and all disruption to regional transit links can impact access to jobs and have cascading effects on the local and regional economy. Significant disruption to major transit lines such as BART or CalTrain could have significant impacts on the local and regional economy and the ability of workers to access jobs. Disruptions to regional transit providers would cause major commute delays, decreased productivity, and impacts on other systems such as roadways and ferries. Increased ferry service (if unaffected) could partially offset loss of BART or Bay Bridge access.

Impacts to regional transit links and transit stops will decrease revenue for regional transit providers, or shift this revenue to other providers such as ferries or bridge tolls.

Disruption of the railway will impact the flow of goods from Piers 90-96 (see Chapter 11, *Port of San Francisco*).

Environment: Increased traffic due to conversion to private vehicle from public transit would lead to more congestion and higher greenhouse gas emissions.

Governance: The regional transit system involves the coordination of multiple agencies over many jurisdictions. Making the transportation system resilient to SLR and coastal flooding requires significant local and regional cooperation regarding capital investments, service operations, reimbursements, financing, and emergency funding. For example, dedicated money for regional transit operators to subsidize emergency service enhancements does not exist. Operators are eligible for reimbursement from FEMA or CalOES in some instances.

5.6 OTHER TRANSPORTATION SERVICES

San Francisco is committed to creating an accessible City, and that includes providing taxi and paratransit options for seniors and people with disabilities, as well as incorporating emerging mobility services and technologies that can provide safe, reliable, sustainable, and equitable transportation choices. SFMTA operates SF Paratransit, a van and taxi program for people unable to independently use or access public transit because of a disability or disabling health condition.

Innovations in transportation are rapidly changing how people navigate San Francisco's streets. These "Emerging Mobility Services and Technologies" include ride-hailing services like Lyft and Uber, ride-pooling services, bike share, autonomous vehicle technologies, and more (Photo 5.32). City agencies are working with community partners to better understand how these services and technologies are influencing San Francisco's transportation network.[27] The City's studies focus on identifying and defining emerging mobility technologies,[28] setting guidelines,[29] and evaluating their services. SFMTA has adopted policies to encourage and facilitate emerging mobility facilities that comply with its 10 principles , as many deliver social, environmental, and transportation benefits to the City. For example, in February 2017, SMFTA expanded commuting options by approving the Commuter Shuttle Program, a partnership with privately operated commuter shuttles that transport workers from their neighborhoods to places of work or transportation hubs.

27 San Francisco County Transportation Authority (SFCTA). Emerging Mobility Studies. Available at https://www.sfcta.org/emerging-mobility/studies.

28 According to SFCTA and SFMTA, an "Emerging Mobility Service or Technology" is one that automates three or more of the following services: Driving, Routing, Reservations/Orders, Vehicle Tracking, Billing, Customer Feedback, Matching/Sharing, Crowd-Sourced Routing, (Un)locking. Source: San Francisco County Transportation Authority (SFCTA). Emerging Mobility Inventory of Service and Technology Types. Available at https://www.sfcta.org/emerging-mobility/inventory.

29 If a service provider or technology does not meet the 10 Guiding Principles, SFCTA and SFMTA will work with the service provider to meet the principles or may choose to limit their access to City resources.

Photo 5.32 Bay Area Bikeshare station on the Embarcadero. Mario Roberto Duran Ortiz (CC BY-SA 4.0)

5.6.1 Potentially Vulnerable Assets

5.6.1.1 Paratransit and Taxis

SF Paratransit provides complementary paratransit services for SFMTA in accordance with the ADA. SF Paratransit performs about 800,000 passenger trips per year, with two-thirds provided by pre-reserved van and the remaining one-third provided by same-day taxis. All vans used to provide SF Paratransit services are wheelchair accessible. In addition, SFMTA issues permits and provides incentives for wheelchair accessible taxis, known as ramp taxis. Like all San Francisco taxicabs, ramp taxis are also part of the SF Paratransit Taxi program.[30]

SFMTA works to promote a vibrant taxi industry through intelligent regulation, enforcement, and partnership with the industry. The City's fleet of licensed cabs exceed clean-air vehicle standards.[31] As of August 2019, the taxi fleet included 1,602 approved taxis in 23 color schemes (fleets). There are no taxi color scheme facilities in the SLR Vulnerability Zone.

SFMTA contracts with a paratransit broker, Transdev, to manage SF Paratransit. The paratransit broker administration offices are currently located in San Francisco, California. Dispatch and reservations are in San Francisco at Executive Park. All operations and maintenance services for SF Paratransit are in Brisbane, in San Mateo County. SF Paratransit also offers Shop-a-Round, a grocery shopping shuttle, and Van Gogh, a recreational shuttle, to older adults and people with disabilities.

The paratransit and taxi systems rely on the roadway network; hence, their vulnerability is tied to the vulnerability of the roadway system (see Section 5.1). The SF Paratransit system has been disrupted during heavy precipitation and flood events. As these shuttles and taxis provide door-to-door service that is not tied to fixed routes, access to SF Paratransit is governed by the impacts to roadways, overall traffic conditions, and how many customers are located in the SLR Vulnerability Zone.

Photo 5.33 San Francisco Paratransit bus. Heather Moran, SFMTA

Although vans can be rerouted to non-impacted roadways, paratransit customers rely more on customized services and prescribed locations than non-disabled customers using the standard public transit system.

5.6.1.2 Emerging Transportation Services

Emerging transportation services including car share, ride-hailing services / transportation network companies (TNCs), electric moped, kick scooter, and bicycle share (Photos 5.34 and 5.35).

SFTMA has adopted policies to encourage and facilitate vehicle sharing that is compliant with its guiding principles, including providing on-street parking spaces within the public right-of-way and off-street parking spaces within SFMTA parking lots and parking garages for shared vehicle storage. Car sharing programs are operated by private companies, and the partnership with SFMTA enhances the overall benefits of car sharing to the City.

More recently, the City has launched a shared electric moped parking permit program. The shared mopeds do not require designated parking spaces; however, when they are not in use, they must be parked at designated charging stations located in parking lots and garages.

30 San Francisco Paratransit. Taxi and Ramp Taxi Services. Available at https://www.sfparatransit.com/taxi-ramp-taxi-services.htm.

31 San Francisco Municipal Transportation Agency (SFMTA). Taxi. Available at https://www.sfmta.com/taxi.

Photo 5.34 **Zipcar vehicle share in downtown San Francisco.** Yusuke Kawasaki (CC BY 2.0)

Photo 5.35 **Ford GoBike bicycle share station.** Paul Sableman (CC BY 2.0)

Bicycle share programs are also expanding in San Francisco. Currently, the BayWheels system has over 170 stations with over 4,000 docks located throughout the City. Stationless bicycle share programs are also emerging; these networks do not require fixed stations for charging and, therefore, are very resilient to potential flooding.

Some of the emerging transportation service providers are using or progressing to electric power and, thus, there is more fixed infrastructure associated with their operations, which also require electricity. These shared vehicles (e.g., cars, mopeds, electric bikes) are sensitive to flooding because they have electrical and mechanical components that may not function if exposed to water. Also, the related vehicle sharing infrastructure (e.g., charging stations) located at street level has more substantial electrical equipment sensitive to inundation and would likely require repair after floodwaters recede. Shared vehicles could be moved offsite prior to a storm event with sufficient notice.

If inundation impacts are localized, there is some redundancy across the shared network to maintain operations with a reduced fleet across roadways that are outside of inundated areas.

5.6.1.3 Commuter Shuttle

Privately operated commuter shuttles, which transport workers from their neighborhoods to places of work or transportation hubs, are common on the streets of San Francisco. Shuttles support local San Francisco and regional goals by decreasing single-occupancy vehicle trips, vehicle miles traveled, and private vehicle ownership, while encouraging walking and transit use.

Through a partnership with SFMTA, commuter shuttles can use a network of up to 125 shuttle-stop locations, including shared Muni zones and shuttle-only loading zones. Commuter shuttle operators are required to develop a Service Disruption Prevention Plan with their permit application.

5.6.2 Exposure Assessment

Consistent citywide GIS information was not available for the emerging mobility services. The location of car share spaces, bike and moped docking stations, and other facilities are subject to change substantially as these services grow, limiting the value of a detailed exposure assessment of these assets. Paratransit drop-off and pick-up locations are also user dependent and not at fixed locations. However, paratransit operations and maintenance services are potentially susceptible to flooding in Brisbane.

5.6.3 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE 1: All services depend on the accessibility and integrity of roadways, sidewalks, bike lanes, and parking areas. If public transit and other shared commuter systems are impacted, there could be a shift in the mode of transport to private or shared vehicles (taxi, ride-hail services), which could increase congestion and associated greenhouse gas emissions and time delays.

KEY ISSUE 2: Flooding could limit paratransit service to affected neighborhoods and vulnerable communities, which would impair the ability of elderly or disabled persons to access these services for healthcare, employment, and basic services such as access to groceries.

Society and Equity: Paratransit door-to-door service for eligible individuals would not be available in flooded areas, leaving members of the community with few mobility services. Lack of available services could make their ability to live independently in their own home impossible over the longer term and force them to relocate.

Economy: If there is reduced paratransit access, those that depend on its service may have to rely on delivery services and in-home care, which some individuals may not be able to afford or have access to through their available support systems.

Emerging mobility systems that require electrical components to function may be impacted by saltwater flooding and damaged causing economic losses. With sufficient notice, they could be relocated out of the SLR Vulnerability Zone, potentially leading to economic losses if the new location is less prominent or convenient for users.

Environment: Reduced use of transit and the shift to private or shared vehicles could increase greenhouse gas emissions.

Governance: Currently, the City outsources paratransit services. The operations and maintenance services are in neighboring Brisbane, so there would be impacts to the ability of the system to respond to localized change in routing or conditions.

Currently private commuter shuttles use the same bus stops and roadways as SFMTA and regional transit. If use of these stops by public transit agencies increase because of rerouted buses, there would be a need for more coordination between public and private use. Public use would generally take precedence, requiring rerouting private commuter vehicles.

5.7 PARKING

San Francisco's parking supply consists of on-street (metered, signed, colored curb and unregulated) and off-street (garages and lots) spaces. Although there are many privately owned parking garages and lots, this assessment focuses only on the City-owned parking supply. SFMTA currently manages approximately 280,000 on-street spaces including 27,000 metered on-street spaces, 12,000 signed or colored on-street curb spaces, and 94,000 on-street spaces in neighborhoods through the City as part of the Residential Permit Program. In addition, SFMTA manages 19 parking garages and 21 metered parking lots.

On-street parking is impacted similar to roadways (see Section 5.1) (see Photo 5.36). Some parking spots would be inaccessible during flood events but would regain full functionality once floodwaters recede. In areas that experience more substantial and regular flooding, parking areas may be lost entirely. Parking along Ocean Beach and the Great Highway was lost permanently due to coastal erosion and flooding during severe winter storms.

Many City garages have mechanical equipment for ventilation, elevator pits, and mechanical/electrical rooms located in lower levels or below-grade. In some garages, this equipment is located on the rooftop and would be less vulnerable to flooding. Garage entry points are usually at grade and could become inaccessible. Parking floors that are at or below grade may also flood. Access can be restored once floodwaters recede. Below-grade parking areas may require pumps to remove standing water.

Other parking garages could provide redundancy (if they are not full and owners agree) if a few garages are impacted during a flood event.

Photo 5.36 On-street parking along the Embarcadero. Heather Moran, SFMTA

Table 5.12 Parking Spaces Exposure Summary

	Parking Spots (#) within Each Scenario									
	1	2	3	4	5	6	7	8	9	10
On-Street Parking	-	4	110	740	2,025	6,650	8,115	9,315	11,275	13,415
Off-Street Parking	-	-	60	1,000	1,775	14,875	26,600	29,800	37,125	40,050
Total Spaces Exposed	-	4	170	1,740	3,800	21,525	34,715	39,115	48,400	53,465

5.7.1 Exposure Assessment

The exposure of the parking spaces was evaluated relative to the 10 SLR scenarios (see Chapter 2) and is presented in Table 5.12. The number of off-street parking spaces (i.e., parking in a parking garage or parking lot) may overestimate the number of impacted spaces. If a parking garage is partially within the SLR Vulnerability Zone, the entire parking garage was considered out of service while inundated.

5.7.2 Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: If an impaired public transit system causes a mode shift to private vehicle usage, this could correlate with an increased demand for parking. The loss of one or more garages could impact the capacity of remaining garages. This could lead to fewer travelers accessing their destinations and increased congestion/travel time.

Society and Equity: Access to parking garages in the SLR Vulnerability Zone could be impacted. Although vehicles parked above grade can be accessed once floodwaters recede, they would not be available for use until that occurs. This could result in mobility impacts, as drivers may need to find alternative transportation. On-street parking spots may remain accessible in flooded areas, and cars left parked in these spots may be damaged by floodwaters. This can impact residents, commuters, and tourists.

Economy: Revenue at parking meters and parking garages would be reduced while parking spots are inaccessible. Some parking meters and garage payment facilities may require repair after floodwaters recede. Vehicles parked at or below grade in impacted garages or at street level in the SLR Vulnerability Zone could be damaged by floodwaters, causing economic losses.

Environment: If drivers must commute further to find parking, the increased driving would increase greenhouse gas emissions. Parking garages and areas often accumulate oil drippings and other hazardous materials, which could be washed into parks, open spaces, wetlands, and to the Bay by floodwaters.

Governance: Fleet parking areas that need to be evacuated prior to a potential storm event could access the upper floors of City-owned parking garages for safe storage of vehicles. This will require coordination and advance planning.

Hetch Hetchy Reservoir.
Photo by Sara Löwgren (CC BY 2.0)

CHAPTER 6

WATER

The City of San Francisco's water assets are managed by the SFPUC Water Enterprise. The three primary water systems are:

- **Regional Water System** – the water supply system that delivers water from the Sierra Nevada Mountains to the City as well as other neighboring communities that are members of the Bay Area Water Supply and Conservation Agency (BAWSCA).
- **Local Potable Water Supply** – the water supply distribution system and low-pressure fire suppression system within the City of San Francisco.
- **Emergency Firefighting Water System (EFWS)** – the high-pressure fire suppression system that is supplied by the local potable water system and saltwater from San Francisco Bay and distributed via a separate distribution pipe network. The EFWS is a separate system from the potable water systems and is designed to provide water for firefighting purposes. This system is described in Chapter 9, *Public Safety*.

The Water Enterprise also manages a recycled water distribution system and groundwater system that are not included within this Assessment because they are outside of the SLR Vulnerability Zone. The recycled water distribution system delivers recycled water from the North San Mateo County Sanitation District to Harding Park Golf Course. The City is also developing its own recycled water treatment facilities at the Oceanside Wastewater Treatment Plant, with storage facilities located at Golden Gate Park to deliver recycled water to Lincoln Park Golf Course, Golden Gate Park, and The Presidio. The groundwater system will comprise a network of six groundwater wells, pump stations, and distribution pipes. Currently, four groundwater wells are active, pumping water from the Westside Groundwater Basin (underlying the southwestern portion of San Francisco County and northern San Mateo County) to supply groundwater to Sunset and Sutro reservoirs and irrigation water to Golden Gate Park.

The following sections describe how each of the three primary water systems operate and provide information about how key assets and asset categories may be vulnerable to SLR and coastal flooding.

6.1 REGIONAL WATER SUPPLY

The SFPUC Water Enterprise manages a complex water supply system stretching from the Sierra to the City, including a series of reservoirs, tunnels, pipelines, and treatment systems (see Figure 6.1). The system is almost entirely gravity fed from the source to the tap. The water supply system serves 2.7 million residential, commercial, and industrial users in the Bay Area. Approximately one-third of the delivered water goes to retail customers in San Francisco, with the remaining two-thirds going to wholesale deliveries to 27 suburban agencies in Alameda, Santa Clara, and San Mateo counties in BAWSCA.

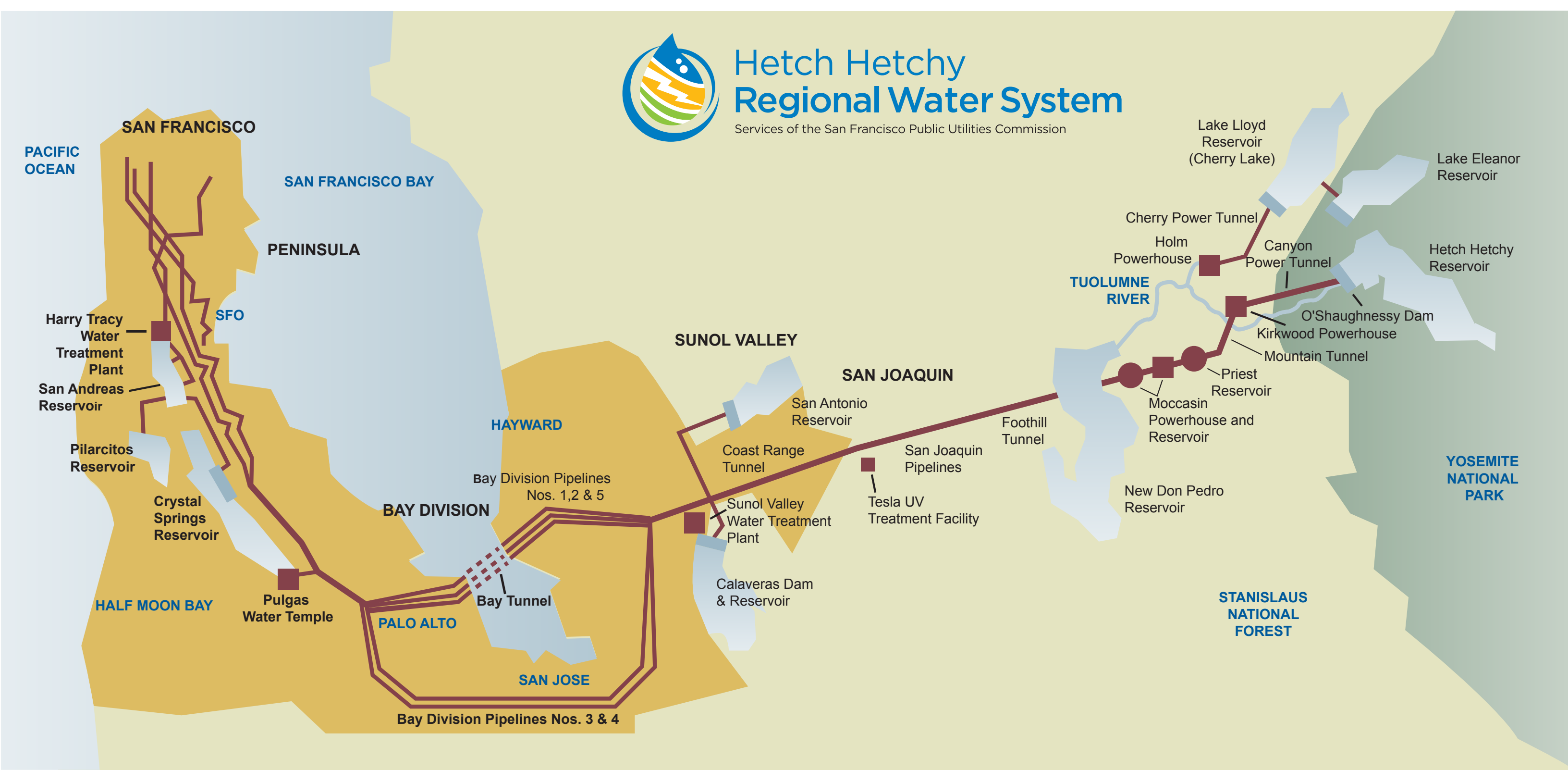
Eighty-five percent of San Francisco's total water needs are provided by the Hetch Hetchy watershed located in Yosemite National Park. Spring snowmelt runs down the Tuolumne River and fills Hetch Hetchy Reservoir, the largest reservoir in the Hetch Hetchy water system. Hetch Hetchy Reservoir can store up to 117 billion gallons of drinking water.

Sources in the Alameda and Peninsula watersheds provide the remaining 15 percent of the total water supply. The Alameda watershed, located in Alameda and Santa Clara counties, contributes surface water supplies captured and stored in two reservoirs: Calaveras and San Antonio. The Sunol Filter Galleries, located near the Town of Sunol, are a groundwater source supplying less than one percent of San Francisco's water. The Peninsula watershed in San Mateo County contributes surface water supplies captured and stored in lower and upper Crystal Springs and San Andreas Reservoirs, and in two smaller reservoirs, Pilarcitos and Stone Dam. The six reservoirs in the Alameda and Peninsula watersheds capture rain and local runoff, and some also store Hetch Hetchy water for use by San Francisco.

SFPUC adopted a large-scale capital improvement program in 2002 to secure regional water delivery reliability for the future. The Water System Improvement Program was designed and implemented to:

- Provide high-quality water to reliably meet current and foreseeable local, state, and federal requirements;
- Reduce system vulnerability to damage from earthquakes;

Figure 6.1 Regional Water System



- Increase system reliability by improving redundancy needed to accommodate outages;
- Improve short-term water supply reliability and drought protection;
- Set forth long-term options to address water supply shortages and manage drought;
- Enhance sustainability through improvements that optimize protection of the natural and human environment; and
- Provide improvements resulting in a cost-effective, fully operational water system.

Photo 6.1 Hetch Hetchy Aqueduct in Fremont, California

6.1.1 Potentially Vulnerable Assets

Although most of the Regional Water System is in upland areas outside of the SLR Vulnerability Zone (i.e., the area that could be inundated with 66 inches of SLR and a one percent annual chance storm surge condition), there are three areas located outside of the City of San Francisco's jurisdiction that could be inundated by SLR or an extreme storm surge event before the end of the century: the connections to the Bay Tunnel crossing in Newark and Ravenswood, and the pipeline crossing in Santa Clara at the Guadalupe River. Within these three areas, the primary assets are transmission lines, valves and connections, air release / air vacuum valves, and control and monitoring systems.

6.1.1.1 Transmission Lines

Hetch Hetchy Aqueduct (Bay Division Pipelines Nos. 1, 2, and 5) carries water from Hetch Hetchy Reservoir in Yosemite to the Crystal Springs Reservoir west of San Carlos. The transmission lines could be inundated at the Bay Crossing from Newark to Ravenswood and near the Guadalupe River crossing in the South Bay (see Figure 6.2).

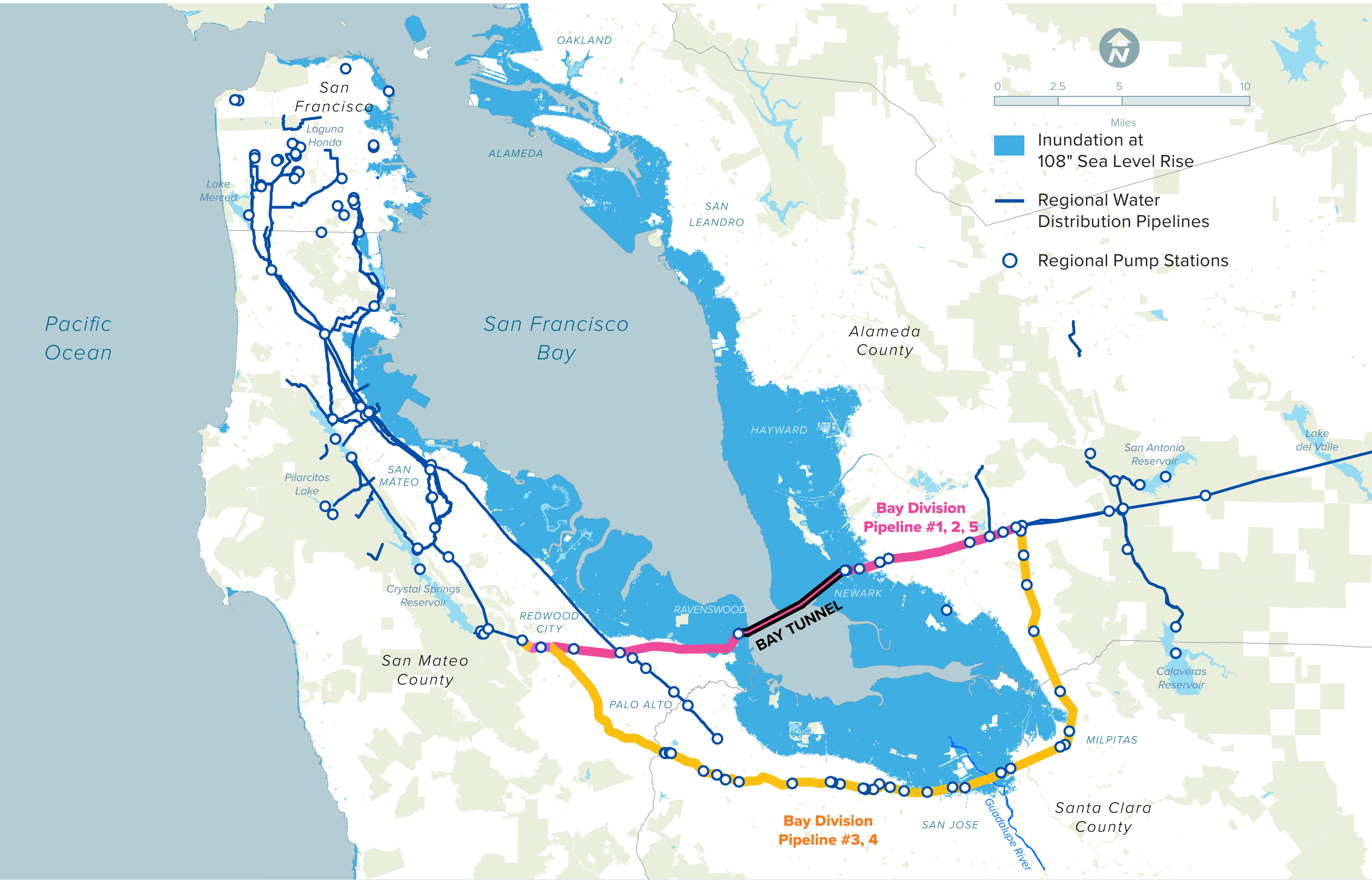
The aboveground pipelines in this area (see Photo 6.1) were replaced in 2014 with an underground pipeline and a Bay Tunnel crossing that runs about 100 feet under the Bay. Photo 6.1 highlights the low sensitivity of the pipelines to saltwater. The original pipelines were constructed in the 1925 (Pipeline No. 1) and 1936 (Pipeline No. 2) and have been subjected to tidal inundation multiple times over the past several decades with limited corrosion. The primary reason for replacing the Bay crossing infrastructure was to improve the seismic stability of pipelines. In general, both the previous Bay crossing infrastructure and the new Bay Tunnel have low adaptive capacity, meaning they are difficult to adapt or retrofit to address changing conditions without significant investments. However, the new Bay Tunnel has capped watertight tunnel shafts, and the Bay Tunnel and shafts are not expected to be affected by SLR.

Hetch Hetchy Aqueduct (Bay Division Pipelines Nos. 3 and 4) crosses under the Guadalupe River, and Hetch Hetchy Trail has been constructed on top of the aqueduct at this location (see Figure 6.2). The most vulnerable components of the transmission system are the buried pipelines and the pump stations that keep the water flowing through the distribution system. As sea level rises and the groundwater rises and becomes more saline, corrosion could shorten the life expectancy of the buried infrastructure, requiring more frequent repair and replacement. The pump station infrastructure, including sensitive electrical equipment, is also vulnerable to overland coastal flooding.

6.1.1.2 Valves and Connections

The flow of water through the Regional Water System is mechanically controlled by pump stations and valves, and the flow of water out of the system to customers and other agencies is controlled by connections. The Ravenswood and Newark areas have valves with electric actuators, which allow the

Figure 6.2 Bay Division Pipelines and Bay Crossing in the South Bay



valves to be opened and closed remotely. Although the valves are designed to be watertight, the electric components are sensitive to inundation. The valves could be operated manually in a temporary flood situation. However, if the valves become permanently inundated by SLR, the electric actuators would need to be replaced with a hydraulically operated system to be controlled remotely.

The Ravenswood and Newark areas have six service connections and an intertie connection that supplies water to the East Bay Municipal Utility District water supply network. The Guadalupe River crossing has two service connections. This infrastructure is designed to be watertight and is not sensitive to inundation, although increased saltwater-induced corrosion could shorten the life expectancy of these assets.

6.1.1.3 Air Release / Air Vacuum Valves

Air release valves help to automatically exhaust unwanted air during system operation to protect against unwanted surges and maintain system efficiency. Air vacuum valves are safety valves that admit air if the pressure within the pipeline is less than that of the atmosphere to prevent a pipeline collapse. Along the Bay Division Pipelines (including at Newark, Ravenswood, and the Guadalupe River Crossing), combination air release / air vacuum valves are typically located at high points in the system where unwanted air may collect. Air release / air vacuum valves are vulnerable assets because they cannot perform their function if inundated – they must maintain a connection to the atmosphere. If an air release / air vacuum valve is inundated, it could contaminate the potable water supply in the pipelines. Even brief inundation is an issue and is prohibited by the State Water Resources Control Board. Per state regulations, air release valves must be above FEMA 100-year flood elevations. The air release valves near the Guadalupe River crossing were designed to be higher than the state requirements due to their proximity to the Bay and the Guadalupe River, which has a potentially higher flood risk. As sea levels rise, the 100-year flood elevations will also rise, and the air release valves will need to be raised to accommodate this change.

6.1.1.4 Control and Monitoring Systems

The Ravenswood and Newark areas include control buildings and other assets that are sensitive to inundation, particularly saltwater inundation. The control buildings include meters and equipment for remote monitoring and control of the system (supervisory control and data acquisition, SCADA). These assets control or collect data from the mechanical and electromechanical components of the system. Temporary flood protection measures could be implemented to address temporary flood events (i.e., sandbags, flood baffles, wet flood proofing). However, significant cost and effort would be required to redesign and elevate/relocate this equipment to address permanent inundation. The control and monitoring systems are the most vulnerable assets in the Regional Water System.

6.1.2 Exposure Assessment

The exposure of the Regional Water Supply assets was evaluated relative to the 10 SLR scenarios (see Chapter 2, *Climate Science*). The miles of buried water distribution pipeline exposed to SLR are presented in Table 6.1, and the regional pump stations located within the SLR Vulnerability Zone are presented in Table 6.2. Although the air release / air vacuum values and the control and monitoring systems are vulnerable to SLR and coastal flooding if they are exposed, a detailed exposure assessment could not completed for the Regional Water System because the locations of this equipment are not included the GIS geodatabase for the Regional Water System.

Table 6.1 Regional Water Supply Distribution Pipelines

	Miles of Buried Water Distribution Pipelines within Each Sea Level Rise Scenario									
County	1	2	3	4	5	6	7	8	9	10
Alameda	-	-	-	-	0.2	0.4	0.5	0.5	0.7	0.8
San Mateo	-	-	1.0	2.0	2.3	3.1	3.5	3.7	4.1	4.9
Santa Clara	-	-	-	0.2	0.3	1.4	1.8	1.9	1.9	2.4
Bay Crossing	0.5	0.9	1.3	1.4	2.2	2.2	2.4	2.4	2.4	2.4
Total	**0.5**	**0.9**	**2.3**	**3.6**	**5.0**	**7.1**	**8.2**	**8.5**	**9.1**	**10.5**

Table 6.2 Regional Water Supply Pump Stations

	Regional Pump Stations within Each Sea Level Rise Scenario									
County	1	2	3	4	5	6	7	8	9	10
Alameda	-	-	-	-	1	3	4	4	4	4
San Mateo	-	1	1	1	1	1	1	1	1	1
Santa Clara	-	-	-	-	-	1	1	1	1	2
Total	**-**	**1**	**1**	**1**	**2**	**5**	**7**	**7**	**7**	**8**

6.1.3 Consequence Summary

KEY ISSUE: The Regional Water System is a critical source and delivery system of potable water not only for San Francisco, but for much of the San Francisco Bay Area. Although emergency reserves within the system are intended to meet basic needs for at least 72 hours after an emergency or natural disaster, longer disruptions to this system could have cascading impacts on local water supply and fire suppression systems that serve both commercial and residential customers throughout the Bay Area. In addition, impacts to the power generation or distribution system can impact the Regional Water System. Although limited infrastructure is located within the SLR Vulnerability Zone, rising sea levels and coastal flooding could impact the control systems, resulting in widespread water shortages.

Society and Equity: Potable water is critical for meeting basic needs and for providing emergency response. Any unforeseen, short- or long-term disruption of water supply could impact all customers. Vulnerable populations, such as the elderly or young children who are particularly reliant on safe drinking water, will be the most impacted. Health issues and disease may spread if public and private sanitary systems are inoperable. If potable water is no longer available on tap, San Francisco residents and visitors will be forced to buy bottled water, which would disproportionately impact already vulnerable communities even more.

Economy: If a short- or long-term water shortage occurs, potable water-dependent industries will be impacted. This includes office buildings, hotels, restaurants, and other industries within the affected area. The longer the water shortage occurs, the larger the impacts to the local and regional economy. Water infrastructure will require inspections and repairs if water delivery is interrupted for a lengthy period and the pipelines are contaminated with saltwater or they become depressurized.

Environment: If potable water is limited or unavailable, irrigation, and other outdoor uses of water will be limited as potable water will likely be prioritized for other uses. Parks, golf courses, and other green spaces that rely on outdoor water use may be damaged, especially if limited use extends to the dry summer months. Animals and wildlife that depend on the open spaces may also suffer. Open spaces that rely on recycled, non-potable water will likely be the most resilient.

Governance: Multi-agency cooperation, public-private partnerships, and coordinated local and regional action will be necessary to help communities meet basic water needs. Coordinated and prioritized distribution of potable water (i.e., via bottled water, portable water tanks, or other means) will be required.

6.2 LOCAL POTABLE WATER SUPPLY SYSTEM

San Francisco's Regional Water System supplies water to three terminal reservoirs within the City (e.g., the Sunset, University Mound, and Merced Manor reservoirs). Terminal reservoirs are shared by San Francisco and its wholesale suburban water customers during emergencies. From these reservoirs, the water is gravity fed or pumped into eight covered distribution reservoirs and tanks. The terminal and distribution reservoirs (see Figure 6.3) can hold nearly 416 million gallons (MG) at full capacity – about a five-day supply for the City. In an emergency, the City can draw upon the surface water supplies in Lake Merced and Laguna Honda, which together hold 2.6 billion gallons of water.

The Sunset Reservoir is the City's largest, located in the Sunset District at 24th Avenue and Ortega Street (Photo 6.2). The subterranean reservoir has a total capacity of 177 MG. The reservoir has 25,000 solar panels installed on the roof, generating five megawatts of power. University Mound Reservoir, located in the Portola District at University Avenue and Felton Street, has a storage capacity of 141 MG. Together, the Sunset and University Mound reservoirs supply over half of the City's water supply. The third terminal reservoir is Merced Manor Reservoir located at Sloat Boulevard and 23rd Avenue, with a total storage capacity of 9.5 MG. College Hill Reservoir located at Appleton Avenue and Elise has a capacity of 13.5 MG and other smaller distribution reservoirs are scattered on the heights across the City serving nearby neighborhoods. The underground transmission pipelines distribute water primarily by gravity from the reservoirs throughout the City.

6.2.1 Potentially Vulnerable Assets

The Local Potential Water Supply System assets within the SLR Vulnerability Zone include distribution pipelines, air release / air vacuum vales, the Bay Bridge Pump Station, and low-pressure fire hydrants (LPFH).

Photo 6.2 Sunset Reservoir.

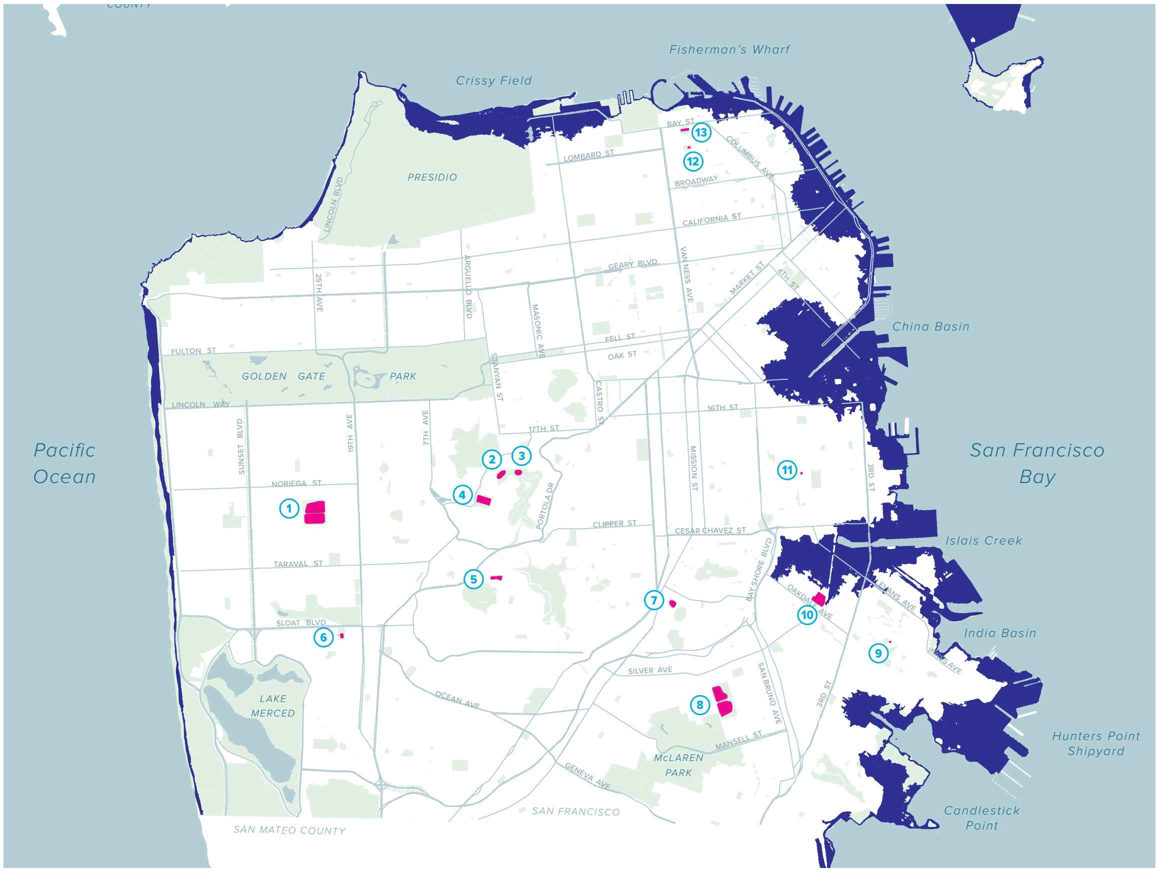


Figure 6.3
Reservoirs and Storage Tanks

2 Summit Reservoir
3 Twin Peaks Reservoir
4 Sutro Reservoir
5 Stanford Heights Reservoir
6 Merced Manor Reservoir
7 College Hill Reservoir
8 University Mound Reservoir
9 Hunters Point Reservior
10 CDD Yard
11 Potrero Heights Reservoir
12 Lombard Reservoir
13 Francisco Reservoir (not is use)

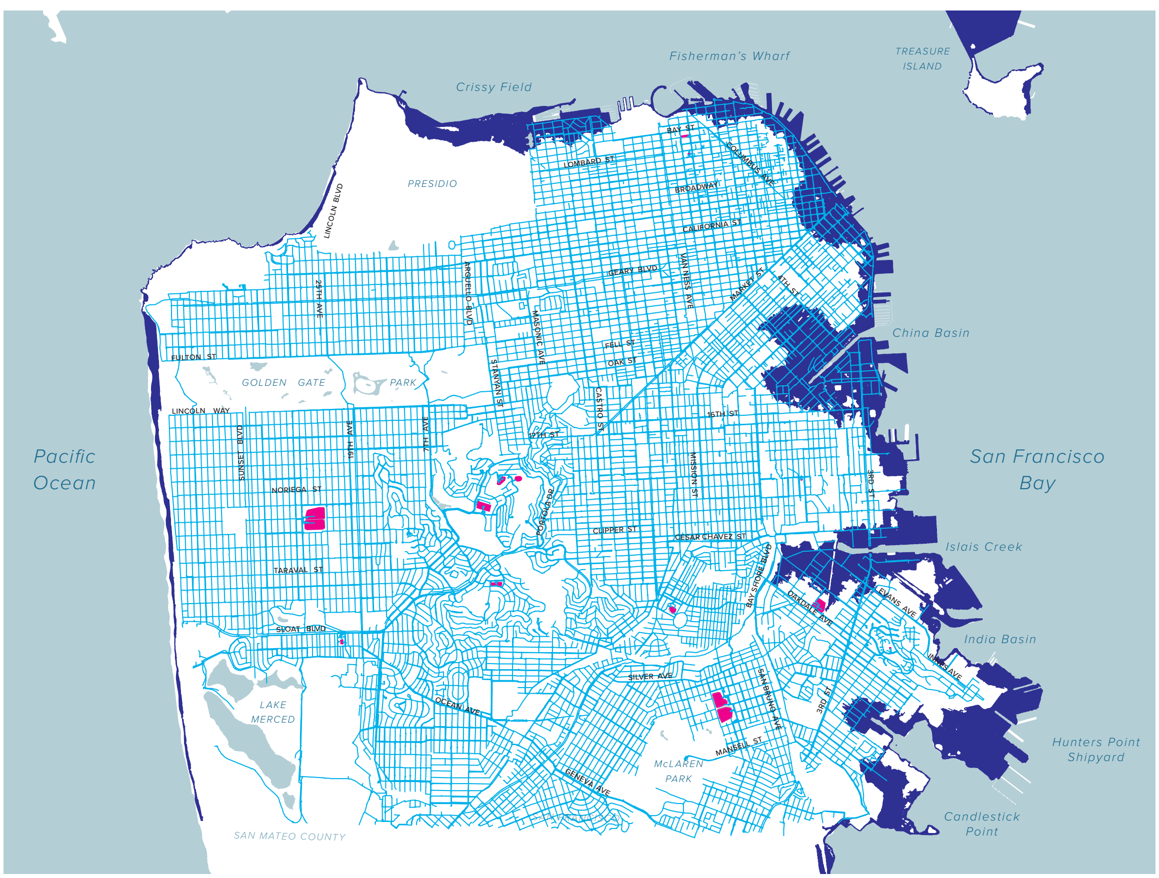


Figure 6.4
Potable Water Supply Distribution Pipelines

6.2.1.1 Potable Water Distribution Pipelines

The underground potable water distribution pipelines, ranging in size from 60 to six inches in diameter, distribute water throughout the City primarily by gravity (see Figure 6.4). Local connections to the distribution pipelines supply water directly to the residential, commercial, and industrial customers. The pipelines are not sensitive to temporary inundation that could occur during an extreme coastal flood event because the infrastructure is buried underground. However, as sea levels rise, and the shallow groundwater table rises and increases in salinity near the shoreline, corrosion could shorten the life expectancy of the buried pipelines and increase the likelihood of pipelines shifting underground. The repair and replacements cycles would shorten, and the frequency of emergency repairs associated with water main leaks, breaks, and sink holes could increase.

In general, buried infrastructure is not easily adaptable to rising sea levels or increases in salinity. All adaptation measures would likely require significant investments, and disruptions to roadways and traffic during repairs and modifications to address changing conditions.

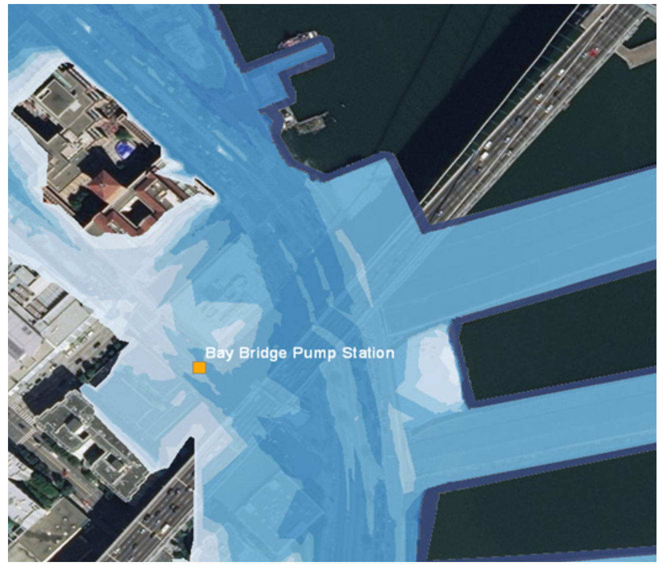
6.2.1.2 Air Release / Air Vacuum Valves

Similar to the Regional Water System (see Chapter 6.1.1.3), air release valves are vulnerable to flooding because they cannot perform their function if inundated – they must maintain a connection to the atmosphere. If an air release / air vacuum valve is inundated, it could contaminate the potable water supply in the pipelines. Even brief inundation is an issue and is prohibited by the State Water Resources Control Board. Per state regulations, air release valves must be above FEMA 100-year flood evaluations. As sea levels rise, the 100-year flood elevations will also rise, and the air release valves will need to be raised to accommodate this change.

6.2.1.3 Pump Stations

The local potable water supply system includes 17 pump stations of varying capacities to supply the reservoirs and tanks at higher elevations. Only the Bay Bridge Pump Station (see Photo 6.3) is located inside the SLR Vulnerability Zone (see Figure 6.5).

Figure 6.5 Bay Bridge Pump Station Location



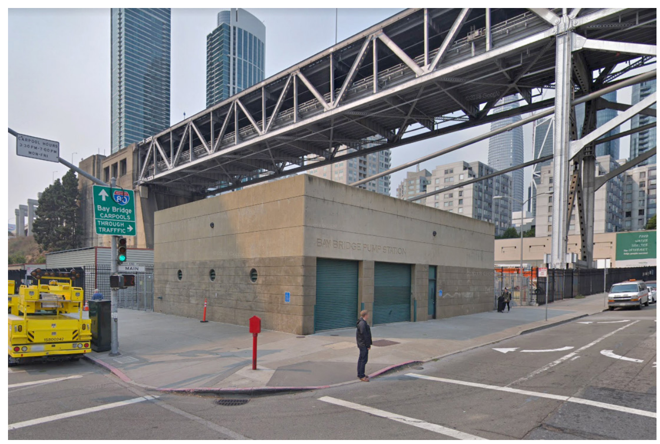


Photo 6.3 New Bay Bridge Pump Station

The Bay Bridge Pump Station is located at the intersection of Bryant and Main Streets in San Francisco. This pump station was originally constructed in 1938 and was housed inside the bridge pier at the intersection of Spear Street and Main Street. It was relocated to its present location in 2003 due to seismic upgrades to the Bay Bridge. This pump station serves as the sole source of water to the Treasure Island/Yerba Buena water distribution system. The pump station transfers water from the University Mound pressure zone to the Treasure Island/Yerba Buena water distribution system. If the Bay Bridge pump station is impacted by SLR or coastal flooding, potable water would not be delivered to Treasure Island.

The Bay Bridge Pump Station has at- and below-grade components, including electrical equipment that is sensitive to any inundation. Multiple flood pathways are available to allow floodwaters into the pump station (i.e., doorways, vents, conduits). Temporary flood protection measures such as sand bags and inflatable baffles could be used to provide short-term protection in advance of a storm event. However, no short-term measures are currently stored onsite, so advance notice of a storm event is required to provide protection. In the longer term, the structure could be modified to include dry flood-proofing measures that would seal the structure and prevent floodwaters from entering.

6.2.1.4 Low Pressure Fire Hydrants

Water for firefighting is supplied to the San Francisco Fire Department by the Local Potable Water Supply System. Throughout the City, white LPFH hydrants are connected directly to the local potable water supply distribution system (see Figure 6.6).

Temporary inundation could make hydrants inaccessible if the roadways are not passable, or if the hydrant is entirely underwater. If inundation is less than 20 inches (i.e., firetruck safe passage depth), a hydrant is likely still usable. However, if an LPFH is inundated, the closest Emergency Firefighting Water System high-pressure fire hydrant should be used to avoid cross-contamination with the local potable water supply.

The vulnerabilities associated with fire hydrants are directly related to the flooding and vulnerabilities along the roadways (see Chapter 5, *Transportation*). Areas with inaccessible (i.e., flooded) LPFH will not have direct access to fire suppression services from fire engines. Services should resume after floodwater recedes. Fire hydrants in flooded areas will require inspections for corrosion to ensure each hydrant is fully operational in the event of an emergency. Properties located on the edge of the flood zone (i.e., within approximately 500 feet) may still have access

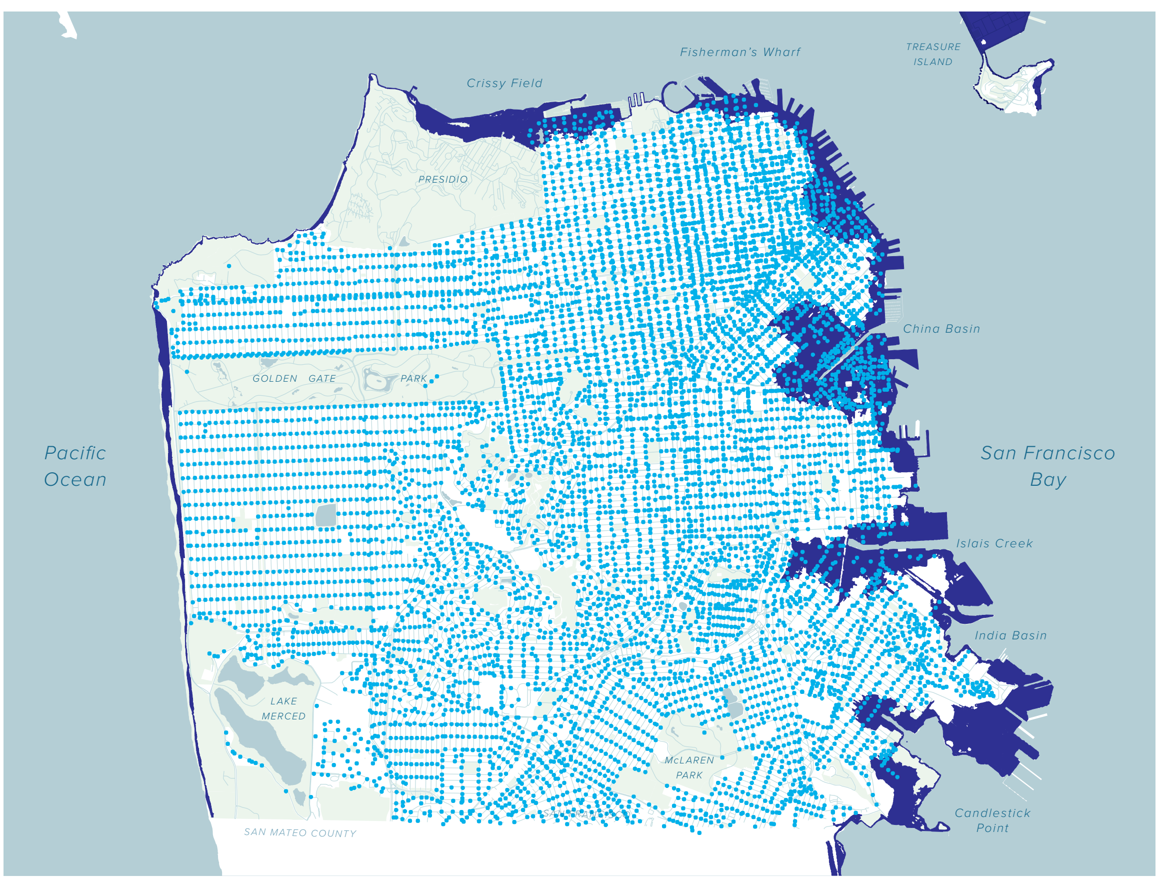


Figure 6.6
Low-Pressure Fire Hydrants

to working hydrants either outside the inundated area or in areas with minimal inundation. If sufficient water or pressure is not available from the local potable water supply system, high-pressure fire hydrants and cisterns are also available to provide redundancy in some areas (see Section 6.3).

6.2.2 Exposure Assessment

The exposure of the Local Potable Water Supply System assets was evaluated relative to the 10 SLR scenarios (see Chapter 2, *Climate Science*). Table 6.3 presents the miles of buried potable water distribution pipeline within each SLR scenario, and Table 6.4 presents the same information by the type of pipeline material. Most of the potentially exposed pipelines are connected to the University Mound pressure zone. Cast iron corrodes quickly when exposed to seawater; however, generally only the surface layer of the pipeline corrodes and then the corrosion stops. Ductile iron pipelines have largely replaced cast iron pipelines for potable water distribution systems, and these pipelines include protective internal lining and external coating to inhibit corrosion. The older, cast iron pipelines are likely the most vulnerable to salinity-related corrosion.

Table 6.5 presents the number of air release / air vacuum valves that are potentially exposed within each SLR scenario[1]; however, the elevation of each air release valve was not available. Because the air release valves are often elevated above the ground surface, they may be inundated under a later scenario than presented in Table 6.5. As with the

1 Although the locations of the air release / air vacuum valves were not available for the Regional Water System, the locations for the Local Potable Water Supply System were available within the GIS geodatabase, and the exposure of the valves could be assessed.

Table 6.3 Potable Water Distribution Pipeline Exposure Summary

University Mound Pressure Zone	Miles of Buried Water Distribution Pipeline within Each Sea Level Rise Scenario									
	1	2	3	4	5	6	7	8	9	10
Bayview South	-	-	-	-	-	0.6	1.1	1.5	2.3	3.0
Bayview North	-	-	-	0.3	1.4	3.4	4.2	5.0	6.3	8.5
Potrero Hill	-	-	-	-	-	0.3	0.5	0.7	1.0	1.8
South of Market	-	-	0.5	2.4	4.4	12.5	15.6	17.7	20.4	22.7
Financial District	-	-	0.1	0.7	1.3	5.4	6.2	6.9	8.0	9.3
North Beach	-	-	-	-	0.1	3.0	3.9	4.5	5.1	5.7
Russian Hill	-	-	-	-	-	-	0.1	0.1	0.1	0.1
Marina	-	-	-	0.1	0.1	1.2	1.8	2.5	3.4	4.7
Total University Mound	-	-	**0.5**	**3.5**	**7.3**	**26.0**	**33.0**	**39.0**	**47.0**	**56.0**

Table 6.4 Potable Water Distribution Pipeline Exposure Summary by Material

Material	Miles of Buried Water Distribution Pipeline within Each Sea Level Rise Scenario									
	1	2	3	4	5	6	7	8	9	10
Ductile Iron	-	-	0.5	3.1	5.6	16.7	20.5	23.2	27.5	31.9
Cast Iron	-	-	-	0.4	1.7	8.6	11.6	14.3	17.5	22.0
Steel	-	-	-	-	-	0.6	0.7	0.8	0.9	0.9
Unknown	-	-	-	-	-	0.4	0.5	0.6	0.8	1.1

Table 6.5 Air Release / Air Vacuum Valve Exposure Summary

Pressure Zone	Number of Air Release / Air Vacuum Valve Exposures under Each Scenario									
	1	2	3	4	5	6	7	8	9	10
McLaren Park Tank										
Bayview South	-	-	-	-	-	-	-	-	2	2
University Mound										
Bayview South	-	-	-	-	-	8	12	15	31	35
Bayview North	-	-	-	3	8	26	34	41	50	62
Potrero Hill	-	-	-	-	-	1	2	5	12	22
South of Market	-	-	19	51	85	214	259	277	316	338
Financial District	-	-	2	8	21	95	109	127	155	173
North Beach	-	-	-	-	-	63	78	88	98	102
Russian Hill	-	-	-	-	-	-	-	-	-	-
Marina	-	-	-	-	-	3	8	12	15	19

Table 6.6 Bay Bridge Pump Station Exposure Summary

Pump Station	Pump Station Exposure under Each Scenario (Y/N)									
	1	2	3	4	5	6	7	8	9	10
Bay Bridge	-	-	-	-	-	-	Y	Y	Y	Y

Table 6.7 Low-Pressure Fire Hydrant Exposure Summary

Neighborhood	Number of Low-Pressure Fire Hydrants Exposed under Each Scenario									
	1	2	3	4	5	6	7	8	9	10
Bayview North	-	-	-	-	-	3	7	10	21	28
Bayview South	-	-	-	-	8	31	43	52	64	87
Financial District	-	-	1	3	7	59	68	76	90	107
Marina	-	-	-	-	-	6	15	19	22	33
North Beach	-	-	-	-	-	21	28	31	37	42
Potrero Hill	-	-	-	-	-	3	5	10	17	35
Presidio	-	-	-	-	-	3	3	3	3	3
South of Market	-	-	6	42	66	170	207	229	262	294
Total	-	-	**7**	**45**	**81**	**296**	**376**	**429**	**514**	**622**

potable water supply distribution system, most of the potentially exposed air release / air vacuum valves are associated with the University Mound pressure zone distribution system. The most vulnerable air valves are the automatic air valves that are spring loaded and could fail if pressure was lost; these valves are attached to larger distribution mains.

The Bay Bridge Pump Station is first exposed to SLR and coastal flooding under Scenario 7 (77 inches of SLR, or 36 inches of SLR coupled with a 100-year coastal storm surge event (see Table 6.6). Table 6.7 presents the number of LPFH exposed – by neighborhood – to SLR and coastal flooding under each SLR scenario.

6.2.3 Consequence Summary

KEY ISSUE 1: The Local Potable Water Supply System relies on a complex and interconnected system of reservoirs and pipelines and infrastructure. Although most of this infrastructure is located outside of the SLR Vulnerability Zone, SLR and coastal flooding could impact potable water delivery and availability throughout the City. The largest impacts would likely occur within vulnerable populations located within the SLR Vulnerability Zone and Treasure Island.

Society and Equity: Potable water is critical to meet basic needs within the City. Any unforeseen, disruption of the potable water supply would impact residential and business customers. Vulnerable populations, such as the elderly or young children, are particularly reliant on safe drinking water and would be the most impacted in the event of a water shortage. Health issues may arise if a sufficient safe water supply is not available for sanitation.

Economy: If the local potable water supply is compromised, water-dependent industries would be impacted, affecting business in these areas. Over a longer period, if businesses are not able to operate and residences become uninhabitable, depopulation could have significant impacts on the economy. Repairs to infrastructure, including private systems, could be extensive.

Environment: If local potable water supplies are limited, outdoor irrigation may be limited. Plants and animals that rely on irrigation services or other regular watering in the City's green spaces, especially during the dry summer months, could suffer or perish.

Governance: Multi-agency cooperation, public-private partnerships, and coordinated local and regional action will be necessary to maintain basic services in the event of a water shortage, and to improve the resilience of San Francisco's water-dependent industries.

KEY ISSUE 2: Many LPFH could be affected, reducing the firefighting capabilities in the low-lying areas of the City. Although the Emergency Firefighting Water System provides back-up fire suppression capabilities, a severe coastal flood event could render both systems inoperable (i.e., the inundation that limits the use of LPFH will also limit the use of the high-pressure fire hydrants.

Society and Equity: Fire suppression services would be limited in low-lying areas of the City, especially in vulnerable communities that cannot be readily served by the City's three fireboats.

Economy: If a large-scale fire occurs and spreads before the fire suppression services can be brought back online, the associated damage and recovery costs could be extensive.

Governance: Multi-agency cooperation will be required to maintain life and safety services if fire suppression services are unavailable for an extended period.

Southeast Treatment Plant. Photo by Marcin Wichary (CC BY 2.0)

CHAPTER 7

WASTEWATER

The City of San Francisco's wastewater assets are managed by the San Francisco Public Utilities Commission (SFPUC) Wastewater Enterprise. San Francisco's combined sewer system collects and treats both stormwater and wastewater (see Figure 7.1). This system includes nearly 1,000 miles of sewer pipelines, 26 pump stations, and three treatment plants that collect, convey, and treat stormwater and wastewater before it is discharged through outfalls to San Francisco Bay and the Pacific Ocean.

The sewer system collects approximately 70 million gallons (MG) of water on average dry days and has the capacity to collect and treat up to 575 million gallons per day (mgd) of combined wastewater and stormwater during wet weather. During dry weather, the collection system conveys wastewater flows for treatment at the Southeast Treatment Plant near Islais Creek and the Oceanside Treatment Plant on the westside of the City near the San Francisco Zoo. During wet weather, combined flows are also conveyed for treatment at the North Point Wet-Weather Facility near Fisherman's Wharf.

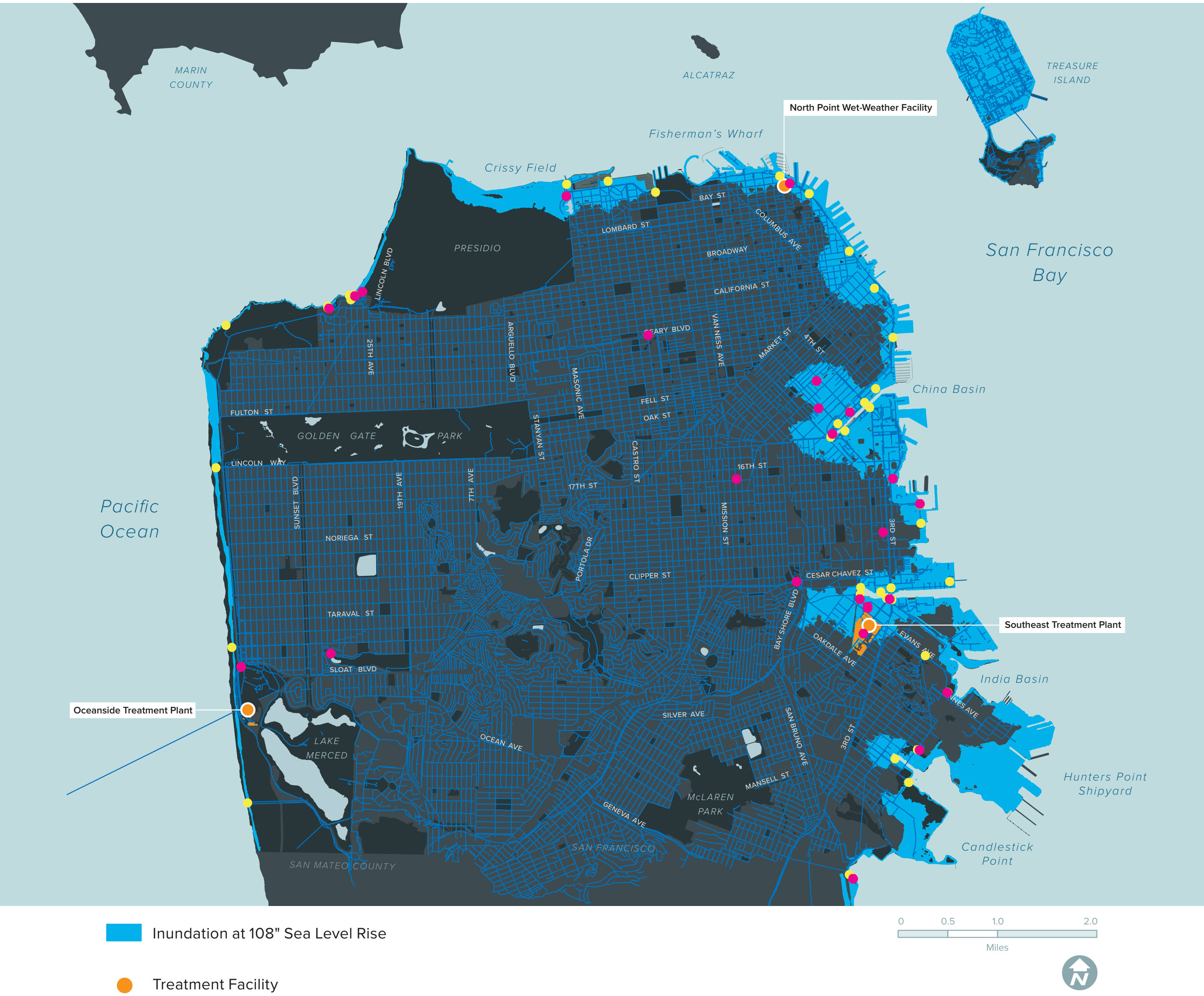
SLR and coastal storm surge will impact the integrity of SFPUC's wastewater infrastructure . Climate change, in particular SLR, is one of many considerations informing SFPUC's Sewer System Improvement Program[1] – a comprehensive program to upgrade the aging sewer infrastructure and ensure the reliability and performance of the City's sewer system. SFPUC completed a Climate Vulnerability and Adaptation Assessment to evaluate the vulnerability of wastewater assets to climate hazards, including SLR, coastal flooding, rising groundwater, and precipitation-driven flooding.[2]

The following sections provide a summary of SFPUC's Climate Vulnerability and Adaptation Assessment, with a focus on how key assets and asset categories may be vulnerable to SLR and extreme tide-related flooding.

1 San Francisco Public Utilities Commission (SFPUC). Sewer System Improvement Program. Available at https://www.sfwater.org/index.aspx?page=116.

2 San Francisco Public Utilities Commission (SFPUC). 2019. Climate Vulnerability and Adaptation Assessment for the Waste Water Enterprise Sewer System Improvement Program.

Figure 7.1 Wastewater System and Assets



Inundation at 108" Sea Level Rise

Treatment Facility

Pump Station

Combined Sewer Discharge

Buried Sewers

7.1 PUMP STATIONS

The wastewater collection sewer system is designed to take advantage of the City's natural topography wherever possible to maximize the benefits of gravity flow; however, pump stations and force mains are required in locations where gravity flow is not feasible. There are 26 pump stations located throughout the City. During dry weather, 14 pump stations transport wastewater to the Southeast and Oceanside treatment plants for treatment. During wet weather, all 26 pump stations transport combined wastewater and stormwater to the City's three treatment plants for treatment and discharge. Continued operation of the pump stations is critical for protecting the environment and public health.

7.1.1 Potentially Vulnerable Assets

Fifteen of SFPUC's 26 wastewater pump stations are located within the SLR Vulnerability Zone, as shown on Figure 7.2.

7.1.1.1 Channel Pump Station

Channel pump station is an abovegrade pump station located at 455 Berry Street near Mission Bay between 6th and 7th Streets in a mixed residential and industrial area directly adjacent to the Mission Bay shoreline (Photo 7.1). Currently, this pump station serves both the Channel and Northshore drainage basins. Constructed in 1979 and upgraded in 2010, Channel pump station has a pumping capacity of 103 mgd and operates continuously in both dry and wet weather. In dry weather, Channel pump station receives and transports wastewater pumped from the North Shore pump station and flows from the Channel drainage area. The pump station conveys wastewater through the Channel force main to the Southeast Treatment Plant. In wet weather, combined flows are conveyed from the local drainage area to the Southeast Treatment Plant. The pump motor, electrical equipment, and controls are located at grade. This station could be exposed to floodwaters under 66 inches of SLR, or 24 inches of SLR coupled with a 100-year extreme tide (Scenario 6).

Photo 7.1 Channel Pump Station (above grade). Sergio Ruiz

Figure 7.2 Wastewater Pump Stations and the SLRVZ

PUMP STATIONS

1. Channel Pump Station
2. Bruce Flynn Pump Station
3. Northshore Pump Station
4. Griffith Pump Station
5. Sunnydale Pump Station
6. Mariposa Pump Station
7. Palace of Fine Arts Pump Station
8. Davidson Pump Station
9. Rankin Pump Station
10. Merlin Morris Pump Station
11. Harriet-Lucerne Pump Station
12. Twentieth Street Pump Station
13. Berry Street Pump Station
14. Booster Pump Station
15. Southeast Lift Station

Inundation at 108" Sea Level Rise

7.1.1.2 Bruce Flynn Pump Station

Bruce Flynn pump station is an above grade pump station located in an industrial area at the intersection of Rankin Street and Davidson Avenue, approximately 500 feet from the Bay shoreline. This wet-weather pump station was constructed in 1996, is presently being upgraded, and will have a pumping capacity of 150 mgd. In wet weather, the pump station receives combined flows from the Islais Creek transport / storage box and pumps to the Southeast Treatment Plant. This pump station serves the Islais Creek, Yosemite, Sunnydale, and Mariposa drainage areas in wet weather. Electrical equipment and controls are located at grade, and the pump motor is located below grade.

This station could be exposed to floodwaters under 66 inches of SLR, or 24 inches of SLR coupled with a 100-year extreme tide (Scenario 6). Pathways for flooding at this asset include roll-up doors at ground level and open ground-level areas with equipment. There are several access points to below grade rooms and water-sensitive equipment inside the station.

7.1.1.3 North Shore Pump Station

North Shore pump station is an abovegrade pump station located at 2001 Kearny Street at the intersection of Bay Street and Kearny Street. The pump station is in a mixed commercial and industrial area, approximately 300 feet from the Bay shoreline.

Constructed in 1982, North Shore pump station serves the Northshore drainage basin during both dry and wet weather. This pump station operates continuously in dry weather and conveys 30 mgd of wastewater to the Channel pump station, which transports wastewater to the Southeast Treatment Plant. During wet weather, the pump station can convey 150 mgd to the North Point Wet-Weather Facility. Electrical equipment and controls are located over 3.5 feet above grade, and the pump motor is located below grade.

7.1.1.4 Griffith Pump Station

Griffith pump station is an abovegrade pump station located in an industrial area at the intersection of Griffith Street and Thomas Avenue, approximately 400 feet from the Bay shoreline. Constructed in 1989 and upgraded in 1998 and 2018, this pump station serves the lower Yosemite and Sunnydale drainage basins with a pumping capacity of 120 mgd. In dry and wet weather, the Griffith pump station conveys wastewater and/or combined flows to the Hunters Point tunnel via two force mains. Electrical equipment and controls are located at grade.

This station could be exposed to floodwaters with 66 inches of SLR coupled with a 100-year extreme tide (Scenario 10). Pathways for flooding at this asset include the north door approximately one foot above ground level and louvers approximately 1.5 feet above ground level.

7.1.1.5 Sunnydale Pump Station

Sunnydale pump station is a belowgrade pump station located on Harney Way between US 101 and the Bay. The pump station is located near an industrial area but is isolated because of its location directly adjacent to the Bay shoreline. Sunnydale pump station currently experiences intermittent coastal flooding, although the impacts thus far have been negligible. Repairs and flood-proofing measures are planned.

Constructed in 1991, Sunnydale pump station serves the Sunnydale drainage basin during wet weather with a pumping capacity of 50 mgd. In wet weather, the pump station conveys flows from the Sunnydale transport / storage box and overflow from the Sunnydale tunnel to the Candlestick tunnel via a force main. Wet weather flows eventually reach Griffith pump station. The pump motor, electrical equipment, and controls are located below grade. This station could be exposed to floodwaters during a 2-year annual extreme high tide today. With 12 inches of SLR, this pump station could be exposed with a 1-year annual extreme high tide, and with 24 inches of SLR, this pump station could experience daily impacts (Scenario 2). Pathways for flooding at this asset include an air intake structure and multiple floor hatches that lead into the station. Once floodwaters enter the station, there are several access points to belowgrade rooms and water-sensitive equipment inside the station. Because this station is located directly along the shoreline, it is also at risk to wave hazards, including wave runup and overtopping over the station structure. Wave hazards may also increase with SLR.

7.1.1.6 Mariposa Pump Station

Mariposa pump station is an abovegrade pump station located in an industrial area on Terry Francois Boulevard, approximately 200 feet from the Bay shoreline. The pump station serves the Mariposa drainage basin. The existing dry weather pump station is in the process of being demolished and replaced and will provide an overall pumping capacity of 15 mgd. In dry and wet weather, the pump station conveys combined flows from the Mariposa transport / storage box to the gravity sewer located at 21st Street and Illinois Street, which then flows to the Southeast Treatment Plant. The original dry-weather pump station was constructed in 1954 and expanded to wet-weather capabilities in 1993.

This station could be exposed to floodwaters with 66 inches of SLR, or 24 inches of SLR coupled with a 100-year extreme tide (Scenario 6). Existing electrical equipment and controls are located approximately one foot above grade, and the pump motor is located below grade. Pathways for flooding at the existing pump station include several hatches, doorways, and ventilation openings at or near ground level. There are louver openings at the control room located four feet above ground level. There are several access points to belowgrade rooms and water-sensitive equipment inside the station. Floodwaters can also reach the wet-weather and dewatering pump equipment in the yard through the ground-level hatches. The new pump station is being designed to accommodate anticipated SLR by raising grades and limiting potential flood pathways into the pump station.

7.1.1.7 Palace of Fine Arts Pump Station

The Palace of Fine Arts Pump Station consists of two facilities, which serve a two-acre drainage area that includes the Palace of Fine Arts and its surrounding lagoon and landscaped areas. The facilities are located in a mixed residential and commercial area at Lyon Street near the Palace of Fine Arts Theatre and Presidio Park, approximately 850 feet from the Bay shoreline. The pump station serves a small area in the North Shore drainage basin with a pumping capacity of 0.43 mgd. The wet-weather pump station was constructed in 1967, and the dry-weather pump station was constructed in 1994. It receives wastewater from the Palace of Fine Arts building, and storm runoff and drainage from the adjacent lagoon. Dry- and wet-weather flow is transported to the Marina transport / storage box. The controls are located at grade and the wet well is located below grade.

This station could be exposed to floodwaters with 66 inches of SLR, or 24 inches of SLR coupled with a 100-year extreme tide (Scenario 6). Pathways for flooding at this asset include several access hatches and manholes at ground level. Once floodwaters enter through these openings, belowgrade rooms and water-sensitive equipment can be affected. The at-grade electrical controls are also at risk from shallow flooding.

7.1.1.8 Davidson Pump Station

Davidson pump station is a belowgrade pump station located on Davidson Avenue in a mixed industrial and commercial area, approximately 250 feet from the Bay shoreline. This pump station was constructed in 1996 and serves a small area adjacent to I-280 near Islais Creek with a pumping capacity of one mgd. Davidson pump station conveys wet-weather flows to an adjacent sewer. Electrical equipment and controls are located approximately 0.5 feet above grade, and the pump motor is located below grade.

This station could be exposed to floodwaters with 52 inches of SLR, or 12 inches of SLR coupled with a 100-year extreme tide (Scenario 5). Pathways for flooding at this asset include hatches at ground level and open areas with equipment at or near ground level.

7.1.1.9 Rankin Pump Station

Rankin pump station is a belowgrade pump station located at the intersection of Rankin Street and Davidson Avenue. This pump station was constructed in 1998 and serves a local area of the Islais Creek drainage basin with a pumping capacity of three mgd. In wet weather, the pump station conveys combined flows into the three-chamber basin dry-weather compartments of the Rankin / Custer sewer. Electrical equipment and controls are located at grade, and the wet well and pump motor are located below grade (on Rankin Street, north of the controls structure).

This station could be exposed to floodwaters with 52 inches of SLR, or 12 inches of SLR coupled with a 100-year extreme tide (Scenario 5). Pathways for flooding at this asset include hatches at ground level and an electrical cabinet on the sidewalk. The at-grade electrical controls are also at risk from shallow flooding.

7.1.1.10 Merlin Morris Pump Station

Merlin Morris pump station is a belowgrade pump station located on Merlin Street (near Harrison Street) in a mixed residential and commercial area, approximately 1,600 feet from the San Francisco Bay shoreline. The pump station serves a local area of the Channel drainage basin with a pumping capacity of 9.2 mgd. This wet-weather pump station was constructed in 1988. The electrical equipment and controls are located at grade and the wet-well is located below grade.

This station could be exposed to floodwaters with 66 inches of SLR, or 24 inches of SLR coupled with a 100-year extreme tide (Scenario 6). Pathways for flooding at this asset include several hatches, doorways, and ventilation openings at or near ground level. There are louver openings at the control room located four feet above ground level and there are several access points to belowgrade rooms and equipment inside the station. Floodwaters can also reach the wet-weather and dewatering pump equipment in the yard through the ground-level hatches.

7.1.1.11 Harriet-Lucerne Pump Station

Harriet-Lucerne pump station is a belowgrade pump station located in a mixed residential and commercial area on Harriet Street, approximately 1,600 feet from the San Francisco Bay shoreline. This pump station was constructed in 2005 and serves a local area of the Channel drainage basin with a pumping capacity of 7.3 mgd. Electrical equipment and controls are located approximately 1.5 feet above grade, and the pump motor is located below grade.

This station could be exposed to floodwaters with 66 inches of SLR, or 24 inches of SLR coupled with a 100-year extreme tide (Scenario 6). Pathways for flooding at this asset include hatches and manholes at ground level that would allow water to reach the equipment.

7.1.1.12 Twentieth Street Pump Station

The Twentieth Street pump station is a belowgrade pump station located in a mixed residential and commercial area on 20th Street, approximately 100 feet from the San Francisco Bay shoreline. This pump station serves the eastern end of Twentieth Street and the old Todd Shipyard in the Mariposa drainage basin with a pumping capacity of three mgd. The pump station conveys dry- and wet-weather flows to the Twentieth Street gravity sewer connection structure. This pump station was constructed in 1993 and last upgraded in 2010. Electrical equipment and controls are located at grade and below grade, and the pump motor is located below grade. The main power is located at grade west of the station.

This station could be exposed to floodwaters with 66 inches of SLR, or 24 inches of SLR coupled a 100-year extreme tide (Scenario 6). Pathways for flooding at this asset include the access hatch and the air exhaust at ground level that can lead to water reaching belowgrade rooms and equipment. This pump station will be placed as part of the Pier 70 development project.

7.1.1.13 Berry Street Pump Station

Berry Street pump station is a belowgrade pump station located at the corner of Berry Street and 5th Street in a mixed residential and industrial area adjacent to Mission Creek, approximately 200 feet from the San Francisco Bay shoreline. This pump station was constructed in 1997 and serves the Berry Street drainage area in the Channel drainage basin with a pumping capacity of 9.2 mgd. During wet weather, this pump station conveys combined flows from the Berry Street drainage area to a sewer on 5th Street. Electrical equipment and controls are located at and below grade.

This station could be exposed to floodwaters with 52 inches of SLR, or 12 inches of SLR coupled with a 100-year extreme tide (Scenario 5). Pathways for flooding at this asset include several access hatches and manholes at ground level. Once floodwaters enter through these openings, belowgrade rooms and equipment can be affected. The at-grade electrical controls are also at risk from shallow flooding.

7.1.1.14 Booster Pump Station

Booster pump station is an abovegrade pump station located in an industrial and commercial area near the 3rd Street bridge crossing, directly adjacent to the San Francisco Bay shoreline. This pump station serves the Southeast Treatment Plant, conveying treated effluent from the plant to the Bay through the Southeast Bay Outfall with a pumping capacity of 110 mgd. During wet weather, treated flows beyond the capacity of the pump station discharge directly to Islais Creek. This dry- and wet-weather effluent pump station was constructed in 1967 and last upgraded in 2002. Electrical equipment and controls are located above grade.

This station could be exposed to floodwaters during 52 inches of SLR, or 12 inches of SLR coupled with a 100-year extreme tide (Scenario 5). Pathways for flooding at this asset include several hatches, doorways, and ventilation openings at or near ground level. The louver openings in the control room are located four feet above ground level. There are several access points to belowgrade rooms and equipment inside the station. Floodwaters can also reach the wet-weather and dewatering pump equipment in the yard through the ground-level hatches.

7.1.1.15 Southeast Lift Station

Southeast lift station is an abovegrade pump station located adjacent to Islais Creek in an industrial and commercial area near the Southeast Treatment Plant Headworks Facility, approximately 750 feet from the Bay shoreline. The original pump station at this location was constructed in 1981. However, this pump station is being demolished and will be replaced with a new pump station designed to accommodate anticipated SLR by raising grades and limiting potential flood pathways into the pump station once the upgrades to the Bruce Flynn pump station are complete. When complete, the new pump station will serve the Islais Creek, Yosemite, Sunnydale, and Mariposa drainage areas with a pumping capacity of 50 mgd. The dry- and wet-weather pump station will convey gravity flows from the Islais Creek, Yosemite, and Sunnydale drainage areas to the Southeast Treatment Plant Headworks Facility for preliminary treatment.

While the original pump station is still in operation, it could be exposed to floodwaters with 52 inches of SLR, or 12 inches of SLR coupled with a 100-year extreme tide (Scenario 5). Pathways for flooding at this asset include several hatches, doorways, and ventilation openings at or near ground level. There are several access points to belowgrade rooms and equipment inside the station. The new pump station will be located just inland of the original facility, and could potentially be impacted under Scenario 6.

7.1.2 Exposure Assessment

The exposure of the pump stations was evaluated relative to the 10 SLR scenarios (see Chapter 2) to assess when each pump station is first exposed to potential inundation. The pump stations located within the SLR Vulnerability Zone are presented in Table 7.1.

Of the 26 pump stations that help convey combined wastewater and stormwater to the City's three treatment plants for treatment and discharge, only one, Sunnydale, could be exposed to temporary flooding from a 100-year extreme tide today, with no SLR (Scenarios 1-3). Sunnydale pump station is located directly adjacent to the shoreline and can also be exposed to coastal wave hazards. Five additional pump stations could be exposed with 52 inches of SLR, or 12 inches of SLR coupled with a 100-year extreme tide (Scenario 5). With 66 inches of SLR coupled with a 100-year extreme tide (Scenario 10), a total of 15 pump stations could be exposed to temporary flooding. As pump station upgrades are planned, or as new pump stations are constructed as part of the Sewer System Improvement Program, SFPUC is addressing potential SLR flooding risks.

Table 7.1 Pump Station Exposure Summary

Pump Station	Pumping Capacity (mgd)	Wet or All Weather	Pump Stations within Each Sea Level Rise Scenario (Y/-) 1	2	3	4	5	6	7	8	9	10
Channel	103	All	-	-	-	-	-	Y	Y	Y	Y	Y
Bruce Flynn	(old 110) new 150	Wet	-	-	-	-	-	Y	Y	Y	Y	Y
North Shore	150	All	-	-	-	-	-	-	Y	Y	Y	Y
Griffith	120	All	-	-	-	-	-	-	-	-	-	Y
Sunnydale	50	Wet	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mariposa*	15	All	-	-	-	-	-	Y	Y	Y	Y	Y
Palace of Fine Arts	0.43	All	-	-	-	-	-	Y	Y	Y	Y	Y
Davidson	1	Wet	-	-	-	-	Y	Y	Y	Y	Y	Y
Rankin	3	Wet	-	-	-	-	Y	Y	Y	Y	Y	Y
Merlin Morris	9.2	Wet	-	-	-	-	-	Y	Y	Y	Y	Y
Harriet-Lucerne	7.3	Wet	-	-	-	-	-	Y	Y	Y	Y	Y
Twentieth Street	3	All	-	-	-	-	-	Y	Y	Y	Y	Y
Berry Street	9.2	Wet	-	-	-	-	Y	Y	Y	Y	Y	Y
Booster	110	All	-	-	-	-	Y	Y	Y	Y	Y	Y
Southeast Lift Station*	50	All	-	-	-	-	Y	Y	Y	Y	Y	Y

* Mariposa pump station and Southeast lift station are currently being demolished and replaced with new pump stations as part of the Sewer System Improvement Program. The new pump stations are designed to accommodate anticipated SLR by raising grades and limiting potential flood pathways into the structures.

7.1.3 Consequence Summary

The consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. However, some actions are currently planned or in progress to address the noted impacts.

KEY ISSUE: Wastewater pump stations are generally located in areas of the City where flows cannot be transported to the treatment plant by gravity alone. These areas are often associated with a higher risk of flooding. Properly functioning pump stations are critical for conveying combined flows to the three treatment plants. Pump station failure could result in localized flooding. The scale of the potential impact may be related to the pumping capacity of the pump station, the average dry weather flows observed at the pump station, and/or the drainage area served by the pump station. Smaller pump stations with localized drainage areas will have fewer cascading impacts than large pump stations that operate 24 hours a day, seven days a week in all weather conditions. The larger pump stations that are connected to transport / storage boxes have some storage capacity during dry weather to mitigate impacts, as well as the potential to discharge excess flows to the Bay through combined sewer discharge outfalls during wet weather (see Section 7.3).

Society and Equity: Pump station operations can impact residences, businesses, schools, hospitals, and healthcare facilities that are within the pump station's service area. Short-term downtime could impact localized flooding during wet weather operations and result in the release of untreated sewage on City streets or to the Bay. Longer-term downtime could impact wastewater service during all weather, potentially resulting in a lack of wastewater services within the pump station's service area or insufficient flows into the treatment plants, which can compromise the biological treatment processes. Vulnerable populations that cannot temporarily relocate during an extreme event may suffer the greatest impact. A lack of wastewater service could also have significant health impacts, particularly on vulnerable populations, including the elderly, medically infirm, and young children.

Economy: If a long-term wastewater outage occurs, it could impact revenue collected by SFPUC for providing services. Providing temporary services (e.g., portable toilets and washing stations) and the cost of repairs would also have economic impacts on SFPUC. If a pump station is inundated, a portable pump will be required to remove floodwater from the pump station itself; many of the pump stations extend one or more floors below grade. After removing floodwaters, electrical equipment will require repair and replacement. Saltwater may also corrode and damage exposed metal surfaces, including pump blades. Pumping bypasses may be installed to provide temporary service to mitigate impacts. Local businesses may be forced to close temporarily until pumping bypasses are installed and wastewater services can resume. Any impacts to local business could result in economic consequences to the greater community, including lost business revenue, lost tourist revenue, and lost work days for local residents and commuters.

Environment: Localized flooding that could occur on City streets during wet weather is likely to be dilute (e.g., the wastewater contribution to the localized flooding is likely to be small relative to the stormwater contribution). However, health and environmental hazards may still exist. Localized flooding in vulnerable communities pose the greatest health risk. Combined wastewater and stormwater flows may also flow directly to the Bay; however, the SFPUC wastewater system includes large underground transport / storage boxes that are capable of holding approximately 200 MG of combined flows for later treatment at one of the three treatment plants, and these boxes help prevent direct overflows to the Bay.

Governance: A large-scale failure or disruption of the City's wastewater system due to flooding has not happened to date in San Francisco. Responding to a flood event that could impact multiple pump stations located throughout the City will require multi-agency coordination. Repair work may need to be coordinated with SFMTA and Public Works in tandem with roadway clearing and other City cleanup efforts, as needed.

7.2 TREATMENT FACILITIES

SFPUC operates three wastewater treatment plants in San Francisco (Figure 7.3). Each treatment plant has an integral role in treating wastewater and stormwater before it is discharged into the Bay or the Pacific Ocean. The Southeast Treatment Plant is located near Islais Creek and serves the City's Bayside, while the Oceanside Treatment Plant, located near the San Francisco Zoo, serves the City's Westside neighborhood. Both operate 24 hours a day, 365 days a year. During large rain events, the North Point Wet-Weather Facility is activated to reduce the demand on the Southeast Treatment Plant to treat Bayside flows. The treatment plants are highly complex facilities, with multiple structures, treatment processes, and infrastructure that collectively process the combined wastewater and stormwater for the City and County of San Francisco.

7.2.1 Potentially Vulnerable Assets

7.2.1.1 Southeast Treatment Plant

The Southeast Treatment Plant operates 24 hours a day, 365 days a year, serving the Bayside of the City. It is located in the mixed industrial, commercial, and residential area of Bayview/Hunters Point, with the northern corner located approximately 750 feet from the Bay shoreline (see Photo 7.2). The Southeast Treatment Plant is San Francisco's largest wastewater facility, responsible for treating flows from the City's Bayside in addition to minor flows from Daly City and Brisbane. The treatment plant serves about two-thirds of San Francisco residents, or over 580,000 people as of 2016. The service areas include the Marina, Financial District, South of Market Area, Mission, Hunters Point, and Visitacion Valley, which generate more than 80 percent of the total annual wastewater flow from the City. Wastewater and stormwater are

Photo 7.2 Southeast Treatment Plant. Marcin Wichary

transported through a network of transport and storage facilities, sewers, and five high-capacity pump stations prior to the Southeast Treatment Plant. Treated effluent is then discharged to the Bay.

The treatment plant treats, on average, 57 mgd of wastewater during dry weather, including handling 160 wet tons of biosolids each day. It has the capacity to treat up to 250 mgd during heavy precipitation. The Southeast Treatment Plant includes the following processes: pretreatment, primary, secondary, disinfection, and sludge stabilization and dewatering. These processes occur over numerous facilities both above and below ground. Most facilities have a unique configuration of mechanical and electrical equipment and are interconnected to other facilities through a network of conduits or tunnels.

Several facilities at the Southeast Treatment Plant could be exposed to coastal floodwaters with 66 inches of SLR, or 24 inches of SLR coupled with a 100-year extreme tide (Scenario 6). Flooding is limited to the northern corner of the plant, which includes the Southeast Lift Station, Headworks Facilities, and Primary Sedimentation Facilities. New facilities are currently under construction in this area, including the new Headworks Facility and Lift Station and Biosolids Digester Facilities, as part of the Sewer System Improvement Program. The new facilities are designed to accommodate anticipated SLR by raising grades and limiting potential flood pathways into the structures. The existing facilities have several entryways or pathways that could allow flooding to reach sensitive components, including doorways, tunnels and tunnel entrances, vents and louvers, open areas, utility holes, or ground-level entrances. Many tunnel entrances are at grade and could allow water to reach belowground equipment and regions of the treatment facility further inland.

If a large flood event occurs that impacts the treatment facilities, it may take several days to restore full service. The subterranean location of many treatment system components makes it challenging to modify or retrofit facilities to accommodate temporary flooding. Although some facilities have backup components onsite for redundancy, they are often at the same elevation as other station components and will likely be impacted at the same time.

Photo 7.3 North Point Wet-Weather Facility

7.2.1.2 North Point Wet-Weather Facility

Located on Bay Street approximately 300 feet from the Bay shoreline, the North Point Wet-Weather Facility is the City's oldest wastewater treatment facility, originally built in 1951, and was the main treatment facility until 1983 (see Photo 7.3). As part of the 1972 Clean Water Act upgrades, the North Point facility was converted to a wet-weather-only treatment facility. During wet weather, this facility provides pretreatment and primary treatment with disinfection of combined wastewater and stormwater flows collected in the northeast part of the City. The treatment plant is only brought online during wet weather when the Southeast Treatment Plant approaches capacity (i.e., approximately 250 mgd). With the North Point facility online, an additional 150 mgd of capacity is added to the citywide treatment capabilities.

The treatment processes at the North Point facility occur over numerous facilities both above and below ground. Most facilities have a unique configuration of mechanical and electrical equipment and are interconnected to other facilities through a network of conduits or tunnels. Many of these facilities have both belowground and aboveground components that could potentially be exposed to floodwaters or convey floodwaters to other areas. While the treatment facilities will likely recover after repairs, it may take several days to restore full function.

Figure 7.3 Treatment Facilities

Oceanside Treatment Plant

Built in 1993

Receives 20% of the City's flows

Treats 13 MGD and up to 175 MGD during rain storms

Located off the Great Highway between Lake Merced and San Francisco Zoo

North Point Wet Weather Facility

Built in 1951

Only active during wet weather

Treats up to 150 MGD during rain storms

Located at Bay Street and The Embarcadero

Southeast Treatment Plant

Built in 1952

Receives 80% of the City's flows

Treats 57 MGD and up to 250 MGD during rain storms

Located on Phelps Street near Third and Evans streets in the Bayview District

Source: San Francisco's Wastewater Treatment Facilities, SFPUC. https://sfwater.org/modules/showdocument.aspx?documentid=5801

Several individual North Point facility structures could be exposed to coastal floodwaters with 66 inches of SLR, or 24 inches of SLR coupled with a 100-year extreme tide (Scenario 6). This flooding is limited to the northern edge of treatment plant, which includes the Sedimentation Building No. 1 and the Materials Testing Laboratory (which has recently been vacated). There are several entryways at the North Point facility that could allow flooding to reach sensitive components, including doorways, tunnels and tunnel entrances, vents and louvers, open areas, utility holes, or ground level entrances. However, because the potential for flooding is limited, the treatment plant is likely to retain most of its operational capacity during a flood event that occurs when this facility is in operation.

Photo 7.4 Oceanside Treatment Plant

7.2.1.3 Oceanside Treatment Plant

The Oceanside Treatment Plant operates 24 hours a day, 365 days a year serving the City's Westside. It is located on the Great Highway near the San Francisco Zoo, approximately 100 feet from the edge of the Great Highway and 250 feet from the Pacific Ocean (see Photo 7.4). Built almost entirely underground, the Oceanside Treatment Plant is the City's newest wastewater facility, providing all-weather wastewater collection and treatment for approximately 20 percent of the City's wastewater and combined stormwater flows. Wastewater and stormwater from the Westside service areas is routed through the Richmond tunnel, Westside transport / storage box, and the Lake Merced Tunnel to the Westside pump station, where it is pumped to the Oceanside Treatment Plant through a 48-inch force main. On an average day, the plant treats 13 mgd. During rain storms, the wet-weather treatment capacity is 65 mgd. The Oceanside Treatment Plant discharges to a deep-water ocean outfall located more than three miles offshore.

The Oceanside Treatment Plant is located outside of the SLR Vulnerability Zone, and no flooding hazards are expected under current SLR projections. However, the large wave hazards on the open Pacific coast have caused shoreline erosion along Ocean Beach, and the potential for shoreline erosion is likely to increase over time with SLR.

The Lake Merced Tunnel, a critical component of the wastewater collection system that carries wastewater and combined storm water and wastewater to the treatment plant via a 14-foot-diameter pipe, is within the SLR Vulnerability Zone. SFPUC is coordinating with other agencies on the implementation of the Ocean Beach Master Plan,[3] a comprehensive vision to address SLR and coastal erosion, protect critical wastewater and transportation infrastructure, restore coastal ecosystems, and improve public access.

7.2.2 Exposure Assessment

The exposure of the treatment plants was evaluated relative to the 10 SLR scenarios (see Chapter 2). The assessment considered the exposure of individual treatment plant facilities, calculating the percent of each facility's building footprint within the SLR Vulnerability Zone and within each scenario, as shown in Table 7.2. This exposure assessment does not include individual facility floodproofing that may exist, including raised grades for new facilities such as the new Headworks and Biosolids Digester Facilities to minimize the potential for flooding impacts on sensitive infrastructure.

3 San Francisco Bay Area Planning and Urban Research Association (SPUR). 2012. Ocean Beach Master Plan. Available at https://www.spur.org/featured-project/ocean-beach-master-plan.

Table 7.2 Treatment Plant Exposure Summary

	Treatment Plant Inundated (Y/N) within each Sea Level Rise Scenario Building % inundated in each Sea Level Rise Scenario									
	1	2	3	4	5	6	7	8	9	10
Southeast Treatment Plant	-	-	-	-	Y	Y	Y	Y	Y	Y
Southeast Lift Station **	-	-	-	-	1	75	100	100	100	100
New Headworks Facilities *	-	-	-	-	-	20	50	85	95	95
Wet-Weather Headworks **	-	-	-	-	-	2	40	80	90	95
Headworks **	-	-	-	-	-	55	90	100	100	100
New Biosolids Digester Facilities*	-	-	-	-	-	-	5	20	60	90
Oxygen Plant*	-	-	-	-	-	-	10	70	100	100
Primary Sedimentation	-	-	-	-	-	-	40	90	100	100
Primary Clarifiers	-	-	-	-	-	-	10	20	50	70
Secondary Sludge Control Building	-	-	-	-	-	-	-	1	20	100
Engineering Annex	-	-	-	-	-	-	-	70	100	100
Primary Effluent Pump Station	-	-	-	-	-	-	-	-	1	20
Grease Handling Facility	-	-	-	-	-	-	-	-	10	75
Gravity Belt Thickeners**	-	-	-	-	-	-	-	-	45	51
Sodium Hypochlorite Tanks*	-	-	-	-	-	-	-	-	70	95
Primary Power Switching Station*	-	-	-	-	-	-	-	-	90	100
Secondary Sludge Thickening	-	-	-	-	-	-	-	-	90	95
Wet-Weather Primary Clarifiers	-	-	-	-	-	-	-	-	-	1
Sludge Filtration Building**	-	-	-	-	-	-	-	-	-	5
Water Pump Station **	-	-	-	-	-	-	-	-	-	10
Secondary Clarifiers	-	-	-	-	-	-	-	-	-	15
Dryer Building	-	-	-	-	-	-	-	-	-	20
Post Chlorination Building	-	-	-	-	-	-	-	-	-	95
North Point Treatment Facility	-	-	-	-	-	Y	Y	Y	Y	Y
Primary Clarifiers	-	-	-	-	-	2	10	15	20	25
Materials Testing Laboratory ***	-	-	-	-	-	25	60	95	100	100
North Shore Pump Station	-	-	-	-	-	-	5	50	75	85
Water Pump Station, Garage, Machine Shop, Polymer Room	-	-	-	-	-	-	-	5	15	25
Pre-Treatment and Grit Removal Building	-	-	-	-	-	-	-	-	55	75
Sodium Bisulfite Tanks	-	-	-	-	-	-	-	-	85	100
Storage Yard	-	-	-	-	-	-	-	-	100	100
Oceanside Treatment Plant	-	-	-	-	-	-	-	-	-	-

* Although the footprint of the new facilities remains within the SLR Vulnerability Zone, the facilities are designed and being constructed to address anticipated SLR by raising grades and limiting potential flood pathways into the structures.

** These facilities will be demolished once the new facilities are brought online.

*** This facility has been vacated and is not currently in use.

7.2.3 Consequence Summary

The consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. However, some actions are currently planned or in progress to address the noted impacts. For a list of the current SFPUC projects, see Section 7.5.

KEY ISSUE: Wastewater treatment is a critical service provided by the City. Without sufficient wastewater treatment, water-borne pathogens and microorganisms can spread, resulting in health hazards to human and animal populations and degradation of receiving water bodies. Although the risk of complete loss of wastewater treatment facilities is small in San Francisco, a reduction in wastewater treatment capacity is possible.

Society and Equity: A lack of wastewater treatment services can increase human health risks and result in the spread of water-borne diseases. Vulnerable populations, particular the elderly, medically infirm, and young children are most at risk. Populations at low-lying elevations that cannot discharge wastewater by gravity to the transport / storage boxes are most at risk of potential adverse health and environmental impacts.

Economy: Any flooding impacts to one of the three treatment facilities could result in significant repair and rehabilitation costs. A priority would likely be placed on preventing the direct discharge of untreated wastewater to the Bay and the prevention of sewer backups. Local businesses within impacted service areas may be forced to close temporarily until wastewater services can resume, resulting in economic consequences to the community, including lost business revenue, lost tourist revenue, and lost work days for local residents and commuters.

Environment: Localized flooding that could occur on City streets during wet weather is likely to be dilute (e.g., the wastewater contribution to the localized flooding is likely to be small relative to the stormwater contribution). However, health and environmental hazards will still exist. Localized flooding in vulnerable communities pose the greatest health risk. Combined wastewater and stormwater flows may also flow directly to the Bay; however, the SFPUC wastewater system includes large underground transport / storage boxes that are capable of holding approximately 200 MG of combined flows for later treatment at one of the three treatment plants, and these boxes help prevent direct overflows to receiving waters.

Governance: A large-scale failure or disruption of the City's wastewater system due to flooding has not happened to date in San Francisco. Responding to a coastal flood event that impacts wastewater treatment plant operations may require multi-agency coordination.

7.3 COMBINED SEWER DISCHARGES

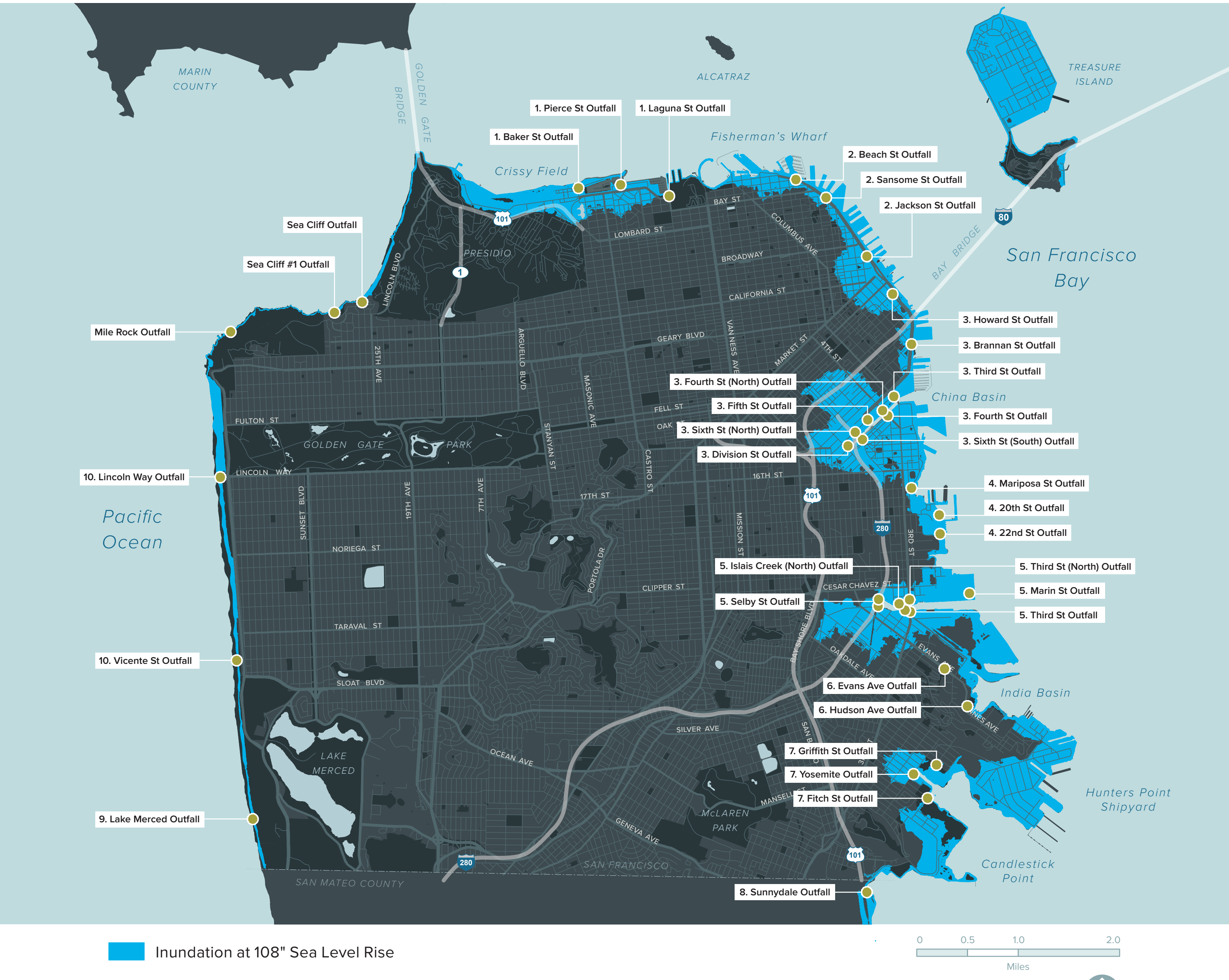
During rainstorms that exceed the capacity of the transport / storage boxes and treatment plants, combined stormwater and wastewater can be discharged through 36 combined sewer discharge outfalls to the Bay and Pacific Ocean (Photo 7.5). Combined sewer discharges include mostly stormwater but may also include wastewater flows in concentrations that vary depending on the intensity and duration of the rainstorm (see Figure 7.4). Twenty-nine of the discharge outfalls are located on the Bayside shoreline, and seven are located on the City's Westside. The physical configurations of the discharge structures vary based on location, but they are most often associated with a transport / storage box, with either an overflow weir or outfall pipe conveying excess flows from a transport / storage box to the Bay. A typical transport / storage box may be associated with more than one outfall to receiving waters; therefore, to consolidate the assessment findings, the discharge structures are grouped by their associated transport / storage box. If the overflow weir of a discharge outfall is not overtopped under any of the SLR scenarios assessed, it was not included in the assessment (i.e., four combined sewer discharge outfall weirs on the City's Westside are not included; however, these structures may still experience impacts related to wave hazards and coastal erosion).

The transport / storage boxes capture combined wastewater and stormwater from the sewer system before it reaches the Bay or Pacific Ocean shoreline.[4] In total, the boxes can hold approximately 200 MG of combined flows for later treatment at one of the three treatment plants. The transport/ storage boxes provide settling and baffling of floatable materials. During prolonged and intense rainstorms, the transport / storage boxes may fill completely.

4 https://sfwater.org/index.aspx?page=399

Photo 7.5 Division Combined Sewer Discharge. SFPUC

Figure 7.4 Combined Sewer Discharges



1 Marina Transport / Storage Box Discharge Outfalls
2 Jackson Transport / Storage Box Discharge Outfalls
3 Channel Transport / Storage Box Discharge Outfalls
4 Mariposa Transport / Storage Box Discharge Outfalls
5 Islais Transport / Storage Box Discharge Outfalls
6 Hunter's Point Discharge Outfalls
7 Yosemite Transport / Storage Box Discharge Outfalls
8 Sunnydale Discharge Outfalls
9 Lake Merced Discharge Outfalls
10 Westside Transport / Storage Box Discharge Outfalls

7.3.1 Potentially Vulnerable Assets

All combined sewer discharge outfalls are located along the shoreline and were engineered to withstand exposure to tides, wave hazard, storm surge, and saltwater. These shoreline structures are generally not sensitive to coastal flooding. However, the structures experience corrosion from the saltwater environment and weakened condition from continued exposure to wave hazards. As sea levels rise, the discharge capacity of each outfall may be reduced, particularly during extreme high tides and prolonged storm surge conditions. In the near term, the impacts to discharge capacity are temporary (e.g., one to four hours) while Bay water levels are elevated above the outfall weir. The ability to discharge through the outfall will resume as the tides fall. Over the longer term with higher SLR projections, the discharge capacity of the outfalls would be substantially reduced. Discharge outfalls that are submerged would not be able to maintain their function as currently designed.

Adaptive measures, such as backflow prevention, are currently being installed to prevent the inflow of Bay water into the discharge structures during periods of elevated water levels. However, maintaining outflow capacity during extreme wet-weather events as sea levels rise will require the addition of pumps in the future.

7.3.1.1 Marina Transport / Storage Box Discharge Outfalls

The Baker Street, Pierce Street, and the Laguna Street combined sewer discharge outfalls convey overflow from the Marina transport / storage box to the Bay. The Marina transport / storage box has a capacity of 8.3 MG and drains combined wastewater and stormwater runoff from the North Shore drainage area. Wet-weather flow is pumped downstream via the North Shore pump station, but excess flows (if they occur) are discharged through the outfalls. Of the three Marina transport / storage outfalls, currently only the Baker Street outfall has backflow prevention installed to mitigate saltwater intrusion into the collection and treatment system. The Pierce Street outfall is being closed, and Laguna Street outfall has a high elevation.

7.3.1.2 Jackson Transport / Storage Box Discharge Outfalls

The Beach Street, Sansome Street, and Jackson Street combined sewer discharge outfalls convey overflow from the Jackson transport / storage box to the Bay. The Jackson transport / storage box has a capacity of 10.4 MG and drains combined wastewater and stormwater runoff from the North Shore drainage area. Wet-weather flow is pumped downstream via the North Shore pump station, but excess flows (if they occur) are discharged through the outfalls. All three of these discharge outfalls will have backflow protection installed as part of the Sewer System Improvement Program.

7.3.1.3 Channel Transport / Storage Box Discharge Outfalls

The Howard Street, Brannan Street, 3rd Street, 4th Street (deactivated), 5th Street, 6th Street North, Division Street, 6th Street South, and 4th Street North combined sewer discharge outfalls convey overflow from the Channel transport / storage box to Mission Creek, China Basin, and the Bay. The Channel transport / storage box has a capacity of 38 MG and drains dry weather flow from the North Shore drainage areas, and dry and wet weather flow from the Channel drainage areas. Wet-weather flow is pumped downstream via the Channel pump station, but excess flows (if they occur) are discharged through the outfalls. The Brannan Street discharge outfall currently has a hydraulic gate that offers an ancillary benefit of mitigating saltwater intrusion into the collection and treatment system. The 5th Street and 6th Street North outfalls will have backflow protection installed as part of the Sewer System Improvement Program.

7.3.1.4 Mariposa Transport / Storage Box Discharge Outfalls

The Mariposa Street, 20th Street, and 22nd Street combined sewer discharge outfalls convey overflow from the Mariposa transport / storage box to the Central Basin in the Bay. The Mariposa transport / storage box has a capacity of 0.9 MG and drains combined wastewater and stormwater runoff from the Mariposa drainage areas. Wet-weather flow is pumped downstream via the Mariposa pump station, but excess flows (if they occur) are discharged through the outfalls.

7.3.1.5 Islais Transport / Storage Box Discharge Outfalls

The Third Street North, Islais Creek North, Marin Street, Selby Street, and Third Street combined sewer discharge outfalls convey overflow from the Islais transport / storage box to Islais Creek and the Bay. The Islais transport / storage box has a capacity of 45.1 MG and drains combined wastewater and stormwater runoff from the Mariposa and Islais Creek drainage areas. Wet-weather flow is pumped downstream via the Bruce Flynn pump station, but excess flows (if they occur) are discharged through the outfalls.

Photo 7.6 Yosemite Street Combined Sewer Discharge

7.3.1.6 Hunter's Point Discharge Outfalls

The Evans Street and Hudson Street combined sewer discharge outfalls convey overflow to the Bay. The Hunter's Point tunnel carries combined wastewater and stormwater runoff from the Yosemite/Sunnydale drainage areas. Excess flows (if they occur) are discharged through the outfalls.

7.3.1.7 Yosemite Transport / Storage Box Discharge Outfalls

The Griffith, Yosemite, and Fitch combined sewer discharge outfalls convey overflow from the Yosemite transport / storage box to the South Basin and the Bay (see Photo 7.6). The Yosemite transport / storage box has a capacity of 11.5 MG and drains combined wastewater and stormwater runoff from the Yosemite and Sunnydale drainage areas. Wet-weather flow is pumped downstream via the Griffith pump station, but excess flows (if they occur) are discharged through the outfalls. The Griffith outfall will have backflow protection installed as part of the Sewer System Improvement Program.

7.3.1.8 Sunnydale Discharge Outfalls

The Sunnydale combined sewer discharge outfall conveys overflow from the Sunnydale transport / storage box to Candlestick Cove and the Bay. The Sunnydale transport / storage box has a capacity of 6.2 MG and drains combined wastewater and stormwater runoff from the Sunnydale drainage areas. Wet-weather flow is pumped downstream via the Sunnydale pump station, but excess flows (if they occur) are discharged through the outfalls.

7.3.1.9 Lake Merced Discharge Outfall

The Lake Merced combined sewer discharge outfall conveys overflow from the Lake Merced Tunnel to the Pacific Ocean. Combined wastewater and stormwater runoff that reaches the Lake Merced Tunnel is conveyed from the Lake Merced drainage areas.

7.3.1.10 Westside Transport / Storage Box Discharge Outfalls

The Vicente Street and Lincoln Way combined sewer discharge outfalls convey overflow from the Westside transport / storage box to the Pacific Ocean. The Westside transport / storage box has a capacity of 49 MG and drains wastewater and stormwater runoff from the Westside and Richmond drainage areas.

7.3.2 Exposure Assessment

The combined sewer discharge outfalls were evaluated to assess when each outfall would be first exposed to potential inundation. The outfall is exposed when tide levels exceed the elevation of an outfall weir structure.

We used different methodologies to assess high water levels along the Bayside and Westside shorelines. Along the Bayside, the elevation of the outfall weir was evaluated relative to the 10 SLR scenarios

Table 7.3 Combined Sewer Discharge Exposure Summary (Bayside CSDs)

Transport / Storage Box	CSD	CSD Inundated (Y/N) within Each Sea Level Rise Scenario 1	2	3	4	5	6	7	8	9	10
Marina	Baker Street *	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Pierce Street ****	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Laguna Street	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
Jackson	Beach Street **	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Sansome Street **	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Jackson Street **	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
Channel	Howard Street	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Brannan Street ***	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	3rd Street	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	4th Street ****	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	5th Street **	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	6th Street North **	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Division Street	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	6th Street South	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	4th Street South	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mariposa	Mariposa Street	-	-	Y	Y	Y	Y	Y	Y	Y	Y
	20th Street	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	22nd Street	-	-	Y	Y	Y	Y	Y	Y	Y	Y
Islais	3rd Street North	-	-	Y	Y	Y	Y	Y	Y	Y	Y
	Islais Creek North	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Marin Street	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Selby Street	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	3rd Street South	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hunter's Point	Evans Street	-	-	-	-	-	-	Y	Y	Y	Y
	Hudson Street	-	-	-	-	-	-	-	-	-	-
Yosemite	Griffith **	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Yosemite Street	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Fitch Street	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sunnydale	Sunnydale	-	-	Y	Y	Y	Y	Y	Y	Y	Y

* This outfall was used as a pilot for assessing backflow prevention measures. Backflow prevention is currently installed to mitigate saltwater intrusion.

** Backflow prevention is installed, or will be installed under the Sewer System Improvement Program.

*** This outfall has a hydraulic gate that also mitigates saltwater intrusion.

**** This outfall will be closed or deactivated.

Table 7.4 Combined Sewer Discharge Exposure Summary (Westside CSDs)

Transport / Storage Box	CSD	CSD Inundated (Y/N) within Each 100-Year Dynamic Water Level* 1	2	3	4	5 DWL 12	6 DWL 24	7 DWL36	8 DWL 48	9	10 DWL 66
Lake Merced Tunnel	Lake Merced	-	-	-	-	Y	Y	Y	Y	-	Y
Westside	Vicente Street	-	-	-	-	Y	Y	Y	Y	-	Y
	Lincoln Way	-	-	-	-	-	Y	Y	Y	-	Y

* The Westside's Dynamic Water Level scenarios are mapped to corresponding Bayside SLR scenario. There is no corresponding Westside scenario for Bayside scenario's 1, 2, 3, 4, or 9.

(see Chapter 2). The discharge outfalls along the Westside are located at higher elevations. The high water levels most likely to exceed the outfall weir elevations incorporate additional coastal processes, including wave setup. As waves break offshore and across the surf zone, they drive water onshore and "set up" the water level at the shoreline.

Temporary flooding at Westside combined sewer discharge outfalls was evaluated relative to the Dynamic Water Level (DWL), which includes wave setup. Five DWL plus SLR scenarios were evaluated, and Table 7.3 maps those scenarios to the most similar Bayside SLR scenario for ease of comparison.

The majority of the Bayside combined sewer discharge outfalls (i.e., 23 of 29) are impacted under Scenario 2, or 24 inches of SLR. Under Scenario 3, or 36 inches of SLR, 27 of the 29 Bayside outfalls are impacted (see Table 7.3). Therefore, before the end of the century, and likely between mid-century and the end of the century, the combined sewer discharge outfalls will no longer function as intended.

Although backflow prevention will prevent saltwater intrusion into the collection system, the higher Bay water levels may impede the gravity-driven flow of excess combined wastewater and stormwater from the transport / storage boxes to the Bay through the outfalls and pumping would be required.

Although SLR alone is not anticipated to raise Bay water levels this high until after mid-century, water levels in the Bay may reach this level (24 to 36 inches above existing high tides) temporarily during King Tides, El Niño conditions, or during a coastal storm surge event today. Therefore, for short durations (i.e., six hours or less), discharge through the outfalls could be impacted under existing conditions. As sea levels rise, the frequency of these short-term high Bay water level conditions may increase.

On the Westside, the outfall weirs are generally located at higher elevations. Only the Lake Merced discharge outfall (Lake Merced Tunnel) could be temporarily exposed to water levels above its weir elevation during a 100-year extreme tide (with wave setup) and no SLR (see Table 7.4). During a 100-year extreme tide with 12 inches of SLR, the Vicente outfall weir could be temporrarily overtopped, and during a 100-year extreme tide with 24 inches of SLR, the Lincoln outfall weir could be temporarily overtopped. The remaining combined sewer discharge outfalls on the Westside are not overtopped under the SLR scenarios that were evaluated in this assessment.

7.3.3 Consequence Summary

The consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. However, installation of backflow prevention is currently planned for multiple discharge outfalls under the Sewer System Improvement Program.

KEY ISSUE: As sea levels rise, the combined sewer discharge outfalls that currently help mitigate localized flooding during prolonged and intense rainfall events will be impacted. When an outfall weir is submerged, either temporarily during a coastal storm surge event or permanently due to SLR, the ability of the outfall to discharge excess combined wastewater and stormwater will decrease. With 24 inches of SLR, the overall functioning of the combined sewer discharge system would be impaired and could result in increasing instances of localized flooding, particularly in low-lying areas.

Society and Equity: Localized flooding will impact residences, businesses, and human health. Vulnerable populations in the low-lying areas of the City are most at risk of potential adverse health and environmental impacts.

Economy: Localized flooding could result in damage to buildings and structures, requiring repairs. Environmental cleanup efforts will also be required to help mitigate potential adverse health impacts. The extent of damage and the impact to the local economy from business closures will depend on the intensity and length of the rainstorm, and the amount of time that Bay water levels are impeding discharge through the combined sewer discharge outfall.

Environment: Localized flooding that could occur on City streets during wet weather is likely to be dilute (e.g., the wastewater contribution to the localized flooding is expected to be small relative to the stormwater contribution). However, health and environmental hazards will still exist. Localized flooding in vulnerable communities pose the greatest health risk. Combined wastewater and stormwater flows may also flow directly to the Bay if discharge through the combined sewer discharge outfalls is feasible; however, the SFPUC wastewater system includes large underground transport / storage boxes that are capable of holding approximately 200 MG of combined flows for later treatment at one of the three treatment plants, and these boxes help prevent direct overflows to the Bay.

Governance: In the near term, backflow prevention is being installed on the combined sewer discharge outfalls to prevent intrusion of saltwater into the system. In the long term (i.e., between mid-century and end of the century), a more substantial modification of the transport / storage boxes and the combined sewer discharge outfalls may be required. As large-scale shoreline adaptation projects are planned, coordination with the SFPUC will be required to allow for continued functioning of the combined sewer discharge outfalls.

7.4 BURIED SEWERS

SFPUC's wastewater system relies on a network of more than 1,000 miles of force mains, tunnels, sewers, and transport / storage boxes to transport and discharge wastewater and stormwater flows. Each type of buried sewer has a unique configuration and purpose, but ultimately serves to convey or store wastewater and/or stormwater as needed for treatment prior discharge into the Bay or Pacific Ocean. Since the buried sewers have similar physical characteristics and function, they are evaluated as a group, rather than by individual type or asset (Photo 7.7).

- **Gravity sewers** – The primary collection and conveyance features in the sewer system that carry storm and sanitary flows downstream by gravity flow;
- **Force mains** – Typically, buried conduits that link pump stations to other parts of the conveyance system or deliver combined wastewater to treatment facilities;
- **Tunnels** – Typically, deeper sewers that convey flows via gravity; and
- **Transport / storage boxes** – Large interconnected underground structures buried along the perimeter of the City that intercept, temporarily store, and transport combined wastewater to treatment facilities and/or combined sewer discharge outfalls.

Photo 7.7 New installation of concrete sewer pipes. Robert J. Pierce, SFMTA

Figure 7.5 Vulnerable Buried Sewers

Inundation at 108" Sea Level Rise

Buried Sewers

Table 7.5 Buried Sewers (Bayside) Exposure Summary

	Miles Inundated within Each Sea Level Rise Scenario									
	1	2	3	4	5	6	7	8	9	10
					DWL 12	DWL 24	DWL36	DWL 48		DWL 66
Sewers (< 18")	-	-	5.1	11.1	16.9	34.7	43.2	46.8	51.7	57.1
Sewers (18-36")	-	-	1.1	3.3	5.1	11.7	14.6	16.9	18.4	20.5
Gravity Sewers (>36")	-	-	-	-	-	-	-	14.8	17.9	20.6
Tunnels	-	-	-	-	-	-	-	-	-	-
Transport/Storage Facilities	-	-	0.2	0.7	1.9	4.6	5.9	6.5	7.1	7.6
Force Mains	-	-	0.6	2.5	3.4	6.9	8.6	8.9	9.5	9.8
Catch Basins (# in SLRVZ)	2	7	30	92	319	1,222	1,535	1,750	2,052	2,345

* The Westside's Dynamic Water Level scenarios are mapped to corresponding Bayside SLR scenario. There is no corresponding Westside scenario for Bayside scenario's 1, 2, 3, 4, or 9.

7.4.1 Potentially Vulnerable Assets

The majority of these sewers are buried beneath the City and are not directly exposed to overland flooding due to SLR in the same manner as the pump stations and treatment facilities. However, buried sewers are susceptible to overland inflow and infiltration into the collection system (see Photo 7.8). Water can enter sewers, tunnels, and transport / storage boxes through joints and connections, cracks, catch basins, or through utility hole covers. This can reduce the overall storage capacity of the collection system. Pressurized force mains are less susceptible to inflow and infiltration. As water levels continue to rise, the potential for infiltration into the system will also increase. The increasing frequency of exposure to saltwater may result in accelerated corrosion of materials sensitive to saltwater, reducing the lifespan of some sewers.

Catch basins within the SLR Vulnerability Zone could also be inundated during a coastal flood event, providing another mechanism for saltwater inflow to the system. Sewer components made of materials sensitive to saltwater (e.g., iron), regardless of physical condition, could corrode and compromise the integrity of the asset. Maintenance and access to sewers could also be impacted, and subsurface soils may erode around the sewers, which could result in sewer breaks, operational impacts, and sink holes.

7.4.2 Exposure Assessment

The exposure of the buried sewers was evaluated relative to the 10 SLR scenarios (see Chapter 2) to assess when either the Bay or Pacific Ocean floodwaters cover the ground above each sewer segment (see Table 7.5). Areas that can be exposed to permanent inundation by SLR are the most likely to be exposed to rising saline groundwaters. The exposure of the catch basins was also evaluated, as the catch basins represent a significant pathway for floodwaters to enter the sewer system.

7.4.3 Consequence Summary

The consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. However, some actions are currently planned or in progress to address the noted impacts. For a list of the current SFPUC projects, see Section 7.5.

KEY ISSUE: In general, buried infrastructure is less sensitive to coastal flooding and SLR; however, as sea levels rise, frequency of exposure to saltwater will increase, both internally due to saltwater intrusion, and externally due to more saline groundwater. This will result in accelerated corrosion of materials sensitive to saltwater, reducing the lifespan of some sewers.

Society and Equity: The possibility of localized sewer failures associated with saltwater intrusion, infiltration, and corrosion are most likely to occur in the low-lying areas of the City along the shoreline. A sewer failure could result in localized flooding of wastewater, creating potential adverse health and environmental impacts. The vulnerable populations within the low-lying areas are at greatest risk. Sewer failures can also cause sink holes and roadway disruption, and impact wastewater services at nearby residences and businesses. Smaller-scale, localized sewer failures can be contained, mitigated, and repaired quickly to minimize adverse consequences.

Economy: As sewer lifespans decrease, the cost to maintain and rehabilitate the overall sewer system will increase. Localized sewer failures will also require prompt repair. Roadway damage, and any associated building and/or structure damage will also need to be addressed. Local businesses may be forced to close temporarily until wastewater services can resume, resulting in economic consequences to the local community, including potential lost business revenue, tourist revenue, and lost work days for local residents and commuters, depending on the area impacted by the sewer failure.

Environment: Localized flooding that occurs on City streets during wet weather is likely to be dilute (e.g., the wastewater contribution to the localized flooding is likely to be small relative to the stormwater contribution). However, health and environmental hazards will still exist. Localized flooding in vulnerable communities pose the greatest health risk. Combined wastewater and stormwater flows may also flow directly to the Bay if some form of containment is not put in place promptly.

Governance: SFPUC has an ongoing program for rehabilitation and replacement of existing sewers. As sea level rises and functional lifespans decrease, this program may require modifications.

7.5 PLANNED ADAPTATION ACTIONS

SFPUC's planned adaptation actions include general adaptation strategies, as well as specific planned projects. These various strategies are listed below.

7.5.1 General Adaptation Strategies

Flood proofing with external barriers, such as flood gates, can be implemented to protect buildings from temporary flooding. Additionally, access points such as vents, and electrical gear can be raised to a higher elevation to reduce the likelihood of water entering a building or damaging electrical equipment. If needed, external barriers could be used to adapt the facility to higher levels of flooding.

In general, switchgear and electrical equipment can be placed on the second floor of buildings. Flood proofing of belowground conduits can be incorporated. New facilities can place critical elements (e.g., electrical gear and transformers) above the flood risk elevation.

7.5.2 Planned Projects

Community Center

Electrical elements will be placed at or above the elevation reached by a 100-year extreme tide with 33 inches of SLR. Flood-proofing strategies will also be implemented for belowgrade structures. To increase the adaptive capacity of the community center to accommodate larger potential flood events or higher amounts of SLR, temporary barriers (e.g., removable floodwall) or permanent perimeter flood protection (e.g., levees or floodwalls) could be implemented over time, as needed.

Griffith Pump Station

The lowest ground elevation at the Griffith pump station project location is already above the 100-year extreme tide elevation plus 23 inches of SLR for the planning horizon year 2049. Any access points to belowgrade infrastructure (e.g., maintenance access to electrical conduits) could be flood proofed to prevent floodwaters from reaching belowgrade equipment.

Photo 7.8 Rendering of Mariposa Pump Station. San Francisco Public Works

Photo 7.9 Rendering of Biosolids Digester facilities. SFPUC

Photo 7.10 Rendering of Headworks Facility and Lift Station. SFPUC

Mariposa Pump Station

Building openings will be placed above the elevation of the 100-year extreme tide plus 20 inches of SLR (Photo 7.8). Abovegrade electrical and mechanical elements will also be placed at or above this elevation. Flood-proofing strategies will be implemented for belowgrade structures. Adaptive capacity to reach higher elevations of temporary inundation could be achieved with temporary barriers (e.g., removable flood gate) or permanent perimeter flood protection (e.g., levees or floodwall). Electrical equipment can be raised in the future if necessary, if the roof level will accommodate.

Treasure Island

The new Treasure Island wastewater treatment plant will be built at an elevation that provides six inches of freeboard above the 100-year extreme tide elevation with 39 inches of SLR.

Flood-proofing strategies will be implemented for belowgrade structures. To increase the adaptive capacity of the new wastewater treatment plant to larger potential flood events, temporary barriers (e.g., removable floodwall) or permanent perimeter flood protection (e.g., levees or floodwalls) are being considered and will be implemented as needed.

Biosolids Digester Facilities

Abovegrade facilities for the new Biosolids Digester Facilities at the Southeast Treatment Plant are being constructed with an elevated grade that will provide 12 inches of freeboard above the 100-year extreme tide elevation with 36 inches of SLR (Photo 7.9). Abovegrade electrical and mechanical elements will also be placed at or above this elevation, and flood-proofing strategies will be implemented for below-grade structures. Adaptive capacity for larger flood events or higher SLR scenarios could be achieved with temporary barriers (e.g., removable flood gate) or permanent perimeter flood protection (e.g., levees or floodwalls).

Headworks Facility and Southeast Lift Station

The new Headworks Facility and Lift Station at the Southeast Treatment Plant is being constructed with raised grades that provide six inches of freeboard above the 100-year extreme tide elevation with 36 inches of SLR (Photo 7.10). Above grade electrical and mechanical elements will also be placed at or above this elevation, and flood-proofing strategies will be implemented for below grade equipment. Adaptive capacity to larger flood events and higher SLR scenarios could be achieved with either temporary barriers (e.g., removable flood gate) or permanent perimeter flood protection (e.g., levees or floodwalls).

Combined Sewer Discharge Outfalls

Vulnerable combined sewer discharge outfalls will be outfitted with backflow preventers to reduce the potential for inflow into the collection system by rising Bay. The backflow prevention mechanism for each combined sewer discharge outfall will be designed individually as each discharge structure is slightly different.

Photo by Steve Rhodes (CC BY-NC-ND 2.0)

CHAPTER 8

POWER

This chapter focuses on power assets and facilities that are owned by the Pacific Gas and Electric (PG&E), and the relationship between PG&E and SFPUC. PG&E is an investor-owned utility that owns and maintains the local power grid in San Francisco and for most of the northern two-thirds of California. SFPUC and PG&E partner together to deliver cleaner energy to residents and businesses. SFPUC is responsible for providing power to municipal facilities and public transportation, while PG&E provides most of the power to residents and businesses.

This chapter provides an assessment of the PG&E assets where information is available for dissemination to the public. Information on some PG&E assets is not publicly available for security reasons. However, PG&E is conducting its own SLR assessment to ensure that power assets are resilient to SLR, coastal flooding, and other climate hazards. The City coordinates with PG&E, and will include its findings, as appropriate, as adaptation projects move forward toward towards planning, design, and implementation. A safe and reliable power distribution system is one of the most critical components to maintaining public safety, and many of the assets described throughout this Assessment, including public transportation, water supply, wastewater services, and healthcare facilities, rely on power to sustain their critical functions that, in turn, allow us to survive and thrive in San Francisco.

The following sections describe the power assets and their potential vulnerability to SLR and coastal flooding.

8.1 SFPUC POWER

SFPUC owns and operates the Hetch Hetchy Power System (Photo 8.1). Power is generated primarily through hydroelectricity. When San Francisco's Hetch Hetchy Reservoir releases drinking water for the City, the water passes through hydroelectric turbines and creates electricity, which is transmitted to the Bay Area. San Francisco also generates local, renewable energy from City-owned solar, wind, and biogas facilities. SFPUC has been generating some of the cleanest energy available in California since 1918. In total, SFPUC provides about 17 percent of San Francisco's total electricity.

Photo 8.1 Dam at Hetch Hetchy Reservoir. Michael Macor, The Chronicle

San Francisco customers get 40 percent renewable energy, or they can opt to pay a little more through the CleanPowerSF Community Choice Aggregation program to get 100 percent renewable energy. Under this program, SFPUC procures the energy and PG&E continues to maintain the power grid, responds to outages, and handles the monthly billing for customers.

Large facilities, and all new facilities on City-owned land, can apply for 100 percent Hetch Hetchy Power. SFPUC provides power to San Francisco's most critical facilities, including SFO, SFMTA, San Francisco Unified School District, San Francisco General Hospital, the Salesforce Transit Center, and San Francisco's police and fire stations. SFPUC also provides power to San Francisco Housing Authority low-income housing developments and will provide power to some new developments such as Treasure Island and Candlestick/Hunters Point. Although power is transmitted across the PG&E distribution grid, the Hetch Hetchy Power System provides the power to meet the energy demand from these facilities.

8.1.1 Substations

Substations are generally locations in the power system where power can be pooled from generating sources and transformed for distribution to customers. Substations also control the flow of power to customers so that just the right amount is provided and the flow of power is unimpeded. Between the generating station and the customer, power may flow through several substations.

SFPUC is constructing a new substation on Quint Street within the SLR Vulnerability Zone. The design of the substation accommodates up to 36 inches of SLR. SFPUC owns two additional substations near SFO, one in the city of Millbrae, and one in the city of San Bruno. These electrical substations act as an interface between the transmission lines from PG&E to the distribution system. The substations contain equipment that step down the voltage that is suitable for the distribution system and various electrical safety equipment. The SFO Shoreline Protection Program (see Section 4.9), a multi-year program to address SFO's risk of flooding, is addressing existing future flood risks for the campus proper (e.g., airfield, terminals, campus buildings, and infrastructure). SFO is also coordinating with the SFPUC in an evaluation of current and future SFO electrical capacity needs to service SFO's future growth and changing electrical demands. Flood protection of critical power assets, including the two existing substations, will be addressed as this electrical capacity project moves forward.

8.1.2 Transformers and Switchgear

A transformer is an electrical device that transfers electrical energy between two or more electric circuits. Switchgear controls, regulates, and can switch on or off the electric circuit controlling the flow of electricity. Both transformers and switchgear are linked to the reliability of the power supply. When these assets are located at or below grade, they are vulnerable to localized flooding and would not perform their function as designed if flooded.

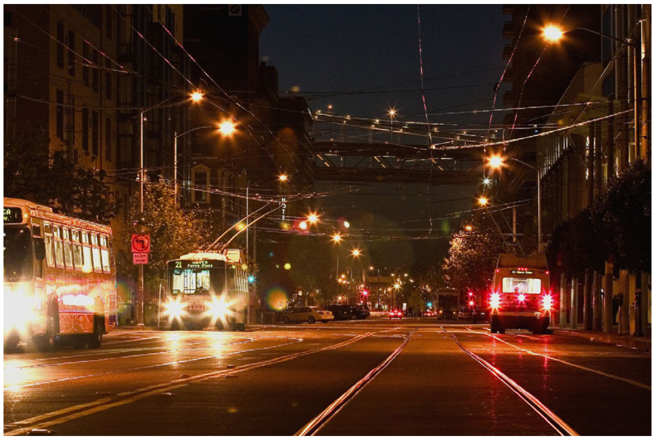


Photo 8.2 San Francisco street lights. Thomas Hawk (CC BY-NC 2.0)

SFPUC owns multiple transformers and switchgear that are located along the Embarcadero to provide power to Port facilities(see Chapter 11, *Port of San Francisco*), within Hunters Point (to provide power to San Francisco Housing Authority low-income apartments and future new developments), and at the Salesforce Transit Center, Laguna Honda Hospital, and San Francisco public schools. Transformers and switchgear are typically contained within an enclosure. Although the enclosures provide protection during rainfall events, they are generally not flood proof.

8.1.3 Streetlights

Streetlights (a.k.a., light poles, lampposts, streetlamp, light standard) are elevated lights that are typically found along roadways, sidewalks, and trails (Photo 8.2). Most streetlights have light-sensitive photocells that turn the light on at dusk and off at dawn. Streetlights are critical for pedestrian, bicycle, and traffic safety.

In San Francisco, most streetlights are connected to underground power. If the streetlights are flooded temporarily for a short period, limited damage is likely to occur, and the streetlight will remain functioning. The electrical infrastructure is designed and rated to endure bad weather and heavy rainfall. However, if streetlights are flooded for a prolonged period, the electrical infrastructure is likely to fail, rendering the streetlight inoperable and the roadway or sidewalk dark during the night.

8.1.4 Exposure Assessment

The exposure of the SFPUC power assets was evaluated relative to the 10 SLR scenarios (see Chapter 2). The exact number and location of the transformers and switchgear are currently being evaluated; however, most of these assets are located within the SLR Vulnerability Zone based on their location along the Embarcadero and in the Hunters Point area. The location of the streetlights was available in GIS and the exposure information is presented in Table 8.1.

8.1.5 Consequence Summary

The SPFUC Power Enterprise power assets and PG&E power assets are closely intertwined to provide a reliable and consistent power supply for all San Francisco residents, businesses, and City facilities. Because of the interrelation between the two systems, the consequences of power disruptions due to sea level rise or coastal flooding cannot be separated into distinct consequences related to SFPUC assets verses PG&E assets. The potential consequences related to both systems are summarized in Section 8.2.6 after a discussion of PG&E assets.

Table 8.1 Transmission Line Exposure Summary

Neighborhood	Number of Streetlamps (x 1000) Inundated within Each SLR Scenario									
	1	2	3	4	5	6	7	8	9	10
Bayview South	-	-	0.9	1.2	1.2	1.50	1.5	1.8	2.4	3.1
Bayview North	-	-	-	-	1.6	6.9	9.2	11.5	15.8	19.4
Potrero Hill	-	-	-	-	-	-	1.0	1.0	1.7	3.9
South of Market	-	-	3.8	13.0	24.1	73.4	93.0	104.0	117.5	127.0
Financial District	-	-	1.1	9.2	14.6	37.8	42.7	46.0	49.7	54.5
North Beach	-	-	-	0.1	0.4	31.5	43.5	46.1	49.3	52.0
Russian Hill	-	-	-	-	-	0.2	0.4	0.4	0.4	0.4
Marina	-	-	-	0.1	0.1	1.7	4.3	6.2	9.3	13.7

8.2 PG&E POWER

PG&E provides power and natural gas to approximately 16 million people throughout a 70,000 square mile service area in Northern and Central California. The San Francisco Gas and Electric Company merged with the California Gas and an Electric Company to form PG&E in 1905. In total, PG&E operates 106,681 miles of electric distribution lines and 18,466 miles of transmission lines. PG&E's transmission lines and high-voltage substations in San Francisco are shown in Figure 8.1.

8.2.1 Transmission Lines

PG&E maintains a network of transmission lines that move electrical energy from power generation plants to electrical substations located near demand centers (Photo 8.3). The lines that distribute the energy from the substations to the customers are generally called distribution lines. The distribution lines were not evaluated in this Assessment.

Most of the transmission lines within the SLR Vulnerability Zone run overhead on utility poles (see Table 8.1), reducing the vulnerability of the transmission lines to SLR and coastal flooding. The utility poles are managed by the Joint Pole Association, a combination of the electric utilities, telephone and wireless companies, and municipalities. Although utility poles are more resilient to flooding, they can be damaged by high winds that often accompany large storm events. Utility poles can also be damaged by falling trees and waterborne debris during a flood event. The overhead lines and utility poles are first exposed under Scenario 5 (52 inches of SLR, or 12 inches of SLR coupled with a 100-year extreme tide).

Underground transmission lines are present in the South of Market neighborhood and are first exposed under Scenario 6 (66 inches of SLR, or 24 inches of SLR coupled with a 100-year extreme tide). Underground power lines are more vulnerable to flooding; however, many communities prefer underground power lines for aesthetic reasons.

8.2.2 Trans Bay Cable

The Trans Bay Cable, owned by Trans Bay Cable LLC, a subsidiary of NextEra Energy Transmission LLC, is a 53-mile direct current electrical transmission cable with fiber optic communication cables bundled together and buried in San Francisco Bay. The cable extends from Pittsburg, California, to San Francisco, connecting to PG&E's Potrero substation. The cable can transmit 400 megawatts (MW) of power, enough to provide approximately 40 percent of San Francisco's peak power needs. The Trans Bay Cable is a federally identified critical asset in the Northern California electric grid. The submarine nature of the cable reduces its vulnerability to SLR and coastal flooding. The cable is most vulnerable at its connection with the Potrero substation.

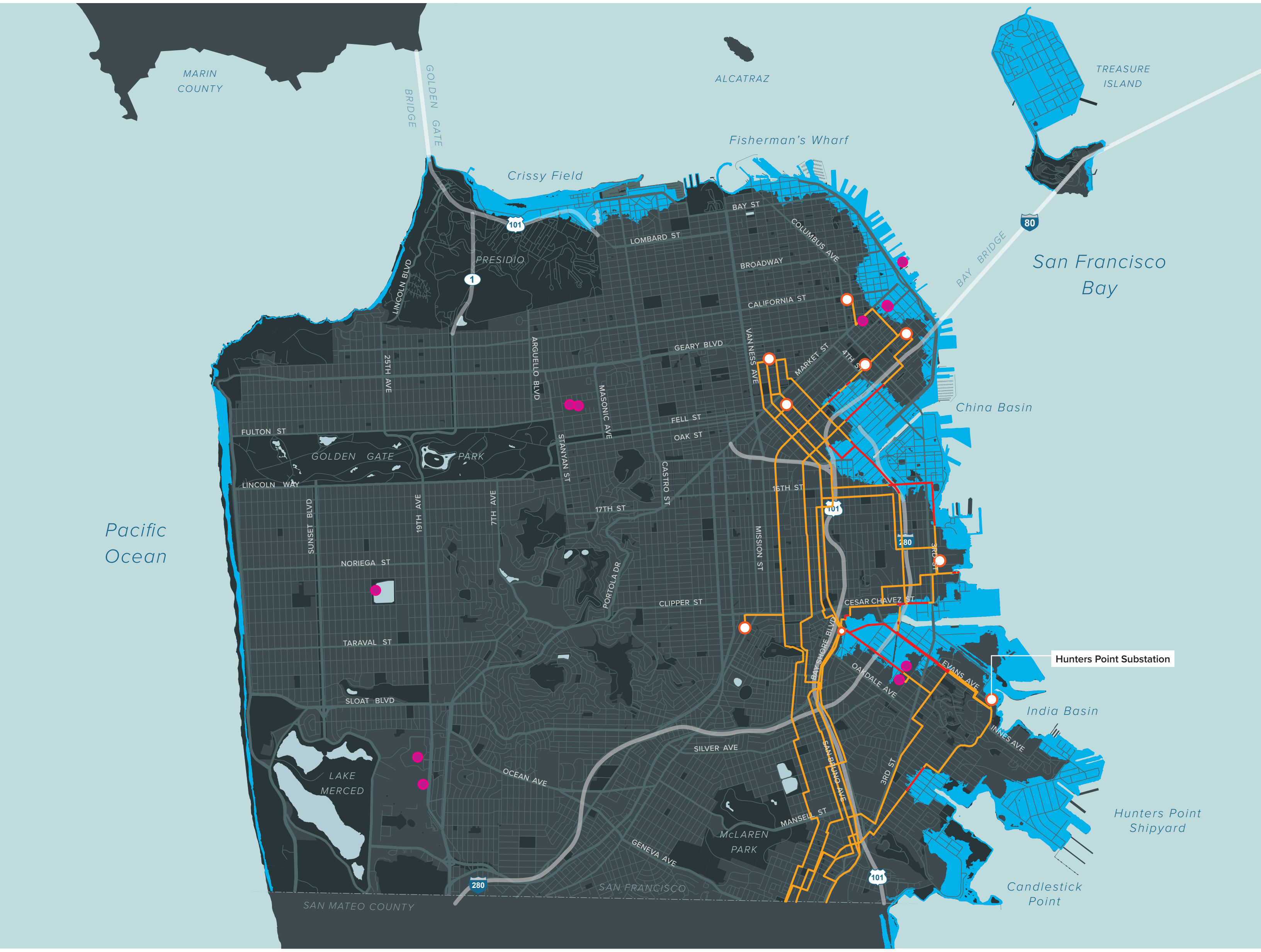
8.2.3 Substations

PG&E owns or maintains nine substations within San Francisco (see Figure 8.1). Only one substation, the 110 – 161 kilovolt Hunters Point substation (Photo 8.4) is within the SLR Vulnerability Zone (see Table 8.2). Electric substations are extremely vulnerable to SLR and coastal flooding, and flooding of any type could interrupt power service for hours to weeks depending on the extent of damage. The Hunters Point substation is first exposed at Scenario 8 (84 inches of SLR, or 42 inches of SLR coupled with a 100-year extreme tide).

Photo 8.3 PG&E transmission lines. Lynn Friedman (CC BY-NC-ND 2.0)

Photo 8.4 PG&E Hunters Point substation. Salim Virji (CC BY-SA 2.0)

Figure 8.1 PG&E Assets in San Francisco



Inundation at 108" Sea Level Rise

PG&E Substation

Solar Power Generation Source

Transmission Line

Transmission Line Exposed to Innundation

Photo 8.5 Solar roof installation in downtown San Francisco. Flickr user Luminalt

8.2.4 Solar Energy Generation

San Francisco has more than enough sunlight throughout the year to make solar electricity feasible. Between 2010 and 2012, nine photovoltaic power systems were installed in San Francisco, adding 15.9 MW of power generation (see Figure 8.1). Three photovoltaic systems with a combined power generation capacity of 3.7 MW are located within the SLR Vulnerability Zone, all located within the Financial District.

The solar arrays are generally installed at high elevations on the roof tops of buildings and are integrated within the building's infrastructure to meet the building's power demand (Photo 8.5). However, the systems are connected to the overall power grid, excess generated power (i.e., above the building's demand) can be provided to the City's power grid. If insufficient power is generated to meet the building's demand, the building can draw power from the City's grid. The photovoltaic systems themselves are not vulnerable to SLR and coastal flooding. Depending on its location and connection type, the connection to the existing power grid can be the most vulnerable part of the photovoltaic system.

8.2.5 Exposure Assessment

The exposure of the PG&E power assets was evaluated relative to the 10 SLR scenarios (see Chapter 2) and is presented in Tables 8.2 and 8.3.

8.2.6 Consequence Summary

KEY ISSUE: A reliable and consistent power supply is critical for the operation and functioning of most City assets and facilities, including wastewater, public transit (e.g., electric buses, Muni, BART), traffic lights, and public safety and emergency operations (e.g., police stations, fire stations, hospitals, schools, shelters, etc.). If power assets are inundated and service is interrupted for any length of time, cascading consequences can occur across the City.

Many City facilities have backup power generation; however, the power supplied by backup generators is often limited and not intended to last for more than a few hours of downtime. Power service interruptions due to SLR and coastal flooding would most likely be localized to specific areas of the City, such as areas served by the Hunters Point substation, or areas served by the underground transmission lines in the South of Market neighborhood. With enough warning before a large storm event, potentially impacted facilities could be better prepared to withstand a potential power outage.

Society and Equity: Disruptions in power service would impact all residents and businesses within the impacted area. Business closures can occur, resulting in lost wages for employees. People may become trapped in elevators, and residents and workers in high-rise buildings will be required to climb flights of stairs. Residents, particularly the elderly and infirm, that rely on home medical equipment will have interrupted medical service. Access to local services, such as grocery stores and gas stations, will be impacted. Commuters and others that rely on the public transit system will need to rely on alternate transportation methods during the outage, and some commuters will become stranded if the outage occurs while on electric-powered public transit, such as Muni. Power outages can increase traffic and congestion due to non-operational traffic lights, which can also increase ambulance and other emergency response times. PG&E's one power substation in the SLR Vulnerability Zone is in the Bayview/Hunters Point neighborhood adjacent to several vulnerable communities. Impacts to this station could disproportionately impact these communities.

Table 8.2 Transmission Line Exposure Summary

Asset Type	Miles Inundated within Each SLR Scenario									
	1	2	3	4	5	6	7	8	9	10
Transmission Lines (Underground)										
South of Market	-	-	-	-	-	0.2	0.3	0.4	0.4	0.6
Transmission Lines (Overhead)										
Bayview North	-	-	-	-	0.2	0.9	1.2	1.4	1.8	2.6
Bayview South	-	-	-	-	-	-	-	-	0.1	0.3
Potrero Hill	-	-	-	-	-	0.1	0.3	0.4	0.6	0.9
South of Market	-	-	-	-	-	0.1	0.4	0.6	0.7	0.9
Trans Bay Cable										
Potrero Hill	-	-	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table 8.3 Substation and Energy Generation Exposure Summary

Asset Type	MW	Number of Assets Inundated within Each SLR Scenario									
		1	2	3	4	5	6	7	8	9	10
Substation											
Bayview North	N/A	-	-	-	-	-	-	-	1	1	1
Solar Energy Generation											
Financial District	1.5	-	-	-	-	-	-	1	1	1	1
Financial District	1	-	-	-	-	-	-	1	1	1	1
Financial District	1.2	-	-	-	-	-	-	1	1	1	1

Economy: Power outages can cause significant cascading economic consequences, including lost revenue for both public agencies and private business and tremendous indirect economic costs in lost work time and limited services to some San Francisco neighborhoods. The longer the power outage, the larger the direct and indirect economic costs. Emergency response personnel, PG&E repair workers, and other City staff may be required to work long hours to repair the impacted facilities and bring the power service back online. If a substation is flooded, it likely cannot be brought back online until after the floodwaters reside. If the repair time is estimated to be lengthy, mobile substations can be brought in as a backup to reduce customer downtime.

Environment: Although flooding of power assets may not cause direct environmental consequences, cascading consequences can occur, including reduced air quality due to increased traffic and congestion, and potential impacts to the Bay and other waterways due to wastewater overflows if power is disrupted at wastewater treatment facilities or pump stations.

Governance: Managing response to power outages caused by flood events requires coordination between PG&E, the SFPUC Power enterprise, emergency responders, and other City agencies. In 2017, a fire at PG&E's Larkin substation caused a large-scale power outage that disrupted traffic, impacted 21 schools, shut down the Montgomery BART station, and required hospitals to operate on emergency power backup systems. Improving the City's response plan is a critical governance step that can help avoid disaster and aid recovery.

Photo by Todd Lappin (CC BY-NC 2.0)

CHAPTER 9

PUBLIC SAFETY

This chapter focuses on City facilities that enhance or provide public safety benefits, such as fire and police stations, homeless shelters, and other community safety buildings that are managed by the City and County of San Francisco and that have been identified as potentially vulnerable. They are either wholly or partially located in the SLR Vulnerability Zone. This chapter also discusses potentially contaminated lands and known facilities that handle hazardous materials that could pose a public safety or health hazard risk if they are inundated by floodwaters or rising groundwater levels.

The following sections describe the assets and discuss how these assets may be vulnerable to SLR and coastal flooding.

9.1 FIRE DEPARTMENT

Established in 1866, the San Francisco Fire Department serves an estimated 1.5 million people, providing fire suppression and emergency medical services to residents, visitors, and workers. SFPUC manages and maintains both the low-pressure fire hydrants connected to the local potable water supply (see Section 6.2.1.4) and the Emergency Firefighting Water System for the use of the Fire Department.

9.1.1 Potentially Vulnerable Assets

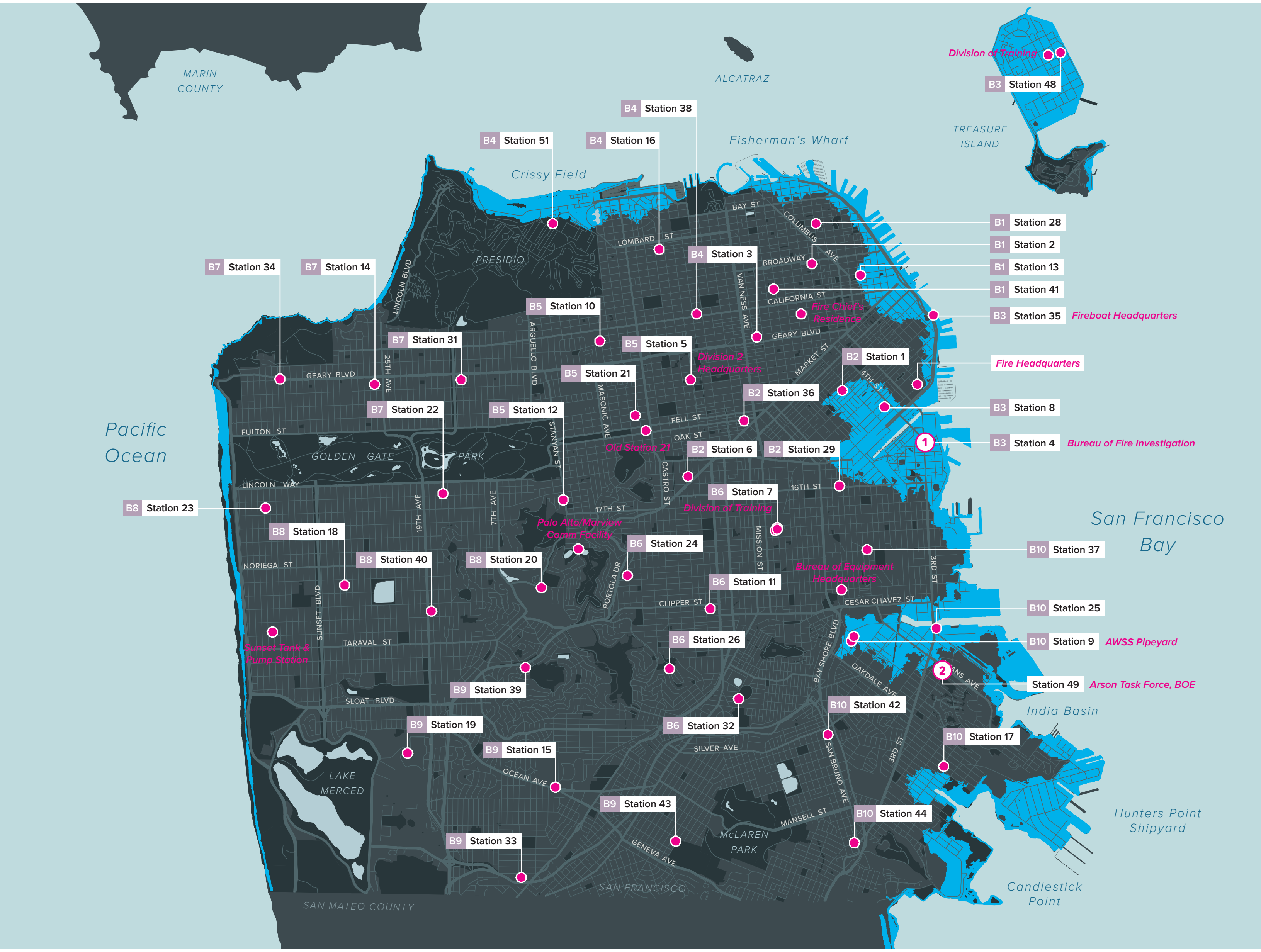
San Francisco has 45 fire stations located through the City, with seven fire stations located within the SLR Vulnerability Zone, as well as the Bureau of Fire Investigation and the Arson Task Force. The fire stations are organized geographically into two divisions (Divisions 2 and 3), with five battalions in each division (see Figure 9.1). Division 2 serves the northern and western regions within the City, and Division 3 serves San Francisco's eastern and southern regions. Only Battalions 1, 2, 3, and 10 have fire stations within the SLR Vulnerability Zone. There are no Fire Department facilities in the SLR Vulnerability Zone on the open Pacific shoreline. SFO also has three fire stations organized under the Airport Division, and these fire stations are not included in this Assessment.

The primary responsibility of the Fire Department is the delivery of fire suppression and emergency rescue services. To provide responsive and effective service, crews must be able to respond within a minimum amount of time after an incident has been reported, and with sufficient resources to initiate fire, rescue, or emergency medical activities. Each fire station is associated with a Fire Response Area that considers the amount of time it takes for a Fire Department vehicle or ambulance to travel from the fire station to an incident scene (i.e., the response time).[1] If a given fire station is out of service, adjacent fire stations in the same battalion provide alternate service, although response times will be longer. If an entire battalion is out of service, adjacent battalions will provide additional backup service. For severe or significant incidents, multiple response vehicles may be dispatched to the incident; however, the first

1 Total fire station reflex time considers: dispatch time (the time it takes to receive and process an emergency call), turnout time (the time from when a unit acknowledges notification to respond to an incident to when the response vehicles leaves the station), response time (the time the response vehicle is in route to an incident, from wheel start to wheel stop), access time (time it takes for responders to move from the wheel stop location to the incident location), and setup time (the time required for responders to set up and activate emergency equipment).

A fire truck parked in front of Fire station 35. Nicolas Lannuzel

Figure 9.1 Fire Stations and Battalions



Inundation at 108" Sea Level Rise

Fire Station

DIVISION 2 Battalions

- B1 Battalion 1
- B4 Battalion 4
- B5 Battalion 5
- B7 Battalion 7
- B8 Battalion 8

DIVISION 3 Battalions

- B2 Battalion 2
- B3 Battalion 3
- B6 Battalion 6
- B9 Battalion 9
- B10 Battalion 10

1. Bureau of Fire Investigation
2. Fire Station 49, Emergency Medical Services

Photo 9.1 **Fire Station 13.** Frank Farm (CC BY-NC-ND 2.0)

Photo 9.2 **Fire Station 4 at the new Public Safety Campus.** Flickr user throgers (CC BY-NC-ND 2.0)

Photo 9.3 **Fire Station 35, Fireboat Headquarters.** Melinda Young (CC BY-NC-ND 2.0)

Photo 9.4 **Bureau of Fire Investigation Building at 1275 Third Street.** HOK

responder on the scene is generally from the fire station located within the Fire Response Area of the reporting incident.

9.1.1.1 Battalion 1

Battalion 1 includes four fire stations (2, 13, 28, and 41) that provide coverage for the Financial District. Fire Station 13, located at 530 Sansome Street, is within the SLR Vulnerability Zone (see Photo 9.1 and Figure 9.2).

9.1.1.2 Battalion 2

Battalion 2 includes four fire stations (1, 6, 29, and 36) that provide coverage for the South of Market (SOMA) Area. Fire Station 1, located at 935 Folsom Street, is within the SLR Vulnerability Zone.

Fire Station 1 is located at 935 Folsom at 5th Street, Division 3, Battalion 2 (see Figure 9.3).

9.1.1.3 Battalion 3

Battalion 3 includes four fire stations (4, 8, 35, and 48) that provide coverage for the southern portion of the Embarcadero, SOMA waterfront, and Treasure Island. Fire Stations 4, 8, and 35 are all within the SLR Vulnerability Zone (Photo 9.2 and Figure 9.4). Fire Station 48, located on Treasure Island, is also within the SLR Vulnerability Zone; Treasure Island, however, is not included in this Assessment.

Because all fire stations of Battalion 3 are in the SLR Vulnerability Zone and since several of the neighboring fire stations from Battalions 1, 2, and 10 (Fire Stations 1, 13, and 25) are also in the SLR Vulnerability Zone, impacts from SLR and coastal flooding could compromise emergency and fire response times in SOMA's waterfront area south of Market Street (Figure 9.5).

Figure 9.2
Fire Station 13 Response Area

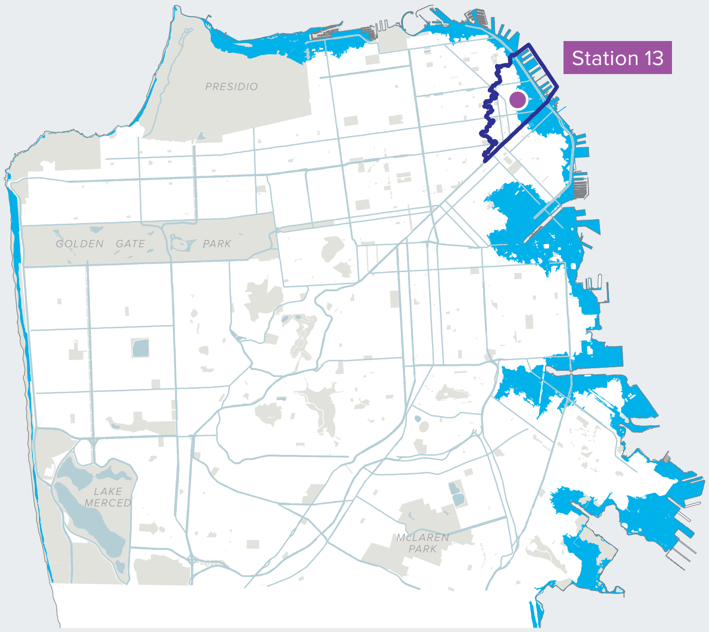


Figure 9.3
Station 1 Response Area

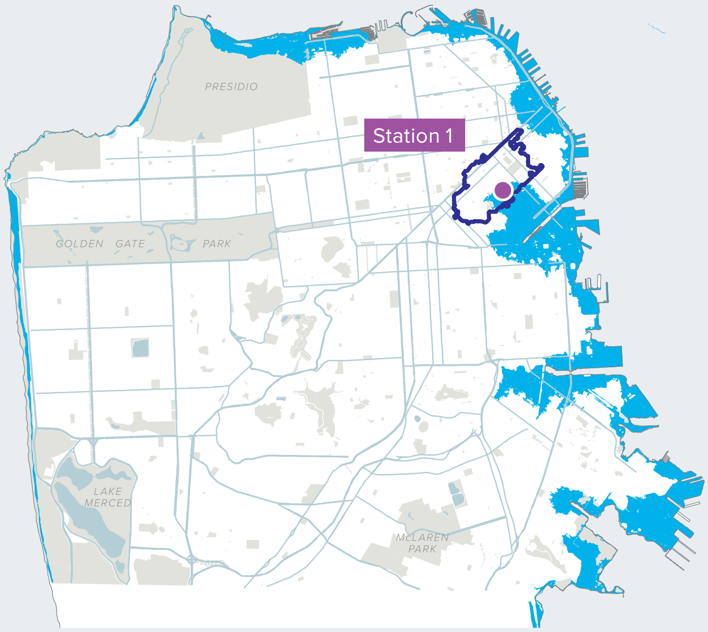


Figure 9.4
Fire Station 4, 8, and 35 Response Areas

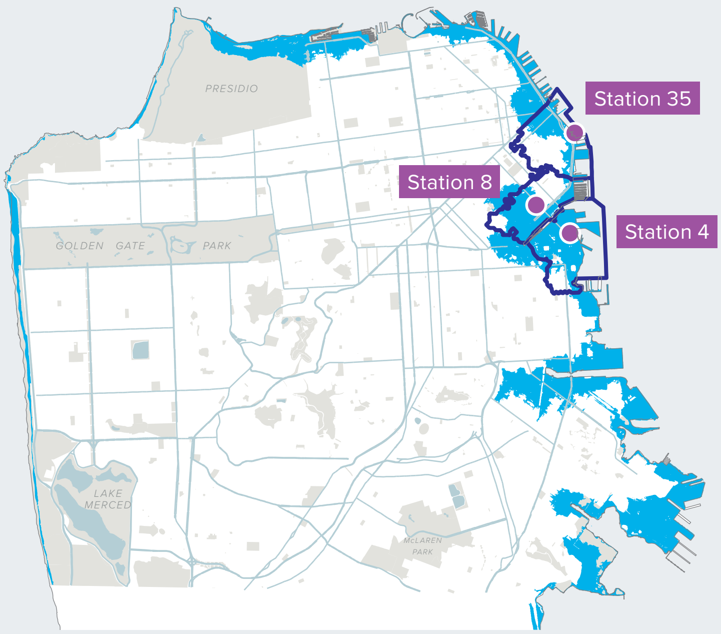
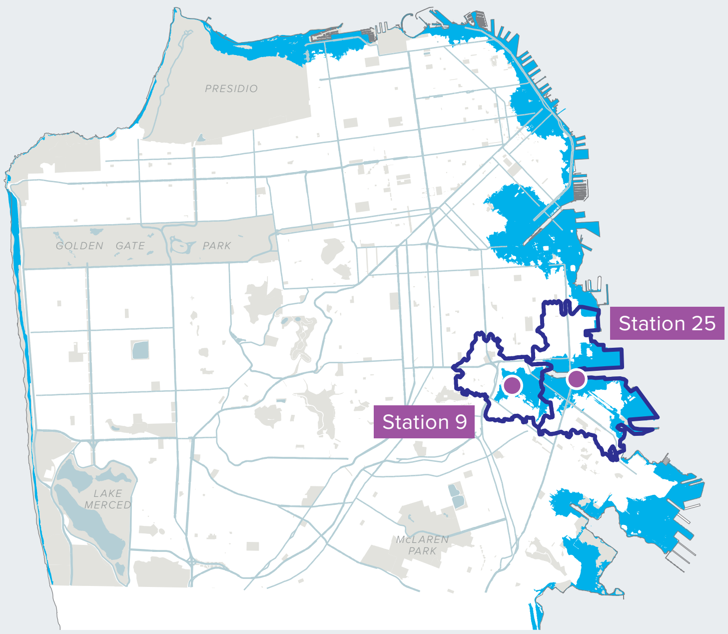


Figure 9.5
Fire Station 9 and 25 Response Areas



Fire Station 4 is located at 449 Mission Rock at 3rd Street (see Photo 9.2 and Figure 9.4). This station is part of the new (April 2015) Public Safety Campus that also contains the San Francisco Police Department headquarters (discussed below), the Arson Task Force, and a Community Room to serve the growing Mission Bay neighborhood.[2]

Fire Station 8 is located at 530 Sansome Street between 4th Street and 5th Street (Figure 9.4).

The new Fireboat Station No. 35 at Pier 22 ½ will be a two-story, 15,000+ sq. ft. fireboat station behind the existing fireboat house. The fireboat house is a San Francisco Landmark, and will continue to function as Engine Company No. 35. The new structure will be built on top of a steel float and anchored by four guide piles. This will allow the new fireboat station to rise and fall with the natural tide of the Bay, King Tides and projected Sea Level Rise. San Francisco Fire Department's three fireboats and rescue watercraft will be moored at the new floating facility. The existing dilapidated Piers 22 1/2 and 24 will be demolished. Fire Station 35 is the fireboat headquarters located on Pier 22 1/2, along the Embarcadero at Harrison Street (see Photo 9.3). This fire station is located on Port land and is located within the Seawall Program area discussed in Chapter 4. Three fireboats, the Phoenix, Guardian, and Saint Francis, can connect directly to the emergency firefighting water distribution system via five manifold connections along the shoreline, and pump saltwater from the Bay into the distribution system for fire suppression. The manifolds and the overall emergency firefighting water system are described Section 6.3. The fireboats provide emergency backup protection in the event of a failure of the reservoirs and/or pump stations.

9.1.1.4 Battalion 10

Battalion 10 includes six fire stations (9, 17, 25, 37, 42, and 44) that provide coverage for the Islais Creek and Bayview Hunters Point neighborhoods. Fire Stations 9 and 25 are located within the SLR Vulnerability Area (see Figure 9.5).

Fire Station 9 is located at 2245 Jerrold Avenue at Bush Street. Fire Station 25 is located within Port property at 3305 3rd Street at Cargo Way, and is also discussed in Chapter 11, *Port of San Francisco*.

9.1.1.5 Bureau of Fire Investigation

The Bureau of Fire Investigation is located at 1275 3rd Street. It is housed in a refurbished brick building as part of the public safety campus in the Mission Bay District (see Photo 9.4).

The Bureau of Fire Investigation is responsible for investigating the origin and cause of all fire incidents and explosions to which it is assigned. Investigators prepare detailed fire investigation reports and coordinate with the National Incident Fire Investigation Reporting System for these incidents. Investigators are responsible for the collection of evidence and for providing testimony in court when subpoenaed. Bureau of Fire Investigation members work cooperatively with the Police Department and the District Attorney to make up the Arson Task Force.[3]

9.1.1.6 Fire Station 49, Emergency Medical Services

Fire Station 49, Division of Emergency Medical Services is located at 1415 Evans Avenue. San Francisco Fire Department’s emergency medical services are currently housed in this cramped, seismically-deficient warehouse on Evans.
The new Ambulance Deployment Facility replacement project is under construction as of October 2018. This new facility located at 2241 Jerrold Street behind Fire Station 9 is part of the 2016 voter-approved Public Health and Safety Bond, which dedicated $350 million toward capital improvements for City facilities to meet the critical health and safety needs of San Francisco.

The new ambulance deployment facility will be a four-story seismically-safe structure sited at 14 feet. The designed building will serve the needs of a growing, 21st-century San Francisco. In addition to bolstering emergency response time and efficiency, the Ambulance Deployment Facility will become headquarters for the state-of-the-art new building and site will be equipped with ample parking for the fleet and storage for ambulance supplies and vehicle restocking, as well as emergency medical services offices, conference and training rooms, locker rooms and communal space. The location also will have on-site fueling and 72-hour emergency generator.

2 https://sanfranciscopolice.org/san-francisco-police-department-headquarters.

3 https://sf-fire.org/about-division. Accessed August 18, 2018.

Table 9.1 Fire Department Facility Exposure with Sea Level Rise

	Structure	Exposure under Each Scenario (Y/N) 1	2	3	4	5	6	7	8	9	10
Battalion 1	Fire Station 13	-	-	-	-	-	-	-	-	Y	Y
Battalion 2	Fire Station 1	-	-	-	-	-	-	-	-	-	Y
Battalion 3	Fire Station 4	-	-	-	Y	Y	Y	Y	Y	Y	Y
	Fire Station 8	-	-	-	-	-	Y	Y	Y	Y	Y
	Fire Station 35, Fireboat Headquarters	-	-	-	-	Y	Y	Y	Y	Y	Y
Battalion 10	Fire Station 9	-	-	-	-	-	-	-	Y	Y	Y
	Fire Station 25	-	-	-	-	-	Y	Y	Y	Y	Y
Other Fire Department Facilities	Bureau of Fire Investigation	-	-	-	Y	Y	Y	Y	Y	Y	Y
	Fire Station 49, Arson Task Force	-	-	-	-	-	-	-	-	-	Y*

* Inundated under H++ Scenario.

9.1.2 Exposure Assessment

The exposure of each fire station, associated facilities, and Fire Department buildings was evaluated relative to the 10 SLR scenarios (see Chapter 2) and presented in Table 9.1.

9.1.3 Consequences

Key consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: Fire stations in the SLR Vulnerability Zone are susceptible to flooding because the facilities generally have at-grade openings and were not built to withstand flooding. In addition, emergency response services rely on roads that could be flooded and power supplies that could be disrupted. Ensuring that emergency and disaster response services are not interrupted will require actions to improve the individual facilities to increase flood resilience, and coordination across the fire stations and battalions to provide backup or alternate services from fire stations that are not flooded outside of the Flood Response Area. Coordination will also be required with City, county, and state transportation agencies to ensure road access and utility services are maintained.

Society and Equity: Fire station personnel respond to large-scale disasters and smaller emergencies in the community, benefitting residents and those who work in the area. Emergency response could be impacted in Fire Response Areas with flooded fire stations, resulting in delays in response time and dangers to public health and safety.

Economy: By protecting the local community, fire stations provide value to the local economy. If emergency response is delayed or impaired due to flooding, recovery costs could increase, and local communities and the region could suffer long-term economic consequences.

Environment: Emergency response facilities and personnel play a critical role in hazardous materials spills and emergencies, including oil spills and other environmental contamination events. Emergency responders provide a critical function in helping protect environmental and human health from these events.

9.2 EMERGENCY FIREFIGHTING WATER SYSTEM

The Emergency Firefighting Water System (EFWS; also known as the Auxiliary Water Supply System or AWSS) is a high-pressure water supply network built in response to the failure of the emergency water system during the 1906 earthquake and the ensuing fires (see Figure 9.6). The system includes one water reservoir, two pump stations, two storage tanks, and approximately 135 miles of buried pipelines.

Anticipating the possibility of the high-pressure pipelines rupturing during an earthquake, the distribution system was divided into three zones: the West of Twin Peaks Zone (connected to the Twin Peaks Reservoir), the Upper Zone (connected to the Ashbury Tank), and the Lower Zone (connected to the Jones Street Tank). Isolation gate valves are also located at frequent intervals throughout the zones so that a damaged section can be isolated, leaving the remainder of the system in operation. The isolation gate valves are located in areas of Bay fill, because pipeline in these areas are more likely to experience movement that could cause pipeline rupture during an earthquake.

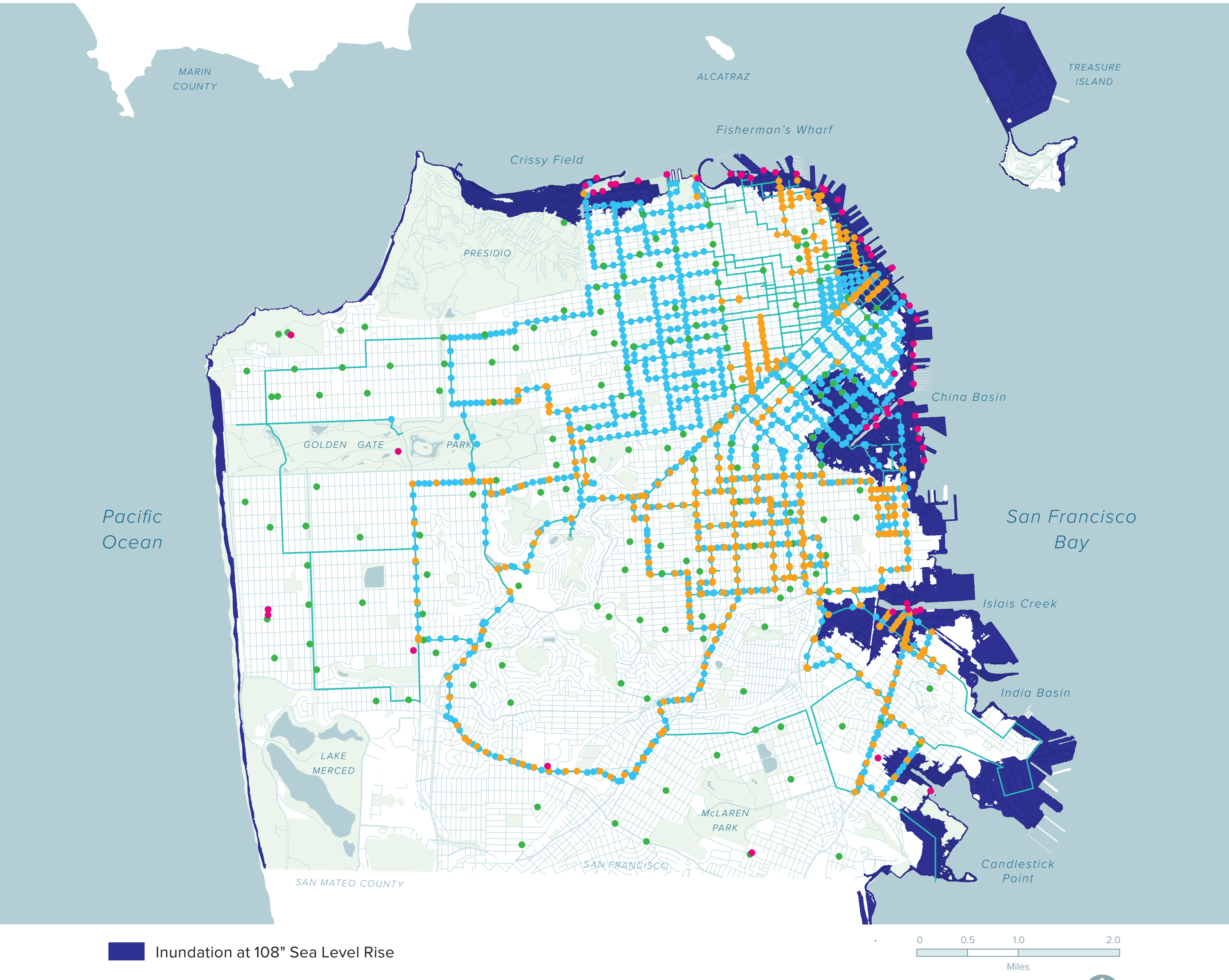
If there is insufficient freshwater within the system during a fire emergency (i.e., if there is a loss of water pressure that affects firefighting abilities), two pump stations have direct underground connections to the Bay that can pump 10,000 gallons per minute (gpm) of saltwater into the firefighting water distribution system using onsite generators. Pump Station No. 1 is in the basement of the San Francisco Fire Department Headquarters at 698 Second Street, and Pump Station No. 2 is in Fort Mason .

Although the SFPUC maintains the Emergency Firefighting Water System, the Fire Department is the primary end user of this system. Information on the City's Fire Stations and Fire Department operations is presented in Section 9.1.

The Fire Department also maintains three fireboats that can connect to one of five manifolds located along the San Francisco shoreline and deliver saltwater to the Emergency Firefighting Water System in an extreme emergency. The fireboats provide additional backup protection in the event of a failure of the reservoirs and/or pump stations. The three fireboats currently dock at Pier 22 ½ (see Section 9.1.1.3). There

Fire boat. Geo Swan

Figure 9.6 Emergency Firefighting Water System



Inundation at 108" Sea Level Rise

- AWSS Fireboat Pump Stations
- AWSS Hydrants
- AWSS Valves
- AWSS Cisterns
- AWSS Pipes

are 41 additional suction connections located along the northeastern shoreline, which allow fire engines to pump water directly from San Francisco Bay for fire suppression.

As a final back-up fire protection measure, there is a network of approximately 210 operational[4] and independent underground water cisterns located primarily at roadway intersections. The cisterns are large, underground concrete tanks that store water for firefighting purposes.

9.2.1 Potentially Vulnerable Assets

The Emergency Firefighting Water System assets within the SLR Vulnerability Zone include distribution pipelines, a pipe yard, high-pressure fire hydrants, isolation gate valves, pump stations, manifolds, suction connections, and cisterns.

9.2.1.1 Distribution Pipelines

The emergency firefighting water distribution system is constructed of cast iron pipe that is primarily 10 to 12 inches in diameter, although some sections have diameters as large as 20 inches. Much of the pipeline that was installed in 1912 is still in service today, and the system was expanded and improved over time in the 1930s, 1970s, 1980s, and today through the Earthquake Safety Emergency Response Bond passed in 2014.

The distribution system was installed with restrained pipeline joints, using fewer branches than the local potable water supply, and no service connections. This makes the system less vulnerable to earthquake damage due to land movement than the local potable water supply distribution pipelines. Although the system is intended for use with both freshwater and saltwater, the primary (i.e., non-earthquake/land movement) vulnerability of the system is associated with saltwater corrosion. The use of freshwater within the system is preferred, and saltwater can be pumped in via the pump stations or fireboats in case of extreme emergency. As sea levels rise and the shallow groundwater layer rises and becomes more saline, portions of the distribution pipelines will be subjected to enhanced external corrosion.

4 There are additional cisterns that are currently no longer operational (i.e., they may leak, be damaged, or may no longer be accessible), and these cisterns were not included in this Assessment.

9.2.1.2 Pipe Yard

A pipe yard for the emergency firefighting water distribution system is located behind Fire Station 9 at 2245 Jerrold Avenue. The pipe yard stores materials for maintenance and repairs. If the pipe yard is inundated by SLR or a coastal flood event, materials stored onsite could be damaged and maintenance delays could occur.

9.2.1.3 Isolation Gate Valves

Isolation gate valves are located throughout the system and are used to isolate portions of the AWSS in the event of damage. These isolation gate valves can be operated via a truck-mounted actuator. Additionally, the 1986 Bond provided funding to motorize and enable remote operation of 30 of these isolation valves, mostly in the low-lying areas of the City built on fill. Remote operation allows the AWSS to close valves much more quickly in response to pipe breaks.

In an emergency such as an earthquake, this will reduce the loss of stored water. Remotely operated valves are monitored and operated from the Jones Street Tank control building and can also be operated from a control system near the Lake Merced Pump Station. Operation of the valves relies on electricity. After the Loma Prieta earthquake in 1989, loss of power resulted in an inability to close some of the isolation gate valves, rendering portions of the Emergency Firefighting Water System inoperable. The motorized isolation gate values are highly vulnerable to inundation, and floodwaters could affect the electrical equipment and render the valves inoperable, potentially compromising the entire Lower Zone of the Emergency Firefighting Water System.

9.2.1.4 High-Pressure Fire Hydrants

High-pressure fire hydrants are connected to the emergency firefighting water distribution system and located throughout the City for fire suppression. The color of the fire hydrant indicates which pressure zone the hydrant is in (i.e., which reservoir or tank the hydrant is connected to). Black-topped hydrants are in the West of Twin Peaks Zone and fed by the Twin Peaks Reservoir; red-topped hydrants are in the Upper Zone and fed by the Ashbury Street tank; and blue-topped hydrants are in the Lower Zone and fed by the Jones Street Tank (see Photo 9.6).

In general, fire hydrants are moderately vulnerable to SLR and coastal flooding, with vulnerabilities directly related to flooding along the roadways (see Chapter 5, *Transportation*). Areas with inaccessible (i.e., flooded) high-pressure fire hydrants will not have direct access to fire suppression services from fire engines. Services should resume after floodwater recede. Fire hydrants in flooded areas will require inspections for corrosion to ensure each hydrant is fully operational in the event of an emergency. The suction connections along the shoreline provide redundancy for the high-pressure fire hydrants, and the cisterns provide an additional emergency back-up firefighting water supply.

Photo 9.6 **High-pressure fire hydrant.** Kitty DuKane (CC BY-NC 2.0)

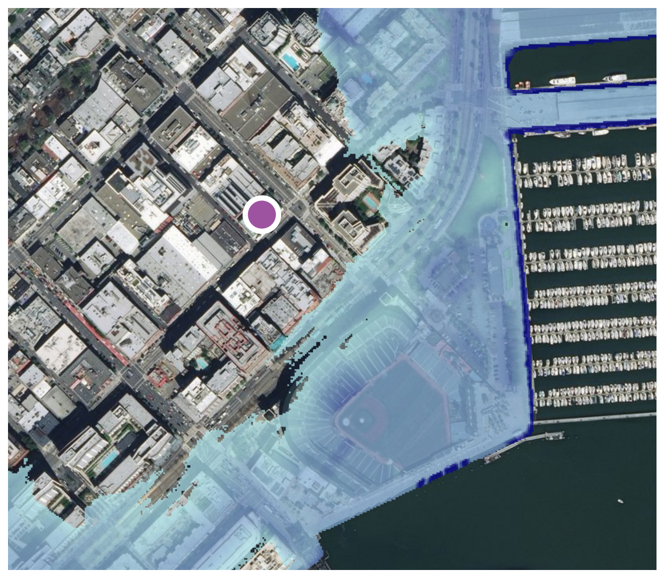
9.2.1.5 Pump Station No. 1

Pump Station No. 1 was built in 1911 and is located in the basement of the San Francisco Fire Department Headquarters on the corner of Second and Townsend streets (see Photo 9.7). The Fire Department Headquarters building was built on top of the existing Pump Station No. 1 in 1998. The pump station contains four diesel-driven pumps, each with a pumping capacity of 2,700 gpm at 300 pounds per square inch (psi).

An approximately 1,100-foot concrete intake tunnel located underneath the pump station floor runs under Townsend Street and connects directly to the Bay (see Photo 6.5). The tunnel conveys seawater from the Bay to the pumps and ultimately to the Emergency Firefighting Water System for emergency fire suppression. This pump station is manually operated. A backup generator powers the electrical systems at the pump station in the event of a power outage. The pumps were originally steam powered but were converted to diesel in the 1970s.

Although Pump Station No. 1 is outside of the SLR Vulnerability Zone (see Figure 9.7), its direct connection to the Bay through the tunnel makes it potentially vulnerable to SLR. The pump station tunnel connection has limited freeboard during King Tides (i.e., Bay waters can be seen at the tunnel connection to the pump station during King Tide conditions in the Bay). As sea levels rise, the lower levels of the pump station could flood. The tunnel connection would require modifications to maintain a watertight seal during extreme high tides.

Figure 9.7 Pump Station No. 1 / Fire Department Headquarters



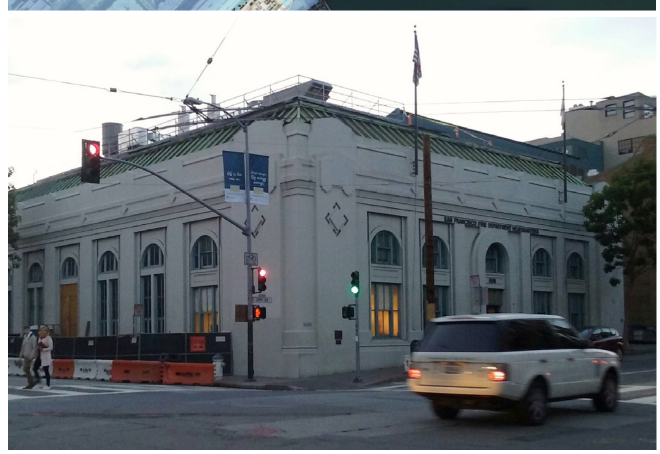


Photo 9.7 Pump Station No. 1. Photo by Flickr user sftrajan.

9.2.1.6 Pump Station No. 2

Pump Station No. 2 pumps saltwater from the San Francisco Bay to the AWSS. Pump Station No. 2 is located at the foot of Van Ness Avenue near Fort Mason (see Figure 9.8 and Photo 9.8). This pump station contains four diesel-driven pumps, each with a pumping capacity of 2,700 gpm at 300 psi. An approximately 160-foot concrete intake tunnel located underneath the pump station floor conveys seawater from the Bay to the pumps. A back-up generator powers the electrical systems at the pump station in the event of a power outage. The pumps were originally steam powered but were converted to diesel in the 1970s. This pump station connects directly to the Ashbury Tank and Jones Street Tank. However, the connection from the pump station to the Ashbury Tank is normally closed, and the connection to the Jones Street Tank is normally open.

Pump Station No. 2 is directly adjacent to the shoreline and could be inundated by Scenario 9 (i.e., 96 inches of SLR, or 54 inches of SLR coupled with a 100-year coastal flood event). The pump station includes sensitive electrical equipment that is at and below grade and sensitive to any inundation. A combination of wet- and dry-floodproofing would be required to increase the resilience of this pump station to rising sea levels.

9.2.1.7 Manifolds

Three fireboats anchored at Pier 22 ½ can supply Bay water to the Emergency Firefighting Water System along the City's northeastern waterfront (see Photo 9.9). The fireboats connect to the distribution system via five manifolds located along the Bay shoreline (see Figure 9.9). The manifold connections have moderate to low vulnerability to SLR and coastal flooding. Manifold connections are suction driven and can still be operated if they are underwater if the fireboat is able to connect. It is possible that a suction connection can even be made if the manifold is fully inundated – in this instance, the safety of emergency fire personnel making the connection may control whether the manifolds can be used.

9.2.1.8 Suction Connections

There are 52 suction connections in the City (see Figure 9.10), with 41 suction connections located directly along the Bay shoreline that allow fire

Figure 9.8 Pump Station No. 2

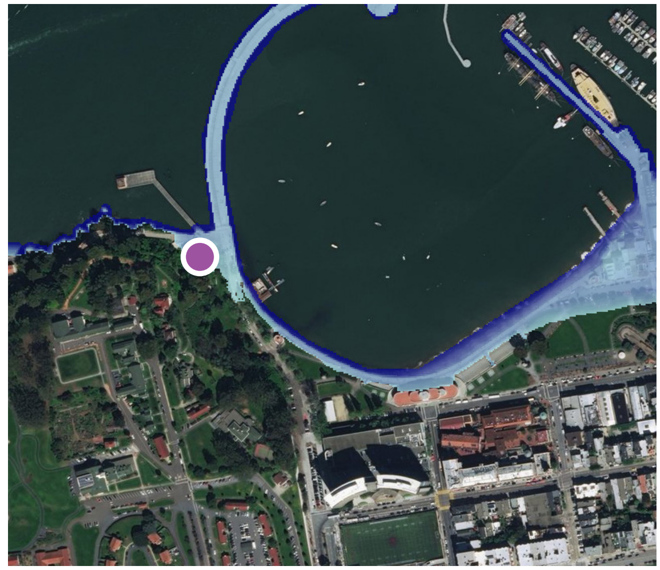
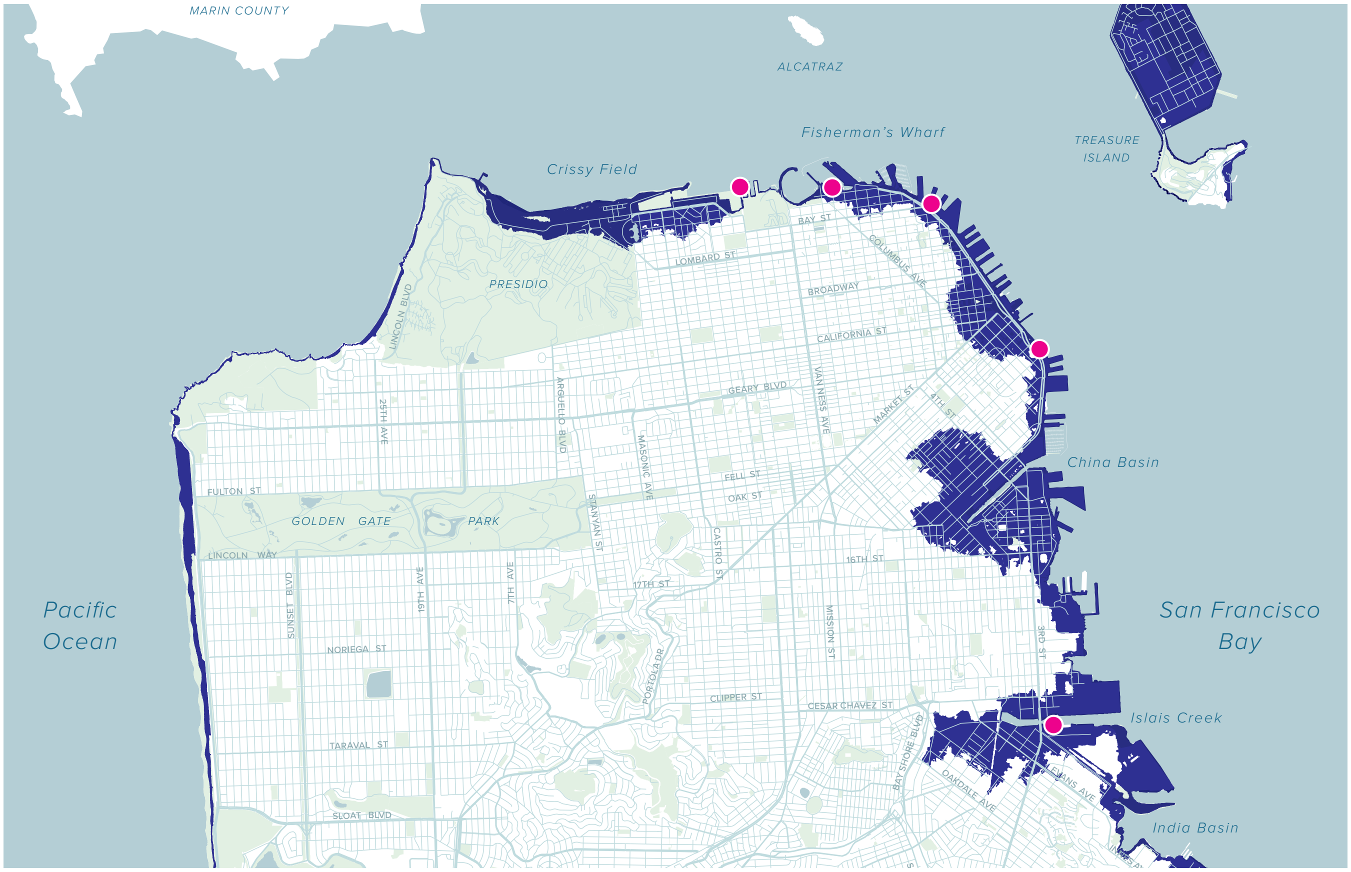


Photo 9.8 **Pump Station No. 2.** Katherine Du Tiel, SFPUC

Photo 9.9 **Pier 22 ½ with docked fireboats.** Dave R (CC BY-NC 2.0)

Figure 9.9 Manifold Locations



engines to draw water from the Bay for fire suppression. The suction connections resemble fire hydrants and are painted light green (see Photo 9.10). Suction connections become unusable if they are inundated, and if the fire engines cannot access the connections due to roadway flooding (see Chapter 5, *Transportation*).

9.2.1.9 Cisterns

One of the most basic and reliable means for storing large amounts of water for firefighting is an individual fire cistern. The cisterns are underground water storage tanks that are completely disconnected from the rest of the AWSS system and the City's water domestic water supply. The cisterns range in size from 75,000 to more than 200,000 gallons, with a total storage capacity of over 11 MG of water. The stored water is accessed by firefighters through green-topped fire hydrants adjacent to each cistern. Water levels in the cisterns are checked periodically and they are filled manually, usually with water from a nearby LPFH. Cisterns are the last water resource of Fire Department.

Photo 9.10 Suction connection (Baywater 'fire hydrants'). Jason Randall

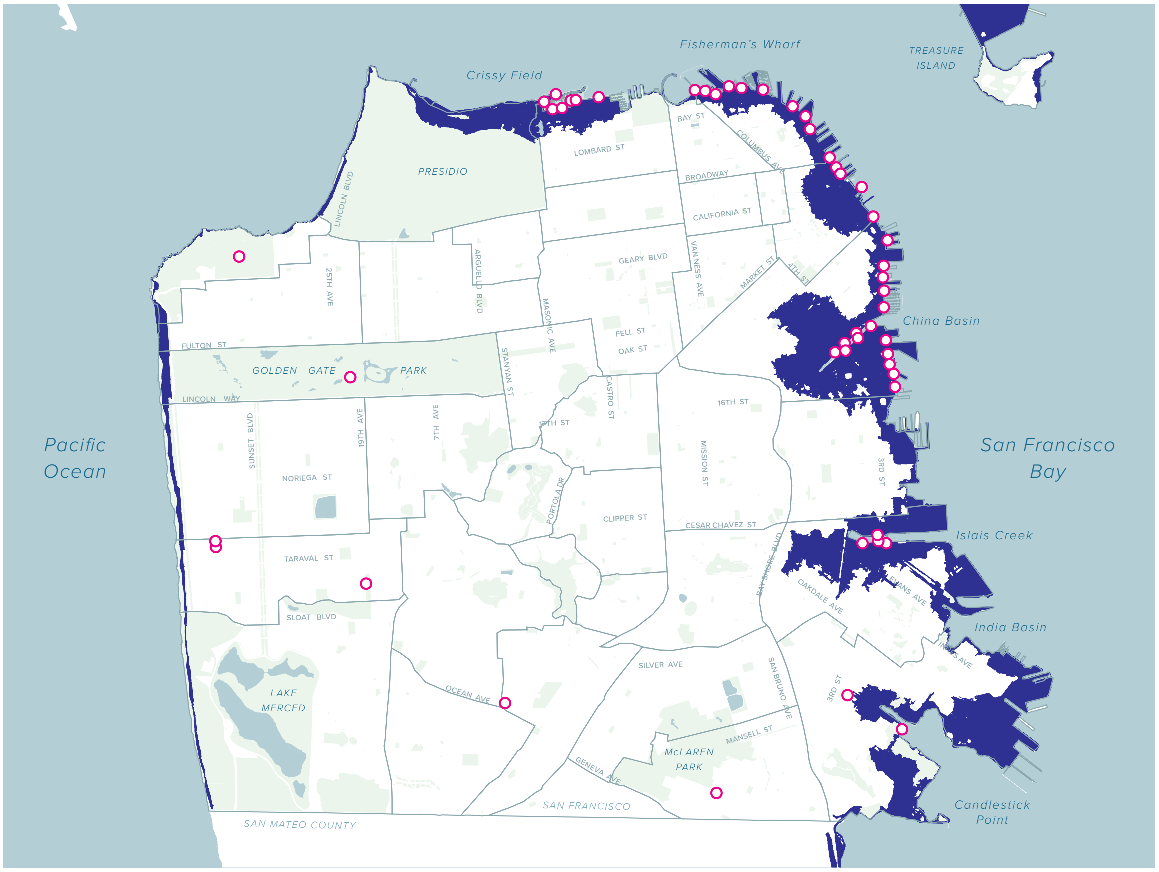


Figure 9.10
Suction Connection Locations

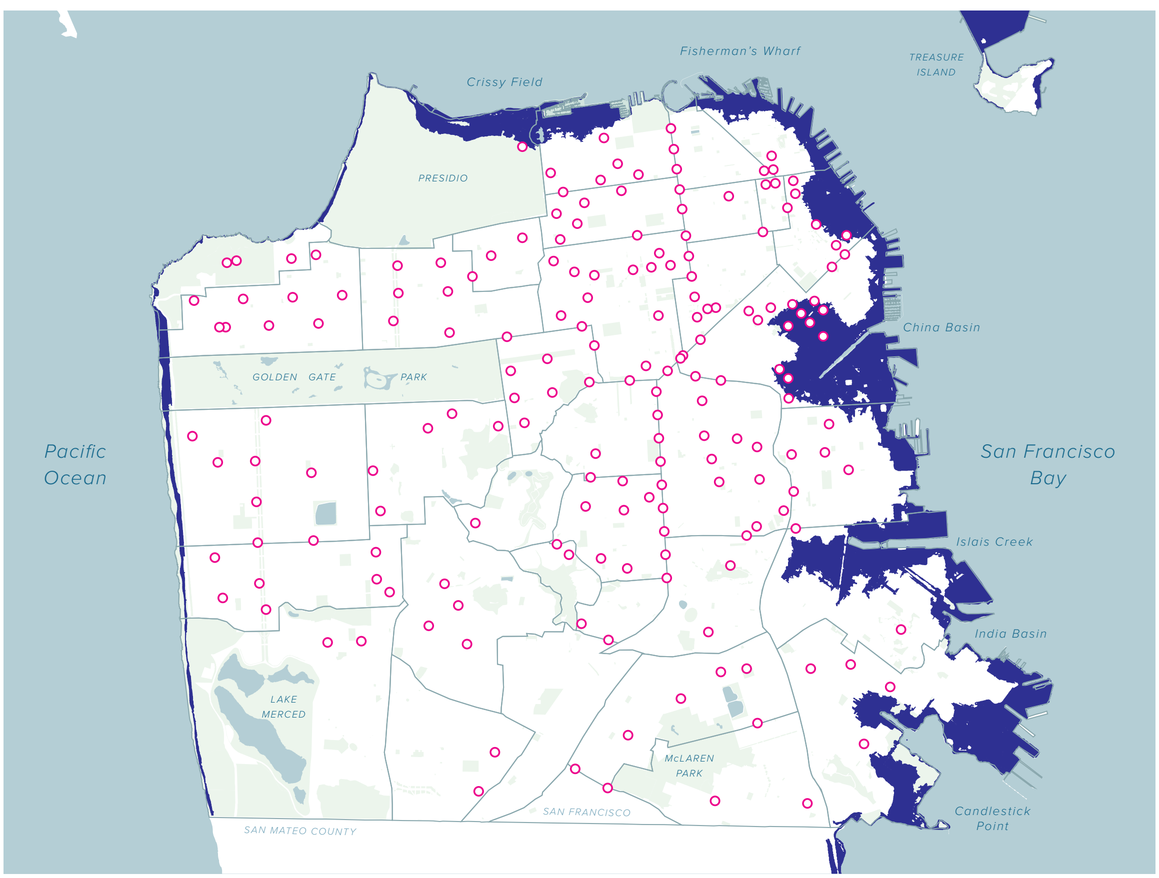


Figure 9.11
Cistern Locations

There are approximately 200 operational cisterns located throughout the City (see Figure 9.11). Fifty-four cisterns were built in the mid-1800s, and an additional 85 were built in the early 1900s after the 1906 earthquake. The oldest cisterns are constructed of brick, but most of the operational cisterns are constructed of reinforced concrete. SFPUC is currently making repairs to aging cisterns and has installed 30 new cisterns to improve coverage throughout the City.

Cisterns are below grade, and the water within them is non-potable and would not be impacted if saltwater leaked in during a flood event. The cisterns are the least vulnerable components of the Emergency Firefighting Water System. Although the cisterns may become unusable during a flood event, they will return to service once floodwaters recede. These low-technology, last-resort fire suppression water supply tanks can remain in service until they are permanently inundated. Although rising groundwater salinity levels may shorten repair cycles, the stored water is considered non-potable and would still be usable for fire suppression if it is contaminated by saltwater.

9.2.2 Exposure Assessment

The exposure of the Emergency Firefighting Water System was evaluated relative to the 10 SLR scenarios (see Chapter 2, *Climate Science*). The exposure assessment is presented relative to the neighborhoods, and if a neighborhood is not listed in a specific exposure table, then no respective assets were found to be within the SLR Vulnerability Zone.

Only the Lower Zone connected to the Jones Street Tank is within the SLR Vulnerability Zone. Table 9.2 presents the miles of distribution pipeline located within the SLR Vulnerability Zone that could be exposed to SLR and coastal flooding under each scenario. The distribution pipelines are buried underground and have limited vulnerability to temporary flooding.

However, as sea levels rise, and the shallow groundwater layer also rises and increases in salinity near the shoreline, corrosion could shorten the life expectancy of the buried pipelines. The repair and replacements cycles would shorten, and the frequency of emergency repairs could increase. The Pipe Yard, which supports maintenance and repair activities, is first inundated under Scenario 8 (i.e., 84 inches of SLR, or 42 inches of SLR coupled with a 100-year coastal flood event).

Buried infrastructure is not easily adaptable to rising sea levels or increases in salinity. All adaptation measures would likely require significant investments, as well as disruptions to roadways and traffic during repairs and modifications to address changing conditions.

Table 9.3 presents the number of motorized isolation gate valves located within the SLR Vulnerability Zone. If an isolation gate valve is inundated, the floodwaters could affect the electrical equipment, resulting in an inability to close the isolation gate valves, rendering portions of the Emergency Firefighting Water System inoperable.

Table 9.4 presents the number of hydrants that are inundated under each SLR scenario. As with the LPFH, hydrants become unusable when the depth of flooding exceeds about 20 inches because fire engines can no longer safely access the hydrants via flooded roadways. The hydrants should resume operability once floodwaters recede.

Table 9.5 presents the suction connections within the SLR Vulnerability Zone Most of the suction connections are at or near the shoreline, and the connection itself is typically located within three feet of the ground surface (see Photo 9.10). Therefore, most of the suction connections are inundated under Scenarios 2 and 3 (i.e., 24 and 36 inches of SLR, respectively).

An exposure assessment of the manifold connections was not completed. Although the suction connections become unusable when inundated, largely due to limitations in fire engine access, the manifold connections can remain in service when inundated as long as a fireboat can safely establish a connection.

Table 9.6 presents the number of cisterns that are exposed under each SLR scenario. Most of the cisterns are not located within the SLR Vulnerability Zone.

Table 9.2 Emergency Firefighting Water Distribution Pipeline Exposure Summary

Neighborhood	Miles of Emergency Firefighting Water Distribution Pipelines Exposed under Each Scenario									
	1	2	3	4	5	6	7	8	9	10
Bayview North	-	-	-	-	0.6	1.5	1.7	1.9	2.2	2.7
Bayview South	-	-	0.7	0.8	1.0	1.8	2.1	2.4	2.6	2.7
Financial District	-	-	-	0.2	0.5	2.9	3.4	3.7	4.3	4.9
Marina	-	0.1	0.1	0.1	0.1	0.3	0.3	0.5	0.6	1.1
North Beach	-	-	-	-	-	0.9	1.3	1.6	2.0	2.3
Potrero Hill	-	-	-	-	-	-	-	-	0.2	0.3
South of Market	-	-	-	0.5	1.3	3.7	4.6	5.2	5.9	6.6
Total	-	**0.1**	**0.7**	**1.5**	**3.5**	**11.1**	**13.5**	**15.3**	**17.8**	**20.6**

Table 9.3 Isolation Gate Valve Exposure Summary

Neighborhood	Number of Isolation Gate Valves Exposed under Each Scenario									
	1	2	3	4	5	6	7	8	9	10
Bayview North	-	-	-	-	-	-	-	-	1	1
Bayview South	-	-	-	-	-	-	-	-	-	-
Financial District	-	-	-	-	1	1	1	1	1	1
Marina	-	-	-	-	-	-	-	-	-	1
South of Market	-	-	-	1	2	7	7	8	9	9
Total	-	-	-	**1**	**3**	**8**	**8**	**9**	**11**	**12**

Table 9.4 High-Pressure Fire Hydrant Exposure Summary

Neighborhood	Number of Isolation Gate Valves Exposed under Each Scenario									
	1	2	3	4	5	6	7	8	9	10
Bayview North	-	-	-	-	12	19	20	21	24	32
Bayview South	-	-	-	-	-	2	5	5	5	6
Financial District	-	-	-	2	8	41	46	51	58	66
Marina	-	-	-	-	-	2	2	5	7	13
North Beach	-	-	-	-	-	16	20	22	28	31
Potrero Hill	-	-	-	-	-	-	1	2	4	5
South of Market	-	-	-	4	13	49	59	70	80	86
Total	-	-	-	**6**	**33**	**129**	**153**	**176**	**205**	**238**

Table 9.5 Suction Connection Exposure Summary

Neighborhood	Number of Suction Connections Exposed under Each Scenario									
	1	2	3	4	5	6	7	8	9	10
Bayview North	-	4	4	4	4	4	4	4	4	4
Bayview South	-	1	1	1	1	1	1	1	1	1
Financial District	1	2	2	3	3	4	4	4	4	4
Marina	1	7	7	7	7	7	7	7	7	7
North Beach	4	8	8	8	8	8	8	8	9	9
Russian Hill	1	1	1	1	1	1	1	1	1	1
South of Market	3	15	16	16	16	16	16	16	16	16
Total	**10**	**38**	**39**	**40**	**40**	**41**	**41**	**41**	**42**	**42**

Table 9.6 Cistern Exposure Summary

Neighborhood	Number of Cisterns Exposed under Each Scenario									
	1	2	3	4	5	6	7	8	9	10
Financial District	-	-	-	-	-	-	-	-	1	2
South of Market	-	-	-	-	-	3	3	3	7	7
Total	-	-	-	-	-	**3**	**3**	**3**	**8**	**9**

9.2.3 Consequence Summary

KEY ISSUE: The Emergency Firefighting Water System provides back-up water for fire suppression in the event of a loss of pressure in the low-pressure system (i.e., the LPFH connected directly to the Local Potable Water Supply System). However, portions of the Emergency Firefighting Water System can be rendered inoperable in the event of a coastal flood event. The lack of firefighting services could prevent adequate protection of homes, businesses, or entire neighborhoods in the SLR Vulnerability Zone.

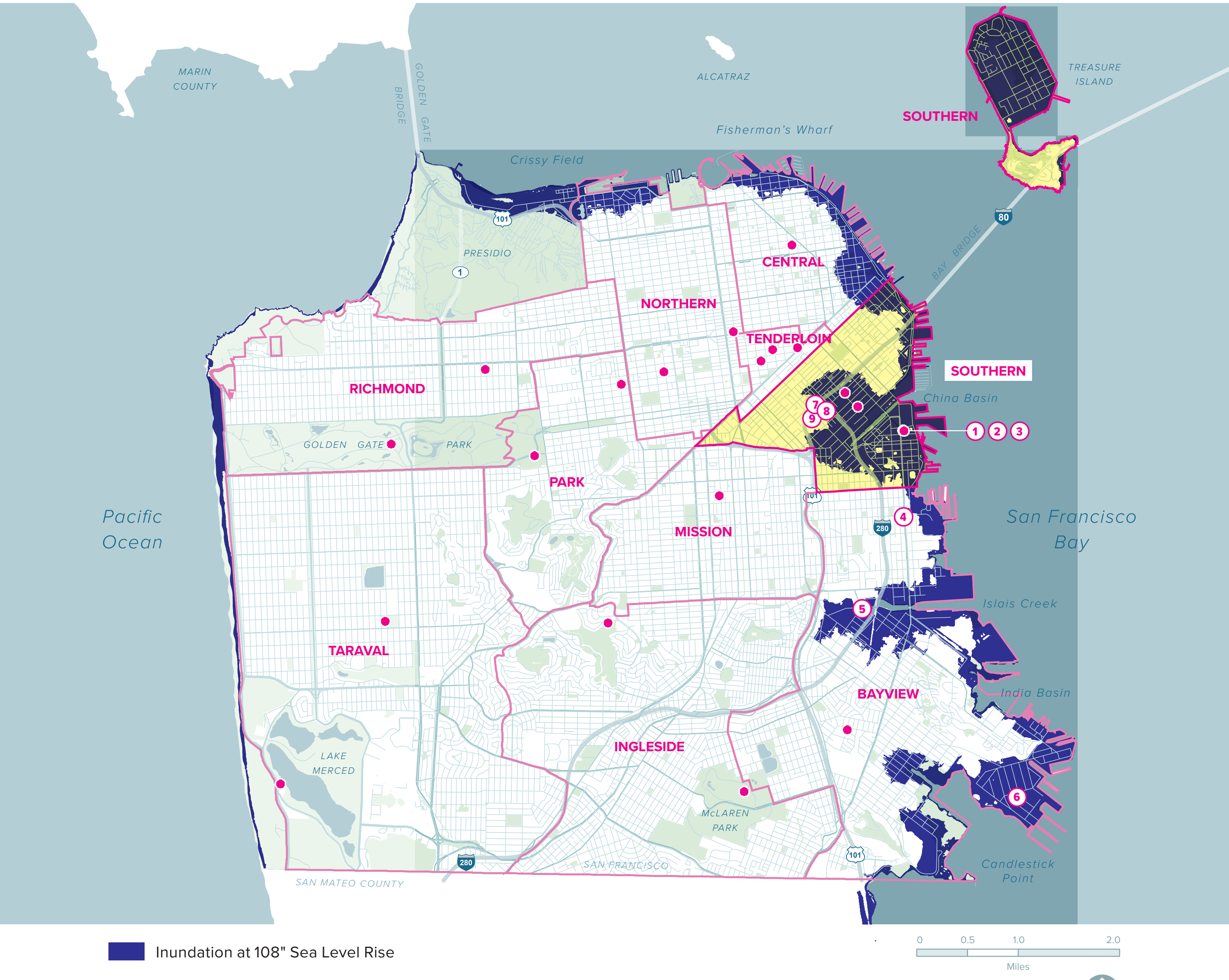
Society and Equity: The neighborhoods in the SLR Vulnerability Zone, many of which include vulnerable populations, could be left without functioning firefighting infrastructure.

Economy: The cost of infrastructure repairs, including fire damage to private systems, could be extensive.

Environment: If a fire spreads because of containment issues due to lack of firefighting water supplies to extinguish it, it could lead to loss of life, air quality issues, and contaminated water runoff into the Bay.

Governance: Multi-agency cooperation, public-private partnerships, and coordinated local and regional action will be necessary to improve the resilience of San Francisco's Emergency Firefighting Water System. The fireboats and the fireboat manifold connections currently provide the most resilient to SLR back-up firefighting water supply.

Figure 9.12 Law Enforcement Facilities in the SLR Vulnerability Zone



Inundation at 108" Sea Level Rise

Law Enforcement Facility

Police District Boundary

1. Public Safety Building
2. Police Headquarters
3. Southern District Station
4. Old Potrero Station
5. Traffic Company and Forensic Services Division
6. Additional Forensic Services
7. County Jail
8. Hall of Justice
9. Public Defenders Office

9.3 SAN FRANCISCO LAW ENFORCEMENT

The Police Department and the San Francisco Sheriff's Department serve an estimated population of 1.5 million, including the daytime-commuter population, tourists, and visitors. San Francisco maintains the 11th largest police department in the United States. The Police Department has 10 districts and respective stations, with two police stations located in the SLR Vulnerability Zone (see Figure 9.12). The Forensic Service/Traffic Company and the Crime Laboratory at Hunters Point Shipyard Building 606 are also located in the SLR Vulnerability Zone.

9.3.1 Potentially Vulnerable Assets

The following facilities are owned and maintained by the Police Department and the Sheriff's Department.

9.3.1.1 Public Safety Building

The Public Safety Campus (opened in April 2015) is in the Mission Bay neighborhood between 3rd Street, between Mission Rock and China Basin streets (Photo 9.11). The building has a seismically advanced structure to maintain is capabilities during an earthquake event, and the latest in law enforcement technology and amenities. The Public Safety Building also houses the new Fire Station 4 (see Section 8.1.1.2).

9.3.1.2 Police Headquarters

The Police Department's Headquarters moved into the new Public Safety in 2015. The office houses approximately 430 department personnel, and this facility enables the Police Department to coordinate public safety services during major events and/or critical incidents promptly and properly.

9.3.1.3 Southern District Station

The Police Department's Southern District Station moved into the new Public Safety Building in 2015. The Southern District includes the SOMA neighborhood, from the Ferry Building and extending south from Mission Street to Mariposa Street and east to the Bay (see Figure 9.12). Originally an industrial area, in recent years the Southern District has been the center of residential loft development, a nightlife destination, and the home of the San Francisco Giants at Oracle Park.

Photo 9.11 Public Safety Building / Southern District Police Staion. HOK

9.3.1.4 Old Potrero Station

The Police Department's Old Potrero Station is located on the corner of 3rd Street and 20th Street and is adjacent to but outside of the SLR Vulnerability Zone and the H++ zone. The Old Potrero police station was originally called the Southeast station and is situated in the Dogpatch and remains one of the few historic buildings in the Potrero Hill neighborhood located in the northern portion of District 10, The building is in close proximity to District 9 and District 6 and is served by the Bayview Police station. The parcel is approximately 12,000 square feet, hosting a 9,000 square foot structure that was constructed in 1915. The building consists of a two-story portion on the northern wing and a single-story on the southern wing.

The 1915 building housed the Potrero Police station (now called Bayview police station) until a modern Bayview police station was constructed in 1995. A fire in 2012 rendered the Old Potrero Police station unusable. In 2016, the Dogpatch neighborhood and outlying community requested the building to be revitalized, as the surrounding community experienced an influx of new residents and businesses. The surrounding community and buildings consist of commercial space, high density residential, mixed-use residential, and access to public transportation infrastructure.

The Old Potrero police station is expected to house the Police Department Community Engagement Division (CED) as the primary use of the building. The intent of the building is to include a space for many of the department's community discussions and events. It will also provide a community facility that will be utilized for meetings and events that do not include the police department.

The police department plans to include the Muni Enforcement Team due to the close proximity to the transit system. The department recognizes that with the ongoing development in the area (e.g. Chase Center, new housing, commercial buildings, and open space), the area will be experiencing an influx in commuters which will demand a greater transit police presence.

9.3.1.5 Traffic Company and Forensic Services Division

The Traffic Company and Forensic Services Division are located at 1995 Evans Avenue in the Hunters Point – Bayview Neighborhood. These facilities were recently relocated from a seismically deficient structure at 850 Bryant Street. Both the Police Department's Traffic Company (i.e., motorcycle police) and the Forensic Services (i.e., crime laboratory) play major roles in earthquakes and disasters, as well as providing public safety services on a daily basis. When a disaster strikes, traffic emergency responders and investigative forensic personnel must be housed in seismically safe structures, professional work environment, with the facilities necessary for a citywide response. These facilities are where emergency response efforts are assembled, organized, and deployed.

9.3.1.6 Additional Forensic Services

The Police Department operates a second crime laboratory at Hunters Point Shipyard in Building 606. Approximately 41 personnel were stationed at this location; however, there are plans to co-locate the two crime laboratories at 1995 Evans Avenue and demolish the existing structure to make way for new residential development (see Chapter 13, *A Changing Shoreline*).

9.3.1.7 County Jail

The Sheriff's Department is organized into divisions and units to efficiently provide a variety of services. The Custody Division is the Sheriff's Department's largest division. It is charged with the operation of six County Jails, the Hospital Ward, the Classification Unit, and the various Jail Programs. The Custody Division strives to maintain a safe and secure jail system and to facilitate an environment in which the various educational and rehabilitation programs can accomplish their mission. These in-custody programs offer a variety of educational, vocational, substance abuse treatment, and violence intervention classes. Jail programs help offenders prepare for re-entry into the community and assist in transitioning sentenced individuals to a community-based program setting.[5]

The County Jail located at 425 7th Street in the SOMA neighborhood is just outside of the SLR Vulnerability Zone and within the H++ zone (see Chapter 2). This facility includes County Jail 1, County Jail 2, and the Classification Unit. County Jail 1 is the Intake and Release Center and is the facility where all persons are booked into and released from the San Francisco County Jail system. Inmates are not housed

5 http://www.sfsheriff.com/about.html. Accessed August 2018.

at County Jail 1. They are only at County Jail 1 for the period of time required to complete the booking and release processes.

County Jail 2 is a direct-supervision facility that uses pod architecture for inmate housing areas. This design plan offers deputized staff better visual and audio monitoring of the inmate population. The rated capacity for this jail is 392 inmates. Although County Jail 2 holds both men and women, it is the only jail where women are housed. This jail is used to confine both sentenced and pre-sentenced inmates. County Jail 2 has its own infirmary in addition to a dental office and medical observation pod that provides specialized medical and psychiatric care to those with special needs (see Photo 9.12). Medical care is provided 24 hours a day, seven days a week.

The Classification Unit is also located at this facility. The Deputy Sheriffs assigned to the Classification Unit determine the safest and most appropriate housing for each inmate that will be remaining in the custody of the Sheriff.

Photo 9.12 San Francisco County Jail at 425 Seventh Street.

County Jail 4 is located at 850 Bryant Street and is a traditional linear jail facility located on the 7th floor of the Hall of Justice. This jail is the maximum-security facility of the San Francisco County Jail system. The rated capacity for this jail is 402 inmates and it houses both sentenced and pre-sentenced inmates.. This jail offers inmate programs such as parenting, independent study, alcoholics anonymous, and narcotics anonymous. Parenting skills classes and inmate-child visitation is also offered to mend and heal broken family relationships. County Jail 4 has an industrial size kitchen that feeds about 850 inmates three meals a day. This jail has a full-scale laundry operation for providing clean clothing and linens to the inmates. This jail has its own infirmary and provides medical care to the inmate population 24 hours a day, seven days a week.

9.3.1.8 Hall of Justice

The Hall of Justice Building at 850 Bryant Street houses the Criminal Court, Behavioral Health Court, and Traffic Court of the Superior Court of California, County of San Francisco, as well as multiple supporting services for the Superior Court, including Office of Court Reporting, the Interpreter Division, and jury services.

The Hall of Justice also houses County Jail 4, and serves as the base of operations and headquarters for the San Francisco Sheriff's Department. The San Francisco Police Department's motorcycle traffic division is also located in the Hall of Justice, and the Hall of Justice parking garage houses most of the San Francisco Police Department vehicles.

9.3.1.9 Public Defenders Office

The San Francisco Public Defender's Office at 555 7th Street provides legal representation for people who are charged with a crime and unable to afford an attorney. The office provides legal representation to over 25,000 people charged with crimes each year and employs over 100 attorneys and 60 staff members. Courts within its jurisdiction include the San Francisco Superior Court, the California Court of Appeal for the First District, and the California Supreme Court.

9.3.2 Exposure Assessment

The exposure of each police station and department associated facilities was evaluated relative to the 10 SLR scenarios (see Chapter 2). The percentage of each station that could be inundated under each scenario was calculated and is presented in Table 9.7.

Table 9.7 Law Enforcement Facility Exposure with Sea Level Rise

Name	Exposure under Each Scenario (Y/N)									
	1	2	3	4	5	6	7	8	9	10
Police Headquarters and Public Safety Building	-	-	-	Y	Y	Y	Y	Y	Y	Y
Southern District Station	-	-	-	Y	Y	Y	Y	Y	Y	Y
Forensic Service/Traffic Company	-	-	-	-	-	Y	Y	Y	Y	Y
Additional Forensic Services	-	-	-	Y	Y	Y	Y	Y	Y	Y
County Jail 1	-	-	-	-	-	-	-	-	-	Y *
County Jail 2	-	-	-	-	-	-	-	-	-	Y *
County Jail 4	-	-	-	-	-	-	-	Y	Y	Y
Hall of Justice	-	-	-	-	-	-	-	Y	Y	Y
Public Defenders Office	-	-	-	-	-	-	Y	Y	Y	Y

* Inundated under H++ Scenario.

9.3.3 Consequences

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: Law enforcement facilities in the SLR Vulnerability Zone are vulnerable to flooding because the facilities generally have at-grade openings and were not built to withstand flooding. In addition, emergency response services rely on roads that could be flooded and power supplies that could be disrupted. Ensuring that emergency and disaster response services are not interrupted will require actions to improve the individual facilities to increase flood resilience, and coordination across the police stations to provide backup or alternates. Coordination will also be required with City, county, and state transportation agencies to ensure road access and utility services are maintained.

Society and Equity: Law enforcement personnel respond to large-scale disasters and smaller emergencies in the community, protecting public safety and maintaining a safe environment for all residents during large- and small-scale incidents and events. These services benefit residents, commuters, tourists, and those who work in the area. Incident response could be impacted in flooded areas, resulting in delays in response time and dangers to public health and safety.

Economy: By protecting the local community, law enforcement provide value to the local economy. If incident response is delayed or impaired due to flooding, recovery costs could increase, and local communities and the region could suffer long-term economic consequences.

Environment: Law enforcement personnel play a critical role in protecting public safety during emergencies, including oil spills and other environmental contamination events. Emergency responders provide a critical function in helping protect the environment and human health during these events.

Governance: If the County Jail is flooded, capacity and services at the remaining facilities would be compromised. Coordination with Sheriff Departments outside of San Francisco may be required to maintain intake and release services, and to house female inmates (i.e., no other jails in San Francisco currently house women).

9.4 OTHER PUBLIC SAFETY FACILITIES

9.4.1 Potentially Vulnerable Assets

The following assets are also important to public safety, health, and wellbeing and are either owned, maintained, or supported by the City. The facilities are located either wholly or partially within the SLR Vulnerability Zone.

9.4.1.1 Southeast Health Center

Southeast Health Center at 2401 Keith Street is a full-service health clinic that provides affordable, comprehensive, and quality care to people of all ages (see Photo 9.14). Located in the Bayview Hunters Point neighborhood since 1979, the center provides care for common illnesses, high blood pressure, and sexually transmitted diseases. The center also provides additional services such as confidential HIV testing and counseling, pregnancy testing, prenatal care, mental care, and vision care. Although additional private medical clinics are available to provide healthcare, the Southeast Health Center is the only City-owned and operated healthcare center located within the SLR Vulnerability Zone. Eleven additional City-owned and operated healthcare centers are located outside of the SLR Vulnerability Zone.

9.4.1.2 Fifth Street Homeless Center

Located at 525 5th Street and bounded by Bryant and Welch Streets, the Saint Vincent de Paul Society Homeless Shelter is San Francisco's largest and most extensive homeless facility (see Photo 9.15). It is also the largest homeless shelter in Northern California, offering a wide range of services and assistance programs aimed to improve the basic quality of life for the individuals and families served. Each day, this center shelters, feeds, and supports over 340 homeless men and women, in addition to providing drop-in care to another 70 people struggling to find adequate food or shelter throughout the City.[6]

9.4.1.3 Waste Management (i.e., Recology)

Waste management in San Francisco is not managed directly by the City; however, it is considered an essential City function that is an important part of public health and safety and, therefore, is included in this Assessment. In San Francisco, waste management services are provided by Recology. Recology maintains two major waste management facilities in the SLR Vulnerability Zone.

Recology Golden Gate at 900 Seventh Street in San Francisco is located at the head of the Mission Creek inlet. Recology Golden Gate offers compost, recycling, and landfill collection and disposal services to residential and commercial customers in the Financial District, SOMA, the Marina, and North Beach neighborhoods. The facility includes offices and a large parking area for collection trucks.

Recology Recycle Central at Pier 96 is a materials recovery facility that extracts recyclables from the waste stream. This site also hosts a recycling buy-back center. Pier 96 is a low-lying area built on fill material and is vulnerable to near-term inundation from SLR.

6 https://svdp-sf.org/what-we-do/msc-shelter/. Accessed August 2018.

Photo 9.14 Southeast Health Center

Photo 9.15 5th Street Homeless Center, St Vincent de Paul Society, MSC-South

Table 9.8 Other Public Safety Facility Exposure with Sea Level Rise

	Exposure under Each Scenario (Y/N)									
Name	1	2	3	4	5	6	7	8	9	10
Southeast Health Center	-	-	-	-	-	-	-	-	-	Y*
Fifth Street Homeless Center	-	-	-	-	-	Y	Y	Y	Y	Y
Recology Golden Gate	-	-	-	-	-	Y	Y	Y	Y	Y
Recology Recycle Central at Pier 96	-	-	Y	Y	Y	Y	Y	Y	Y	Y

* Inundated under H++ Scenario.

9.4.2 Exposure Assessment

The exposure of the other public safety facilities was evaluated relative to the 10 SLR scenarios (see Chapter 2) and presented in Table 9.8.

9.4.3 Consequences

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: Public safety facilities, including healthcare, homeless shelters, and public services such as waste management, need to ensure continuity of services for the community. Individuals with ongoing medical needs – particularly those in vulnerable communities – are more likely to be at risk in a disaster. The buildup of household waste products, lack of reliable and safe shelter, and the loss of local medical services could impact the health and welfare of vulnerable populations and create a wider public health and safety hazard.

Society and Equity: Healthcare facilities and homeless shelters serve already vulnerable community members who rely on these services for care and quality of life. Disruption of facilities can result in significant hardships for these community members and their families, who may not have access to alternative care and housing that is equivalent, affordable, and in an easily accessible location. Damage to neighborhoods where staff and clients live may also result in access issues and disconnection from healthcare and homeless services. Nearby healthcare and homeless facilities that are located outside the SLR Vulnerability Zone may be further strained.

Disruption of Recology's waste management and recycling services could have a citywide impact on waste collection and recycling efforts, resulting in additional public safety and health hazards from the local buildup of household waste.

Environment: Healthcare facilities often store materials such as medical waste, pharmaceuticals, cleaners, and toxics that can impair water quality if released into the Bay or near-shore habitats. The displacement of the homeless population from homeless shelters to homeless encampments can lead to an increase in public health hazards and waste management issues. The buildup of household waste throughout the City could result in garbage impacting local parks, open space, and sensitive environmental areas, including waterways and the Bay.

Economy: Damage to healthcare, homeless, and waste management facilities can result in financial burdens for building owners and operators, as well as staff that may end up out of work. Specialized equipment and facilities can be extremely costly and difficult to replace if damaged. This can result in lost wages for employees and lost revenues for the facilities.

9.5 CONTAMINATED LANDS

Contaminated lands are sites with substances or materials that pose a health hazard to people and/or the environment. The degree of the hazard generally depends on the potential for the substance(s) to be released, the characteristics of the substance (e.g., toxicity and quantity), and the sensitivity of the people, wildlife, waterways, etc. potentially affected. The release of hazardous substances from a contaminated site generally occurs through four pathways: groundwater migration, surface water flow, soil exposure, and release to the air. These pathways can result in direct exposure to human populations and sensitive ecosystems, as well as contamination of drinking water and food chains.

Contaminated lands are vulnerable to SLR and storm events that could cause flooding or groundwater intrusion. Temporary or permanent surface flooding, erosive tidal or wave energy, and elevated groundwater levels could disturb the contaminated soils. This could cause the release of hazardous substances with potentially significant consequences on public health, the environment, and the local economy. Known contaminated sites are often remediated in place due to the technical challenges and environmental risks of hazardous substance removal and disposal.

The extent to which contaminated lands are cleaned up depends on the site's current land use designation or on its intended reuse. Sites intended for heavy industrial uses have less stringent cleanup standards than those intended for light industrial or commercial uses. In addition, cleanup standards vary depending on the location of the site relative to the Bay, with dry upland sites having less stringent requirements than wet (e.g., aquatic) locations.

Depending on the cost of remediation and the level of risk posed to public health and the environment, some contamination can be allowed to remain onsite. In these cases, there are often restrictions placed on the future use of the site. Long-term monitoring, maintenance plans, and site reviews are required when some contamination remains in place. Additionally, these sites are generally subject to deed restrictions, covenants, and administrative, institutional, or engineering controls.

Along the San Francisco shoreline, some hazardous sites have been remediated through the removal of the top layer of heavily contaminated soils, and the placement of clean topsoil and a cap to minimize soil disturbance of remaining contamination (see Figure 9.13).

While there have been many advances in the field of remediation, most cleanup practices have not considered the potential for climate change, such as SLR and changing groundwater conditions. While remediation of contaminated lands offers opportunities for economic growth, redevelopment, and the creation of new parks and open space, the cleanup of contaminated lands must consider future SLR and groundwater conditions to ensure the safety of the public and environment.

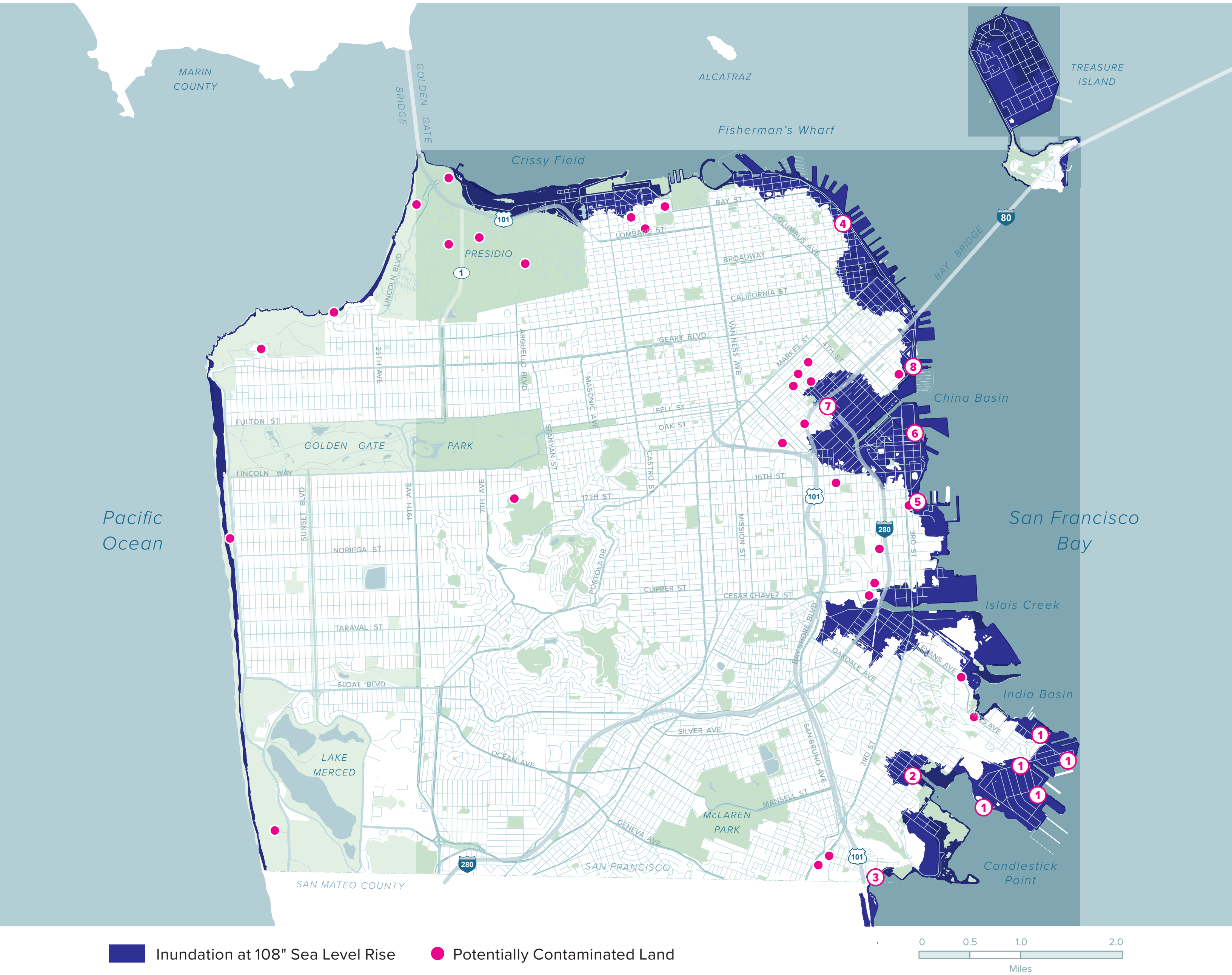
9.5.1 Potentially Vulnerable Locations

The California Department of Toxic Substances Control (DTSC) tracks the status of known, potentially contaminated sites, including cleanup efforts, permitting, enforcement, and investigation efforts at hazardous waste facilities and sites with known contamination or sites where further investigation is required. The potentially contaminated lands in San Francisco include: Federal Superfunds, State Response, Voluntary Cleanup (by the responsible party), Evaluation (sites that are at a pre-cleanup and investigation stage), Military Evaluation, Tiered Permit Facilities, and sites where Corrective Action is required.

There are 51 known potentially contaminated land sites in San Francisco that are currently tracked by DTSC, 11 of which are located in the SLR Vulnerability Zone. Four of the known locations are associated with contamination in the Hunters Point Naval Shipyard. This section presents the information contained with DTSC's EnviroStor tracking database.[7] For each site, several attributes were reviewed, including site type, past uses, potential media affected, regulatory agencies involved, and the status of the site.

7 https://www.envirostor.dtsc.ca.gov/public/.

Figure 9.13 Potentially Contaminated Lands within the SLR Vulnerability Zone



Inundation at 108" Sea Level Rise

Potentially Contaminated Land

1. Hunters Point Naval Shipyard
2. Mobile Debris Box Service
3. Super Excavators
4. Naval Industrial Reserve Plant
5. Pier 70, Port of San Francisco
6. H & H Ship Service Company
7. 820 Bryant Street
8. Site K (Seawall Lot 333)

9.5.1.1 Hunters Point Naval Shipyard

The Hunters Point Naval Shipyard has been identified as a federal superfund site (Photo 9.16). The former Hunters Point Naval Shipyard is located in the Bayview South neighborhood on a peninsula that extends into the San Francisco Bay. The facility consists of approximately 965 acres of land (with approximately 443 acres of submerged land). The shipyard was divided into multiple parcels to help expedite the environmental cleanup efforts and to facilitate the timely transfer of the property to the City. In December 2004, the Navy transferred the first 75-acre parcel (known as Parcel A) to the City for residential and commercial development and community parks. The remainder of the shipyard will be transferred to the City as the environmental cleanup efforts are complete.

Previous land uses that have led to potential contamination include:

- Shipyard activities including port operations, dry dock, ship building and repair including sand blasting, metal plating, paint stripping, and painting operations
- Fuel terminal, vehicle storage, refueling, fuel hydrant pumping stations, oil/water separators, and a degreasing facility
- Naval Radiological Defense Laboratory (i.e., radioactive laboratory)
- Machine Shop activities, including metal plating and finishing, sand blasting, paint stripping and painting, and onsite landfill disposal of waste products

See also Chapter 13, *A Changing Shoreline*

9.5.1.2 Mobile Debris Box Service

The 0.5-acre site is located at 1301 Yosemite Avenue in the Bayview South/Hunters Point neighborhood on reclaimed land that was from the Bay between 1943 and 1955 (i.e., bayfill was used to fill the Bay and create upland space to expand the City shoreline). Operations at the site included a lumber yard (1954-1986), storage, and debris box operations. A waste pile was created that contains friable asbestos at levels above hazardous waste criteria. The City is currently suing the property owner and tenants to address the waste located on the site. As of July 2009, this site is listed in EnviroStor as inactive and in need of further evaluation to assess the need for any additional corrective actions.

Photo 9.16 **Hunters Point Naval Shipyard.** Todd Lappin (CC BY-NC 2.0)

9.5.1.3 Super Excavators

This less than 1-acre site is located at Harney Way and Alana Way just south of the Candlestick Point State Recreation Area, California's first urban state park, which is currently undergoing an extensive renovation, including wetland rehabilitation. EnviroStor classifies this location as a tiered-permit site.

9.5.1.4 Naval Industrial Reserve Plant

The Naval Industrial Reserve Plant in San Francisco was established in 1942. The General Engineering and Dry Dock Company formerly owned the 1-acre site. Facilities on the site that may contain hazardous materials include oil tanks, steam plants, painting sheds, and a boiler house. In 1959, the 0.53-acre site was turned over to the General Services Administration. The current owner of the site is Blue Jeans Equities West, and the site is currently part of the Levi Strauss Corporate Headquarters complex known as Levi's Plaza. The site is currently classified as a formally used defense site (FUDS).

9.5.1.5 Pier 70, Port of San Francisco

Most of Pier 70 is listed on the National Register of Historic Places as the Union Iron Works Historic District and is home to the headquarters for both Union Iron Works and Bethlehem Steel. Pier 70 has been the home of shipbuilding and repair operations from the time of the Spanish American War in 1898 through today, supporting multiple war efforts. The

Historic District contains many contributing resources, including buildings, piers, slips, cranes, segments of a railroad network, and landscape elements. Most of the buildings are of an industrial architectural style and historic use, and made of unreinforced brick masonry, concrete, and steel framing, with corrugated iron or steel cladding.

Pier 70, and much of San Francisco's eastern waterfront, is comprised largely of fill that was historically placed in the Bay to construct new land. These "fill soils" contain chemical constituents that were present in the debris, soil, and native serpentine rock that comprise the fill. In some areas, the soil was also impacted by the former industrial uses and legacy shipbuilding activities. The constituents found in the Pier 70 soils include naturally occurring and introduced metals (lead, arsenic, cadmium), petroleum hydrocarbons, polychlorinated biphenyls (PCBs), and asbestos. Some contaminants may be present at concentrations above environmental screening levels. Environmental investigations of Pier 70 have found that the contaminants present are associated with the soil and are not soluble or volatile. The risk of exposure to hazardous materials is only associated with direct exposure to contaminated soil. Historic buildings at Pier 70 may also contain hazardous building materials such as lead-based paint and asbestos.

The soil within the Pier 70 area is subject to a "Risk Management Plan" that functions as the remedial action plan for the site and ensures that contaminants in the existing soil do not pose a risk to human health or the environment. The remedial action includes installation of durable cover over contaminated soil areas to prevent exposure to, or dispersion of, the soil by wind, water, or construction activities. The required durable cover also mitigates the potential for soil mobilization during a flood event. Abatement of hazardous building materials is accomplished as buildings are rehabilitated and renovated for reuse. Pier 70 is in the process of being redeveloped and required environmental cleanup and decontamination are part of the agreements the Port has created with developers and in conjunction with the building of nearby Crane Cove Park.

Work to rehabilitate the iconic historic buildings is underway and being spearheaded by Orton Development, Inc., the Port's tenant and development partner. With General Obligation Bond funds and other funding, the Port is beginning work on site preparation for Crane Cove Park, a 9-acre park on the northwest corner of the site. The Port has entered into an Exclusive Negotiation Agreement (ENA) with Forest City Development to develop a 25-acre mixed-use development at Pier 70. See Chapter 13, *A Changing Shoreline* for details on proposed site redevelopment.

9.5.1.6 H & H Ship Service Company

The Port of San Francisco currently owns this 8.6-acre site located near Pier 50 in Seawall Lot 337-MB1. H&H Ship Service Company formerly treated waste sludge and wastewater in various steel aboveground storage tanks at this location. The site was previously a permitted facility for the treatment and storage of hazardous wastes. Soil and groundwater were found to be contaminated with arsenic, polychlorinated biphenyls, and polynuclear aromatic hydrocarbons. The facility was cleaned up and closed, with a Land Use Covenant that restricted future usage of the site to commercial/industrial uses in the terms of closure. The City is pursuing redevelopment plans for this location to transform it into a mixed-use residential and commercial area with open park areas. The Port has submitted a request for variance to DTSC in 2018 to allow residential redevelopment.

9.5.1.7 820 Bryant Street

Site K, owned by the San Francisco Redevelopment Agency, occupies approximately 1.4 acres located at 1 through 59 1/2 Townsend Street in San Francisco. The site was reclaimed from the Bay by 1913 with soil and construction debris from the 1906 earthquake. Previous site occupants included a paint warehouse, ship service company, and a forklift service company that left contaminants in the soil. The land use restriction includes prohibiting disturbing the remedy and monitoring systems without approval. Additional excavation of contaminated soils is also prohibited. Currently, the building and sidewalks act as a cap over the contaminated soil. A site inspection was last performed in February 2018.

9.5.1.8 Site K (Seawall Lot 333)

Site K, owned by the San Francisco Redevelopment Agency, occupies approximately 1.4 acres located at 1 through 59 1/2 Townsend Street in San Francisco. The site was reclaimed from the Bay by 1913 with soil and construction debris from the 1906 earthquake.

Previous site occupants included a paint warehouse, ship service company, and a forklift service company that left contaminants in the soil. The land use restriction includes prohibiting disturbing the remedy and monitoring systems without approval. Additional excavation of contaminated soils is also prohibited. Currently, the building and sidewalks act as a cap over the contaminated soil. A site inspection was last performed in February 2018.

9.5.2 Exposure Assessment

The exposure of the contaminated lands was evaluated relative to the 10 SLR scenarios (Table 9.9). The EnviroStor database notes an approximate point location and size of each potentially contaminated site but does include a detailed delineation of each site's geographic boundaries. Therefore, this Assessment may overestimate the potential area of each site that is located within the SLR Vulnerability Zone.

9.5.3 Consequences

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: Flooding of contaminated sites – including sites that have been cleaned and closed with some remaining contamination – by SLR, coastal storm surge, or rising groundwater levels could result in the release and mobilization of hazardous substances and could cause significant impacts to public health and the environment.

Society and Equity: The flooding or other disruption of contaminated sites can expose communities to substances that are harmful to human health and safety.

Environment: The flooding or other disruption of contaminated sites can have significant environmental impacts. The release of persistent and mobile hazardous materials can have long-lasting and far-reaching consequences for wildlife and habitats and can affect water quality.

Economy: Flooding of contaminated sites can strain local emergency resources and result in high cleanup and recovery costs. It may render surrounding land unusable and hinder further development, affecting real estate values.

Governance: Redevelopment of contaminated lands along the San Francisco shoreline does consider future flood risks associated with SLR. However, rising groundwater levels may pose an additional hazard. This threat is not currently well understood. For sites that have been cleaned up and closed, long-term monitoring plans should consider changing environmental and climate conditions.

Table 9.9 Potentially Contaminated Lands Exposed under Each Scenario

Name	Acres	Exposure under Each Scenario (Y/N)									
		1	2	3	4	5	6	7	8	9	10
Hunters Point Naval Shipyard	965	-	-	-	Y	Y	Y	Y	Y	Y	Y
Mobile Debris Box Service	0.5	-	-	Y	Y	Y	Y	Y	Y	Y	Y
Super Excavators	< 1	-	-	-	-	-	-	-	-	-	Y
Naval Industrial Reserve Plant	1	-	-	-	-	-	Y	Y	Y	Y	Y
Pier 70	30	-	-	-	-	-	Y	Y	Y	Y	Y
H&H Ship Service Company	8.6	-	-	-	-	-	Y	Y	Y	Y	Y
820 Bryant Street	1	-	-	-	-	-	-	-	Y	Y	Y
Site K (Seawall Lot 333)	1.4	-	-	-	-	-	Y	Y	Y	Y	Y

* Inundated under H++ Scenario.

9.6 HAZARDOUS MATERIAL SITES

There are a variety of industries that handle potentially hazardous substances as a part of their regular business activities. The U.S. Environmental Protection Agency (EPA) requires that all such facilities report their activities and follow proper procedures regarding waste handling, management, and disposal as well as pollution prevention activities. This section provides information on the industries that handle potential hazardous materials within the City of San Francisco and within the SLR Vulnerability Zone (see Figure 9.14).

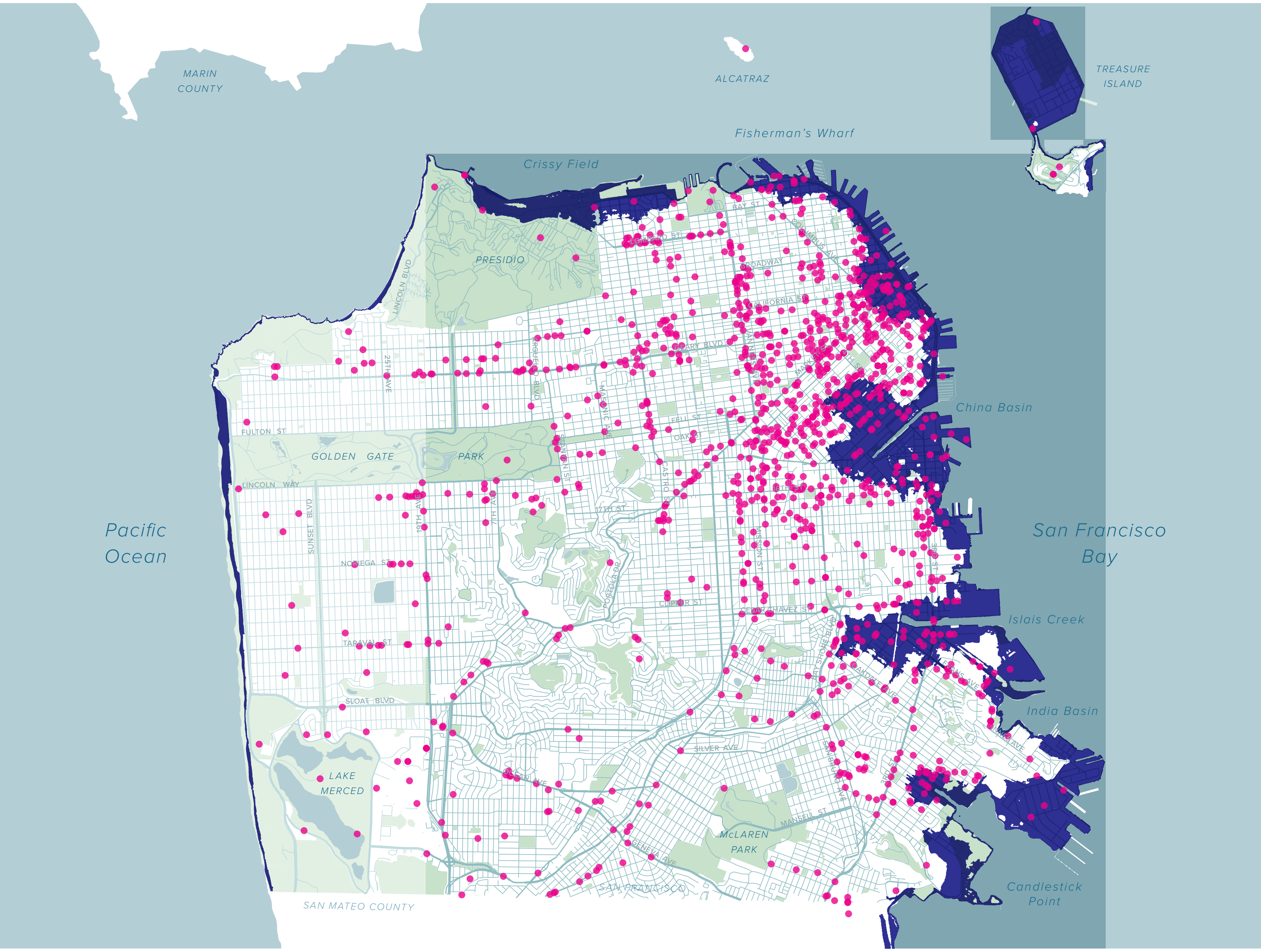
9.6.1 Potentially Vulnerable Locations

EPA maintains a database of all industries that handle potentially hazardous materials, separated by industry and facility type. A detailed evaluation of each facility was not completed as part of this Assessment. However, the number of each type of industry within the SLR Vulnerability Zone was evaluated. Table 9.10 presents the industries that are currently regulated by EPA, along with a brief definition of the breadth of services included under each industry.

Table 9.10 Hazardous Material Industries and Services

Industry	Definition / Type of Services
Buildings	Parking lots, garages, housing construction sites, and commercial buildings
Construction	Construction services and development locations
Culture	Motion picture and video production, museums, churches, and other large events venues
Education	Elementary- to university-level schools, including the many Academy of Art University buildings and locations
Finance	Large banks and finance corporations
Government	Federal and state buildings, municipal buildings and transportation operations, wastewater treatment plants, municipal water supply, fire stations, and military sites
Healthcare	Hospitals, medical centers, pharmacies, and general freight and marine services
Infrastructure	Highway, street, and bridge infrastructure sites
Manufacturing	Chemical, clothing, construction, electronics, food, leather goods, machinery equipment, metal, paint, petroleum, and pharmaceutical products wholesalers or manufacturers
No Industry Information	Hazardous material sites without industry/use information
Oil and Gas	Gas stations
Professional and Technical	Animal control center, antique restoration sites, auto repair and car dealerships, courier and postal services, pest control, paint and photography services and supply, and printing and graphic design services
Dry Cleaning/Laundry	Dry cleaning and laundry facilities
Real Estate Rental/ Leasing	Hotels, general warehouses, and property management facilities
Retail	Supermarkets, department stores, cosmetic and perfume (salon) locations and auto parts suppliers
Scientific R&D Services	Medical laboratories
Telecom	Telecom providers
Transport	Taxi cabs, van and tour buses, trucking and hauling services, and transportation logistics
Utility	Electric power distribution and control and natural gas distribution

Figure 9.14 Hazardous Material Sites



Inundation at 108" Sea Level Rise
Hazardous Material Sites

Table 9.11 Hazardous Material Sites Exposed under Each Scenario

Industry	Total Facilities Citywide	Exposure under Each Scenario (Number of Facilities)									
			2	3	4	5	6	7	8	9	10
Buildings	27	-	-	-	-	1	1	3	3	3	5
Construction	23	-	-	-	2	2	2	3	3	4	5
Culture	11	-	-	-	1	1	1	3	3	3	3
Education	56	-	-	-	-	2	2	4	5	6	7
Finance	4	-	-	-	-	-	-	-	-	-	1
Government	62	-	-	-	1	3	10	10	10	12	14
Healthcare	132	-	-	-	-	-	-	15	17	19	20
Infrastructure	5	-	-	-	-	-	-	2	2	2	3
Manufacturing	157	1	1	2	5	7	7	34	39	44	48
No Industry Information	8	-	-	-	-	-	-	1	1	2	3
Oil and Gas	83	-	-	-	-	1	1	4	5	8	10
Professional and Technical	338	-	-	-	-	3	3	22	27	32	38
Dry Cleaning/Laundry	96	-	-	-	-	-	-	2	2	2	2
Real Estate Rental/Leasing	57	-	-	-	-	-	-	8	8	8	11
Retail	29	-	-	-	-	-	-	2	2	2	2
Scientific R&D Services	12	-	-	-	-	-	-	2	2	2	3
Telecom	44	-	-	-	-	-	-	2	2	2	2
Transport	82	-	-	-	2	7	7	11	13	14	19
Utility	18	-	-	-	-	-	-	2	2	5	5

9.6.2 Exposure Assessment

The exposure of the hazardous material sites was evaluated relative to the 10 SLR scenarios (see Chapter 2). The total number of each facility type exposed under each scenario is presented in Table 9.11).

9.6.3 Consequences

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below.

KEY ISSUE: Flooding of facilities or locations with hazardous substances stored onsite could result in the release and mobilization of hazardous substances and could cause significant impacts to public health and the environment. Facilities with hazardous materials stored at or below grade, or improperly contained, are the most vulnerable. Facilities without a plan to safely shut down operations in advance of a storm event are also vulnerable. Managers and owners of sites not currently in the floodplain may not be aware of the current or future flood risks; therefore, these locations may not be operated with sufficient plans in place to reduce the impacts of flooding, should they occur.

Society and Equity: The flooding or other disruption of hazardous material sites can expose communities to substances that are harmful to human health and safety.

Environment: The flooding or other disruption of hazardous material sites can have significant environmental impacts. The release of persistent and mobile hazardous materials can have long-lasting and far-reaching consequences on wildlife and habitats and can affect water quality.

Economy: Facilities that generate, treat, or transport hazardous materials are usually job sites, and their disruption or closure can result in lost wages and larger-scale economic impacts. Additionally, flooding of hazardous materials sites can strain local emergency resources and can result in high cleanup and recovery costs.

Governance: Current emergency planning and response for many hazardous material sites do not require consideration of future flood risk. The number and locations of hazardous material sites, and the potential extent of flooding that could occur during a large storm may stress available resources and require a high degree of coordination and contingency planning.

San Francisco Bay Trail at Heron's Head Park. Photo by Ed Brownson (CC BY-NC-ND 2.0)

CHAPTER 10

OPEN SPACE

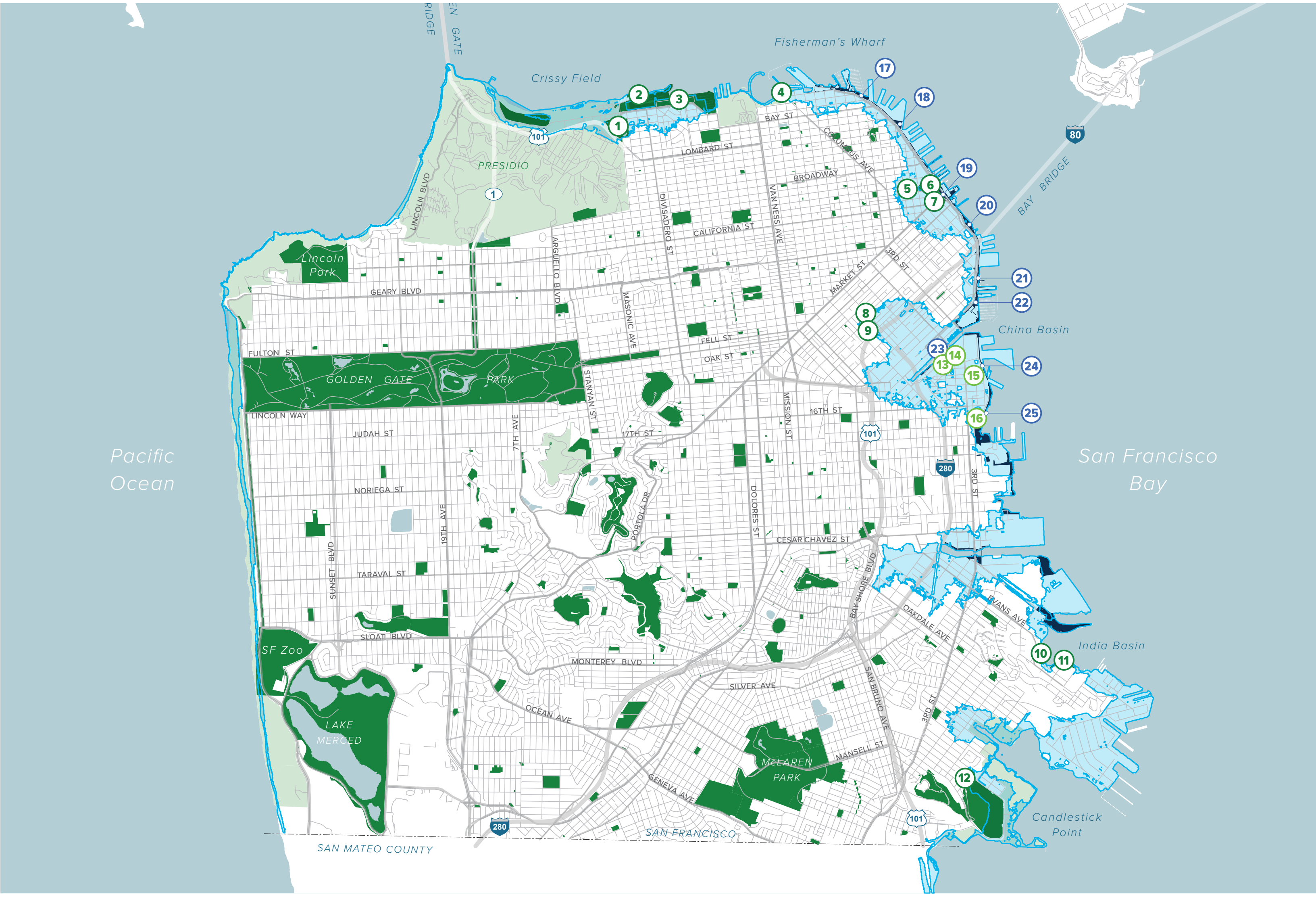
Open spaces preserve the environment for the wellbeing of everyone in our diverse community, and provide community facilities and resources with a variety of programming. The Recreation and Parks Department (RPD) also has initiatives that focus and strengthen the connections to parks and youth and senior programs in disadvantaged communities to ensure park users in every neighborhood across the City have access to clean, safe, and fun parks and programs. These include urban trails, dog play areas, golf courses, marinas, urban agriculture, and natural areas.

Some of the larger parks in San Francisco are owned and managed by other agencies such as the National Park Service (e.g., Presidio, Baker Beach, Ocean Beach, Crissy Field, and San Francisco Maritime National Historical Park and Aquatic Park Historic District), California State Parks (e.g., Candlestick State Recreation Area), and the Office of Community and Infrastructure, (e.g., Yerba Buena Gardens and Mission Creek Park).

The City of San Francisco's parks and open space are managed by several agencies, including RPD, the Port of San Francisco, the Office of Community Investment and Infrastructure, State and Federal agencies, and others (Figure 10.1).

This chapter focuses on the parks, playgrounds, marinas, recreation fields, and trails that are managed by the City and County of San Francisco and that have been identified as potentially vulnerable, by being wholly or partially located in the SLR Vulnerability Zone. The following sections describe these assets and how they may be vulnerable to SLR and coastal flooding, as well as provide information on interdependencies and consequences. Port-owned open spaces are discussed in Chapter 11, *Port of San Francisco*.

Figure 10.1 Parks, Playgrounds, and Recreation Areas within the SLR Vulnerability Zone



San Francisco Parks and Open Space

Port of San Francisco Parks and Open Space

State and Federal Parks

Inundation at 108" Sea Level Rise

RECREATION & PARKS

1. Palace of Fine Arts
2. San Francisco Marina Small Craft Harbor
3. Marina Green
4. Dolphin Club/South End Rowing Club
5. Maritime Plaza
6. Sue Bierman Park
7. Embarcadero Plaza
8. Gene Friend Recreation Center
9. Victoria Manalo Draves Park
10. India Basin Shoreline Park
11. India Basin Natural Areas
12. Gilman Playground

OCII

13. Mission Bay Dog Park
14. Mission Bay Kids' Park
15. Mission Bay Commons Park
16. Mission Bay Parks 23 & 24

PORT OF SAN FRANCISCO

17. Public Park (near Pear 39)
18. Pier 27 (Cruise Ship Terminal)
19. Harry Bridges Plaza
20. Rincon Park
21. Brannan Street Wharf
22. South Beach Park
23. Mission Creek Park
24. Pier 52 Boat Launch
25. Agua Vista Park
16. Mission Bay Parks 23 & 24

10.1 PARKS, PLAYGROUNDS, AND RECREATIONAL AREAS

Parks, playgrounds, and recreational areas owned and managed by RPD in the SLR Vulnerability Zone are vulnerable to future SLR and coastal storm surge inundation and flooding. The assets are shown on Figure 10.1 and discussed in the sections below.

10.1.1 Potentially Vulnerable Assets

The assessment follows San Francisco's shoreline beginning on the Bay shoreline at the intersection of San Francisco with the County of San Mateo and continuing north along the Bay shoreline to the Golden Gate Bridge, and then south along the Westside shoreline to the intersection with the County of San Mateo on the open Pacific shoreline. Recreation and open space assets that are owned and managed by the Port are included in Chapter 11, *Port of San Francisco*.

10.1.1.1 Gilman Playground

Gilman Playground is bounded by Gilman Avenue, Griffith Street, Ingerson Avenue, and Giants Drive in the Candlestick Point area of Bayview. The park is approximately 224,000 square feet and includes playfields, picnic areas, a basketball court, a children's play area, a clubhouse, and restrooms (see Photo 10.1). The clubhouse functions as a community recreation center and includes a community room and kitchen. The site is predominately open space and play areas, with the clubhouse and restrooms situated near Ingerson Avenue. A recent renovation of the children's playground was completed in the summer of 2016.

The open space areas have had drainage problems during heavy rains accompanied by high tides. The fields can remain wet and swampy for extended periods after heavy rain events. Inundation with saltwater could damage the vegetation and affect the growing patterns of the lawns if the soils retain the salt for a prolonged period. Onsite irrigation systems could help mitigate saltwater damage.

The Gilman Playground is first impacted by flooding and inundation under Scenario 7, with 12 percent of the site subject to inundation. By Scenario 10,

Photo 10.1 Gilman Playground. SF Rec Park

approximately 50 percent of the park could be subjected to temporary coastal flooding. To date, the clubhouse and other structural assets at the park have not been adversely affected by flooding.

The clubhouse is an at-grade wood-frame building. Floodwaters could enter the building through doors and other entry pathways, resulting in damage. Temporary flood-protection measures such as sand bags could be used to mitigate damage. The building may contain asbestos, which reduces its ability to be upgraded cost effectively to be more flood resilient. However, the presence of asbestos could also result in more significant damage and contamination if the building is flooded.

Temporary flooding would only have a minor impact on the playground and playground equipment, but access to the facility would be limited during a flood event. Most aspects of the park would recover once floodwaters recede; however, repeated flooding could shorten the lifespan of the playground equipment. During permanent inundation, the park would not be able to perform its primary functions.

RPD has other parks and recreation centers within its portfolio that could provide substitute services during a flood event. However, after-school services would be affected. Parents and children that rely on the park for after-school care may either lose access to this service or require temporary bus service to another location for after-school care.

Photo 10.2 **India Basin Shoreline Park.** SF Rec Park

Photo 10.3 **Kayaks near India Basin Shoreline Park.** SF Rec Park

10.1.1.2 India Basin Shoreline Park[1]

India Basin Shoreline Park is an existing 5.6-acre open space located east of Hunters Point Boulevard between Hawes Street to the north and Hudson Avenue to the south. India Basin has one of the few remaining tidal wetlands of the Bay Area and is the only Natural Area[2] within the RPD system that borders the Bay (Photo 10.2). The shoreline areas adjacent to the Bay include tidal salt marsh and upland habitat that provide food and shelter for a variety of shorebirds and foraging habitat for raptors.

The park also has two play structures, a basketball court, landscaping, a portion of the Blue Greenway/Bay Trail with informal access for kayakers, artwork by local artists and students, barbeque grills, seating areas, a water fountain, and educational signage (Photo 10.3). Two buried ship hulls, the Bay City and the Caroline, are located within the tidal coastline of the India Basin Shoreline Park property.

The shoreline is not engineered (it consists of debris, rip rap, and natural tidal marsh) and is exposed to the Bay's wave climate and subject to some wave-driven erosion. Table 10.1 indicates that the India Basin Park area is 14 percent inundated under Scenario 1; however, the areas inundated are largely marsh and mudflat areas along the shoreline that are subject to regular tidal inundation today. The inland park areas are not expected to experience regular tidal inundation until Scenario 4.

The park areas have not been disrupted by extreme weather events or flooding to date. The recreational structures are located at a higher elevation than the shoreline open spaces; therefore, the park is expected to regain functional use after temporary flood waters recede with minimal repair other than cleanup. Permanent inundation of the lower-lying areas would impact some the park's current function, but the play areas would likely remain unaffected and the shoreline areas could retain value for bird watching, wildlife habitat, and other connections with nature.

The India Basin Ideas Competition generated ideas to bring this location and the adjacent post-industrial sites together to create a larger park with a resilient marsh shoreline.[3] The project would include features to enhance the future adaptive capacity and overall resilience of the park. With other sites and assets planned nearby, there is some potential redundancy.

1 Currently, there are two parks at India Basin: India Basin Shoreline Park and India Basin Natural Area. In addition, there is the planned expanded India Basin Open Space, which includes the two parks previously cited plus the area at 900 Innes, with a plan to create a larger 64-acre open space park.

2 India Basin Shoreline Park is a part of RPD's Natural Areas Program, which aims to preserve, restore, and enhance remnant Natural Areas, and to develop and support community-based site stewardship of these areas. It places a high value in supporting habitat for native plants and wildlife; ecosystem functions such as soil and water retention; and socioeconomic values, as well as being outdoor classrooms and living museums protecting natural heritage.

3 http://ibwaterfrontparks.com/#landing

Photo 10.4 SOMA/Gene Friend Recreation Center. James Watkins

Photo 10.5 Victoria Manalo Draves Park. Payton Chung (CC BY 2.0)

10.1.1.3 Gene Friend Recreation Center

The Gene Friend Recreation Center occupies a 1-acre site at the northwest corner of Folsom and 6th Streets in the South of Market area (Photo 10.4). Indoor facilities include a full gymnasium, activity room, weight room, auditorium, badminton and volleyball courts, ping pong, and foosball tables. Outdoor facilities include a basketball court, playground, and open space/lawn area. The facility provides recreational programs and activities for youth and seniors. The facility is also used as a Red Cross emergency evacuation center.

The recreation center is located within the historic Hayes Creek bed, and hydrology and drainage issues could occur as sea levels and the groundwater table rise. The recreation center is not anticipated to be directly inundated until Scenario 10 (Table 10.1). However, the shallow groundwater table is already high and sump pumps are needed in the building to prevent flooding. As sea levels rise, the potential for groundwater flooding will increase.

The building includes mechanical and electrical equipment that is at grade and sensitive to saltwater flooding. The building has at-grade doors and pathways that could allow floodwaters to enter. Sandbags could be used to mitigate flood damage during a temporary flood event. The southernmost structure along 6th Street which houses a multipurpose room, office, and kitchen is most at risk of flooding.
The facility is part of a feasibility study and concept design development program that would rehabilitated or rebuild the recreational center Current draft plans for the new building include two basketball courts inside the new gym on the south end of the new building.

This is the only public recreation center south of Market, and the center serves a large elderly population and provides services for at-risk youth. There are no nearby RPD assets that could provide the same services and accessibility for the users of this facility.

10.1.1.4 Victoria Manalo Draves Park

This recently built 2-acre park, located at Sherman and Folsom Streets, is a new addition to the SOMA neighborhood, adjacent to Bessie Carmichael School (Photo 10.5). The park includes a softball field, basketball court, dual-level playground, picnic area, community garden, and field.

Like the Gene Friend Recreation Center, the park is on the boundary of the SLR Vulnerability Zone and not anticipated to be directly affected by coastal flooding and SLR until Scenario 10 (Table 10.1). The park is located within the South of Market urban area, making it vulnerable to potential flooding if no adaptation measures are implemented along Mission Creek. It is also located within the historic Hayes Creek bed, and hydrology and drainage issues could occur as sea levels and the groundwater table rise.

Most of the park areas could recover after inundation subsides. However, the community garden, and lower-lying grassy areas and park vegetation, may be impacted from rising groundwater and eventual saltwater inundation. The basketball court and lower playground surfaces could degrade after repeated inundation and require replacement sooner than expected. The park would not function as currently intended with permanent inundation.

Other San Francisco parks could provide similar services and amenities if this park is temporarily impacted; however, there are few alternative recreational spaces in the South of Market area.

9.1.1.5 Embarcadero (formerly Justin Herman) Plaza

Embarcadero Plaza is located in San Francisco's Financial District at the eastern end of Market Street across from the Ferry Building (Photo 10.6). Local vendors and weekly farmers markets utilize the plaza spaces, while local commuters and tourists pass through the thoroughfare between the Embarcadero and Market Street. A hardscape plaza with the Vaillancourt Fountain is situated north of Market Street and bocce ball courts are located to the south. The eastern edge of the plaza is landscaped with lawn and palm trees.

The plaza is adjacent to multiple transit lines, including the San Francisco Bay Ferries, BART, MUNI buses, Market Street Railway F-line and E-line, and cable cars, all of which have stops nearby or adjacent to the plaza. The plaza is a popular venue for multiple events, including ice skating during the holidays, sport events, protests, concerts, and other large events.

The plaza is located near the Bay shoreline and could be exposed to temporary periodic flooding in the near term (under Scenario 5, see Table 10.1) along the western, hardscape portions both north and south of Market Street. Although function of this site would be impaired during a flood event, it could return to full use with minimal repair and cleanup after initial flood waters recede. More frequent saltwater exposure could impact plants and other assets that are sensitive to saltwater flooding and could lead to faster deterioration and increase maintenance of the hardscape features. Permanent inundation would make this site and the surrounding infrastructure unusable.

Other open-space plazas in the RPD portfolio provide some redundancy for the recreational facilities; however, the gateway character, prominent civic location, and proximity to transit make the Embarcadero Plaza a unique place in the City landscape.

Photo 10.6 Embarcadero (formerly Justin Herman) Plaza. Dennis Jarvis (CC BY-SA 2.0)

Photo 10.7 Sue Bierman (formerly Ferry) Park. TheTokl (CC BY-SA 3.0 DE)

Photo 10.8 Sue Bierman Park Children's Payground. SF Rec Park

10.1.1.6 Sue Bierman Park

Sue Bierman Park occupies two City blocks, extending from The Embarcadero on the east to Davis Street on the west, between Washington and Clay Streets (Photos 10.7 and 10.8). Drumm Street bisects the park between Washington and Clay Streets. The park occupies 4.4 acres of land that previously served as on- and off-ramps for the elevated Embarcadero Freeway, which was demolished after being damaged by the 1989 Loma Prieta earthquake.

The park includes a children's playground and lawn areas with trees and walking paths throughout the park. SFPUC owns a small building near the park at the northeast corner of Washington and Drumm Street. RPD uses this building and lot for fuel storage, power equipment, and RPD vehicle parking. If the SFPUC building is damaged during a flood event, it would affect the RPD maintenance activities beyond Sue Bierman Park.

Sue Bierman Park is projected to be 16 percent inundated under Scenario 5 (Table 10.1), with the inundation impacts limited to the eastern parcel until Scenario 7. The western park parcel is located at a slightly higher elevation than the eastern parcel. The eastern parcel presently floods during major storm events and it can take 24 to 48 hours for the water to fully drain. The drainage issues could worsen with SLR and rising groundwater levels.

The park is also popular with a non-native flock of parakeets, which like to roost in the equally non-native trees of the park. If the trees are negatively impacted by saltwater flooding and rising groundwater, the well-adapted birds are likely to find alternative suitable habitat in the surrounding urban environment.

There are alternative RPD sites nearby that can provide similar recreation opportunities, offering some redundancy should the park be temporarily flooded.

10.1.1.7 Palace of Fine Arts

Originally constructed in 1915 as part of the Panama-Pacific International Exhibition, the Palace of Fine Arts is situated generally between Marina Boulevard, Baker Street, Bay Street, and Richardson Avenue (Photo 10.9). It consists of a large open-space area with a landscaped park, footpaths, an artificial lagoon, historic Greco-Roman style rotunda/dome and colonnades, warehouse, and theater. The iconic assembly of buildings is one of the most photographed sites in the City and is featured in numerous film and TV productions. It is also used as a wedding location and popular performance venue. The Palace of Fine Arts is listed (2005) on the National Register of Historic Places.

RPD is currently looking for a long term or permanent tenant to move in and seismically retrofit the building, which could include adaptation strategies to address SLR, rising groundwater levels, and localized flooding. As a temporary measure, sandbags can be placed at the doors of the building to prevent indoor

Photo 10.9 **Palace of Fine Arts.** Michael Fraley (CC BY 2.0)

Photo 10.10 **Sharp Park & Golf Course.** SF Rec Park

flooding. The building also has storm drainage issues. The aging combined sewer system in this location has been clogged in the past, resulting in localized flooding in the rear parking lot.

The historic rotunda and colonnades were originally constructed in 1915 of wood and staff, a mixture of wood and a burlap-type fiber. The structure was intended to be demolished after one year. However, the structure was saved from demolition and was repaired and rehabilitated in the 1930s and 1960s, replacing much of the wood and staff structure with concrete. The most recent restoration and seismic retrofit efforts were completed in 2008. The dome of the historic structure is made from plaster and damage caused by flooding could be permanent.

The Palace of Fine Arts is first inundated under Scenario 6, with 75 percent of the grounds and structures impacted by temporary flooding. However, high groundwater levels and drainage issues are present today, and SLR is likely to exacerbate these issues before overland coastal flooding occurs.

10.1.1.8 Sharp Park & Golf Course

Sharp Park is a golf course in Pacifica that is owned and managed by RPD (see Photo 10.10). It is situated between Milagra and Sweeney Ridges, two regionally significant open spaces managed by the Golden Gate National Recreation Area (GGNRA), and is immediately north of Mori Point, another GGNRA-managed open space to which it has trail connections. The park's natural area encompasses diverse and important habitats, including coastal wetlands (Laguna Salada and Horsestable Pond), coastal scrub, forest, and grasslands. It supports populations of federally listed and protected species such as the California red-legged frog, the rare San Francisco garter snake, and the mission blue butterfly. The park is part of RPD's Natural Areas Program. Sharp Park's other features include an 18-hole golf course and a nationally recognized archery range.

RPD is developing plans for public access improvements along the coastal trail at Sharp Park in the City of Pacifica. The improvements are required as part of RPD's Coastal Development permit for the berm that separates the Sharp Park golf course and the beach at Sharp Park. The permit issued by the California Coastal Commission requires the installation of the two overlook areas, two vertical access ways, interpretive signage, and other trail-related amenities.

The coastal wetlands and coastal shrub habitats located near the open Pacific coast are low-lying and have existing hydrologic connections to the ocean. Temporary flooding is not expected to cause any lasting impacts; however, the wetlands' upward migration to keep pace with SLR may be impeded if there is not enough sediment and they may drown. Generally, the area provides some room for the coastal wetlands to migrate upland, but continued migration would result in a loss of portions of the golf course. Coastal erosion from large wave hazards is also an issue for coastal habitats such as this one. As the sea level rises, larger waves may increasingly erode the shoreline.

10.1.2 Exposure Assessment

The exposure of each park was evaluated relative to the 10 SLR scenarios (see Chapter 2). The percentage of each park that could be inundated under each scenario was calculated and is presented in Table 10.1.

10.1.3 Consequences

Key consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below. However, several actions are currently planned or in progress to address some of the noted impacts. For a description of the current or planned projects, see Chapter 13, *A Changing Shoreline*.

KEY ISSUE: Many of the parks and open spaces providing recreation opportunities and preserving the environment for the wellbeing of the community, especially in already underserved vulnerable communities, would become unavailable to residents and visitors. These park and open-space areas are surrounded by dense urban or industrially use spaces. If temporarily, and eventually permanently, unavailable due to flooding, most of these spaces will not have room to be relocated to higher ground and could be lost.

Society and Equity: Residents could lose shoreline and park and open-space access as well as other recreational opportunities if these areas are damaged or disrupted. These impacts would disproportionally impact vulnerable communities for whom the loss could be considerable, as they may not have the ability take advantage of open space, parks, and/or programs in locations not impacted.

Environment: Parks and open spaces often reduce the percentage of impervious surface within a neighborhood, reducing the impacts of urban heat islands and serving as habitat for wildlife species. Coastal flooding would reduce and eventually remove these benefits to the community and environment. At India Basin, the small remaining patches of tidal wetland habitat for threatened and endangered species will be impacted. Storm-event flooding makes these species more vulnerable to predation and can reduce reproductive success if nests are flooded. Downshifting habitat means marshes will be flooded more often, exacerbating

Table 10.1 Percentage of each RPD Park Inundated with Sea Level Rise

Park	Total Area (acres)	Percent Inundated under Each Sea Level Rise Scenario 1	2	3	4	5	6	7	8	9	10
Gilman Playground	5.2	-	-	-	-	-	-	12	24	38	49
India Basin Shoreline Park	11.6	14	19	23	28	30	34	36	38	39	41
Gene Friend Recreation Center	1.0	-	-	-	-	-	-	-	-	-	33
Victoria Manalo Drakes Park	2.5	-	-	-	-	-	-	-	-	-	12
Embarcadero Plaza	4.1	-	-	-	-	22	85	91	95	100	100
Sue Bierman Park	4.3	-	-	-	-	16	39	61	72	80	85
Palace of Fine Arts	19.4	-	-	-	-	-	75	80	86	94	96
Sharp		-	-	-	-	-	-	-	-	-	-

Sharp Park was not included in the exposure assessment because it is located in Pacifica and outside of San Francisco's SLR Vulnerability Zone boundaries.

these population stresses, until conversion of marsh to mudflat results in complete loss of tidal marsh species at this location, assuming there is no accommodation space for inland migration.

Economy: Access to open space, recreation areas, programs, and the shoreline provide quality of life for San Francisco residents and visitors and are part of the unique experience of living in or visiting San Francisco. The Embarcadero, Ferry Plaza, and other parks and shoreline areas play an important role in attracting tourists and creating jobs and revenue for the City and its businesses. Temporary and permanent flooding and inundation could negatively affect nearby businesses through direct costs from damages and indirectly from less business. City parks also provide recreation value to residents, help maintain healthy and safe communities, and can increase the property values of surrounding land, which could also be negatively impacted. In addition, maintenance costs for parks and open spaces could increase and where even possible, substantial funding would be needed to relocate or improve infrastructure due to the high degree of scrutiny and environmental compliance required. These increased costs would potentially be passed on to the taxpayers and park users, creating potential disproportionate impacts across economic brackets.

Governance: Although San Francisco's low-lying parks and open spaces in the SLR Vulnerability Zone will all likely be impacted to a similar degree, many of the open spaces are managed by different entities that will need to coordinate to mitigate impacts.

10.2 MARINAS AND AQUATIC RECREATION CENTERS

The Port owns and manages the majority of the direct Bay shoreline land use from Herons Head Park to the south and Aquatic Park to the north; however, Aquatic Park is owned and managed by the San Francisco Maritime National Historic Park as part of the National Park Service. The facilities owned and maintained by the Port are described in Chapter 11, Port of San Francisco. RPD manages a selection of marinas, harbors, and aquatic recreation centers that are outside of the Port's authority. These facilities are described below.

10.2.1 Potentially Vulnerable Assets

The following marinas and aquatic recreation centers are owned and maintained by RPD and are located within the SLR Vulnerability Zone as shown in Figure 10.2.

10.2.1.1 Marina Small Craft Harbor

The San Francisco Marina is the oldest recreational marina operating in San Francisco and a popular international destination. The San Francisco Marina includes two harbors, West Harbor (Photo 10.11) and East Harbor (Photo 10.12), three park greens (i.e., Little Marina Green, Big Marina Green, and Marina Green Triangle), and several buildings. It is situated along the City's northern waterfront, between Fort Mason on the east and Crissy Field on the west. The entire site consists of about 35 acres, with 727 berths, pump-out stations, and a commercial fuel dock. It also includes a structure with the Harbor Master's Office and public restrooms as well as other buildings (Marina Buildings, discussed below).

Over 500 parking spaces are available to the general public at all times. Approximately 93 parking spaces throughout the Marina Green are striped for the exclusive use of "permitted" harbor tenants whose

Figure 10.2 Overview Map of Marinas and Aquatic Recreation Centers in the SLR Vulnerability Zone

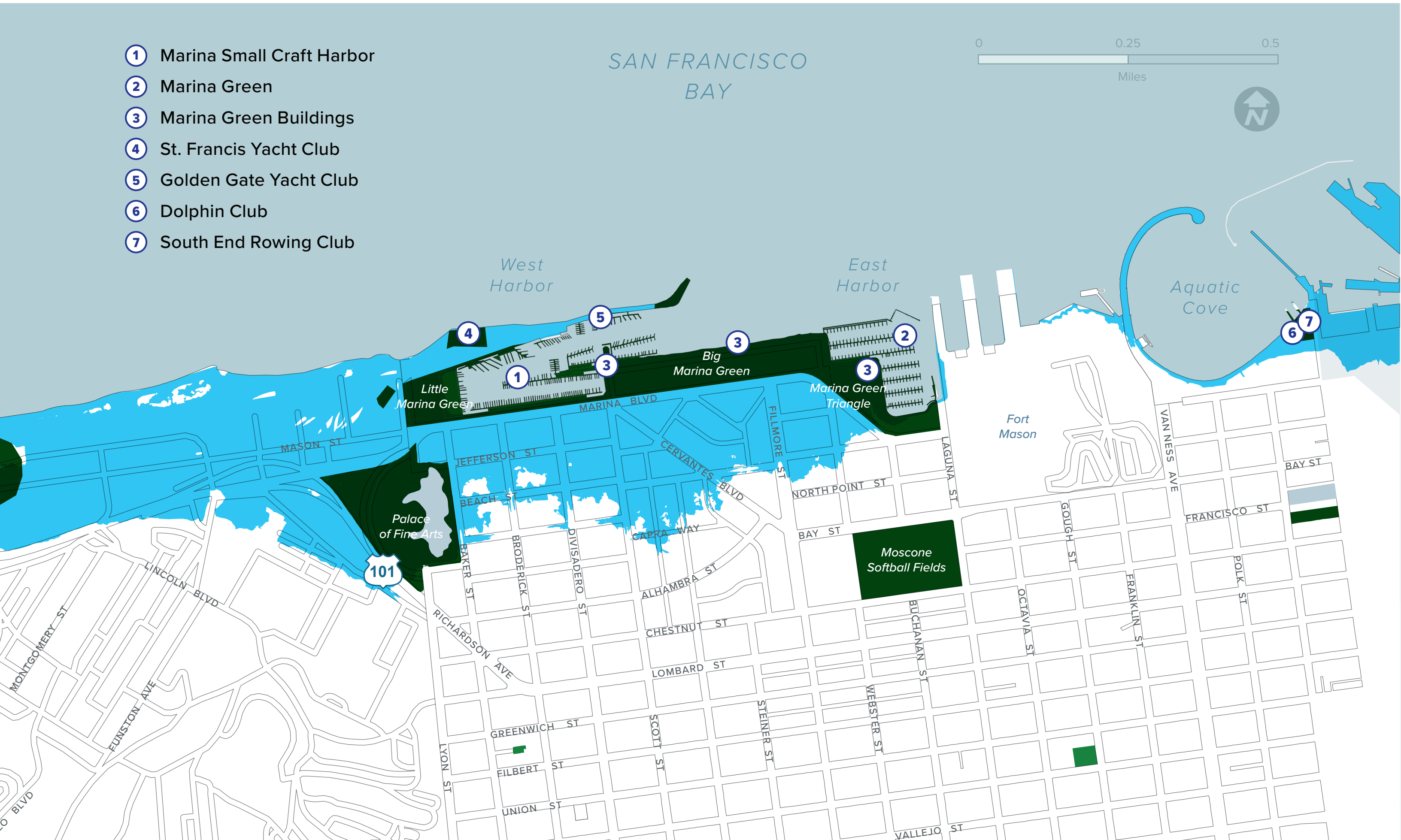


Photo 10.11 Marina Small Craft Harbor (West Harbor) and Little Marina Green.

Photo 10.12 Marina Small Craft Harbor (East Harbor) and Marina Green Triangle.


Photo 10.13 Marina Green. David Jones (CC BY 2.0)


Photo 10.14 A building along the Marina Green. James Watkins

vehicles have 24/7 parking privileges subject to availability. In addition, 74 parking spaces are reserved for boaters on Saturday, Sunday, and official holidays, and available to the general public on weekdays.

The West Harbor, also known as “Yacht Harbor,” is located north of Marina Boulevard, between Baker Street and Scott Street. The East Harbor, also known as “Little Marina” and “Gashouse Cove,” is located north of Marina Boulevard, between Webster and Laguna Street. The West Harbor generally serves public sailboats and motorboats, but also provides berths to fireboats, and other agency boats for critical services, such as Fire Jet Ski's, U.S. Fish and Wildlife boats, and Homeland Security law enforcement boats.

The marina's small boat berthing facilities are located behind a locked gate within the marina, with access to the docks via gangways. At-grade utilities, including water and power, are connected to the docks. The main electrical switchgear in the west is at ground level and could fail if exposed to seawater. The power services the docks, street lighting and office / buildings, and the two yacht clubs (discussed below). Fire suppression and storm sewer services are also provided onsite. The historic internal marina seawalls in the west are in poor condition and continue to fail, due to their construction type. The northern marina shoreline adjacent to the west marina also has had failures and heavy erosion due to ship speed and size and amount of traffic type wave action against the northern seawall of the Bay.

Approximately 75 percent of site is subject to tidal, wind, and wave hazards. The West Harbor has more substantial wave protection than does the East Harbor. The Marina Shop’s lower level floods during very high tides, and the floodwater impacts mechanical equipment, including pumps, motors, and valves. At-grade utilities, including water and power, are connected to the docks.

The marina operates at 98 percent occupancy in the West Harbor and 76 percent-percent occupancy in the east and there are no other nearby public small craft harbor facilities available, thus there are no alternative sites for redundancy. The East Harbor’s planned replacements include gangways to the docks above King Tide level for those that have risk levels of failure and/or wouldn’t be useable. The West Harbor is on pilings, which may be too low to withstand SLR. There are utility systems under the docks that are vulnerable, especially if exposed to storms, high tides, and SLR. In addition, there is a lack of adequate shoreline armoring (e.g., stone rip rap or similar) to reduce wave hazards on the Bayfront side of the marina.

10.2.1.2 Marina Green

Marina Green is a large expanse of predominantly grassy open space on the waterfront, extending from Laguna Street (Fort Mason) on the east to Lyon Street/ Yacht Road (The Presidio) on the west, between Marina Boulevard and San Francisco Bay (Photo 10.13). Footpaths and jogging paths run around the perimeter of Marina Green, along Marina Boulevard

Photo 10.15 **The Naval Degaussing Station in the Marina Green.** Google Street View

Photo 10.16 **St. Francis Yacht Club.** Scott Chernis (CC BY 2.0)

and extend out to the Wave Organ at the end of a jetty past St. Francis Yacht Club.

The lawns at Marina Green are used heavily by neighboring children and schools for athletic practices for children 11 and under. They are also used every Saturday in the fall and spring for microsoccer. There are limited athletic fields in this area and no alternative locations to accommodate the weekday practices. For the Saturday games, there are limited options short of converting baseball fields in the southeast part of the City.

The site has existing drainage issues and the lawns could be damaged by intermittent saltwater flooding. Marina Green hosts major RPD and other public events such as Fleet Week staging, marathons, and the 2013 America's Cup.

10.2.1.3 Marina Green Buildings

Marina Green includes several buildings, including an administration building, restrooms, and other RPD facilities (Photo 10.14). The buildings are not anticipated to be inundated until Scenario 9; however, access issues will likely occur at an earlier scenario due to inundation of the surrounding areas (see Table 9.3). The buildings do not house any critical electrical or mechanical equipment, and the use of the building could resume once floodwaters recede and cleanup is complete. Floodwaters could enter the buildings through doorways, vents, and other openings. Sandbags can be used as a temporary flood protection measure, but no sandbags are currently housed onsite.

Permanent inundation of these facilities would render them inaccessible and unusable. The Naval Degaussing Station, a 720-square-foot clapboard building, is currently being remodeled with a completion date of late 2019 (Photo 10.15). This will be the future marina office; the existing office will then be modified for revenue-generating boater services.

10.2.1.4 St. Francis Yacht Club

St. Francis Yacht Club was founded in 1927 and is located at 700 Marina Boulevard (Photo 10.16). The main building is located directly on the Bay, on a broad spit with a parking lot and vehicular access between the Bay shoreline and the West Harbor. Rip rap is placed along the shoreline directly in front of the yacht club to reduce wave impacts. Much of the shoreline is hardened with either rip rap or concrete.

As sea levels rise and wave hazards increase, the rip rap protection will require improvements to dissipate large wave hazards. Although the structure is not anticipated to be inundated by coastal floodwaters until Scenario 6, the structure is directly adjacent to the rip rap revetment and likely to be damaged under an earlier scenario by wave hazards that exceed the design criteria of the revetment.

Land side transformers southeast of St. Francis Yacht Club are at ground level and serve the yacht clubs and the north side docks north. SLR and king tides in this area would potentially put the transformers underwater. There are other yacht clubs and clubhouses that could provide services if St. Francis Yacht Club is damaged during a storm. However, if St.

Photo 10.17 **Golden Gate Yacht Club.** Yasuhiro Chatani (CC BY 2.0)

Photo 10.18 **Dolphin Club and South End Rowing Club.** Pax Ahimsa Gethen (CC BY-SA 4.0)

Francis and Golden Gate yacht clubs were damaged at the same time, alternative clubs and clubhouses are many miles away from this location.

10.2.1.5 Golden Gate Yacht Club

Golden Gate Yacht Club was founded in 1939 and is located at 1 Yacht Road in the protected harbor near St. Francis Yacht Club (Photo 10.17). The structure is built on pilings over water and could be inundated by temporary floodwaters as early as Scenario 2. The structure is less exposed to wave hazards than the larger St. Francis Yacht Club; however, wave action is causing erosion issues for the access road/jetty to Golden Gate Yacht Club. There are other yacht clubs and clubhouses that could provide services if Golden Gate Yacht Club is damaged during a storm. However, if Golden Gate and St. Francis yacht clubs were damaged at the same time, alternative clubs and clubhouses are many miles away from this location.

10.2.1.6 Dolphin Club

The Dolphin Club is located at 502 Jefferson Street (Photo 10.18). The building is owned by RPD but managed and leased by the club. Founded in 1877, the club currently has about 1,500 members. They swim in Aquatic Park, row in the Bay, and participate in the annual Escape from Alcatraz Triathlon. The site has boat houses for stowing rowboats and kayaks. The two-story facility has locker rooms, lounge areas, boat building and repair room, and a weight room.

The building is more than a century old, and although well maintained, would likely sustain damage during temporary or permanent inundation. The structure is projected to be inundated by temporary coastal flooding under Scenario 3. Some areas of the facility are built on pilings over beach areas. The facilities are being protected from wave hazards by the aquatic pier; however, the pier is deteriorating and will need rehabilitation to maintain protecting the club building.

10.2.1.7 South End Rowing Club

South End Rowing Club, located at 500 Jefferson Street, was founded in 1873 and currently has about 1,300 members (Photo 10.18). Rowing, handball, swimming, and running are the primary club sports. The nearly 150-year-old structure is located directly on the shoreline adjacent to the Dolphin Club. Although well maintained, it would likely sustain damage during temporary or permanent inundation. The structure is projected to be inundated by temporary coastal flooding under Scenario 3. The only alternative location to the Dolphin and South End Rowing Clubs is at Lake Merced, which does not provide the same suite of Bay watercraft opportunities.

10.2.2 Exposure Assessment

The exposure of each marina and aquatic recreation center was evaluated relative to the 10 SLR scenarios (see Chapter 2). The percentage off each marina that could be inundated under each scenario was calculated and is presented in Table 10.2. For aquatic recreation structures, exposure under each SLR scenario was assessed as either inundated or not inundated, based on a structure's ground elevation relative to the flood elevation of each SLR scenario, as presented in Table 10.3.

Table 10.2 Marina and Harbor Exposure with Sea Level Rise

Name	Total Area (acres)	Percent Inundated under Each Sea Level Rise Scenario 1	2	3	4	5	6	7	8	9	10
Marina Small Craft Harbor	30.0	-	-	-	-	-	30	35	36	37	39
Marina Green Three Lawns	27.1	-	-	-	-	-	13	40	52	69	84

Table 10.3 Aquatic Recreation Exposure with Sea Level Rise

Name	Percent Inundated under Each Sea Level Rise Scenario 1	2	3	4	5	6	7	8	9	10
Marina Green Buildings	-	-	-	-	-	-	-	-	Y	Y
St. Francis Yacht Club	-	-	-	-	-	Y	Y	Y	Y	Y
Golden Gate Yacht Club	-	Y	Y	Y	Y	Y	Y	Y	Y	Y
Dolphin Club	-	-	Y	Y	Y	Y	Y	Y	Y	Y
South End Rowing Club	-	-	Y	Y	Y	Y	Y	Y	Y	Y

10.2.3 Consequences

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below. However, several actions are currently planned or in progress to address some of the noted impacts. For a description of the current or planned projects, see Chapter 13, *A Changing Shoreline*.

KEY ISSUE: The Marina Green and yacht harbors provide key access and unique views of the San Francisco Bay to residents and visitors, and are important for San Francisco's tourism and sailors. The marinas (the physical structures, supporting buildings, and electricity supply) could be damaged and/or become inaccessible due to flooding and secondary hazards, such as wave impacts, creating potentially long-lasting and costly effects. Impacts to some of the historic seawall and shoreline fortifications will become worse, eventually cutting off access to the yacht clubs and marina facilities.

Society and Equity: Despite being in a more affluent area of San Francisco, this open space is used for many public and free events and provides prime shoreline access for everyone.

Environment: Marinas create, store, and transport hazardous materials such as fuel and motor oil. If these facilities are flooded, hazardous materials may be mobilized and lead to impaired water quality and environmental habitat degradation.

Economy: Marinas provide unique shoreline recreation value and direct economic activity through berth rentals and nearby businesses, such as the yacht clubs and neighborhood restaurants. The closure of marinas may impact local economies and tax revenue. Because this area is also used to stage large events of international interest, inaccessibility would also negatively impact revenue from tourism. In addition, maintenance costs could increase and where even possible, substantial funding would be needed to relocate or improve infrastructure due to the high degree of scrutiny and environmental compliance required. These increased costs would potentially be passed on to the taxpayers and marina users, creating potential disproportionate impacts across economic brackets.

Governance: RPD owns many of the aquatic recreation sites, with facilities that are leased and managed by other entities. Coordination between these entities will be required to address SLR vulnerabilities and maintain the desired level of service.

10.3 TRAILS

In addition to San Francisco's Urban Trails Program,[4] RPD supports trails of regional and national importance. All or portions of these trails are located within the SLR Vulnerability Zone, including the Anza Trail, San Francisco Bay Trail, Blue Greenway, and the Coastal Trail. All of these trails allow residents to escape the City's hectic pace and explore nature within their own neighborhoods and beyond.

10.3.1 Potentially Vulnerable Assets

The following trails owned, maintained, or supported by RPD and are located either wholly or partially within the SLRVZ (Figure 10.3).

10.3.1.1 San Francisco Bay Trail

San Francisco Bay Trail is a planned 500-mile walking and bicycling path around the entire San Francisco Bay. Along its course, the trail will link 47 cities through nine counties, providing numerous connections to local employment hubs, transit, parks and open spaces, schools, and other civic centers (Photos 10.19 and 10.20). As of 2017, more than 300 miles of trail are open, consisting of off-road trails with a mix of surface types, as well as stretches of bike lanes and sidewalks.

For now, gaps separate the open portions. An urban section includes the rail-trail stretch of the trail on the Embarcadero in San Francisco. Here, the trail follows the path of the old State Belt Railroad, which transferred cargo from ships to main line railroads and cars onto ferries for trips across the Bay.[5]

Within San Francisco, there are 14.1 miles of Bay Trail spine and 1.7 miles of Bay Trail spurs. Due to the shoreline nature of the trail location, the trail is subject to inundation by temporary coastal floodwaters and SLR. Impacts to recreation use start in Scenario 2. By Scenario 7, more than 50 percent of the Bay Trail segments are projected to be inundated (Table 10.4).

4 San Francisco Recreation and Park Department (RPD). Urban Trails Program. Available at http://sfrecpark.org/parks-open-spaces/urban-trails/.

5 Rails-to-Trails Conservancy. TrailLink: San Francisco Bay Trail. Available at https://www.traillink.com/trail/san-francisco-bay-trail/.

Photo 10.19 Aerial of the Bay Trail at Herons Head Park. Port of San Francisco

Figure 10.3 Trails within the SLRVZ

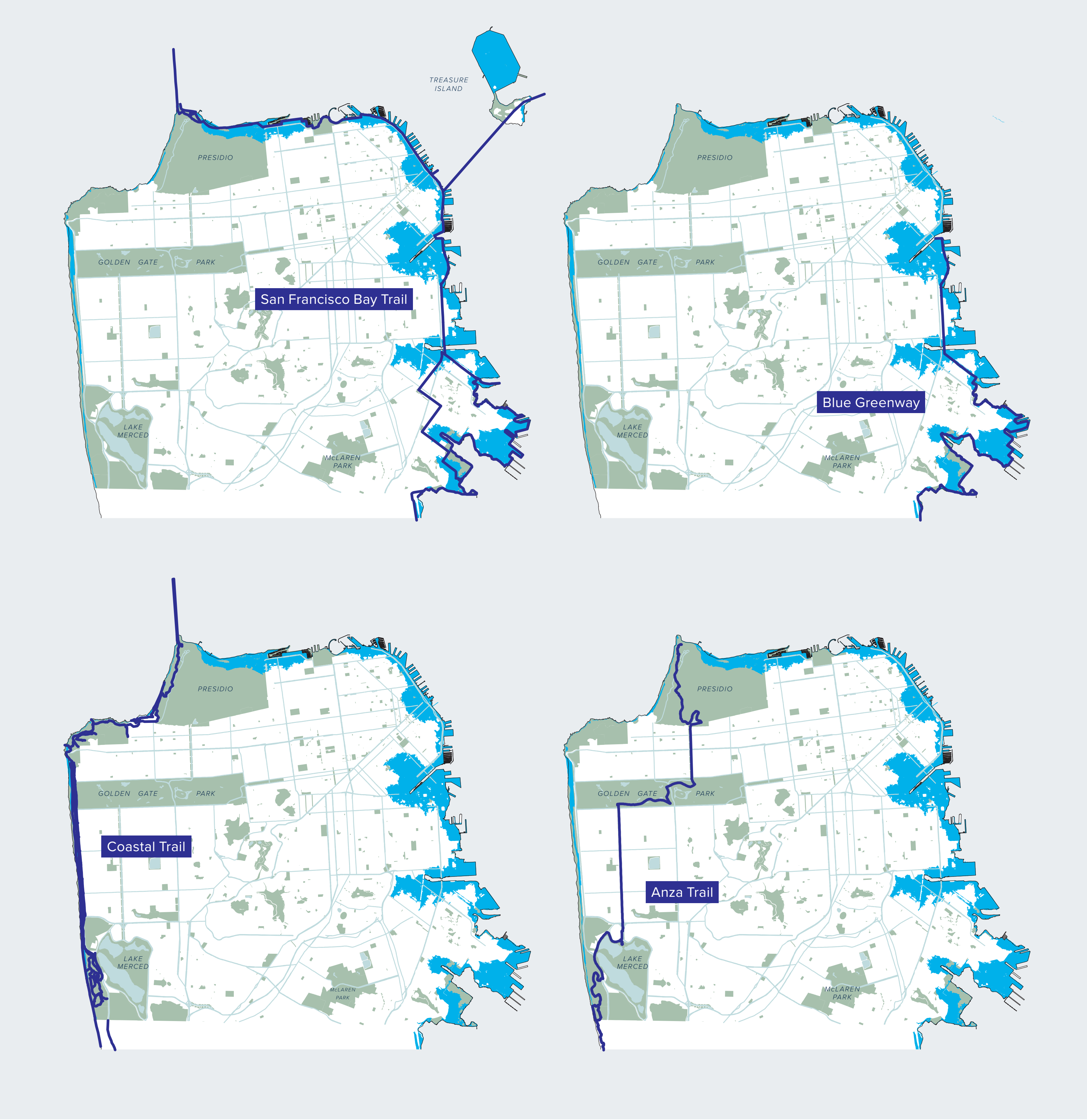


Photo 10.20 **Bay Trail at Herons Head Park.** Port of San Francisco

Photo 10.21 **Blue Greenway at Agua Vista Park.** Port of San Francisco

A number of connecting trails feed into and spur off from the San Francisco Bay Trail, offering additional opportunities to explore the surrounding communities.

10.3.1.2 Blue Greenway (Southern portion of Bay Trail and Bay Area Water Trail)

The Blue Greenway (see Photo 10.21) is the City of San Francisco's project to improve the City's southern portion of the 500-mile, nine-county, regionwide San Francisco Bay Trail, as well as the newly established Bay Area Water Trail and associated waterfront open space system. The alignment of the Blue Greenway generally follows the alignment of the San Francisco Bay Trail and Bay Area Water Trail from Mission Creek on the north to the county line on the south. Like the San Francisco Bay Trail, the projected impacts from temporary coastal inundation and SLR begin early, and by Scenario 7 more than 50 percent of the Blue Greenway trail segments are projected to be inundated (see Table 10.4).

10.3.1.3 Coastal Trail

The Coastal Trail in San Francisco is 10.5 miles long, linking tourist attractions along scenic natural and human-made landscapes. The trail connects the Golden Gate Bridge, Fort Point, the Presidio, the Palace of the Legion of Honor, Sutro Heights Park, the historic Cliff House, Golden Gate Park, Ocean Beach, and Fort Funston (Photo 10.22).

Along the westside of San Francisco, the trail along the beach has been closed during high tides and some areas are exhibiting erosion. The trail also has seasonal closures when snowy plovers are present. The western snowy plover is currently listed as a threatened species.

The entire length of the Ocean Beach/Fort Funston Shoreline trail (adjacent to the roadway) is projected to be inundated by temporary coastal flooding and SLR by Scenario 5 (see Table 10.4). The trail also includes a bike path within the roadway right-of-way. This pathway is located outside of the SLR Vulnerability Zone, offering potential alternative access. However, this pathway would not provide the same user experience as direct beach access. The planned South Ocean Beach trail would provide coastal access south of Sloat Boulevard through National Park Service connecting trains. Portions of the Coastal Trail along the Great Highway and Baker Beach are also projected to be inundated by coastal floodwaters and SLR.

10.3.1.4 Anza Trail

The Juan Bautista de Anza National Historic Trail runs from Nogales, Arizona, to San Francisco. This trail commemorates the path that Lt. Colonel Juan Bautista de Anza used to lead more than 240 men, women, and children on the eve of the American Revolution. It is a legacy to the epic journey they took across the frontier of New Spain to establish a settlement at San Francisco Bay.[6] Only a small segment of the Anza Trail, located along the open Pacific coast near Fort Funston, is located within the SLR Vulnerability Zone (Photo 10.23).

6 Juan Bautista de Anza. Welcome. Available at http://www.anzahistorictrail.org/. Accessed August 2018.

Photo 10.22 Coastal Trail in the Presidio. Sergio Ruiz

Photo 10.23 Anza Trail at Fort Funston. Sergio Ruiz

10.3.2 Exposure Assessment

The exposure of each trail was evaluated relative to the 10 SLR scenarios (see Chapter 2). The percentage and miles of each trail that could be inundated under each scenario were calculated and are presented in Table 10.4 and Table 10.5, respectively.

10.3.3 Consequences

Key consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below. However, several actions are currently planned or in progress to address some of the noted impacts. For a description of the current or planned projects, see Chapter 13, *A Changing Shoreline*.

KEY ISSUE: The trails described above provide important public shoreline access, views, and a unique recreation experience across different landscapes, connecting neighborhoods and communities. This public access could become unavailable to residents and visitors. The trail often traverses dense urban or industrially used spaces, having been carved out and fought for over the past decades. If temporarily, and eventually permanently, unavailable due to flooding, some of the trail will not have room to be relocated to higher ground and could be lost.

Society and Equity: Residents could lose shoreline access, recreation opportunities, and non-motorized transportation corridors if trails are damaged or closed due to future flooding or erosion. For those with limited mobility or transportation options, the loss of trail segments in their neighborhoods could be significant, reducing the transportation and recreation opportunities provided by these segments.

Environment: Trail segments provide nature viewing and environmental education opportunities that may be lost if the trail is flooded or damaged. Damage of the trail can also increase erosion and result in impacts to the natural areas surrounding the damaged trail segments.

Economy: Trails provide recreation value and non-motorized transportation options for San Francisco residents and visitors. Proximity to one of the trails is an attractive feature to businesses and residential land uses and can increase the value of adjacent properties. This economic value may be lost if a trail is flooded or inundated.

Governance: The trail segments occupy rights-of-way along the shoreline with complex land ownership. Adaptation strategies to address vulnerable trail segments will require cooperation with landowners and other agencies.

Table 10.4 Trail Exposure with Sea Level Rise (Percent Inundated)

Park	Total Length (mi)	Percent Inundated under Each Sea Level Rise Scenario 1	2	3	4	5	6	7	8	9	10
Bay Trail											
Spine	14.1	-	-	4	11	15	44	54	57	62	66
Spur	1.7	1	5	19	29	33	40	45	50	57	65
Blue Greenway	11.9	2	5	11	18	24	49	54	58	63	69
Coastal Trail*						DWL 12	DWL 24	DWL 36	DWL 48		DWL 66
Ocean Beach / Fort Funston Shoreline trail	4.7	-	-	-	-	98	98	98	98	-	98
Great Highway	3.8	-	-	-	-	10	14	18	20	-	22
Baker Beach	0.6	-	-	-	-	91	93	93	93	-	93
China Beach	0.2	-	-	-	-	33	33	33	33	-	40
Anza Trail	12.9	-	-	-	-	2	2	2	2	-	2

* Exposure along the open Pacific coast shoreline was evaluated using the 100-year dynamic water level (DWL) coupled with SLR. The 100-year DWL considers the influence of wave setup.

Table 10.5 Trail Exposure with Sea Level Rise (Miles Inundated)

Park	Total Length (mi)	Percent Inundated under Each Sea Level Rise Scenario 1	2	3	4	5	6	7	8	9	10
Bay Trail											
Spine	14.1	-	0.1	0.6	1.6	2.2	6.2	7.7	8.0	8.8	9.3
Spur	1.7	-	0.1	0.3	0.5	0.6	0.7	0.8	0.9	1.1	1.1
Blue Greenway	11.9	0.3	0.7	1.3	2.2	2.9	5.6	6.4	7.0	7.5	8.3
Coastal Trail*						DWL 12	DWL 24	DWL 36	DWL 48		DWL 66
Ocean Beach / Fort Funston Shoreline trail	4.7	-	-	-	-	4.6	4.6	4.6	4.6	-	4.6
Great Highway	3.8	-	-	-	-	0.4	0.5	0.7	0.8	-	0.8
Baker Beach	0.6	-	-	-	-	0.5	0.5	0.5	0.5	-	0.5
China Beach	0.2	-	-	-	-	0.1	0.1	0.1	0.1	-	0.1
Anza Trail	12.9	-	-	-	-	0.3	0.3	0.3	0.3	-	0.3

Aerial view of the Embarcadero. Photo by Sergio Ruiz

CHAPTER 11

PORT OF SAN FRANCISCO

The Port's jurisdiction provides a variety of uses along the waterfront, including maritime activities and services such as fishing, ferry transportation, water-based recreation, harbor services, and cargo shipping, as well as public access, parks, and open spaces, protection of natural and cultural resources, and space for much of San Francisco's last remaining critical industrial uses. The Port is also home to several well-loved institutions, including the Exploratorium, Oracle Park, the Ferry Building, Heron's Head Park and EcoCenter, and Fisherman's Wharf. The Port provides shoreline protection for 7.5 miles of the City and County of San Francisco's waterfront, including regional and citywide assets such as BART, Muni, utilities, homes, jobs, and critical emergency response facilities and services.

From its establishment in 1863 until 1968, the State of California oversaw management of the Port. In 1968, the Burton Act mandated the transfer of Port lands from state management to the City and County of San Francisco. Subsequently, the Port Commission was established as an enterprise department of the City to develop, lease, administer, manage, and maintain Port lands.

In addition to an enterprise department of the City, the Port is also a trustee for the Public Trust for the State of California. The Public Trust Doctrine recognizes the public's right to natural resources such as air, water, and access to the sea. In California, the Public Trust generally refers to lands that are submerged, tidal, or filled and retained in public ownership.[1]

1 Port of San Francisco (Port). 2009. "Chapter 3: General Land Use Policies." Waterfront Land Use Plan. https://sfport.com/ftp/uploadedfiles/about_us/divisions/planning_development/ch3.pdf. Revised October.

The State Lands Commission administers public trust lands that were not granted to a local agency and oversees the activities of local grantees such as the Port. As a trustee, the Port ensures that land uses within its jurisdiction are consistent with the Public Trust, reserving these lands for uses that promote navigation, fisheries, and waterborne commerce; enhance natural resources; and attract people to use and enjoy the Bay.[1] The Port works closely with state agencies, including the State Lands Commission and BCDC. As a port and waterfront land manager, the Port also works closely with federal agencies, including the U.S. Army Corps of Engineers.

The Port's primary shoreline ownership runs from Fisherman's Wharf in the north to India Basin in the south. This assessment focuses on Port assets located in the southern waterfront outside of the three miles of Embarcadero Seawall. The Embarcadero Seawall extends from Fisherman's Wharf to Mission Creek and faces both flooding and seismic risks and is undergoing a separate vulnerability and risk assessment as part of the Embarcadero Seawall Program. The Embarcadero Seawall Program is a separate but coordinated effort to create a more sustainable and resilient waterfront and is described further in Section 4.8.

This Assessment focuses on Port lands in the southern waterfront from Mission Creek to India Basin (Figure 11.1). The following sections describe various Port assets and provide information about how key assets and asset categories may be vulnerable to SLR and coastal flooding.

For the purposes of this assessment, the Port's assets are organized by the following asset categories:

- **Port Structures** – Piers, bulkhead buildings, wharves, seawall lots, and harbors

- **Recreation and Public Open Space** – public realm and open space areas

- **Transportation** – Ferries, streets, bridges, shipping berths, cargo facilities, and railroads

- **Utilities** – over land (buried) and over water (under pier) stormwater utilities

- **Adaptation Projects** – planned or completed SLR adaptation projects

Each asset is categorized further by Port use and service type. Port use was included as another metric to help assess the vulnerability and consequences of coastal flooding. The following uses are included below and defined in Table 11.1:

- Natural Resources and Public Open Spaces
- Historic Districts and Potential Historic Features
- Maritime
- Industrial
- Environmental Hazards
- Commercial
- Residential
- Emergency Response
- Utilities
- Transportation

Table 11.1 Port Use and Service Category Classifications

Port Use Category	Description
Natural Resources and Public Open Spaces	Uses that protect or enhance natural resources and provide public access to open spaces.
Historic District	The area of the Port discussed in this report contains two historic districts – the Union Iron Works Historic District designated on April 17, 2014, and a portion of the Embarcadero Historic District designated on May 12, 2006.
Potential Historic Feature	Structures and objects that may be historic or may contain historic features but have not yet been evaluated or identified as a historic resource or part of a historic district.
Maritime*	Uses that depend on a waterfront location to operate or uses that support maritime activities. Examples include cargo shipping, ship repair, the fishing industry, harbor services, excursions, water recreation, ferries and water taxis, passenger cruise ships, historic ships, and maritime support services and offices.
Industrial	Industrial operations that support maritime and general industrial activities. This includes industrial buildings on piers and seawall lots as well as open land operations and berthing activities.
Commercial*	Commercial uses on piers and seawall lots. Those on piers include artist studios and galleries, entertainment, recreational/fitness services, museums, parking for acceptable uses, retail, visitor services, warehousing and storage, wholesale trader, and general offices. Those on seawall lots include the same as commercial piers as well as hotels, general offices, parking, and warehousing/storage.
Residential	Sites that include residential housing.
Emergency Response	Assets identified by the Port's Embarcadero Seawall Program, in close coordination with the Department of Emergency Management and the Water Emergency Transportation Authority, as being part of the City, Port, and region's emergency response system.
Utilities	Assets that include utilities on them. This includes utilities owned by the Port and utilities owned by other agencies or companies.
Transportation	Assets that include a component related to transportation (parking, roadway, bridges, ferries, freight and commuter rail, etc.).

*Port of San Francisco (Port). 2009. "Chapter 3: General Land Use Policies." Waterfront Land Use Plan. https://sfport.com/ftp/uploadedfiles/about_us/divisions/planning_development/ch3.pdf. Revised October.

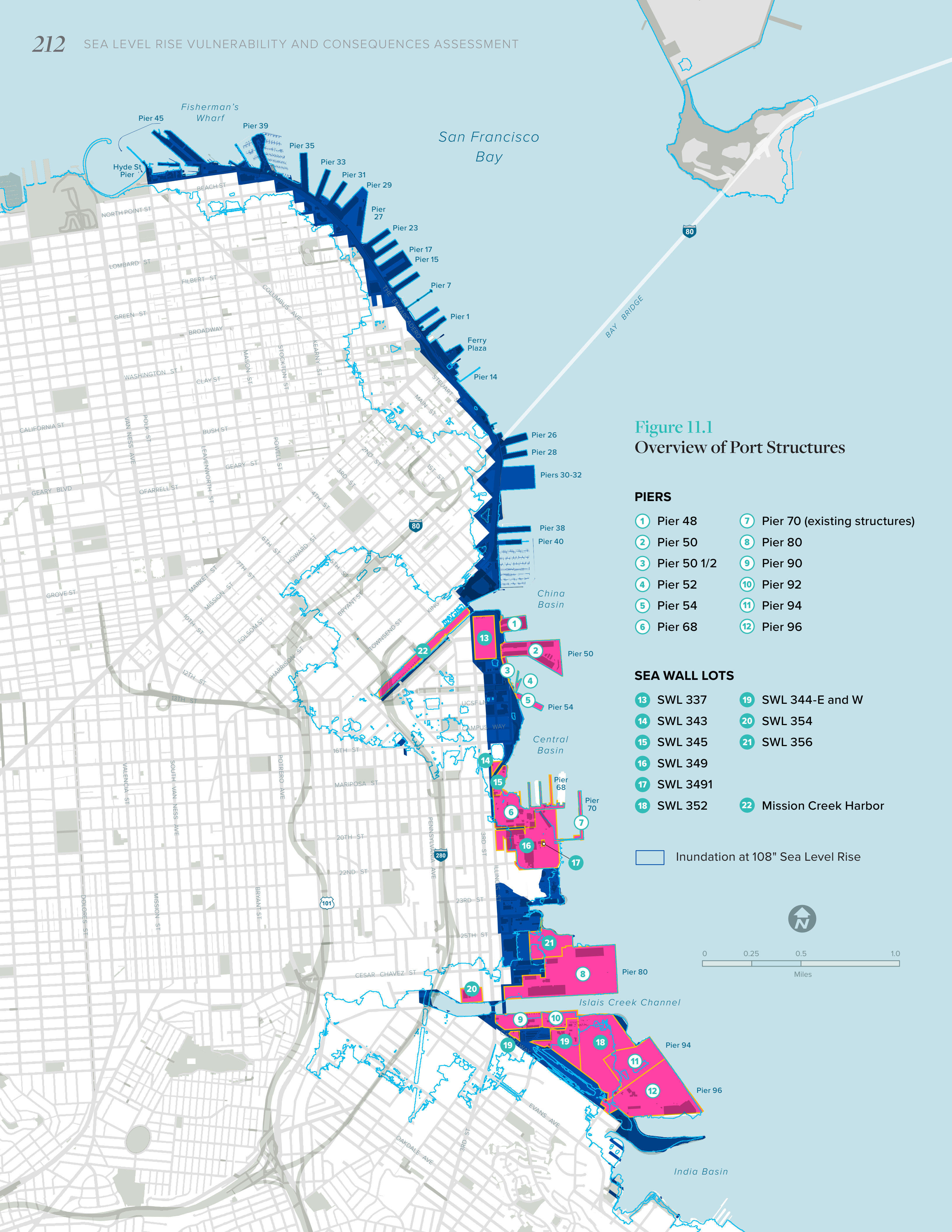


Figure 11.1
Overview of Port Structures

11.1 PORT STRUCTURES

Port structures include piers, bulkhead buildings, wharves, seawall lots, and harbors. This section describes the Port structures located in the southern waterfront, describes their vulnerabilities, and highlights the consequences that could occur if the structures are flooded. Figure 11.1 shows the Port structures and the SLR Vulnerability Zone.[2] Table 11.2 summarizes the Port use type categories for each Port structure.

2 The SLR Vulnerability Zone was adopted by the City in 2014. It is the area that could be flooded by a 100-year coastal flood event coupled with 66 inches of SLR, a probable worst-case scenario by the end of the century. Chapter 2, *Climate Science*, provides additional information on the SLR Vulnerability Zone, climate science, and SLR scenarios.

11.1.1 Potentially Vulnerable Port Structure Assets

Because the Port's jurisdiction is along the city's bayside shoreline, all Port structures were considered potentially vulnerable and were included in the vulnerability assessment. A description of the various Port structures, uses, and their vulnerabilities is included below.

Table 11.2 Port Structure Assets by Use Category

	Port Use Category									
Asset	Natural Resources and Open Spaces	Historic District	Potential Historic Feature	Maritime	Industrial	Commercial	Residential	Emergency Response	Utilities	Transportation
Pier 48	●	●		●		●		●	●	
Pier 50	●		●	●	●	●		●	●	
Pier 50 1/2			●	●		●			●	
Pier 52	●			●		●			●	●
Pier 54				●	●	●		●	●	
Pier 68	●	●		●	●			●	●	●
Pier 70 (existing structures)		●		●		●			●	
Pier 80	●			●	●			●	●	●
Pier 90					●	●		●	●	
Pier 92	●			●	●			●	●	●
Pier 94	●				●			●	●	
Pier 96	●			●				●	●	
SWL 337	●				●	●	●	●	●	●
SWL 343				●		●			●	
SWL 345	●			●		●			●	●
SWL 349						●			●	●
SWL 3491						●			●	●
SWL 356						●			●	
SWL 344 - E and W					●			●	●	
SWL 352					●			●	●	
SWL 354									●	●
Mission Creek Harbor				●			●		●	

11.1.1.1 PIERS

The piers primarily consist of finger piers built over water (see Photo 11.1), except Piers 80-96, which are primarily "filled" piers created with a soldier pile wall. There is a mix of open piers that have no buildings on them as well as piers with warehouse sheds and bulkheads with office space on the marginal wharf. The Port leases the piers to various entities for a mix of industrial, commercial, and maritime activities.[3] Pier uses and conditions vary greatly between individual piers and may change over time due to rehabilitation, maintenance, or aging.

Because the piers are primarily located over water, they are vulnerable to wind, tidal, and wave forces in addition to flooding by SLR. The piers' infrastructure includes structural support piles located in water and associated utilities that are continuously exposed to the same wind, tidal, and wave forces and are vulnerable to corrosion and deterioration over time.

3 Specific tenants mentioned include those present at the time this Assessment was conducted. Individual leases may vary over time.

Pier 48 is a historic pier within the Embarcadero Historic District located south of Oracle Park adjacent to the mouth of Mission Creek (Photo 11.2). It is leased by several companies and serves a variety of maritime, commercial, environmental, and emergency response uses. Part of the pier, including Shed A, Shed C, and the outdoor space between them, is leased by Giants Enterprises and rented as an event, entertainment, and conference space. Westar Marine Services provides tugboat services, warehousing and storage, and hazardous waste storage and transportation at this location. In the event of an emergency or disaster, Pier 48 could provide a staging area for people waiting to evacuate from the City.

The pier is generally in good condition, except the apron that needs rehabilitation.

Pier 50 is a large pier that provides maritime, industrial, commercial, and emergency response services. The Maritime Administration Ready Reserve (MARAD) provides a critical fleet of roll-on/roll-off ships. These large vessels are designated to carry wheeled cargo

Photo 11.1 Piers along the Embarcadero. Flickr user bobglennan (CC BY-NC-ND 2.0)

Photo 11.2 Pier 48 at night. Dave Rauenbuehler (CC BY-NC 2.0)

such as cars, trucks, semi-trailer trucks, trailers, and railroad cars. They have ramps that enable vehicles to drive directly onto the ship and can be mobilized and at sea within 96 hours to respond to emergencies. These ships can also provide auxiliary power to the City and serve as emergency medical facilities in the event of a disaster. In addition to Pier 50, the MARAD fleet includes two vessels at Pier 80 and one vessel at Pier 96.

Westar Marine Services is headquartered at Pier 50 and provides a variety of marine services, including marine construction support, ship assist, barge and tanker escort, storage and delivery to vessels anchored in San Francisco Bay, ship staff water taxi service, offshore towing, and specialty barge services.

Additional commercial tenants at Pier 50 include private transportation companies. The southern edge of the pier provides transient and long-term lay berths (berths used for idle vessels). Pier 50 also houses the Port's primary maintenance facilities and personnel, including the more than 100 skilled craftspeople that are responsible for the preservation and improvement of the Port's fishing harbors, ferry landings, public parks, cargo terminals, piers, and baseball stadium.

The maritime and emergency response services provided at Pier 50 are important resources for the Port and City. Access to vessels from the pier would be moderately impacted by temporary flooding and highly impacted by permanent flooding, potentially eliminating the ability for the vessels to operate from Pier 50. Relocating the maritime assets may prove difficult as they require a waterfront location to operate. Additionally, the pier houses a significant number of Port maintenance shops and employees, which would be difficult, but not impossible, to relocate.

Pier 50 ½ is located south of Pier 50. It consists of small public access yacht clubs that include private guest docks for overnight mooring. The current tenants include Mariposa Hunters Point Boat Club and Bayview Boat Club. Marinas and guest docks are generally able to respond to a range of water levels and may be able to be adapted to address higher water levels. However, land-based auxiliary facilities and access to the yacht clubs could be limited by temporary and permanent flooding.

Pier 52 is a wooden pier in poor condition. It serves as a wave attenuator to the adjacent public boat launch, which is the City's only trailered boat launch (discussed in section 10.2).

Pier 54. The eastern side of Pier 54 is an open paved area where floats are built for various events, including Burning Man, Carnival, and Bay-to-Breakers. The pier also includes a shed that houses the American Red Cross, the Chinese Chamber of Commerce, and a variety of construction consultants. The pier also has a long-term lay berth. The current uses at the site could be relocated relatively easily.

Pier 68 is within the Union Iron Works Historic District and has historically provided maritime and industrial services. It consists of large ship dry docks, cranes, and industrial buildings, and has most recently been used for ship repair. The use of the pier could continue under temporary flooding scenarios as activities could resume after flood waters recede. However, permanent inundation would eliminate the ability to use the pier for ship repair. Pier 68 is part of the greater Pier 70 project described below and in Chapter 13, *A Changing Shoreline*.

Pier 70 (existing structures). Pier 70 is within the Union Iron Works Historic District due to its role in ship construction and repair over the last 150 years (Photo 11.3). Existing structures at the site have

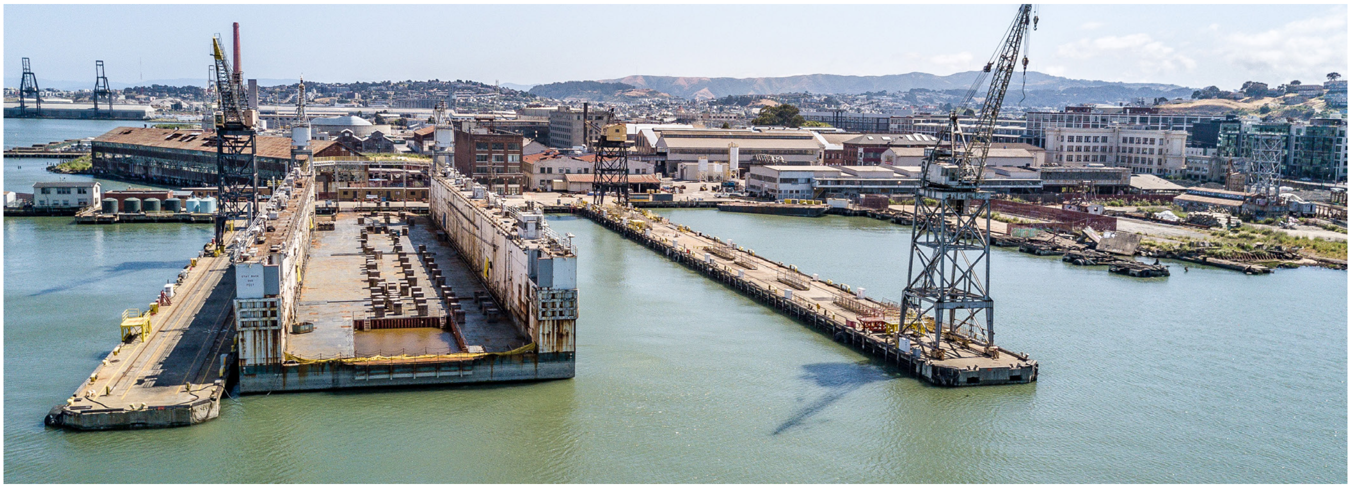


Photo 11.3 Existing structures on Pier 70. Jim Maurer (CC BY-NC-ND 2.0)

deteriorated over time and the pier itself is largely unused. However, a Port-led process to create a new, mixed-use development in the area is underway and is referred to as Pier 70. The Pier 70 project will revitalize the area east of Illinois Street extending from Mariposa to 22nd Street by rehabilitating historic resources, supporting ongoing ship repair, providing new waterfront parks and shoreline access, and creating space for new residential, office, retail, and production, design, and repair uses.[4] The Pier 70 project area encompasses Piers 68 and 70, and SWLs 349 and 3491. The project includes SLR adaptation components and is further described in Chapter 13, *A Changing Shoreline*. Additionally, information regarding potential hazards related to contaminated lands at Pier 70 is discussed in Chapter 9, *Public Safety*.

Pier 80 is a 60-acre working cargo pier with two warehouses, four deepwater berths, and two cranes used to offload materials from ships (Photo 11.4). The pier is primarily located on Bay fill and is not pile-supported except for the pier edges. It is connected to the San Francisco Bay Railroad, which connects to the regional Joint Powers Board Caltrain line that provides access to Union Pacific Railroad. The railroad serves as a conduit to move goods and materials from vessels to the regional railroad system and is critical to the City's emergency response and recovery plan. San Francisco Bay Railroad is described further in Section 11.3.

Pier 80 is included in FEMA's emergency response plan as a location for staging and moving debris following a disaster. It also serves as an oil spill response equipment storage location. The pier has been generally well maintained and its fendering and pilings are in good condition. However, issues related to fill settlement and stormwater drainage have led to ponding issues. This ponding may be exacerbated by SLR, resulting in additional flooding.

Pier 80 provides important maritime, industrial and disaster response services. It is the only pier that can unload materials from ships directly to railroad cars. Due to the importance of the pier and lack of redundancy of services elsewhere, Pier 80 is highly sensitive to both temporary and permanent flooding.

Pier 90 is located at the southern entrance of the Islais Creek Third Street and Illinois Street Bridges. The Pier 90 area consists of both pile-supported and "filled" pier areas using fill behind a seawall. It is used by the Port for maritime maintenance and is also home to San Francisco Fire Department Station 25. The vulnerability of fire stations to SLR is discussed in Chapter 9, *Public Safety*. In addition to the fire station, an Emergency Firefighting Water System manifold is located at Pier 90. Further information regarding the Emergency Firefighting Water System is described in Chapter 9, *Public Safety*. Additional industrial and commercial tenants are located at Pier 90 as well.

4 Port of San Francisco. 2010. Pier 70 Preferred Master Plan. Available at https://sfport.com/ftp/uploadedfiles/about_us/divisions/planning_development/southern_waterfront/pier70masterplan_intro-overview.pdf.

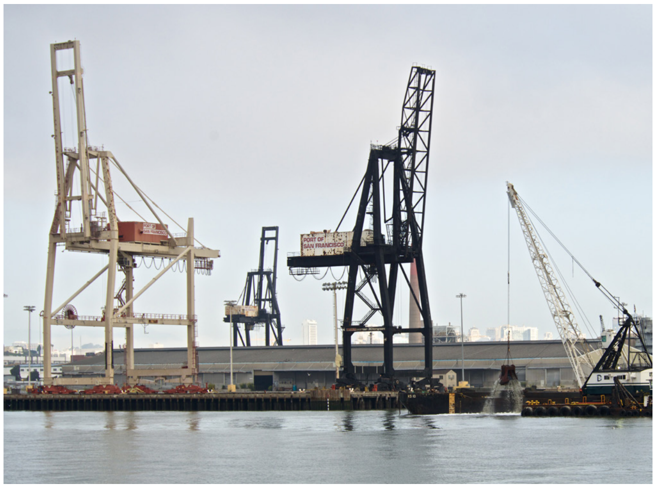


Photo 11.4 Pier 80 Cranes used to offload materials from ships. Dave Rauenbuehler (CC BY-NC 2.0)

Photo 11.5 Aerial view of sand storage site (front) and Recology recycling center (back) at Piers 94 and 96. Dave Rauenbuehler (CC BY-NC 2.0)

Pier 92 is leased by Hansen Aggregates, Cemex, and Central Concrete. Like Pier 90, Pier 92 is both pile-supported and filled land behind a seawall. The pier provides maritime services through cargo ship loading and includes two concrete batch plants that are the City's sole providers of concrete. These concrete plants are essential for both new commercial development and critical City infrastructure construction and maintenance. Both Cemex and Central Concrete bring their aggregate products over the Pier 92 docks for batching into concrete. Pier 92 could provide emergency response services with its large vessel berth. The Pier has not been evaluated for contaminants, but likely contains creosote-treated piles, similar to other piers.

This site provides essential industrial services. Most of its operations could continue under minor flooding of 12 inches or less. However, flooding could hinder some of the sustainability practices at the site, such as rain water harvesting and concrete recycling. Additionally, the distribution of concrete to project sites could be hindered if access roads are flooded.

Pier 94 is also leased by Hansen Aggregates and other similar industrial operations. The facility includes storage space for sand and aggregate materials delivered to Pier 94 or mined from the Bay and is connected to the San Francisco Bay Railroad (Photo 11.5). The location is identified by FEMA as a staging area for goods as well as a debris removal site in the event of a disaster. The industrial and emergency response services would be difficult to relocate or replace.

Pier 96. A Recology recycling center is located at Pier 96 (Photo 11.5). The pier also has a large open paved area currently under negotiations to be used as a roll-on/roll-off marine cargo terminal. The pier is connected to the San Francisco Bay Railroad. The site also includes a long term lay berth used by MARAD, Westar, and Silverado. Pier 96 is identified by FEMA as a staging area for goods as well as a debris removal site in the event of a disaster. The seawall on the south face of the pier is deteriorated and in need of repair. It is currently subject to flooding during extreme high tides and this flooding will become more severe as sea levels rise.

Pier 96 provides important community services, including recycling and emergency response, that could be impacted by both temporary and permanent flooding. The regional importance of the recycling center is discussed further in Chapter 9, Public Safety. As discussed in Section 11.3, rail is highly vulnerable to flooding and cannot operate if the tracks are not visible. The maritime, industrial, and emergency response services at Pier 96 would be difficult to relocate or replace.

11.1.1.2 SEAWALL LOTS

The Port's seawall lots (see Photo 10.3) originally served as backlands for cargo shipping, warehousing, cruise ships, and ferry operations or as railyard facilities.[5] Now, the Port leases out these spaces for a variety of uses, including storage space, artist work studios, restaurants, and maintenance facilities. The seawall lots' vulnerabilities to SLR vary based on their location and proximity to the Bay.

SWL 337. Seawall Lot 337 is the site of the 28-acre Mission Rock Mixed Use Development Project (Photo 11.6). The Mission Rock project includes approximately 2,000 residential units, one million square feet of commercial space, and 10 acres of new open space. The project plan includes SLR adaptation strategies that protect the mixed-use development to six feet of SLR. It also includes a buffer area that begins as a park space designed to accommodate temporary inundation and has a funding mechanism that will contribute to onsite and offsite SLR adaptation. The phasing of the development allows the site to continue to serve as surface parking to support Oracle Park and Chase Event Center games and events. Further detail on the Mission Rock project is included in Chapter 13, *A Changing Shoreline*. SWL 337 could serve as a staging area for people waiting to evacuate after an emergency or disaster.

SWL 343. Seawall Lot 343 (also known as Mission Bay Parcel P23/24) includes a small park and an SFMTA substation and provides stormwater benefits to the area. The park includes green space and a basketball court. The substation has sewer, fuel, electrical, and communication utility lines running through it and provides power to the T and Central Subway Muni lines. In addition to providing open space and housing the substation, Seawall Lot 343 provides stormwater treatment for the Mission Bay southern watershed, including the University of California, San Francisco (UCSF) Medical Center at Mission Bay. Stormwater flows through a gravity system to the northern portion of site (referred to as P23) and is then pumped to the southern portion of the site (referred to as P24) for treatment in landscape swales before being released into the Bay.

5 Port of San Francisco. 2017. Waterfront Plan Land Use Subcommittee Slideshow, "Port Seawall Lots" June 7. Available at https://sfport.com/sites/default/files/2017-06-07%20Presentation%20on%20Seawall%20Lots-%206-7-17%20NOTES_0.pdf.

Photo 11.6 Rendering of Mission Rock development on SWL 337. Perkins&Will

Flooding of this area could have major implications for mobility and stormwater management in Mission Bay. If the electrical equipment in the substation were to flood, the substation may no longer function. While waterproofing and moving water-sensitive components, such as electrical equipment, out of the flood zone could reduce the risk of temporary flooding, a larger-scale strategy may be needed to reduce disruption and damage to the substation. Inundation of the area could also limit the function of the stormwater treatment system and lead to stormwater management issues for the Mission Bay southern watershed, resulting in degradation of the water quality entering the Bay after a storm.

The park's bioswale and bioretention areas were designed to integrate with a nearby pump station, which collects runoff from a drainage basin area. The remainder of the park is used for active and passive recreation. The park was not designed to accommodate temporary flooding associated with SLR or coastal flooding; therefore, the landscaping and other surfaces could be disrupted and possibly damaged by temporary coastal flooding. Such temporary flooding would also increase maintenance and operations needs for the park.

SWL 345. Seawall Lot 345 houses a restaurant, a small private boatyard leased by San Francisco Boatworks, self-storage units, and the Ruby Sailing Charter Company. The restaurant has a dock that guests can sail directly up to. Ruby Sailing is also operated out of the dock. The lot includes parking for the restaurant and boatyard as well.

The boatyard and restaurant may be able to continue operations with localized flooding by using deployable flood measures during high water events and flood proofing the facilities to reduce damage during temporary flood events. However, as flooding becomes more frequent and widespread, access to the area becomes unreliable, maintenance and operations costs would increase, and the costs of disruption and damage would increase. Once the flooding become a daily tidal event, the uses would need to be adapted or lost. Additionally, flooding of the boatyard could mobilize hazardous materials that are used by the boatyard, degrading water quality.

SWL 349 and 3491. As mentioned above, Seawall Lots 349 and 3491 are part of the greater Pier 70 project (described in Chapter 13, *A Changing Shoreline*). The Pier 70 project includes remediation of environmental contamination as well as SLR adaptation measures. Chapter 9, *Public Safety*, includes additional information regarding potential hazards related to contaminated lands.

SWL 356. Seawall Lot 356 is currently rented by a self-storage company. Using deployable flood measures during high water events could reduce the damage and disruption to the facility from localized flooding . Nonetheless, it may prove challenging to fully flood proof the facility, and inundation of stored items could occur. As flooding becomes more frequent and widespread, access to the area would become unreliable, maintenance and operations costs would increase, and the costs of disruption and damage would also increase. Because self-storage does not require a waterfront location, this use could be relocated. Future plans for this site include allocating two acres to the expansion of Warm Water Cove Park and using the remaining six acres to expand the Pier 80 Cargo Terminal.

SWL 344 E and 344 W. Seawall Lots 344 East and West, also referred to as the Pier 90-96 Backlands, were recently improved by elevating the sites approximately 12 feet on the northern and eastern boundaries, except for the location of Darling Delaware, an industrial facility that repurposes meat byproducts and processes them to reclaim bio-nutrients, fats, oils, proteins, meals, and other by-products. Currently, the site has four primary uses that include:

1. Building resources at the northwest corner, which is under lease to the San Francisco Department of Environment for building material recycling;

2. A lease to Darling Delaware for industrial use;

3. Concrete crushing and recycling; and

4. A self-storage facility.

Future tenants for the recently improved areas include construction laydown space. In the long-term, this site will likely become warehouse space to

Photo 11.7 **Mission Creek houseboats.** Travis Wise (CC BY 2.0)

support cargo operations and help meet the City's demand for production, distribution, and repair uses.

SWL 352. Seawall Lot 352 hosts Hanson Aggregates, which provides sand import and processing. It also has a tidal wetland and buffer area (referred to as the Pier 94 wetlands) that provides open space and habitat. Future development plans include the development of an asphalt batch plant or expanded Hanson Bulk cargo import operations.

SWL 354. The Islais Creek Division SFMTA facility, completed in June 2018, is located at SWL 354. The eastern portion is Port-owned and leased to SFMTA. The facility houses a bus yard, fuel wash facility, and operations center. The development also included the construction of Islais Creek North-West Park, a shoreline park with art installations.

11.1.1.3 Mission Creek Harbor

Mission Creek Harbor includes a community of approximately 20 houseboats moored on docks (Photo 11.7). The community has been present since the 1960s when it was relocated from Islais Creek. The harbor is also home to a wide variety of wildlife, including shorebirds, manta rays, and sea lions.

Harbors and marinas are usually able to accommodate higher water levels, but the support facilities would be sensitive to disruption. The utilities have been designed to accommodate SLR and flooding. However, permanent inundation would eliminate the ability to use the site, and due to its water-dependent nature, the harbor would not be easy to relocate. Higher water levels would make it difficult for this use to remain without a larger-scale intervention.

11.1.2 Port Structures Exposure

The exposure of piers, wharves, bulkhead buildings, seawall lots, and harbors was evaluated relative to the 10 SLR scenarios defined in Chapter 2, *Climate Science*. The percentage and area of each asset that would be inundated under each scenario were calculated and are presented in Tables 11.3 and 11.4, respectively.

Table 11.3 Pier and Harbor Exposure with Sea Level Rise (% Inundated and Area Inundated)

Port Structure	Pier and Harbor Exposure under Each Scenario (% Inundated)									
	1	2	3	4	5	6	7	8	9	10
Pier 48	0%	0%	0%	0%	5%	12%	100%	100%	100%	100%
Pier 50	0%	0%	0%	0%	0%	4%	100%	100%	100%	100%
Pier 50 1/2	3%	7%	15%	32%	39%	72%	86%	87%	87%	87%
Pier 52	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%
Pier 54	0%	0%	0%	0%	1%	1%	99%	99%	99%	99%
Pier 62	3%	8%	13%	24%	28%	56%	72%	83%	97%	97%
Pier 68	1%	2%	3%	7%	8%	56%	76%	82%	89%	91%
Pier 70	0%	0%	0%	0%	0%	0%	0%	85%	85%	85%
Pier 80	0%	0%	0%	1%	52%	77%	93%	95%	98%	99%
Pier 90	0%	0%	0%	1%	66%	85%	86%	86%	86%	86%
Pier 92	0%	0%	0%	18%	31%	90%	97%	97%	97%	97%
Pier 94	0%	0%	1%	17%	21%	42%	54%	59%	71%	79%
Pier 96	3%	16%	28%	55%	61%	75%	84%	88%	93%	96%
Mission Creek Harbor	1%	1%	1%	1%	1%	2%	2%	2%	2%	2%

Port Structure	Pier and Harbor Exposure under Each Scenario (Acres Inundated)									
	1	2	3	4	5	6	7	8	9	10
Pier 48	0.00	0.00	0.01	0.02	0.28	0.70	5.96	5.96	5.96	5.96
Pier 50	0.00	0.00	0.00	0.00	0.00	0.85	20.09	20.09	20.09	20.09
Pier 50 1/2	0.04	0.09	0.20	0.41	0.50	0.93	1.12	1.13	1.14	1.14
Pier 52	0.00	0.00	0.00	0.00	0.57	0.57	0.57	0.57	0.57	0.57
Pier 54	0.00	0.00	0.00	0.00	0.01	0.02	2.66	2.66	2.66	2.66
Pier 62	0.05	0.11	0.18	0.33	0.38	0.75	0.98	1.13	1.32	1.32
Pier 68	0.13	0.36	0.76	1.53	1.79	12.78	17.31	18.67	20.23	20.66
Pier 70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.59	2.59	2.59
Pier 80	0.02	0.05	0.09	0.50	34.28	50.75	61.11	62.99	64.38	65.51
Pier 90	0.00	0.00	0.00	0.14	7.20	9.36	9.43	9.44	9.46	9.47
Pier 92	0.01	0.01	0.02	1.29	2.21	6.31	6.82	6.83	6.83	6.83
Pier 94	0.01	0.02	0.35	4.30	5.49	10.84	14.01	15.40	18.47	20.54
Pier 96	1.39	8.54	14.57	28.51	31.71	38.99	44.00	46.10	48.29	49.94
Mission Creek Harbor	0.09	0.13	0.17	0.20	0.21	0.25	0.26	0.26	0.26	0.26

Table 11.4 Seawall Lot Exposure with Sea Level Rise (% Inundated and Area Inundated)

Seawall Lot Number	Seawall Lot Exposure under Each Scenario (% Inundated)									
	1	2	3	4	5	6	7	8	9	10
Seawall Lot 337	0%	0%	0%	54%	65%	98%	100%	100%	100%	100%
Seawall Lot 343	0%	0%	0%	0%	0%	29%	98%	100%	100%	100%
Seawall Lot 345	6%	20%	27%	49%	59%	87%	91%	94%	97%	97%
Seawall Lot 349	0%	1%	1%	2%	2%	22%	41%	53%	78%	84%
Seawall Lot 3491	0%	0%	0%	0%	0%	5%	100%	100%	100%	100%
Seawall Lot 349	0%	0%	0%	0%	0%	1%	28%	52%	64%	70%
Seawall Lot 356	0%	0%	0%	0%	0%	0%	12%	37%	78%	98%
Seawall Lot 356	0%	1%	1%	9%	13%	27%	37%	44%	67%	76%
Seawall Lot 344-East	0%	0%	0%	15%	24%	43%	51%	58%	60%	61%
Seawall Lot 344-West	0%	0%	0%	0%	29%	98%	100%	100%	100%	100%
Seawall Lot 352	8%	9%	10%	13%	14%	17%	20%	22%	27%	32%
Seawall Lot 354	0%	0%	0%	0%	77%	85%	90%	93%	100%	100%

Seawall Lot Number	Seawall Lot Exposure under Each Scenario (Acres Inundated)									
	1	2	3	4	5	6	7	8	9	10
Seawall Lot 337	0.00	0.00	0.00	7.97	9.54	14.51	14.76	14.76	14.76	14.76
Seawall Lot 343	0.00	0.00	0.00	0.00	0.00	0.32	1.07	1.09	1.09	1.09
Seawall Lot 345	0.25	0.86	1.17	2.09	2.53	3.72	3.91	4.02	4.15	4.16
Seawall Lot 349	0.14	0.28	0.42	0.63	0.72	7.82	14.97	19.16	28.30	30.41
Seawall Lot 3491	0.00	0.00	0.00	0.00	0.00	0.01	0.27	0.27	0.27	0.27
Seawall Lot 349	0.00	0.00	0.00	0.00	0.00	0.02	0.49	0.92	1.14	1.24
Seawall Lot 356	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.90	1.91	2.39
Seawall Lot 356	0.05	0.12	0.20	1.27	1.83	3.67	5.16	6.05	9.25	10.49
Seawall Lot 344-East	0.00	0.00	0.00	2.58	4.27	7.59	9.06	10.37	10.59	10.75
Seawall Lot 344-West	0.00	0.00	0.00	0.00	0.27	0.93	0.95	0.95	0.95	0.95
Seawall Lot 352	3.51	3.99	4.73	6.02	6.42	7.71	9.23	10.28	12.17	14.50
Seawall Lot 354	0.00	0.00	0.00	0.00	1.22	1.36	1.43	1.49	1.59	1.59

11.1.3 Port Structures Vulnerability Summary

The vulnerability of Port structures to SLR varies for temporary and permanent inundation and is highly depending on the assets' characteristics.

Piers 80, 92 and 94 provide important industrial services that require access to marine terminals. These piers experience significant flooding beginning at SLR Scenario 4 (48 inches of SLR or six inches of SLR and a 100-year extreme tide) and Scenario 5 (52 inches of SLR, or 12 inches of SLR and a 100-year extreme tide). With 52 inches of SLR, 52 percent of Pier 80, 31 percent of Pier 92, and 21 percent of Pier 94 would become inundated.

While many of the activities at these piers could likely resume after floodwaters recede, temporary and localized flood events will result in damage and disruption to the structures and their uses. This damage and disruption will increase as flooding becomes more frequent, resulting in higher maintenance and operations costs, and direct costs associated with the disruption, loss of function, and water quality impacts. Permanent flooding associated with flooding that occurs daily would require adaptation measures or the loss of function. These areas are some of the last remaining industrial and heavy maritime functions in San Francisco and if they are lost, these functions and the associated jobs and opportunities associated with them may also be lost.

Over 55 percent of Pier 96 will be inundated at approximately 48 inches of additional water, or Scenario 4. Pier 96 is the location of Recology, the City's recycling facility. This is a large, critical facility that may be hard to relocate and would be vulnerable to temporary inundation with damage and disruption to both the facility and the function.

The harbor and boatyards have limited redundancy and would be difficult to relocate. While the Mission Creek harbor houseboats are located on the water and will not themselves be flooded, the surrounding areas begin to flood significantly at Scenario 4 (48 inches of SLR or six inches of SLR and a 100-year extreme tide). This would limit access to houseboats and use of auxiliary equipment.

The connection with the San Francisco Bay Railroad and regional transportation network on Piers 80, 92, 94, and 96 and Seawall Lots 354 E and W, and 355, provides a unique service that lacks redundancy and requires proximity to the shoreline. As previously mentioned, Pier 80 experiences significant flooding beginning at Scenario 5 (52 inches of SLR). The pier's function would be reduced and its ability to transport goods on the San Francisco Bay Railroad would be eliminated as the tracks would become flooded with up to four feet of water. This vulnerability is further discussed in Section 10.3, Port Transportation.

Vulnerability is dependent on the location of the asset. Piers and boatyards located over water experience a higher level of impact from SLR from flooding. Additionally, they are more vulnerable to tidal, wind, and wave hazards that could damage pilings and reduce the use of the facility.

Even if the asset itself could withstand temporary or permanent flooding, if access to the asset is limited, the function of the asset would be lost.

11.1.4 Port Structures Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3, Assessment Approach) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below. However, several actions are currently planned or in progress to address some of the noted impacts. For a description of the current or planned projects, see Chapter 13, *A Changing Shoreline*.

KEY ISSUE 1: LOSS OF PORT USES AND SERVICES

Inundation of Port structures or surrounding areas would impact the function and character of the City's waterfront and the Port's Public Trust responsibilities for the State of California. The Port's maritime, water-dependent, public access, open spaces, and historic resources are all part of its Public Trust mission and the loss of these facilities and services would be a significant impact to the State and the City.

The degree of impact varies depending on each structure's elevation, condition, and use, and the type of flooding. Temporary and localized flooding, flooding that increases in frequency, duration, and economic scale, and permanent flooding (or flooding that occurs once a day) will result in different consequences. All types of flooding will reduce access, increase disruption, result in damage to facilities and functions, and increase maintenance and operations costs.

Many of the uses in the southern waterfront are dependent on automobile, truck, and rail access and would become inaccessible if adjacent roads are flooded. Increased frequency and duration of flooding would disrupt business continuity, resulting in losses for those businesses, and directly impact employees as well as other businesses and patrons that rely on those businesses.

Permanent inundation would eliminate these facilities, and the community and economic benefits they provide. Permanent inundation would be especially harmful to industrial operations, which are primarily confined to the southern waterfront, maritime operations, which require a waterfront location to operate, and critical emergency response services. Disruption and damage to industrial and maritime facilities and functions would result in a loss of jobs in these sectors, as well as impacts to small businesses that provide services to these facilities. Damage to critical emergency response facilities and services would impact both community and citywide response and recovery.

Society and Equity: Many Port structures provide emergency response services in the event of a disaster such as an earthquake. These structures are identified by FEMA and the City as staging areas for people and supplies, medical response centers, water-based evacuation locations, and debris removal sites. If these facilities are flooded, or are inaccessible due to flooding, their use for emergency response would become limited resulting in delays in response times and dangers to public safety. An additional discussion of emergency response services is provided in Chapter 9, *Public Safety*.

Piers 48, 50, 50 ½, 68, and 70 are part of historic districts or have potential historic features that pay homage to the rich maritime and industrial history of the area. Historic preservation is a fundamental function of the Port as a steward of the Public Trust. These structures contribute to the nature and character of the waterfront and are an important resource to the City and nation. Flooding of these structures could damage the historic attributes and result in a loss of designation for the City's Historic District or damage to these districts.

All the City's recycling is processed by Recology's waste management facility at Pier 96. Disruption to this facility could have a citywide impact on waste collection and recycling, impacting public health and citywide environmental stewardship goals. The reduction in recycle processing would require alternate means to manage the recycling of waste generated across San Francisco. This is a critical City facility that may be hard to relocate. Temporary inundation would result in disruption to this critical function. More frequent and widespread flooding would result in disruption, damage, and environmental consequences.

Economy: The southern waterfront is home to much of the City's remaining industrial sites. Pier 92 hosts two concrete batching plants that supply a significant amount of concrete to the City. Disruption of concrete batching due to flooding could cascade across the building industry. Additionally, structures in the southern waterfront have several commercial tenants. Disruption to these structures would harm the local economy.

The loss or inability of Port structures to provide industrial, maritime, and commercial uses would also impact local and regional jobs. A significant number of local jobs and businesses rely on these facilities and functions. The loss of these facilities would have significant impacts from neighborhood to regional scale.

Environment: Parking lots and other surfaces on piers and SWLs accumulate oil and other hazardous materials from vehicular use. Flooding could mobilize these contaminants by washing them into parks, open spaces, wetlands, and the Bay.

SLR could limit some of the function of the stormwater management systems installed on seawall lots. This could lead to greater flooding issues at a watershed scale and result in lower-quality water entering the Bay after a storm.

The loss of the wetlands and natural areas in the southern waterfront would eliminate the remaining natural resources along this segment of the Bay shoreline.

Many areas in the southern waterfront are home to past contaminants. Current uses also store industrial and maritime material that if mobilized by a flood event could have water and soil quality impacts.

Governance: Addressing the consequences of flooding and planning for future SLR adaptation will require coordination between multiple agencies at various levels of government. This includes coordination and cooperation with the adjacent neighborhoods, City agencies, BCDC, State Lands Commission, U.S. Army Corps of Engineers, and other agencies. Due to multi-agency involvement, and various permit and other approval requirements, action to address SLR could take a significant period.

Additionally, the Port leases land to tenants including private companies, City agencies, and the U.S. military, and coordination with these tenants will be important. While the Port is the owner of these lands, many are operated by the tenants. Management decisions related to addressing the consequences of flooding and planning for future SLR adaptation could complicate lease terms and will require additional coordination with tenants.

Figure 11.2
Overview of Port-Owned Open Space Assets

1. China Basin Park
2. Mission Creek Shoreline Park South
3. Pier 52 Boat Launch
4. Bayfront Park
5. Agua Vista Park
6. Warm Water Cove Park
7. Islais Creek Parks
8. Bayview Gateway Park
9. Pier 94 Wetlands
10. Pier 98 - Herons Head Park

Inundation at 108" Sea Level Rise

11.2 PORT PUBLIC OPEN SPACE

San Francisco's Bay shoreline is home to a variety of public open spaces including parks, plazas, the waterfront promenade, the Blue Greenway and the San Francisco Bay Trail, open water basins, wetlands, and the Bay Area Water Trail (which connects with the Bay Trail). The Port owns and operates most parks and open spaces located along the eastern waterfront. The Port-owned assets located within the SLR Vulnerability Zone include boat launches, plazas, parks, and wetlands. These are shown on Figure 11.2 and discussed in Section 11.2.1. Table 11.5 summarizes the Port use type categories for each asset.

In addition to Port-owned parks, there are several other parks along the Bayside waterfront, including India Basin Shoreline Park, Aquatic Park, and the San Francisco Maritime National Historic Park. India Basin Shoreline Park (see Photo 10.2) is owned by both the Port and the San Francisco Recreation and Park Department (RPD) and is further discussed in Chapter 10, Open Space. The public open spaces assessed in this section include those in the SLR Vulnerability Zone located south of the Embarcadero Seawall Program area.

11.2.1 Potentially Vulnerable Public Open Space Assets

A description of the various public open space assets and their vulnerabilities is included below.

China Basin Park

China Basin Park is a public park located at the mouth of Mission Creek, across the channel from AT&T Park. It includes picnic areas and a small baseball diamond.

Mission Creek Shoreline Park South

Mission Creek Shoreline Park South runs parallel to the southern shore of Mission Creek. It features walking paths, picnic areas, and community gardens (Photo 11.8).

This park, along with Mission Creek Shoreline Park North (outside of the assessment area), provides viewing and access to Mission Creek. Although the channel between the two parks has been significantly altered, it is the last remnant of the original Mission Bay formed by Mission Creek, and it still supports wildlife. The Mission Creek Harbor Association, located on a portion of its south bank, harbors recreational boats and houseboats (Section 11.1.3), and developed and maintains a landscaped public access area along the adjoining channel shoreline.

Table 11.5 Port Structure Assets by Use Category

Asset	Port Use Category								
	Natural Resources and Open Spaces	Historic District	Maritime	Industrial	Commercial	Residential	Emergency Response	Utilities	Transportation
China Basin Park	●							●	
Mission Creek Shoreline Park South	●		●		●			●	●
Pier 52 Boat Launch	●		●				●	●	●
Bayfront Park	●			●					●
Agua Vista Park	●		●						●
Warm Water Cove Park	●								
Islais Creek Parks	●								
Bayview Gateway Park	●								
Pier 94 Wetlands	●								
Pier 98 - Herons Head Park	●								

Photo 11.8 Mission Creek Shoreline Park South. Sergio Ruiz

Pier 52 Boat Launch

The Pier 52 boat launch is a public facility that also includes a parking lot. Docks and launches are designed to accommodate higher water levels temporarily. Permanent inundation would eliminate the use at this location. Docks and launches are highly adaptable to higher water levels. At permanent inundation levels, the landside services and support will be harder to adapt and protect.

The boat launch is an important asset as there are a limited number of public boat launches in San Francisco. Furthermore, this is the only public motorized boat launch in the City. In addition to providing important public access to the Bay, the boat launch is used by the Port maintenance crews as launch access for pier maintenance activities and emergency response. The boat launch would be sensitive to flooding and would need to be raised to adapt to SLR.

Bayfront Park

Bayfront Park is currently a large open lot with parking and a bike path. The park will be improved and expanded as part of the Mission Bay Redevelopment Plan, as described below.

Agua Vista Park

Agua Vista Park is a small landscaped park and fishing pier located in Mission Bay (Photo 11.9). It includes picnic benches and public art. The park will be redesigned and upgraded in 2020 to incorporate stormwater treatment and shoreline protection measures. Upgrades do not change the current uses and facilities at the park but include elevating the site for added shoreline protection.

Warm Water Cove Park

Warm Water Cove Park consists of open space and walking paths adjacent to the shoreline. The Port and City plan to expand and rehabilitate the park in the future to the Southwest.

Islais Creek Parks

Several Port open space assets are located adjacent to Islais Creek (Photo 11.10). The northern shoreline includes Islais Creek North-West and Tulare Park. Islais Creek North-West provides public access to Islais Creek and connects the northern shoreline of Islais Creek between I-280 and Cesar Chavez to Tennessee Street. This provides nearly continuous shoreline access around Islais Creek. It includes the SFPUC promenade, located on Port property, and the SFMTA promenade, located primarily outside of Port property. Tulare Park is a small park located east of Third Street that provides additional shoreline access.

The southern shoreline includes Islais Creek South, also referred to as Islais Landing. Islais Landing is a small park that includes a picnic area, a

Photo 11.9 Agua Vista Park. Flickr user sfworldsfair

Photo 11.10 Islais Creek Parks. Port of San Francisco

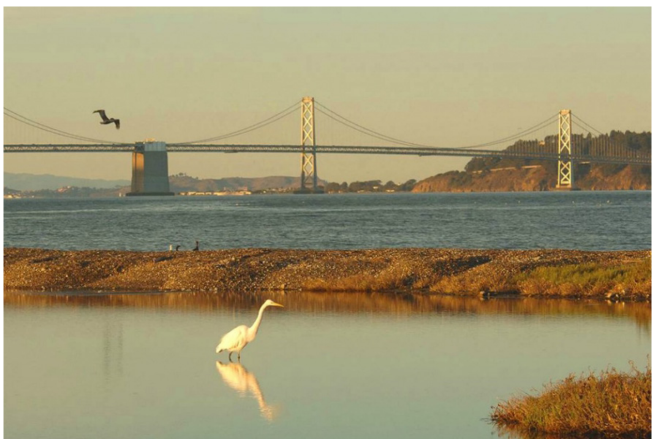


Photo 11.11 Pier 94 Wetlands. Port of San Francisco

Photo 11.12 Heron's Head Park. Port of San Francisco

human-powered boat landing, and storage for small watercrafts. Currently, the park and boat landing are maintained by a cooperative paddling club which stewards the park in exchange for space in the boat storage area.

Bayview Gateway

Bayview Gateway is a small public open space behind San Francisco Fire Department Station 25. The park contains several picnic tables and views of Islais Creek. This park was constructed in 2015 and the design includes and elevated wharf edge to protect the area to an elevation of two feet.

Pier 94 Wetlands

The wetlands at Pier 94 developed when a small salt marsh formed along the northeast shore of Pier 94 after a portion of the pier's fill material subsided and became subject to tidal inundation (see Photo 11.11).

The Port completed the Pier 94 wetland enhancement project in 2006 to improve the physical, hydrologic, and aesthetic features of the wetland in order to increase its functional ecosystem value. Now, these small wetlands provide rare and valuable salt marsh habitat for a variety of plant and animal species, including migratory birds. Along with the Port, the Golden Gate Audubon Society works to continue to restore and protect the wetlands. The Golden Gate Audubon Society adopted the wetlands and hosts regular volunteer events and wildlife viewing events.

Heron's Head Park

Heron's Head Park is a 24-acre park that includes salt marsh habitat, ecosystem restoration activities, walking paths, bird watching, and environmental activities (Photo 11.12). The EcoCenter at Heron's Head Park is a community facility located at the park.

Table 11.6 Open Space Exposure with Sea Level Rise (% inundated and area inundated)

Open Space Asset	Open Space Exposure under Each Scenario (% Inundated)									
	1	2	3	4	5	6	7	8	9	10
China Basin Park	4%	8%	12%	19%	22%	58%	77%	86%	97%	97%
Mission Creek Shoreline South	2%	4%	10%	40%	52%	79%	88%	91%	95%	97%
Mission Creek Shoreline Garden	0%	0%	1%	4%	8%	68%	99%	100%	100%	100%
Pier 52 Boat Launch	4%	10%	21%	39%	46%	67%	78%	80%	81%	81%
Bayfront Park	4%	7%	12%	23%	38%	86%	88%	88%	88%	88%
Agua Vista Park	3%	7%	10%	16%	20%	52%	72%	81%	85%	85%
Agua Vista Park Pier	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Warm Water Cove Park	2%	5%	7%	10%	11%	15%	18%	21%	28%	42%
Islais Creek North (PUC Promenade)	0%	0%	0%	0%	30%	36%	57%	69%	99%	100%
Islais Creek North (MTA Promenade)	0%	0%	0%	0%	99%	100%	100%	100%	100%	100%
Tulare Park	0%	0%	0%	0%	53%	64%	80%	92%	97%	99%
Islais Creek South (Islais Landing)	0%	0%	0%	0%	67%	92%	95%	96%	96%	96%
Bayview Gateway	0%	0%	0%	0%	70%	94%	96%	96%	98%	99%
Pier 94 Wetlands	49%	54%	58%	62%	64%	70%	77%	81%	86%	90%
Heron's Head Park	44%	51%	56%	60%	61%	64%	67%	69%	72%	74%
Heron's Head Extension	0%	0%	0%	0%	0%	0%	2%	9%	22%	44%

Open Space Asset	Open Space Exposure under Each Scenario (Acres Inundated)									
	1	2	3	4	5	6	7	8	9	10
China Basin Park	0.08	0.17	0.25	0.40	0.46	1.19	1.58	1.77	2.00	2.00
Mission Creek Shoreline South	0.07	0.16	0.40	1.66	2.15	3.29	3.65	3.75	3.92	4.02
Mission Creek Shoreline Garden	0.00	0.00	0.00	0.01	0.03	0.25	0.36	0.37	0.37	0.37
Pier 52 Boat Launch	0.03	0.07	0.16	0.30	0.36	0.52	0.61	0.62	0.63	0.63
Bayfront Park	0.08	0.16	0.26	0.53	0.86	1.95	1.99	1.99	1.99	1.99
Agua Vista Park	0.02	0.04	0.06	0.08	0.11	0.28	0.39	0.44	0.46	0.46
Agua Vista Park Pier	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Warm Water Cove Park	0.04	0.08	0.11	0.16	0.17	0.23	0.29	0.33	0.44	0.67
Islais Creek North (PUC Promenade)	0.00	0.00	0.00	0.00	0.26	0.32	0.51	0.61	0.88	0.89
Islais Creek North (MTA Promenade)	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.30	0.30	0.30
Tulare Park	0.00	0.00	0.00	0.00	0.15	0.18	0.23	0.26	0.27	0.28
Islais Creek South (Islais Landing)	0.00	0.00	0.00	0.00	0.67	0.92	0.95	0.96	0.96	0.96
Bayview Gateway	0.00	0.00	0.00	0.00	1.02	1.36	1.39	1.40	1.42	1.44
Pier 94 Wetlands	5.32	5.81	6.28	6.67	6.85	7.57	8.28	8.71	9.23	9.74
Heron's Head Park	8.86	10.17	11.24	12.04	12.18	12.87	13.36	13.75	14.31	14.78
Heron's Head Extension	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.12	0.32	0.64

The EcoCenter is owned and maintained by the Port and is operated by The Bay Institute Aquarium Foundation. It provides educational services and activities related to renewable energy, pollution and greenhouse gas reduction, wastewater treatment, rainwater harvesting, sustainability, and the green economy.

The Port is currently working on a plan to protect the park with a living shoreline (vertical levy) to reduce current erosion and address SLR projections to approximately 2050. If successful, the Port will have the project completed in 2021, which will protect portions of the park for two feet of SLR.

11.2.2 Public Open Space Exposure

The exposure of public open space areas was evaluated relative to the 10 SLR scenarios defined in Chapter 2, *Climate Science*. The percentage and area for each asset that could be inundated under each scenario were calculated and are presented in Table 11.6.

11.2.3 Public Open Space Vulnerability Summary

The Port's public open spaces provide recreation, shoreline access and bay access to San Francisco residents and visitors from the Bay Area and beyond. These public open spaces also provide environmental benefits including wildlife habitat and stormwater treatment.

Because most of the Port's open spaces are located adjacent to the shoreline, they are exposed early to SLR. In fact, many of these areas already experience increased inundation and erosion. Several open spaces, specifically the Pier 94 wetlands and Heron's Head Park, experience significant flooding beginning at SLR Scenario 1 (12 inches of SLR or an annual extreme high tide with a 1-year recurrence interval). At SLR Scenario 5 (52 inches of SLR, or 12 inches of SLR and a 100-year extreme tide) and Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide), the majority of Port open space areas become significantly flooded.

Some of the parks and open space assets and services are highly sensitive to both temporary and permanent flooding. In many cases, this is because the vegetation, habitat, and landscaping present are salt-sensitive or sensitive to periods of inundation. Localized, temporary inundation might be accommodated by some of these spaces. This would require additional Port maintenance and operations staff and resource time to address. As water levels rise and park closures and flood damage increase, the services provided by the Port's public open spaces and habitat assets would be lost even before permanent flooding eliminates the use of shoreline open spaces.

Park space and other open space assets are limited and highly valued in San Francisco both generally and along the waterfront. There is no redundancy for these areas and these parks and natural areas would be difficult to move elsewhere in the City, particularly due to their water dependence.

11.2.4 Public Open Space Consequence Summary

Key consequences were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below. However, several actions are currently planned or in progress to address some of the noted impacts. For a description of the current or planned projects, see Chapter 13, *A Changing Shoreline*.

Key Issue: Port public open spaces provide important parks and shoreline access for visitors and communities located in the southern waterfront. Heron's Head Park and the EcoCenter are valuable resources to the Bayview community due to proximity and lack of other resources in the area. The Pier 52 boat launch is the only public launch point in San Francisco's Bayside waterfront. Damage to the boat launch would impact public access to the Bay. Shoreline areas and the Pier 94 wetlands include tidal salt marsh and upland habitat that provide food and shelter for a variety of shorebirds and foraging habitat for raptors. These public open space areas are sensitive to flooding and the loss of their functionality would impact the environment as well as access for local communities.

11.3 PORT TRANSPORTATION

The Port plays an important role in local and regional transportation. Port facilities host ferry terminals, maritime berths, streets, parking lots, boat ramps, and bicycle and pedestrian paths. It also provides a connection to the regional rail network through the San Francisco Bay Railroad.

There are critical connections between the southern and northern parts of the City located in this geography. Several of these are bridges that are located within Port jurisdiction. These bridges include the Third and Fourth Street bridges that cross the Mission Creek Channel and the Illinois Street and Islais Creek/ Third Street bridges that cross Islais Creek. Most streets located along the waterfront are on Port-owned land. While some streets are maintained by the Port, the majority are maintained and managed by Public Works, SFPUC, and SFMTA.

This section focuses on the Port's railroad assets and maritime berths. The other transportation assets located on Port property are managed and operated by Public Works and other agencies, and are assessed in Chapter 5, *Transportation*. Figure 11.3 shows the San Francisco Bay Railroad and the SLR Vulnerability Zone and the maritime berthing inventory for the southern waterfront.

11.3.1 Potentially Vulnerable Transportation Assets

11.3.1.1 San Francisco Bay Railroad

San Francisco Bay Railroad is an independently owned and operated short line railroad that has operations in San Francisco and Richmond, California. For over a decade, the Port has contracted with the railroad to provide railroad services and rail terminal operations. San Francisco Bay Railroad operates on Port land at Piers 92, 94, 96, and 80 and at the Port's railyard, the Intermodal Container Transfer Facility, adjacent to Seawall Lots 344 East and 352. It hauls soils and other cargos to and from the railyard for interchange with Union Pacific Railroad via the Caltrain line where it can then be transferred to other regions of the United States. The railroad's primary business is transporting contaminated soils and debris from various large construction projects in San Francisco to a landfill in Utah.

San Francisco Bay Railroad is an important asset that lacks redundancy (see Photo 11.13). In addition to providing an important industrial service, it keeps hundreds of trucks off City roads and regional freeways. It could also provide emergency response service by hauling away debris or providing support for reconstruction following an earthquake or other disaster.

Photo 11.13 San Francisco Bay Railroad at Pier 80. Dave Rauenbuehler (CC BY-NC 2.0)

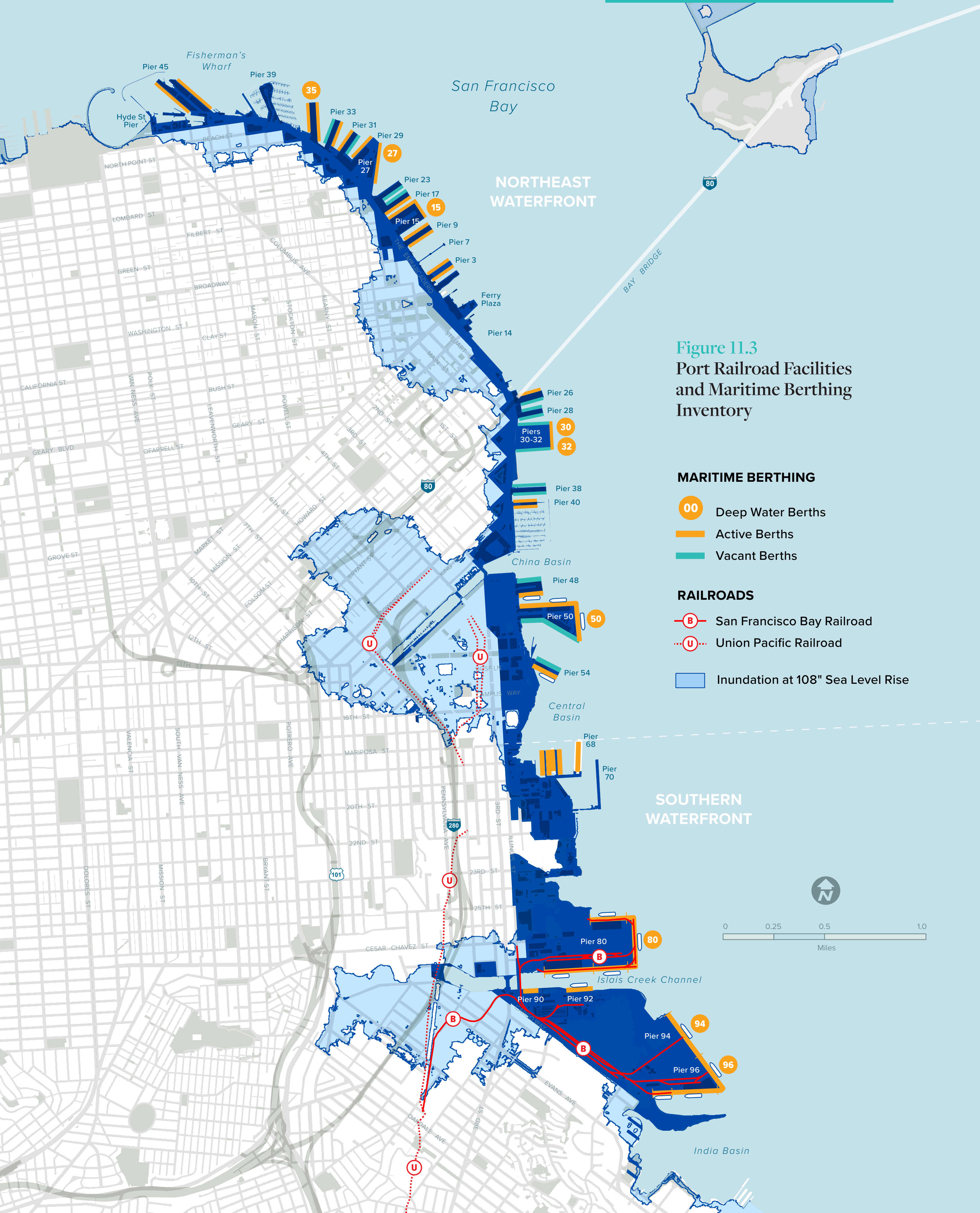


Figure 11.3
Port Railroad Facilities and Maritime Berthing Inventory

Photo 11.14 Ship docked at Pier 80. Dave Rauenbuehler (CC BY-NC 2.0)

In the future, additional passenger rail service is anticipated due to Caltrain electrification efforts and anticipated high-speed rail improvements. This increased traffic will reduce the operating windows for Port cargo rail operations.

Rail is particularly sensitive to flooding because it cannot operate with even minimal flooding and flooding on one section of the rail results in disruption to the whole network. The train is inoperable if the railroad tracks are not visible and, thus, it is sensitive to both temporary and permanent flooding. Regular operations should be able to resume after temporary flooding provided there is no corrosion or debris on the tracks.

11.3.1.2 Maritime Berths

The Port's maritime berths host a number of services, including cruise ships, ferries and excursions, historic ships, fireboats, fishing fleets, and cargo operations (Photo 11.14). The vessels present in the southern waterfront primarily include industrial cargo ships and small watercrafts used for recreational boating (Figure 11.3). While the vessel berths themselves may not be impacted by SLR, the access to the piers they dock at, or the piers themselves, could become flooded under future SLR scenarios. Section 11.1 provides a discussion of the various piers' vulnerability to SLR.

11.3.2 Transportation Exposure

The exposure of San Francisco Bay Railroad was evaluated relative to the 10 SLR scenarios defined in Chapter 2, *Climate Science*. The percentage and distance for each asset that could be inundated under each scenario were calculated and are presented in Table 11.7.

11.3.3 Transportation Vulnerability Summary

Railroad operations are impacted beginning at SLR Scenario 2 (24 inches of SLR or 12 inches of SLR and an annual extreme high tide with a 1-year recurrence interval) when the tracks at Pier 96 are inundated. Temporary inundation of the Port's cargo terminals would not hinder current operations as they could

Table 11.7 Transportation Exposure with Sea Level Rise (% inundated and area inundated)

	Railroad Exposure under Each Scenario (% Inundated)									
Port Transportation	1	2	3	4	5	6	7	8	9	10
San Francisco Bay Railroad	0%	6%	8%	14%	40%	56%	67%	69%	73%	83%
Intermodal Container Transfer Facility	0%	0%	0%	10%	18%	25%	25%	28%	30%	47%

	Railroad Exposure under Each Scenario (Miles Inundated for Railroad and Acres Inundated for Intermodal Container Transfer Facility)									
Port Transportation	1	2	3	4	5	6	7	8	9	10
San Francisco Bay Railroad	0.02	0.39	0.55	0.91	2.63	3.62	4.34	4.46	4.72	5.37
Intermodal Container Transfer Facility	0	0	0	2.4	4.3	5.7	5.8	6.4	7.1	10.9

resume after flood waters recede. The Intermodal Container Transfer Facility experiences minimal flooding at Scenario 4 (48 inches of SLR or six inches of SLR and a 100-year extreme tide) in the northern portion of the facility. Scenario 4 (48 inches of SLR or six inches of SLR and a 100-year extreme tide) results in additional flooding of tracks. At Scenario 5 (52 inches of SLR, or 12 inches of SLR and a 100-year extreme tide), the connection to Union Pacific Railroad would be inundated, rendering the railroad inoperable.

The vulnerability of the marine vessel berths is dependent upon the conditions of the piers they are located at. While the berths could still be functional under future SLR scenarios, access to the piers or the piers themselves could become flooded. Additionally, storm damage to utilities or fenderings could occur and be exacerbated by SLR.

11.3.4 Transportation Consequence Summary

Key consequences and consequences that could occur to society and equity, the economy, environment, and governance (see Chapter 3, *Assessment Approach*) were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below. However, several actions are currently planned or in progress to address some of the noted impacts. For a description of the current or planned projects, see Chapter 13, *A Changing Shoreline*.

KEY ISSUE: The Port's maritime berths and connection to the regional railroad enable important industrial and maritime uses in the southern waterfront. The loss of these modes of transportation would result in additional road congestion and reduce or eliminate much of the remaining industrial and industrial maritime uses in San Francisco.

Society and Equity: Disruption of rail service could result in increased traffic on local roads and interstates. In addition to road congestion, this could result in increased air and noise pollution in nearby neighborhoods. Furthermore, loss of rail in the area would impact local employment given that San Francisco Bay Railroad hires almost exclusively from the local community. This would disproportionately impact workers from the Bayview neighborhood and people living in the southern waterfront.

The railroad and maritime berths serve industrial transportation needs and could also be used during emergencies to transport supplies and remove debris. If these become inaccessible due to flooding, their use for emergency response could become limited resulting in delays in response times and dangers to public safety.

Economy: Disruption of rail service would impact the industrial operations at Piers 80, 92, 94, and 96 and could result in economic losses to the local community and beyond. It could lead to increased truck traffic, or the relocation of these services to a different Port within the Bay Area.

Environment: San Francisco Bay Railroad's primary business is transporting contaminated soils from construction projects in San Francisco to a landfill out of state. Using rail rather than long-haul trucks to transport materials saves approximately one million gallons of diesel fuel annually, producing approximately 90 percent fewer carbon dioxide emissions.[6] If rail became unavailable due to flooding, the use of long-haul trucks would have a large environmental impact.

6 Port of San Francisco. 2017. Request approval of an Amended and Restated Lease No. L-14397 ("Lease") between the Port of San Francisco and San Francisco Bay Railroad, Inc. https://sfport.com/sites/default/files/Commission/Documents/Commission%20Meeting%20Staff%20Reports/Item%2012A%20SF%20Bay%20Railroad.pdf

11.4 PORT UTILITIES

Many utilities are located within or beneath Port property, including water, wastewater, stormwater, communications, electrical, fuel, and maintenance structures (Photos 11.15 and 11.16). Service disruptions to these utilities would have citywide consequences and would impact the ability of the Port and the Port tenants, employees, and small businesses to operate and provide services.

This section focuses on the Port's storm sewer system. The vulnerabilities of other utilities are further described in their respective sections. Chapter 6, *Water*, includes a description of the regional water supply, local potable water supply system, low-pressure fire system and AWSS/high-pressure fire system. Chapter 7, *Wastewater*, details the City's wastewater collection and treatment system. Chapter 8, *Power*, describes SFPUC and PG&E power assets such as sub-stations, switch gear, and transformer boxes.

The majority of the City of San Francisco is served by a combined sewer system where stormwater and residential and commercial sewage is conveyed together to treatment plants prior to discharge into the San Francisco Bay or Pacific Ocean. In addition to this combined system, there are several separate storm sewers operated by the Port or SFPUC. These systems convey stormwater runoff directly to surface waters such as lakes or San Francisco Bay and are subject to the National Pollutant Discharge Elimination System (NPDES) Phase II Municipal General Permit for municipal stormwater discharges. The SFPUC system, discussed in Chapter 7, *Wastewater*, consists of small stormwater systems located in parks throughout the City. The Port's storm sewer serves areas along the City's waterfront and drains into San Francisco Bay.

The Port developed a Stormwater Management Plan and administers a Stormwater Management Program to reduce runoff pollution and protect the water quality of the San Francisco Bay. The program includes public

Photo 11.15 **Sea Wall Lot 349 AWSS piping improvements.** Dave Rauenbuehler

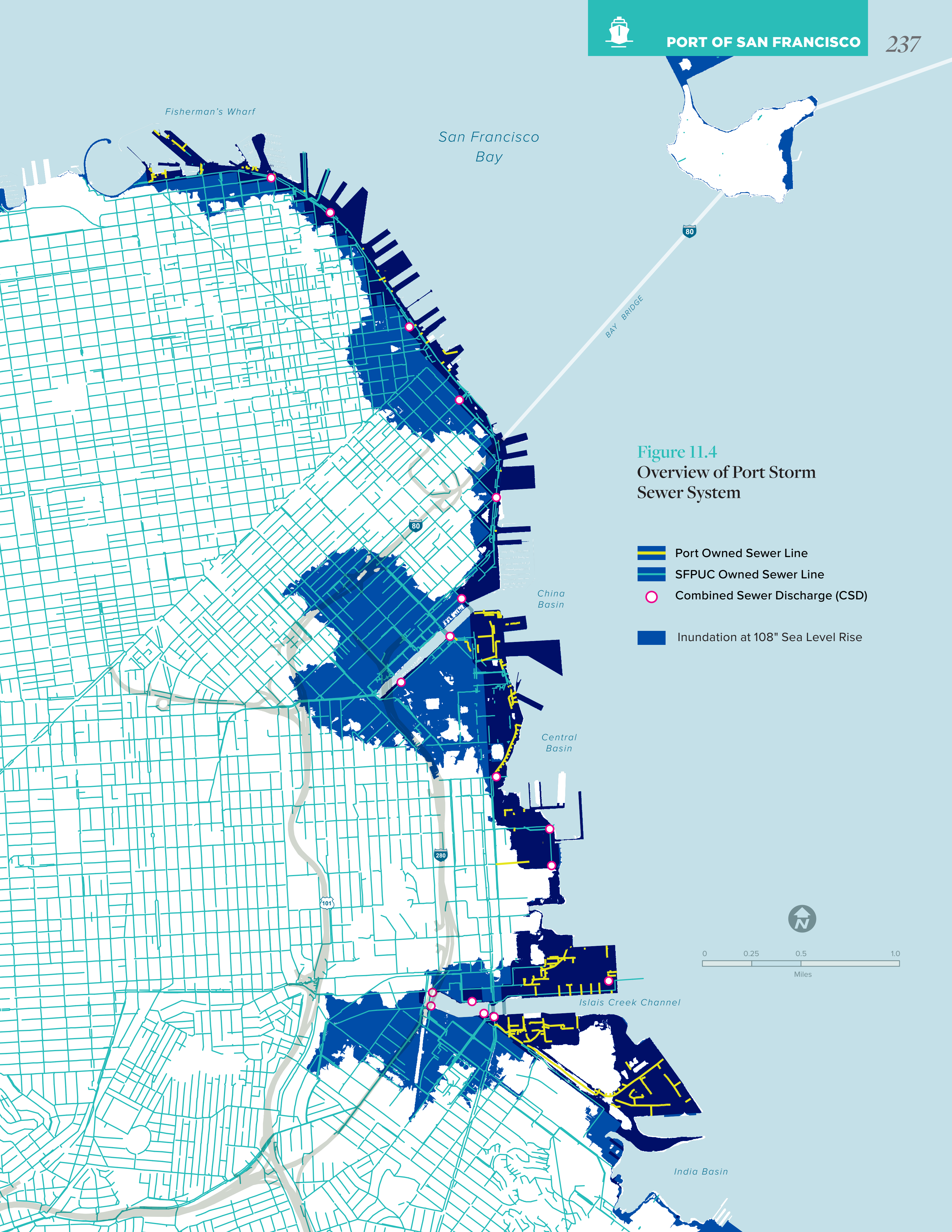


Figure 11.4
Overview of Port Storm Sewer System


Photo 11.16 **Pier 70 Utility Improvements at SWL349.** Dave Rauenbuehler (CC BY-NC 2.0)

outreach and education, industrial facility inspections, illicit discharge investigation and enforcement, construction site management, and maintenance of the drainage system. The program focuses on waterfront areas and provides design guidelines that will apply to new development or redevelopment along the waterfront to limit pollution or improve stormwater quality before it reaches the Bay.

While the majority of the Port's jurisdiction is served by the separate storm sewer system, there are a few areas where stormwater is conveyed to the City's combined sewer system.[7] These include:

- Upland areas of Fisherman's Wharf between Pier 39 and Hyde Street Harbor (excluding Pier 45);
- The southwest edge of South Beach Harbor parking lot at Pier 40, abutting the Embarcadero;
- The majority of Pier 70 extending from the foot of 20th street to the Port's property line on Illinois Street;
- Parcels adjacent to 21st, 22nd, 23rd, and 24th Streets, east to the Port's property line on Illinois Street;
- Pier 80 west of the entrance to the container terminal at the foot of Cesar Chavez Street;
- The Darling Delaware facility at Pier 92, except two drains near the northeast corner of the leasehold; and
- Cargo Way, except the Amador Street entrance at Pier 90.

The Port's stormwater efforts focus on maritime operations and commercial development along the waterfront (see Figure 11.4). The Stormwater Management Plan has a targeted emphasis on the area north of Pier 41 due to the high level of commercial and industrial activities located there, and the southern waterfront extending south of Mariposa Street to India Basin due to the significant level of planned redevelopment. The potential vulnerability of the stormwater drainage system is described below and differs for the utilities located on land or under piers. Additional public and private utilities run through the Port's jurisdiction and their connection with the Port is discussed in Section 11.4.1.

7 Port of San Francisco. 2003. Storm Water Management Plan 2003 – 2004. Available at https://www.waterboards.ca.gov/water_issues/programs/stormwater/swmp/sfport_swmp.pdf.

11.4.1 Summary of Potentially Vulnerable Utility Assets

The vulnerability of the Port's stormwater sewer system varies based on the asset's location – either on land or under pier. Generally, the assets located under piers are more vulnerable to SLR. These utilities run underneath the pier decks where they are constantly exposed to harsh conditions from corrosive Bay waters and impacts from debris mobilized by waves and tidal forces. These utilities have high corrosion rates and will eventually become inaccessible for maintenance and replacement as sea levels rise. Sump pumps are also located below the pier decks and are subject to saltwater intrusion and corrosion.

There is an ongoing plan to move under pier utilities above the piers. This work is programmed to extend 30 years and is not yet fully funded. It does not fully eliminate the risk to utilities as the sump pumps will still be located below deck vulnerable to corrosion and salt water intrusion. The Port is still developing a plan to address this issue.

On land, utilities will experience fewer disruptions and will likely be able to handle temporary flooding. However, if salt water enters the storm sewer system through sump pumps or storm drains, it could corrode the pipes increasing their sensitivity to SLR.

11.4.2 Utilities Consequence Summary

Key consequences were evaluated assuming no action is taken to address the impacts associated with SLR or extreme tide flooding. These consequences are listed below. However, several actions are currently planned or in progress to address some of the noted impacts. For a description of the current or planned projects, see Chapter 13, *A Changing Shoreline*.

KEY ISSUE: Many of the Port's piers have stormwater utilities that run underneath the pier deck where they are exposed to the harsh conditions of corrosive Bay waters and impacts from tidal debris. SLR may increase this exposure and damage to the under-pier utilities can reduce their ability to function and negatively affect water quality.

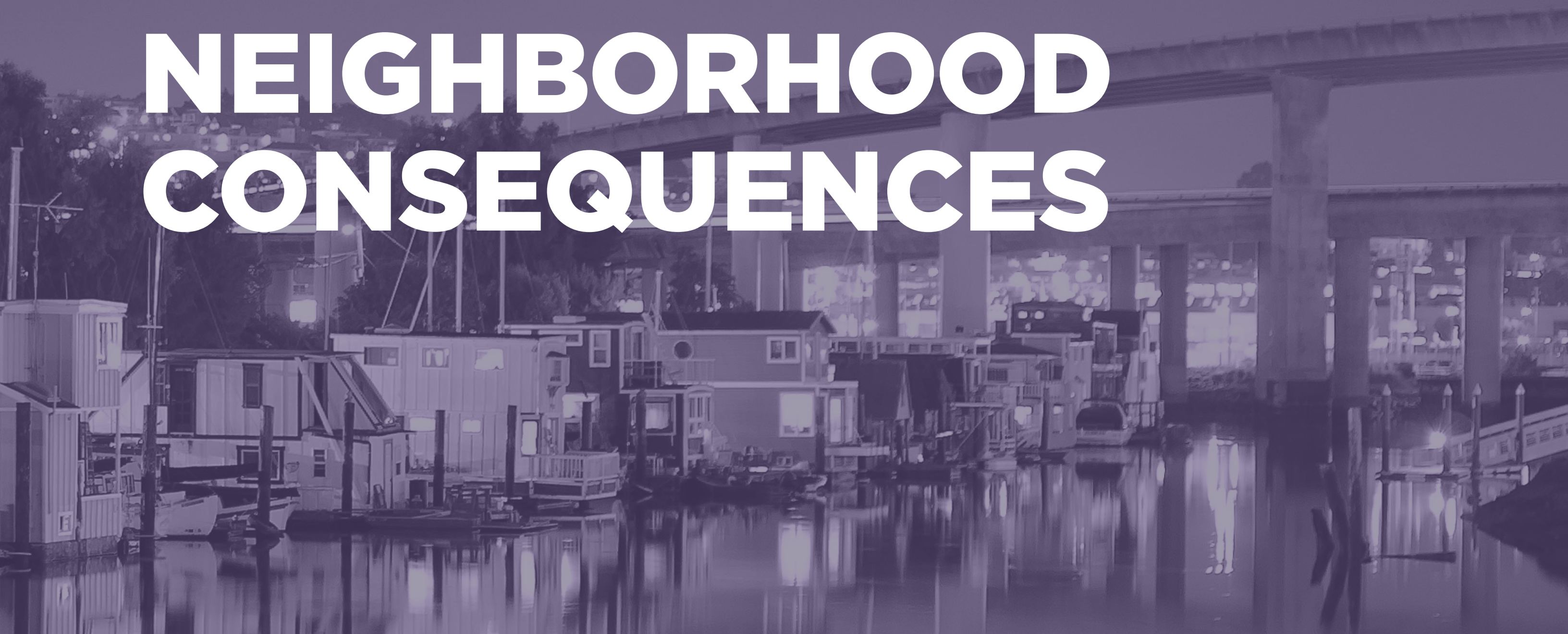
11.5 Port Sea Level Rise Adaptation Projects

The Port has a number of resilience efforts and SLR adaptation projects planned, including park projects, mixed-use development projects, and infrastructure projects to address seismic safety, SLR, and coastal flooding. These are described in Chapter 13, *A Changing Shoreline*.

House boats on Mission Creek.
Photo by Sergio Ruiz.

CHAPTER 12

NEIGHBORHOOD CONSEQUENCES



In this chapter, all assets and infrastructure were evaluated together in each individual neighborhood to tell the story of SLR consequences – when does SLR inundation or coastal flooding due to extreme tides first occur, when do the impacts begin to affect the local residents within the neighborhood, and when do the impacts rise up and start to affect the entire city or larger San Francisco Bay region. This report uses the Planning Department's official neighborhood map to describe neighborhood consequences (Figure 12.1). The 37 neighborhoods provide an appropriate scale to analyze multi-sector consequences overlain with the residents and businesses that may be the most affected.

This Assessment focuses on the neighborhoods that are directly impacted by SLR and coastal flooding – those neighborhoods that directly border the San Francisco Bay and Pacific Ocean shorelines. Although inland neighborhoods may not experience direct flooding and inundation, SLR will indirectly affect them. Many of the City's critical services – including major transportation roadways, regional transit connections, water supply systems, wastewater services, power systems, emergency fire protection services, disaster response staging areas, and more – are located within the City's SLR Vulnerability Zone. Many of the City's desirable shoreline parks and trails will be more frequently flooded over time. Although all of these potential impacts will affect the entire city, those residents that live and work within the SLR Vulnerability Zone, and in particular the City's most vulnerable neighborhoods located near the shoreline, will be most directly affected.

This Assessment focuses primarily on City-owned assets, provides detailed information to better define and understand the City's vulnerabilities to SLR and the consequences of those vulnerabilities across the City, and highlights the timing of when adaptation intervention may be required within each neighborhood. This will help the City identify, plan, and prioritize future adaptation needs.

Numerous historic, cultural, and socially-important assets are at risk within each neighborhood. The vulnerability and consequences associated with these neighborhood assets have not yet been evaluated. As a next step, the City will work with communities to understand the assets they care about at the neighborhood level (Figure 12.1), the vulnerability of those assets to SLR and coastal flooding, and the consequences of flooding to the community. This in turn will help the City define and develop SLR adaptation strategies consistent with community values, goals, and priorities.

12.1 THE SHORELINE

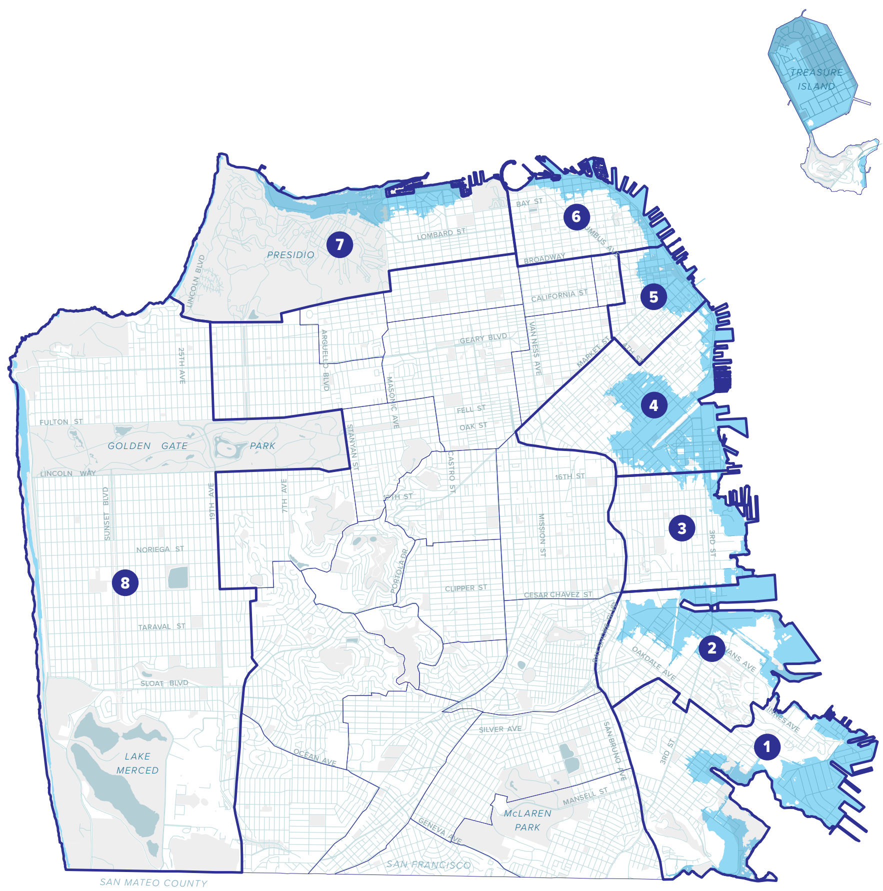
San Francisco is bounded by water on three sides with nearly 40 miles of shoreline. Along the Bay, much of the shoreline is engineered piers, seawalls, and wharves that are owned and managed by the Port of San Francisco. However, pockets of natural wetlands can be found that offer a diversity of wildlife benefits and outdoor recreation, including Heron's Head Park and India Basin Shoreline Park. Along the westside of the city, the shoreline includes both high coastal bluffs and sandy beaches, including the 3.5-mile-long Ocean Beach that attracts more than 300,000 visitors each year.

Shoreline vulnerability is a product of shoreline type (e.g., engineered shoreline structure, beach, wetland, or coastal bluff), the elevation of the shoreline relative to the Bay tides, and wave exposure. Engineered structures such as seawalls and levees[1] are less

1 Engineered levees are not found within the San Francisco city limits; however, SFO is protected by a complex series of levees, seawalls, and floodwalls. SFO is leading a multi-year Shoreline Protection Program to address the airport's risk of flooding, both storm-related and from longer-term SLR (see Chapter 4).

Figure 12.1
San Francisco's Neighborhoods

1. Bayview South / Hunters Point
2. Bayview North / Islais Creek
3. Potrero Hill / Central Waterfront
4. South of Market / Mission Bay
5. Financial District
6. North Beach / Fisherman's Wharf
7. Marina and Presidio
8. Westside / Ocean Beach



vulnerable to SLR and coastal storms until coastal water levels rise high enough to overtop the structures. However, the structural integrity of engineered structures can deteriorate over time, thereby increasing the vulnerability of these structures to extreme events.

San Francisco's Embarcadero seawall was constructed between 1879 and 1916. This structure allowed San Francisco to grow and thrive, but it has outlived its original engineering life. The City and the Port recognize the increasing vulnerability of the seawall, and have embarked on a multi-year Embarcadero Seawall Program to improve the seismic performance of the structure and provide flood protection. The Port and U.S. Army Corps of Engineers Flood Study have partnered to study flood risk and develop flood protection strategies along 7.5 miles of the San Francisco's bayside shoreline from Aquatic Park to Heron's Head Park. (See Chapter 4. *Supporting Assessments*.)

Natural shorelines such as beaches and wetlands are more vulnerable to SLR and coastal storms and are highly vulnerable to wave hazards that can erode the shoreline. Ocean Beach has experienced significant coastal erosion in the past, particularly during El Niño winters when large waves pound the shoreline and carry away large amounts of beach sand sediments. The erosion has damaged the Great Highway and parking areas and is threatening components of the City's combined wastewater system.

As sea levels rise, the potential for wave hazards and coastal erosion will increase (i.e., deeper ocean waters allow for the generation of larger waves). Coastal erosion of oceanfront beaches and bluffs will continue to change the westside shoreline over the coming century. The City was part of an extensive interagency and public process to develop the Ocean Beach Master Plan, a comprehensive long-term vision to address SLR, protect infrastructure, restore coastal ecosystems, and improve public access. The early phases of the master plan are currently in the implementation phase. (See Chapter 13. *A Changing Shoreline*.)

Although the Embarcadero Seawall Program, Flood Study, the Ocean Beach Master Plan are addressing critical near-term vulnerabilities along the shoreline, these projects do not address the entirety of the city's shoreline. In this Assessment, the entire shoreline was evaluated to understand when and where the shoreline is most likely to overtop as sea level rises.

Figure 12.2 highlights the shoreline areas where overtopping can occur based on the existing elevation of the shoreline and shoreline structures for four SLR scenarios. The inland area that could be inundated is also shown. Under Scenario 3, few shoreline reaches are overtopped, and the inland inundation is minimal. Under Scenarios 5 and 6, larger stretches of the shoreline are overtopped, and the extent of inland inundation increases. By Scenario 7, the majority of the shoreline is likely to be overtopped. The extent of shoreline overtopping and inland inundation for each of the 10 SLR Scenarios can also be viewed using the Adapting to Rising Tides Flood Explorer.[2]

Each neighborhood profile (see Section 12.4) includes a summary of the shoreline's characteristics, wave exposure, and where along the shoreline coastal waters could overtop the shoreline and result in inland flooding. The SLR scenario when overtopping is first likely to occur is also identified.

2 The ART Bay Shoreline Flood Explorer allows for interactive exploration and download of the Bay Area SLR and shoreline analysis maps. These maps depict areas at risk of temporary or permanent flooding due to SLR and extreme tides as well as shoreline overtopping. Available at https://explorer.adaptingtorisingtides.org/explorer.

12.2 EXTREME TIDE AND SLR FLOODING

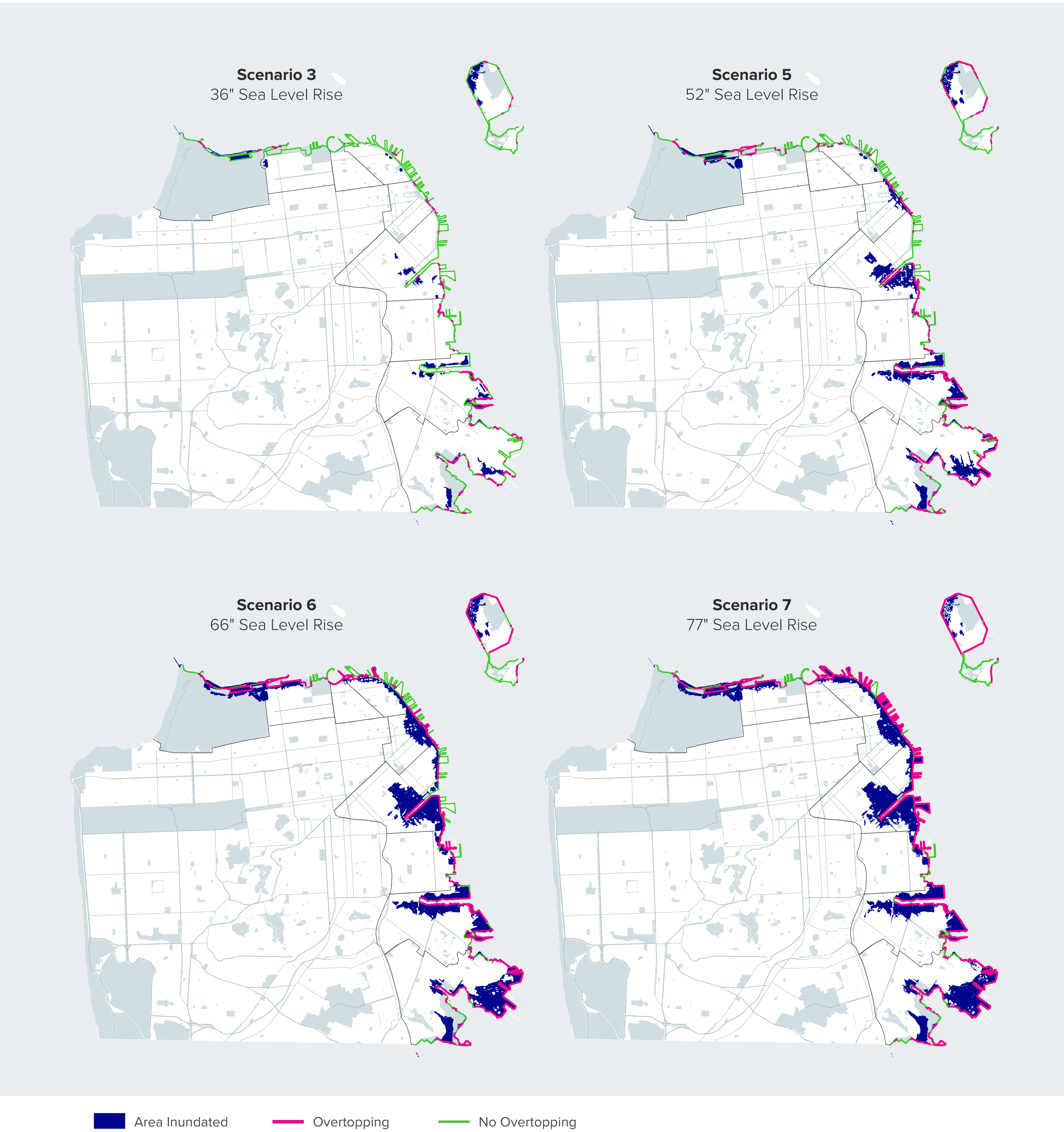
Identifying where along the shoreline floodwaters from extreme tide and SLR may overtop is important. However, identifying what and how many assets will be inundated when that overtopping occurs is also necessary for understanding the consequence story within each neighborhood. As sea levels rise, the extent of inundation will impact more and more assets across all sectors, causing a series of consequences that could range from the local scale (i.e., impacting only the inundated areas within a neighborhood, such as flooding of local streets), to the city-wide scale (i.e., impacting residents and businesses across the city, such as flooding of Recology's waste management and recycling services), to the regional scale (i.e., impacting residents and businesses across the region, such as flooding of the Embarcadero Muni/BART station).

In this Assessment, a "tipping point" has been identified for each neighborhood that highlights when inundation is impacting either multiple assets within a sector, or multiple assets across sectors, that increases the level of consequences to the city or the region. This tipping point is usually associated with a large jump in the number of residents and businesses that are impacted as well.

Each neighborhood profile (see Section 12.4) includes the progression of potential extreme tide and SLR flooding and a brief discussion of the City-owned assets that will be impacted. Additional details on the exposure, vulnerability, and consequences of extreme tide and SLR flooding on the city-owned assets can be found within the respective sector-based chapters.

High tides along Pier 14 / The Embarcadero. Dave Rauenbuehler (CC BY-NC 2.0)

Figure 12.2 Shoreline Overtopping for Select SLR Scenarios



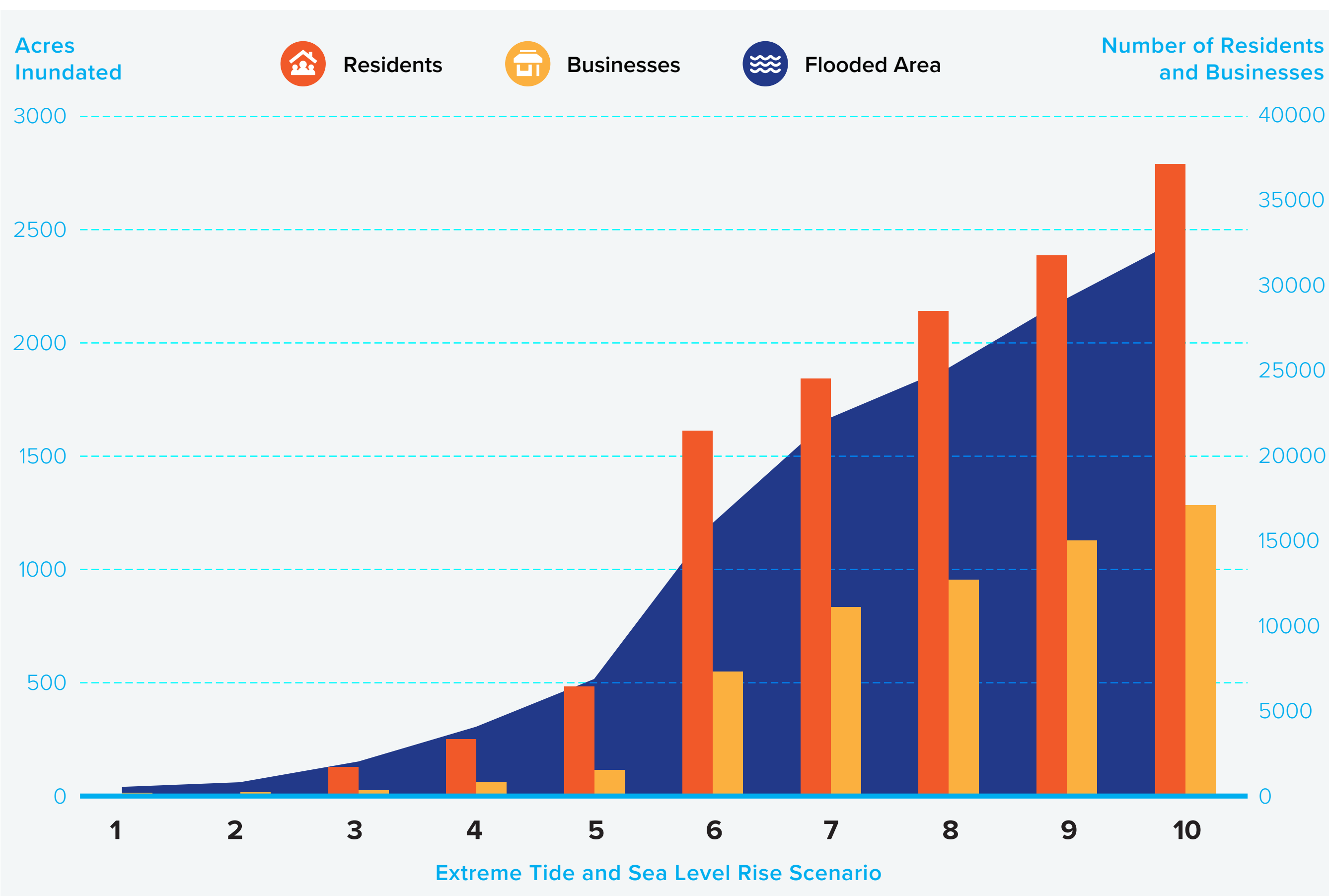
12.3 RESIDENTS AND BUSINESSES EXPOSED TO FLOODING

As extreme tides and SLR cause coastal waters to overtop the shoreline and inundate the City's critical infrastructure, residents and businesses will be directly affected by floodwaters. Figure 12.3 presents the number of residents and businesses that could be inundated under each SLR scenario, along with the total area of the city that could be inundated. The neighborhood profiles (see Section 12.4) include this information relative to each specific neighborhood.

12.4 NEIGHBORHOOD PROFILES

Neighborhood profiles were developed for each neighborhood that borders the shoreline, as shown in Figure 12.1 – including Bayview South/Hunters Point, Bayview North Islais Creek, Potrero Hill/ Central Waterfront, South of Market/Mission Bay, Financial District, North Beach and Fisherman's Wharf, Marina and Presidio, and Westside/Ocean Beach. Due to the distinct geographical differences along the shoreline, the Bayview neighborhood was divided into two profiles, with Bayview/Hunters Point including a higher concentration of residents and Bayview North Islais Creek including more industrial land use. The North Beach, Fisherman Wharf, and Russian Hill neighborhoods were combined into one profile, as Russian Hill has limited assets within the SLR Vulnerability Zone due to its steeper topography. The Marina and Presidio neighborhoods were also combined into one profile; this report does not include a detailed assessment of the Presidio shoreline. All of the westside shoreline neighborhoods were combined into one profile as few assets are located within the SLR Vulnerability Zone and the character of the shoreline is similar for purposes of description of vulnerability.

Figure 12.3 Residents and Businesses Exposed to Flooding



NEIGHBORHOOD PROFILE

BAYVIEW SOUTH HUNTERS POINT

Aerial view of Bayview Hunters Point. Photo by Sergio Ruiz

The Bayview/Hunters Point neighborhood, located on the southeastern edge of San Francisco, contains the southern portion of the Bayview residential neighborhood (south of Palou Avenue), the southern Bayview industrial zone, and the Hunters Point Shipyard and Candlestick Point redevelopment area. The 3rd Street corridor is the primary neighborhood commercial district serving adjacent communities with a variety of neighborhood-serving businesses. The neighborhood's industrial area is the second most important labor market for Bayview residents, next to downtown San Francisco.[1] The neighborhood includes major open spaces, including Bayview Park, India Basin Park, and Candlestick Point State Recreation Area, as well as several neighborhood parks, such as Gilman Playground.

Bayview/Hunters Point is ethnically diverse with large Black, Asian, and Latino populations,[2] and a strong African American cultural legacy. The neighborhood has been subjected to significant historical and environmental injustices, and has high socially vulnerability, with high poverty, crime, unemployment, and hospitalization rates relative to San Francisco.[3] Most of the area is included within MTC's Communities of Concern.[4] The neighborhood has a strong cultural and economic life, including high rates of women- and minority-owned businesses,[5] a burgeoning local food and beverage industry, and a multitude of worship centers and community benefit organizations.

Hunters Point, has serious environmental challenges, with the former Naval shipyard's surrounding census tracts identified by CalEnviroscreen as being in the top 10 percent in California for pollution burden from cleanups, groundwater threat, hazardous waste, solid waste, and impaired water.[6] The Hunters Point Naval Shipyard has been identified as a federal superfund site. See Chapter 9.5 *Public Safety – Contaminated Lands*.

1 United States Census Bureau. Longitudinal Employer-Household Dynamics (LEHD). 2010. On the Map. Zip Code 94124. Available at https://onthemap.ces.census.gov/.

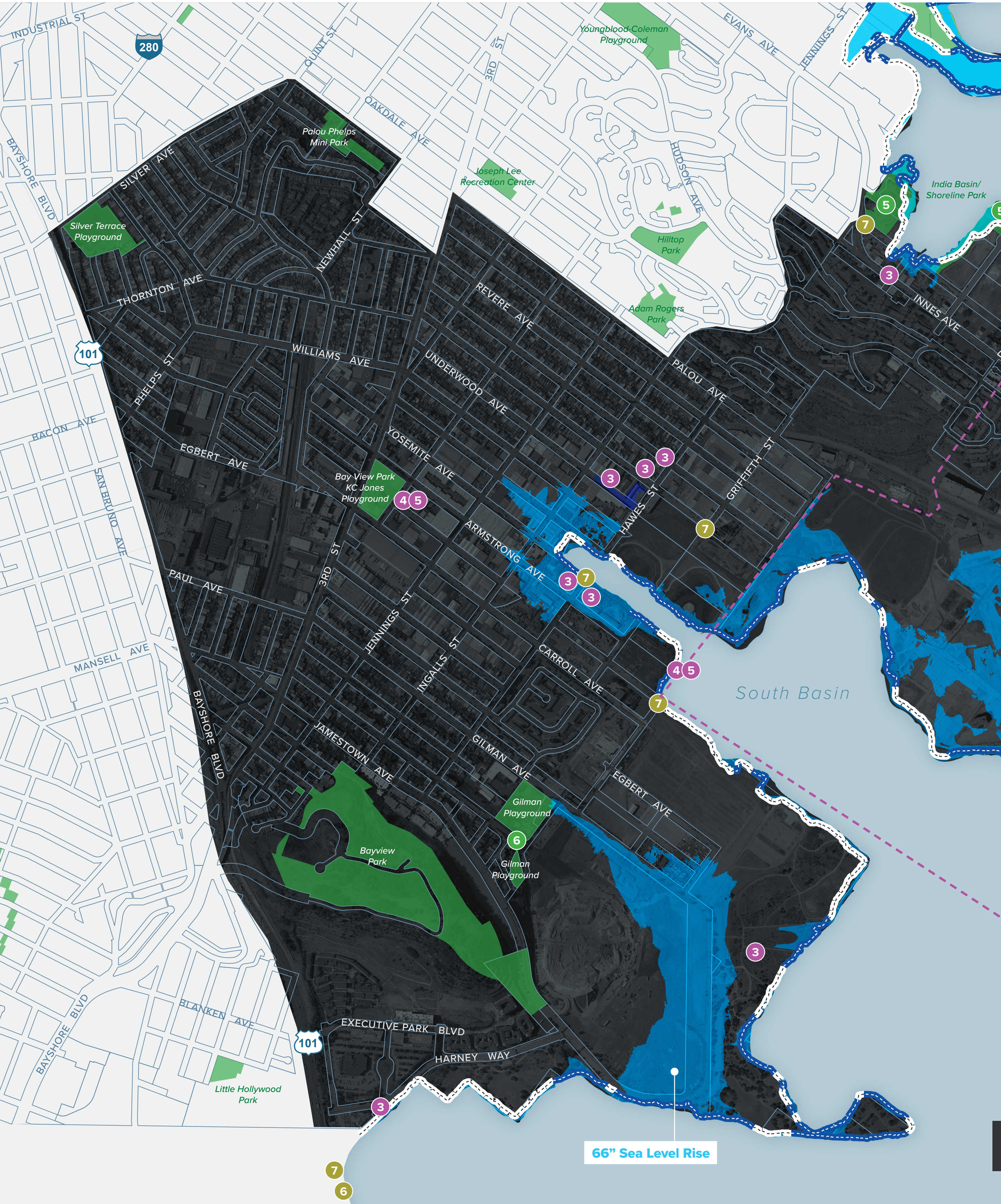
2 American Community Services (ACS). 2016. Social Explorer. Available at https://www.socialexplorer.com/a9676d974c/explore.

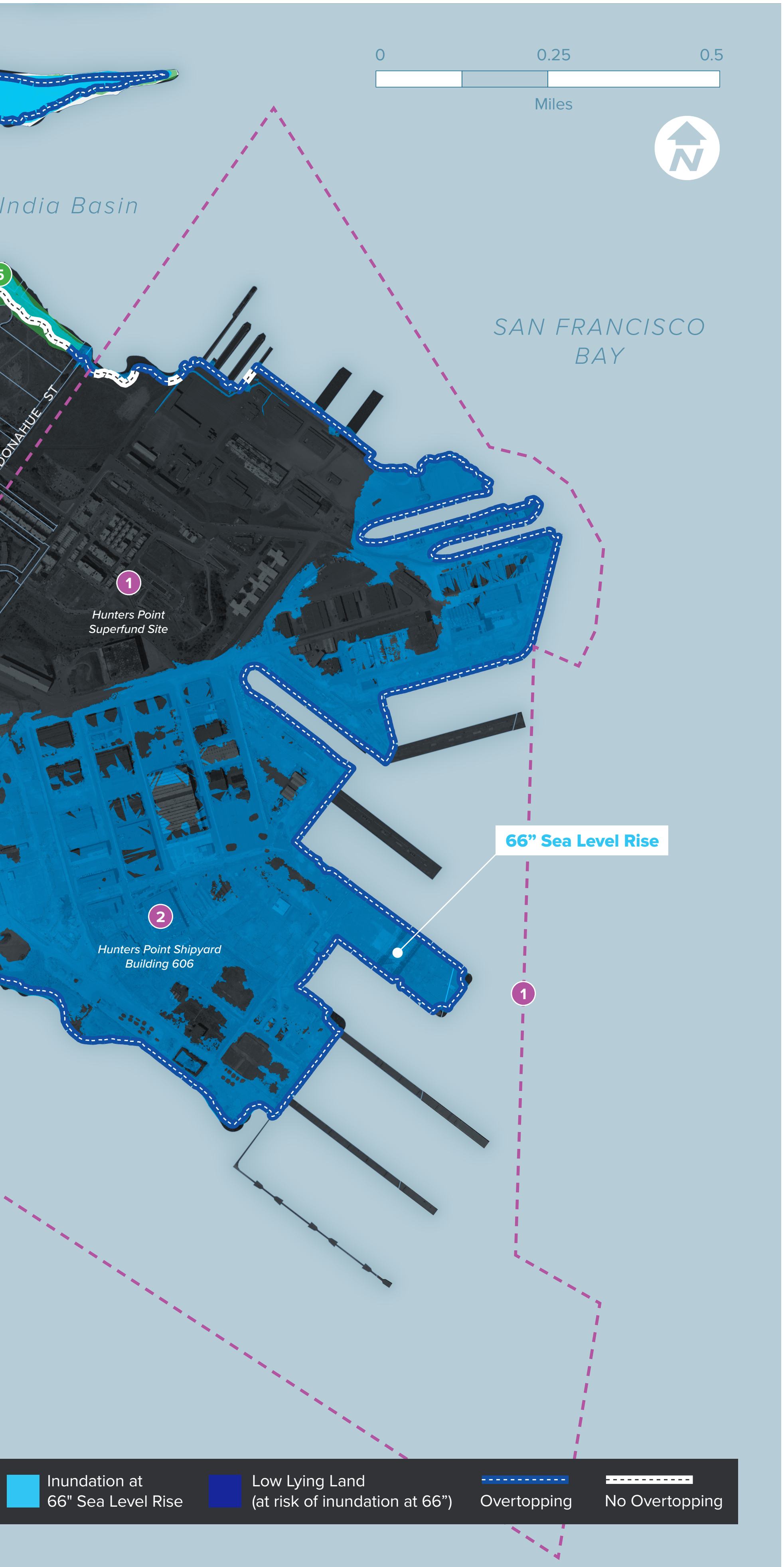
3 American Community Services (ACS). 2016. Social Explorer. Available at https://www.socialexplorer.com/a9676d974c/explore.

4 http://opendata.mtc.ca.gov/datasets/mtc-communities-of-concern-in-2018-acs-2012-2016?geometry=-122.496%2C37.696%2C-122.322%2C37.744

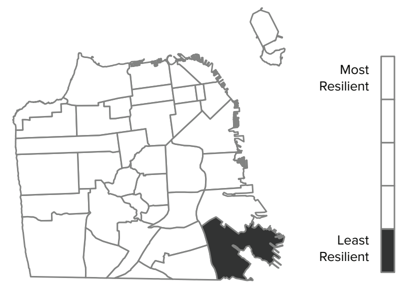
5 The San Francisco Indicator Project. Bayview/Hunter's Point Neighborhood Indicator Profiles. Available at http://www.sfindicatorproject.org/neighborhoods/view/1.

6 California Environmental Protection Agency (CalEPA) and Office of Environmental Health Hazard Assessment (OEHHA). 2017. CalEnviroscreen 3.0. Available at https://oehha.ca.gov/media/downloads/calenviroscreen/report/ces3report.pdf.


INDUSTRIAL ST
280
QUINT ST
3RD ST
Youngblood-Coleman Playground
EVANS AVE
JENNINGS ST
OAKDALE AVE
Palou Phelps Mini Park
Joseph Lee Recreation Center
HUDSON AVE
India Basin/ Shoreline Park
BAYSHORE BLVD
SILVER AVE
Silver Terrace Playground
NEWHALL ST
Hilltop Park
THORNTON AVE
REVERE AVE
Adam Rogers Park
INNES AVE
101
WILLIAMS AVE
UNDERWOOD AVE
PALOU AVE
PHELPS ST
BACON AVE
YOSEMITE AVE
EGBERT AVE
HAWES ST
GRIFFITH ST
Bay View Park KC Jones Playground
SAN BRUNO AVE
ARMSTRONG AVE
PAUL AVE
3RD ST
JENNINGS ST
INGALLS ST
CARROLL AVE
South Basin
MANSELL AVE
BAYSHORE BLVD
JAMESTOWN AVE
GILMAN AVE
EGBERT AVE
Gilman Playground
Bayview Park
Gilman Playground
BLANKEN AVE
EXECUTIVE PARK BLVD
BAYSHORE BLVD
101
HARNEY WAY
Little Hollywood Park
66" Sea Level Rise



Bayview South Hunters Point



NEIGHBORHOOD RESILIENCY SCORE: 1

Hazard Score: 1
Environmental Score: 1
Transportation Score: 1
Community Score: 2
Public Realm Score: 1
Housing Score: 2
Economy Score: 1
Health Score: 1
Demographics Score: 1

Source: San Francisco Climate & Health Program Neighborhood Summary
https://sfclimatehealth.org/neighborhoods/

PUBLIC SAFETY

1. Hunters Point Superfund Site
2. Hunters Point Shipyard Building
3. Contaminated Land
4. Fireboat Pump Station
5. Fire Suction Connection

WASTE WATER

6. Sunnydale Pump Station
7. Combined Sewer Discharge (CSD)

OPEN SPACE

8. India Basin Shoreline Park
9. Gilman Playground

Bayview Farmer's Market. Dale Cruse (CC BY 2.0)

Hunters Point Naval Shipyard. Flickr user Sanfranman59

Bayview/Hunters Point includes the Hunters Point Shipyard/Candlestick Point redevelopment area, which would nearly double the population of the entire Bayview/Hunters Point area by 2030.[7] The Hunters Point Shipyard, a former naval base, is a master-planned community located along the south-eastern waterfront of San Francisco.

Phase I of the Shipyard Project, which includes the Hillside and Hilltop areas, is completing the infrastructure and will ultimately include up to 1,428 homes and 20,000 square feet of commercial space. Hunters Point Shipyard and Candlestick Point Phase II covers approximately 702 acres in San Francisco's Bayview Hunters Point and Hunters Point Shipyard neighborhoods. The amended plan for the area calls for mixed-use development consisting of up to 10,672 residential units that includes a mix of affordable and market rate units, 1,146,000 square feet of neighborhood and regional retail, 4.4 million square feet of research and development/office, and 328 acres of open space.

The Shipyard Project includes SLR adaptation strategies. See Chapter 13. *A Changing Shoreline* for more detail.

The Shoreline

The Bayview South Hunters Point neighborhood has 9.5 miles of Bay shoreline. Approximately 7.2 miles is hardened and engineered shoreline, including piers, seawalls, and wharves. As sea level rises, wave hazards can exceed 3 feet in height[8] along the shoreline fronting the Hunter's Point Naval Shipyard and Hunters Point Shipyard Artists community. Wave hazards can increase the potential for coastal erosion of natural shorelines and wave damage to engineered shorelines. As sea level rises, the potential for wave hazards increases, because deeper Bay waters allow for the generation of large waves.

The remaining 2.3 miles of shoreline is natural, including India Basin Shoreline Park and the 170-acre Candlestick Point State Recreation Area. The parks are popular for fishing and bird watching. Bird watching is best in the winter when migrant waterfowl and shorebirds are numerous in the Bay, but pelicans, egrets, and hawks can also be seen throughout the year. Candlestick Point is also a popular entry point for windsurfing on the Bay.

Under Scenario 3 (36 inches) two small stretches of shoreline are overtopped, leading to minor inundation of the Hunters Point Naval Shipyard and Candlestick Point; however, no structures are impacted. At Scenario 4 (48 inches), overtopping increases and several structures are inundated. By Scenario 6 (66 inches), the inundation extends inland, and the impacts could become widespread.[9]

7 Data SF. SF Development Pipeline 2018 Q1. Available at https://data.sfgov.org/Housing-and-Buildings/SF-Development-Pipeline-2018-Q1/dg6z-zdpi.

8 Federal Emergency Management Agency, Preliminary Flood Insurance Rate Maps.

9 The ART Bay Shoreline Flood Explorer allows for interactive exploration and download of the Bay Area SLR and shoreline analysis maps. These maps depict areas at risk of temporary or permanent flooding due to SLR and extreme tides as well as shoreline overtopping. Available at https://explorer.adaptingtorisingtides.org/explorer.

Extreme Tide and SLR Flooding Vulnerabilities and Consequences

The scenarios below describe the progression of potential extreme tide and SLR flooding, along with a brief discussion of the City-owned assets that will be impacted, within the Bayview South Hunters Point neighborhood. Additional details on the exposure, vulnerability, and consequences of extreme tide and SLR flooding on City-owned assets can be found within the respective sector-based chapters. The relevant chapters are referenced below, as appropriate.

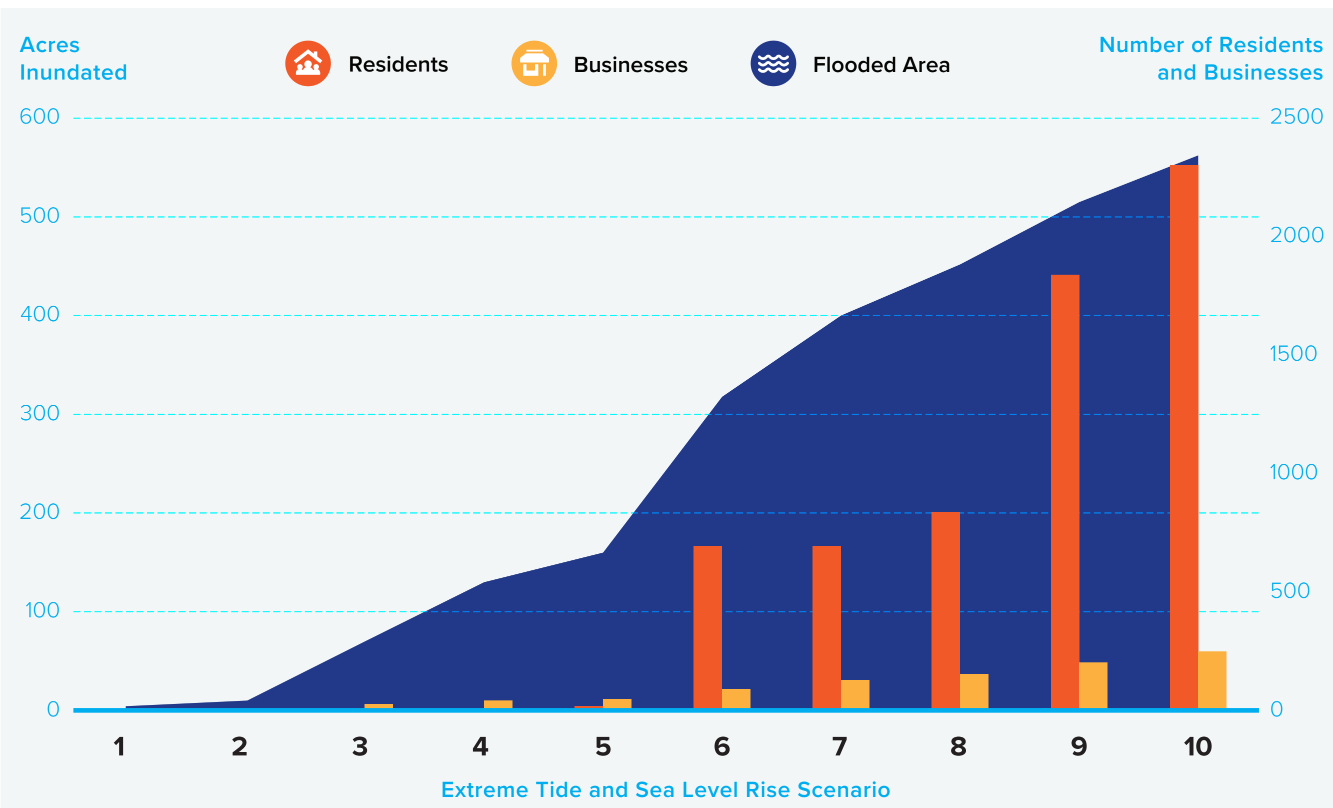
Scenario	Sector	Vulnerabilities and Consequences
Scenario 1 (12 inches of SLR or a high tide with a 1-year recurrence interval)	Open Space	**Open Space:** The fringing wetland areas along the Bay shoreline, including India Basin Shoreline Park, already experience regular inundation during high tides today. As sea levels rise, the wetlands may keep pace with SLR and continue to provide marsh habitat, or they may be submerged. The wetlands are expected to keep pace with SLR until mid-century; however, as SLR accelerates after mid-century, the wetlands may be lost if sediment doesn't accumulate fast enough to support wetland growth (due to deeper Bay levels).
Scenario 2 (24 inches of SLR or 12 inches of SLR and a high tide with a 1-year recurrence interval)	Wastewater	**Wastewater:** Under Scenario 2, the higher Bay water levels may reduce the gravity-driven flow of excess combined wastewater and stormwater from the transport / storage boxes to the Bay through the combined sewer discharge outfalls (Chapter 7). This impact is only of concern during intense and prolonged rainfall events that exceed the capacity of the large underground transport / storage boxes that ring the city. This could result in an increase in localized flooding in low-lying areas. Sunnydale pump station located on Harney Way between US 101 and the Bay is also impacted at Scenario 2. This belowgrade pump station serves the Sunnydale drainage basin during wet weather with a pumping capacity of 50 mgd. The pump station currently experiences intermittent coastal flooding; however, to date, the impacts have been negligible. Repairs and flood proofing measures are planned.
	Public Safety	**Public Safety:** One fire suction connection (part of the emergency firefighting water system) that allows fire engines to draw water from the Bay for fire suppression is inundated. Suction connections become unusable if they are inundated.
Scenario 3 (36 inches of SLR or 12 inches of SLR and a high tide with a 5-year recurrence interval)	Public Safety / Open Space	**Public Safety / Open Space:** Two small stretches of shoreline are overtopped under Scenario 3, resulting in inundation within the Candlestick Point State Recreation Area and the southern edge of Hunters Point Naval Shipyard.
	Power	**Power:** In Scenario 3, flooding would create impacts to streetlights. If the streetlights are flooded temporarily for a short period, limited damage is likely to occur, and the streetlight will remain functioning. However, if streetlights are flooded for a prolonged period, the electrical infrastructure is likely to fail, rendering the streetlight inoperable and the roadway or sidewalk dark during the night.
Scenario 4 (48 inches of SLR or 6 inches of SLR and a 100-year extreme tide)	Public Safety / Open Space	**Public Safety / Open Space:** With Scenario 4, the Hunters Point Shipyard Building is inundated.
Scenario 5 (54 inches SLR or 12 inches SLR and a 100-year extreme tide)	Open Space	**Open Space:** Under Scenario 5, floodwaters overtop the Bay shoreline and impact public access areas within India Basin Shoreline Park.
Scenario 7 (36 inches of SLR and a 100-year extreme tide)	Open Space	**Open Space:** Approximately 12 percent of the Gilman Playground is inundated under Scenario 7. Flooding is limited to the playfields.
Scenario 8 (36 inches SLR and a 100-year extreme tide)	Power	**Power:** At Scenario 8, the Hunters Point substation is first exposed. Electric substations are extremely vulnerable to SLR and coastal flooding, and flooding of any type could interrupt power service for hours to weeks depending on the extent of damage.

Scenario	Sector	Vulnerabilities and Consequences
Scenario 9 (52 inches of SLR and a 100-year extreme tide)	Power	**Power:** Under Scenario 9, overhead lines and utility poles are exposed and vulnerable to flooding.
Scenario 10 (66 inches of SLR and a 100-year extreme tide)	Open Space	**Open Space:** Approximately 50 percent of the Gilman playground is inundated under Scenario 10. The clubhouse and playstructure remain outside of the inundation zone.
	Mobility	**Mobility:** Two SFMTA facilities, the Paint and Meter Shops located at 1538 Yosemite Street and the Sign and Meter Shops located at 1508 Bancroft Street, could be impacted under Scenario 10. These facilities operate together, and impacts to both facilities could result in delays and disruptions to field operations and access to appropriate signage that could result in safety issues and concerns in flooded areas throughout the city.

Residents and Businesses Exposed to Extreme Tide and SLR Flooding

As extreme tides and SLR overtop the Bay shoreline and flood the city's critical infrastructure, residents and businesses in the path of the floodwaters will be affected. Few residents and businesses are affected until Scenario 6 when approximately 90 business and 700 residents could be impacted, primarily in the vicinity of Yosemite Slough and the Candlestick RV Park.

For more information about particular properties and buildings are affected under different scenarios, use the *Adapting to Rising Tides Bay Shoreline Flood Explorer*.[10]



10 https://explorer.adaptingtorisingtides.org/home

NEIGHBORHOOD PROFILE

BAYVIEW NORTH ISLAIS CREEK

Islais Creek at night. Photo by Patrick Boury

The Bayview North Islais Creek neighborhood located on the southeastern edge of San Francisco, and includes the industrial zone surrounding Islais Creek and the northern section of the Bayview residential area (north of Palou Avenue). The area contains several key infrastructure assets that serve the entire City, including the Southeast Wastewater Treatment Plant, Port cargo facilities, Recology Recycle Center, and multiple transportation storage, maintenance, and operation facilities . The neighborhood contains the northern portion of the 3rd Street neighborhood commercial district. Third Street, including the T-Third Light Rail line, is a critical north-south transportation route for Bayview residents. Third Street and the T-Third cross Islais Creek along the 3rd Street Bridge; the Illinois Street bridge is the only other roadway crossing over Islais Creek. . The neighborhood contains several shoreline open spaces and wetland habitat, such as Heron's Head Park.

Bayview Islais Creek is ethnically diverse with large Black, Asian, and Latino populations,9 and has a strong African American cultural legacy. The neighborhood has been subjected to significant historical and environmental injustices, and has high socially vulnerability, with high poverty, crime, unemployment, and hospitalization rates relative to San Francisco.[1] Most of the area is included within MTC's Communities of Concern.[2] The neighborhood has a strong economic and cultural life, with high rates of women- and minority-owned businesses, numerous community benefit organizations, worship centers, and arts and culture organizations, such as the Bayview Opera House.

The Islais Creek watershed has environmental challenges due to the long-standing presence of industrial uses and freight transportation. The neighborhood contains areas identified by CalEnviroscreen as being in the top 10 percent in California for pollution burden from hazardous waste, solid waste, and impaired water.[3] See Chapter 9.5 *Public Safety – Contaminated Lands* and 9.6 *Public Safety – Hazardous Materials Sites*.

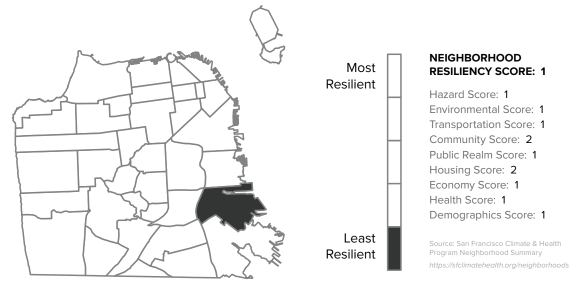
1 American Community Services (ACS). 2016. Social Explorer. Available at https://www.socialexplorer.com/a9676d974c/explore.

2 http://opendata.mtc.ca.gov/datasets/mtc-communities-of-concern-in-2018-acs-2012-2016?geometry=-122.496%2C37.696%2C-122.322%2C37.744

3 California Environmental Protection Agency (CalEPA) and Office of Environmental Health Hazard Assessment (OEHHA). 2017. CalEnviroscreen 3.0. Available at https://oehha.ca.gov/media/downloads/calenviroscreen/report/ces3report.pdf.

Islais Creek
Tulare Park
Potrero del Sol
James Rolph Jr Playground
Selby and Palou Mini Park
Palou and Phelps Mini Park
Joseph Lee Recreation Center
Youngblood-Coleman Playground
Ridgetop Plaza
Hilltop Park
Adam Rogers Park
Silver Terrace Playground
Existing Railway
Muni T-Third Line
CESAR CHAVEZ
NAPOLEON AVE
JERROLD AVE
DAVIDSON AVE
OAKDALE AVE
INDUSTRIAL ST
BAYSHORE BLVD
TOLAND ST
RANKIN ST
PHELPS ST
3RD ST
HUDSON AVE
LA SALLE AVE
NEWCOMB AVE
MCKINNON AVE
MENDELL ST
EVANS AVE
SILVER AVE
QUINT ST
SCOTIA AVE
TOPEKA AVE
NEWHALL ST
REVERE AVE
QUESADA AVE
PALOU AVE
THORNTON ST
LANE ST
KEITH ST
THOMAS AVE
JENNINGS ST
INGALLS ST
SAN BRUNO AVE
POTRERO AVE
DE HARO ST
PENNSYLVANIA AVE
MINNESOTA AVE
ILLINOIS ST
24TH ST
25TH ST
26TH ST
YORK ST
101
280
Inundation at 52" Sea Level Rise
Low Lying Land (at risk of inundation at 52")
Overtopping
No Overtopping

Bayview North Islais Creek



PUBLIC SAFETY

1. Fire Station #25
2. Forensic Service Police Department
3. Emergency Firefighting Water System (EFWS) Yard
4. Fire Station #9
5. Fireboat Pump Station
6. Fire Suction Connection
7. Fireboat Manifold

TRANSPORTATION

8. 3rd Street Bridge
9. Illinois Street Bridge
10. Marin Yard
11. Islais Creek Division
12. Burke Warehouse

WASTEWATER

13. Rankin Pump Station
14. Davidson Pump Station
15. Booster Pump Station
16. Bruce Flynn Pump Station
17. Southeast Pump Station
18. Southeast Treatment Plant
19. Combined Sewage Discharge (CSD)

OPEN SPACE

20. Herons Head
21. Pier 92 Wetlands
22. Islais Plaza/Islais Creek Park
23. Tulare Park
24. Fireman's Plaza Park
25. Gateway Park

PORT

26. India Basin Marina
27. Pier 92: industrial, cargo ship loading
28. Intermodal Container Transfer
29. Pier 80: working pier and railroad connection
30. 3rd Street/Cargo Way Triangle
31. Pier 80 Administration Building
32. Pier 80 Quonset Building

The City received funding from CalTrans to study flood protection and develop strategies to address SLR adjacent to Islais Creek through the Islais Creek Adaptation Strategy. The Strategy will develop a long-range vision for the Islais Creek shoreline that protects transportation infrastructure, enhances shoreline access and habitat, and nurtures community resiliency in adjoining neighborhoods. Islais Creek is also contained with the Port and U.S. Army Corps of Engineers Flood Study, which will study flood risk along San Francisco's bayside shoreline.

Southeast Wastewater Treatment Plant. Marcin Wichary

The Shoreline

The Bayview North Islais Creek shoreline is 5.3 miles long, with 3.1 miles of Bay shoreline and 2.2 miles of shoreline along the Islais Creek inlet. Along the Bay, the shoreline is primarily engineered bulkheads, piers, and wharf structures that are owned and managed by the Port. The shoreline also boasts some of San Francisco's only wetlands, including the 22-acre Heron's Head Park – a thriving wildlife habitat that attracts more than 100 bird species a year. Within the Islais Creek inlet, the shoreline is primarily engineered. However, small strips of natural shoreline are located between the inlet and the inland developed areas. Some of these areas are designated as parks with public shoreline access.

The T-Third muni train at 3rd and Marin street. Patrick Boury

Along the Bay shoreline, the wave hazards can exceed 3 feet in height,[4] creating the potential for coastal erosion of natural shorelines and wave damage to engineered shorelines. As sea level rises, the potential for wave hazards will increase, because deeper Bay waters allow for the generation of larger waves). The shoreline is first overtopped in Scenario 3 (36 inches); however, the inundation impacts are localized to a relatively small area along Islais Creek. The tipping point for Bayview North Islais Creek occurs in Scenario 5 (52 inches of SLR, or 12 inches of SLR coupled with a 100-year extreme tide) when larger stretches of the shoreline are overtopped and significant impacts to transportation occur.[5]

Trail at Heron's Head Park. Bob Gunderson

4 Federal Emergency Management Agency, Preliminary Flood Insurance Rate Maps.

5 The ART Bay Shoreline Flood Explorer allows for interactive exploration and download of the Bay Area SLR and shoreline analysis maps. These maps depict areas at risk of temporary or permanent flooding due to SLR and extreme tides as well as shoreline overtopping. Available at https://explorer.adaptingtorisingtides.org/explorer.

Extreme Tide and SLR Flooding Vulnerabilities and Consequences

The scenarios below describe the progression of potential extreme tide and SLR flooding, along with a brief discussion of the City-owned assets that will be impacted, within the Bayview North Islais Creek neighborhood. Additional details on the exposure, vulnerability, and consequences of extreme tide and SLR flooding on City-owned assets can be found within the respective sector-based chapters. The relevant chapters are referenced below, as appropriate.

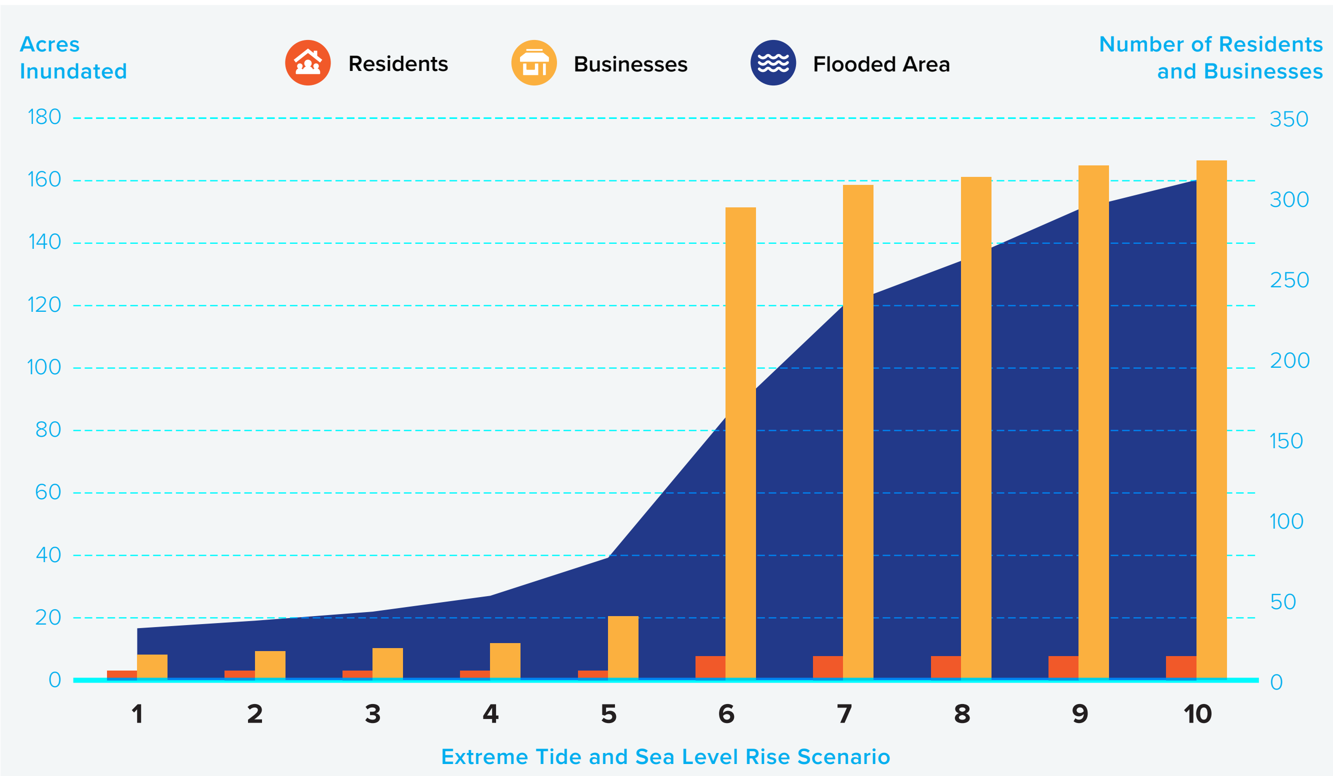
Scenario	Sector	Vulnerabilities and Consequences
Scenario 1 (12 inches SLR or an annual extreme high tide with a 1-year recurrence interval)	Open Space	**Open Space:** The wetland areas along the Bay shoreline and within Islais Creek, including Heron's Head Park and the India Basin Shoreline, already experience regular inundation during high tides today. As sea levels rise, the wetlands will either keep pace with SLR and continue to provide valuable habitat, or they will be submerged. The wetlands are expected to keep pace with SLR until mid-century; however, as SLR accelerates after mid-century, the wetlands may be lost if sediment doesn't accumulate fast enough to support wetland growth (due to deeper Bay levels).
Scenario 2 (24 inches SLR or 12 inches SLR and an annual extreme high tide with a 1-year recurrence interval)	Wastewater	**Wastewater:** Under Scenario 2, the higher Bay water levels may reduce the gravity-driven flow of excess combined wastewater and stormwater from the transport / storage boxes to the Bay (Chapter 7). This impact is only of concern during intense and prolonged rainfall events that exceed the capacity of the large underground transport / storage boxes that ring the city. This could result in an increase in localized flooding in low-lying areas.
	Public Safety	**Public Safety:** Four fire suction connections (part of the emergency firefighting water system, discussed in Chapter 6) that allow fire engines to draw water from the Bay for fire suppression are inundated. Suction connections become unusable if they are inundated.
Scenario 3 (36 inches SLR or 12 inches SLR and an annual extreme high tide with a 5-year recurrence interval)	Public Safety	**Public Safety:** A small stretch of shoreline (< 0.1 miles) is first overtopped under Scenario 3.The flooding is localized to Pier 96, impacting the Recology Recycle Central. Disruption of Recology's waste management and recycling services could have a citywide impact on waste collection and recycling efforts, resulting in additional public safety and health hazards from the local buildup of household and commercial waste.
Scenario 4 (48 inches SLR or 6 inches SLR and a 100-year extreme tide)	Port	**Port:** With Scenario 4, the shoreline is overtopped along the south side of Islais Creek onto Pier 92. The flooding impacts the Port's Pier 92 industrial and cargo ship loading facilities, as well as the Intermodal Container Transfer station (Chapter 10).
	Public Safety	**Public Safety:** One fire boat manifold (part of the emergency firefighting water system) will be inundated at this scenario. Fire boats may still be able to make a secure connection to the manifold even if it is inundated. If the fire boats cannot make a connection, and the emergency firefighting water system loses pressure, the system may become unusable.
Scenario 5 (54 inches SLR or 12 inches SLR and a 100-year extreme tide)	Port	**Port:** Under Scenario 5, Port operations will be impacted at Pier 80, which has two working cranes for loading and offloading, and connections to the rail line for goods movement. Pier 80 is also included in FEMA's emergency response plan as a location for staging and moving debris following a disaster, and the pier serves as an oil spill response equipment storage location. Pier 90, the Port's maritime maintenance facility, and the 3rd Street/Cargo Way Triangle are also impacted under Scenario 5.
	Wastewater	**Wastewater:** Two small wastewater pump stations (Rankin and Davidson) are also inundated under Scenario 5. Davidson is a belowgrade 1-mgd all-weather pump station that serves a small industrial and commercial area adjacent to I-280. Rankin is a belowgrade 3-mgd wet-weather pump station at the intersection of Rankin Street and Davidson Avenue. During wet weather, this pump station serves a local area of the Islais Creek drainage basin. Impacts at these pump stations could result in localized flooding; however, the larger Bayview North Islais Creek neighborhood would not be impacted.
	Power	**Power:** In Scenario 5, flooding would create impacts to streetlights and overhead transmission lines. If the streetlights are flooded for a short period, limited damage would occur, and would remain functioning. However, if streetlights are flooded for a prolonged period, the electrical infrastructure is likely to fail, causing the streetlight to be inoperable. The overhead lines and utility poles would also be impacted and vulnerable under Scenario 5.

Scenario	Sector	Vulnerabilities and Consequences
		Transportation: Under Scenario 5, the impacts to transportation quickly become citywide in scale. The approaches to both bridges across Islais Creek (the 3rd Street Bridge and the Illinois Street Bridge) will be inundated, with cascading consequences to goods movement to and from Pier 90-96 via both the rail line and heavy truck traffic across the Illinois Street Bridge, public transportation across the 3rd Street Bridge via the Muni T-Third line, and pedestrian, bicycle, and vehicle traffic in and out of Bayview. Three SFMTA facilities would be impacted at Scenario 5, including the Marin Yard, Islais Creek Division, and access to Burke Warehouse (Burke Warehouse could be fully inundated with 66 inches of SLR, Scenario 6). SFMTA's ability to store, maintain, repair, and refuel Muni buses would be impaired if these facilities were inundated. Burke Warehouse is the primary location for overhead line repairs for the electric trolley system. Disruption to these facilities could impact citywide transit usage.
		Open Space: Scenario 5 would also create impacts to open space and shoreline access, including Islais Creek Park and Gateway Park.
Scenario 6 (66 inches SLR or 24 inches SLR and a 100-year extreme tide)		**Wastewater:** At Scenario 6, three wastewater pump stations could be inundated (Southeast, Bruce Flynn, and Booster), significantly impacting the conveyance of stormwater and wastewater to and from the Southeast Treatment Plant. The 70-mgd Southeast lift station serves the Islais Creek, Yosemite, Sunnydale, and Mariposa watersheds during both dry and wet weather. The 110-mgd Bruce Flynn wet-weather pump station also serves these watersheds to meet greater stormwater demands during rainfall events. Localized flooding could occur if either of these pump stations are impacted by floodwaters, particularly in lower-lying areas. The 110-mgd Booster pump station conveys treated effluent from the Southeast Treatment Plant to the Bay through the Southeast Bay Outfall. The treated effluent could increase the amount of localized flooding if this pump station is impacted by Bay floodwaters. Several facilities at the Southeast Treatment Plant could be exposed to coastal floodwaters with 66 inches of SLR, or 24 inches of SLR coupled with a 100-year extreme tide (Scenario 6). Flooding is limited to the northern corner of the plant, which includes the Southeast Lift Station, Headworks Facilities, and Primary Sedimentation Facilities.New facilities under construction as part of the Sewer System Improvement Program are being constructed to be resilient to potential SLR and coastal flood hazards.
		Public Safety: Two public safety facilities could be inundated at Scenario 6, including Fire Station 25 and the Forensic Service Police Department. The fire station is part of Battalion 10 that provides coverage for the Bayview North Islais Creek and Bayview South Hunters Point neighborhoods. Emergency response in both neighborhoods could be impacted, resulting in delays in response time and dangers to public health and safety.
Scenario 7 (36 inches SLR and a 100-year extreme tide)		**Port:** At Scenario 7, the entire Pier 80 shoreline is overtopped, inundating the Pier 80 Administration Building and Quonset Building.
		Public Safety: The pipe yard for the Emergency Firefighting Water System is inundated under Scenario 7.
Scenario 8 (36 inches SLR and a 100-year extreme tide)		**Public Safety:** Fire Station 9 is inundated at Scenario 8. This fire station is also part of Battalion 10, further impacting emergency response times in this neighborhood.
		Power: Hunters Point PG&E substation is inundated at Scenario 8. Electric substations are extremely vulnerable and flooding could interrupt power service for hours to weeks.

Residents and Businesses Exposed to Extreme Tide and SLR Flooding

As extreme tides and SLR overtop the Bay shoreline and flood the city's critical infrastructure, residents and businesses in the path of the floodwaters will be affected. Few residents and businesses are affected until Scenario 5. At Scenario 5, floodwaters will overtop the shoreline and impact over 200 businesses, primarily in the areas adjacent to the Islais Creek Channel and on Piers 80 to 92. The areas with the most affected businesses include the areas between the Islais Creek Channel and Cesar Chavez Street to the north, I-280 to the west, and Evans Avenue (at 3rd Street), as well as part of Cargo Way to the south. Under Scenario 6, the commercially-used area south of Napoleon Street (west of I-280) is also inundated.

For more information about particular properties and buildings are affected under different scenarios, use the *Adapting to Rising Tides Bay Shoreline Flood Explorer*.[6]



6 https://explorer.adaptingtorisingtides.org/home

Pier 70 and Central Waterfront. Photo by Flickr user 1Flatworld (CC BY-NC-ND 2.0)

NEIGHBORHOOD PROFILE

POTRERO HILL / CENTRAL WATERFRONT

Potrero Hill/Central Waterfront is located on the eastern edge of San Francisco between the South of Market and Bayview neighborhoods. I-280 splits this neighborhood between the residential hillside and the low-lying area along the shoreline (known as Dogpatch), which was once a heavily industrial area but has added residential uses in recent decades. The existing industrial bands that run through the neighborhood include a number of critical city infrastructure maintenance and operation sites, such as Muni Metro East where Muni's light rail vehicles are stored. The UCSF Medical Center at Mission Bay is a major medical research facility located in the northern portion of the neighborhood.

Third Street, including the T-Third Light Rail line, is the major surface north-south connection between the Central Waterfront and the rest of the City. 22nd Street adjacent to 3rd Street forms a small-scale neighborhood commercial corridor. Several large shoreline developments, including Pier 70 and Potrero Power Station are proposed or approved for this area. These developments would bring significant numbers of new housing and jobs to the area, and contain SLR adaptation as part of their plans. See Chapter 13. *A Changing Shoreline*.

The area contains several shoreline open spaces, including Warm Water Cove, Crane Cove Park (under construction), Agua Vista Park, Bayfront Park, and several new open spaces proposed as part of new shoreline development projects

As a result of its industrial nature and its location along a major transit and highway corridor, this neighborhood sees very high rates of traffic and hazardous and solid waste, including at Pier 70.[1] The soil within the Pier 70 area is subject to a "Risk Management Plan" that functions as the remedial action plan for the site and ensures that contaminants in the existing soil do not pose a risk to human health or the environment. Pier 70 is in the process of being redeveloped and required environmental cleanup and decontamination are part of the agreements the Port has created with developers and in conjunction with the building of nearby Crane Cove Park. See Chapter 9.5. *Public Safety – Contaminated Lands* for more detail.

1 California Environmental Protection Agency (CalEPA) and Office of Environmental Health Hazard Assessment (OEHHA). 2017. CalEnviroscreen 3.0. Available at https://oehha.ca.gov/media/downloads/calenviroscreen/report/ces3report.pdf.

The Shoreline

The 2-mile-long Potrero Hill/Central Waterfront shoreline is comprised entirely of engineered structures, such as piers and seawalls. The wave hazards along this shoreline can exceed 5 feet in height, which leads to a higher potential for wave damage.[2] As sea level rises, the potential for wave hazards increases as deeper Bay waters allow for the generation of larger waves. The wave hazard vulnerability is important to the shoreline located near Potrero Point (between 19th and 22nd and Illinois streets). This shoreline is currently crumbling into the Bay, and dilapidated buildings are the de facto shoreline. There are occasional revetments to break up wave energy and reduce shoreline erosion, which protect the transbay cable, which enters San Francisco via the existing Potrero switchyard. The transbay cable is a 53-mile, 400-megawatt submarine high-voltage direct current transmission line located beneath San Francisco Bay delivering approximately 40 percent of the city's electricity demand.[3] Significant shoreline erosion could compromise the transbay cable.

Significant overtopping of the Potrero Hill shoreline happens during Scenario 6 when over 50 percent (1.1 miles) is overtopped, leading to extensive inland flooding.[4]

View of Potrero Hill from SoMa. Bill Couch (CC BY-NC-ND 2.0)

Dogpatch neighborhood. Wayne Hsieh (CC BY-NC 2.0)

Caltrain 22nd Street Station. Flickr user throgers (CC BY-NC-ND 2.0)

2 Federal Emergency Management Agency, Preliminary Flood Insurance Rate Maps.

3 http://www.transbaycable.com/.

4 The ART Bay Shoreline Flood Explorer allows for interactive exploration and download of the Bay Area SLR and shoreline analysis maps. These maps depict areas at risk of temporary or permanent flooding due to SLR and extreme tides as well as shoreline overtopping. Available at https://explorer.adaptingtorisingtides.org/explorer.

Inundation at 66" Sea Level Rise
Low Lying Land (at risk of inundation at 66")
Overtopping
No Overtopping
Koret Quad
Doggett Park
Bayfront Park
Seawall Lot 337-South
Agua Vista Park
Seawall Lot 343
Seawall Lot 345
Jackson Playground
Mariposa Park
Esprit Park
Potrero Hill Community Garden
McKinley Square
Woods Yard Park
Potrero Hill Recreation Center
Starr King Open Space
Tunnel Top Park
Potrero del Sol
James Rolph Jr Playground
15TH ST
16TH ST
17TH ST
18TH ST
19TH ST
20TH ST
22ND ST
23RD ST
24TH ST
25TH ST
26TH ST
MARIPOSA ST
CESAR CHAVEZ ST
MARIN ST
TUBBS ST
8TH ST
7TH ST
OWENS ST
3RD ST
KANSAS ST
DE HARO ST
CONNECTICUT ST
TEXAS ST
RHODE ISLAND ST
CAROLINA ST
ARKANSAS ST
MISSOURI ST
MISSISSIPPI ST
MINNESOTA ST
MICHIGAN ST
ILLINOIS ST
TENNESSEE ST
PENNSYLVANIA ST
INDIANA ST
WISCONSIN ST
DAKOTA ST
VERMONT ST
POTRERO AVE
EVANS AVE
BAYSHORE BLVD

Potrero Hill / Central Waterfront

TRANSPORTATION

1. Muni Metro East Facility

WASTE WATER

2. Mariposa Pump Station
3. Twentieth Street Pump Station
4. Combined Sewer Discharge (CSD)

PUBLIC SAFETY

5. Pier 70

OPEN SPACE

6. Aqua Vista Park (Port)
7. Warm Water Cove Park (Port)
8. Bayfront Park (Port)

PORT

9. Seawall Lot 345
10. Seawall Lot 337 South
11. Seawall Lot 356
12. Seawall Lot 343
13. Seawall Lot 349
14. Pier 68

Extreme Tide and SLR Flooding Vulnerabilities and Consequences

The scenarios below describe the progression of potential extreme tide and SLR flooding, along with a brief discussion of the City-owned assets that will be impacted, within the Potrero Hill/Central Waterfront neighborhood. Additional details on the exposure, vulnerability, and consequences of extreme tide and SLR flooding on City-owned assets can be found within the respective sector-based chapters. The relevant chapters are referenced below, as appropriate.

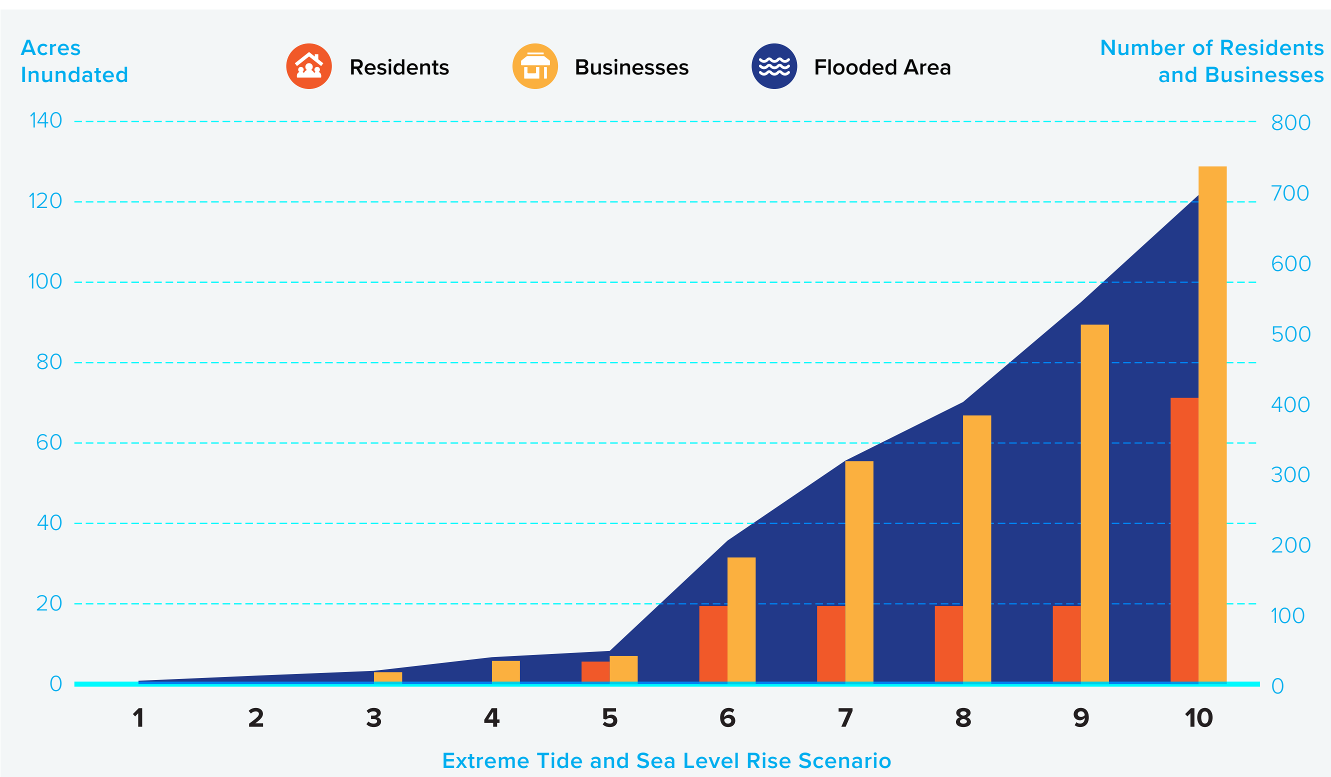
Scenario	Sector	Vulnerabilities and Consequences
Scenario 2 (24 inches of SLR or 12 inches of SLR and a high tide with a 1-year recurrence interval)	Port	**Port:** Port operations could become impacted at Scenario 2 when Seawall Lot 345 is inundated (Chapter 10). This seawall lot houses a restaurant, a small private boatyard, self-storage units, and a sailing charter company.
	Wastewater	**Wastewater:** Under Scenario 2, the higher Bay water levels may reduce the gravity-driven flow of excess combined wastewater and stormwater from the transport / storage boxes to the Bay via combined sewer discharge outfalls (Chapter 7). This impact is only of concern during intense and prolonged rainfall events that exceed the capacity of the large underground transport / storage boxes that ring the city. This could result in an increase in localized flooding in low-lying areas.
Scenario 3 (36 inches of SLR or 12 inches of SLR and a high tide with a 5-year recurrence interval)	Open Space	**Open Space:** Open space and aquatic areas (owned and managed by the Port) along the shoreline of the Potrero Hill neighborhood experience the first SLR impacts at Scenario 3. Both Agua Vista Park and Warm Water Cove Park have overtoped shorelines and inundation of public viewing and access areas.
Scenario 4 (48 inches of SLR or 6 inches of SLR and a 100-year extreme tide)	Port	**Port:** With Scenario 4, Seawall Lot 337 becomes inundated. This seawall lot is part of the Mission Rock Mixed-Use Development Project, which includes SLR adaptation (see Chapter 13).
	Power	**Power:** At Scenario 4, the Trans Bay Cable would be impacted at its connection with the Potrero substation. The Trans Bay Cable is a 53-mile direct current electrical transmission cable with fiber optic communication cables bundled together and buried in San Francisco Bay. The submarine nature of the cable reduces its vulnerability to SLR and coastal flooding.
Scenario 5 (54 inches SLR or 12 inches SLR and a 100-year extreme tide)	Port	**Port:** At Scenario 5, Seawall Lot 356 (currently a self-storage company) becomes inundated. Future plans for this site include expanding Warm Water Cover Park and the Pier 80 Cargo Terminal.
Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide)	Open Space	**Open Space:** Scenario 6 is a tipping point for flooding within the Potrero Hill neighborhood. Shoreline access at Bayfront Park becomes inaccessable and Port and SFPUC operations could be impacted.
	Port	**Port:** Pier 68 and Seawall Lots 343 and 349 could be inundated under Scenario 6. Pier 68 is within the Union Iron Works National Register Historic District. The pier has historically provided maritime and industrial services and is still used today for ship repair. Seawall Lot 343 provides open space and houses an SFMTA substation that is extremely sensitive to inundation. Both Pier 68 and Seawall Lot 349 are part of the greater Pier 70 redevelopment project.
	Wastewater	**Wastewater:** Two wastewater pump stations are inundated at Scenario 6, including Mariposa pump station and the 20th Street pump station. Mariposa pump station has a 15-mgd pumping capacity, conveying both dry weather and wet weather flows for the entire Mariposa drainage basin. SFPUC is currently rehabilitating Mariposa pump station under the Sewer System Improvement Program and is incorporating flood resilience strategies into its design. The 20th Street pump station is a small pump station with a 3-mgd pumping capacity serving the eastern end of 29th Street and the old Todd Shipyard. Impacts at this pump station would be localized.
	Power	**Power:** Under Scenario 6, the overhead lines and utility poles would be impacted and vulnerable.

Scenario	Sector	Vulnerabilities and Consequences
Scenario 7 (36 inches SLR and a 100-year extreme tide)		**Power:** Streetlights are inundated at Scenario 7. If temporarily flooded, the streetlights would have limited damage and would remain functioning. If streetlights are flooded for a prolonged period, the electrical infrastructure is likely to fail, rendering the streetlight inoperable and the roadway or sidewalk dark during the night.
Scenario 8 (48 inches of SLR and a 100-year extreme tide)		**Public Safety:** At Scenario 8, Pier 70's existing structures could experience flooding. This pier is listed on the National Register as the Union Iron Works Historic District due to its role in ship construction and repair over the last 150 years. The Pier 70 mixed-use development project includes SLR adaptation strategies.
Scenario 10 (66 inches of SLR and a 100-year extreme tide)		**Transportation:** At Scenario 10, the Muni Metro East facility would be inundated. This facility spans 13 acres, including storage, maintenance, and operations facilities, and is currently the main facility where light rail vehicles and historic streetcars are repaired and maintained. There are plans to expand this facility eastward into additional areas that may be subject to flooding as sea levels rise. System-wide impacts to the Muni transit lines would occur if this facility is out of service for an extended period.

Residents and Businesses Exposed to Extreme Tide and SLR Flooding

As extreme tides and SLR overtop the Bay shoreline and flood the city's critical infrastructure, residents and businesses in the path of the floodwaters will be affected. Few residents and businesses within the Potrero Hill neighborhood are affected until Scenario 6 when 180 businesses are impacted and more than 110 residents are impacted.

For more information about particular properties and buildings are affected under different scenarios, use the *Adapting to Rising Tides Bay Shoreline Flood Explorer*.[5]



5 https://explorer.adaptingtorisingtides.org/home

NEIGHBORHOOD PROFILE

SOUTH OF MARKET MISSION BAY

View of Mission Creek North and SoMa. Photo by Sergio Ruiz

The SoMa and Mission Bay neighborhoods, located on the eastern edge of San Francisco, are comprised of developing mixed-use neighborhoods on both sides of Mission Creek. The neighborhood includes extensive housing and commercial buildings as well as regional destinations including UCSF Mission Bay, Oracle Park, and Chase Center. The shoreline includes historic piers and the Mission Creek tidal inlet. SoMa/Mission Bay also includes significant city and regional infrastructure, including Caltrain 4th and King Station and railyards, future California High Speed Rail, the Bay Bridge touchdown, the SFPUC's Channel Force Main, the T-Third Muni Line, and a planned new 16th Street Ferry Terminal.

SoMa/Mission Bay includes residents across a wide range of income levels and racial and ethnic groups. New development includes extensive market rate housing as well as thousands of below market rate units both north and south of Mission Creek.[1] Portions of SoMa that would be affected by SLR are included in MTC's Communities of Concern.

Historically, SoMa has housed many low-income residents in SROs[2] and has high numbers of residents with disabilities, preventable hospitalizations, and in overcrowded and poor-quality housing[3]. SoMa is home to many community-based organizations. SoMa Pilipinas, San Francisco's Filipino Cultural Heritage District, provides arts, employment, and cultural events and services for Filipino-American residents.[4] The Central SoMa Plan, adopted in 2018, plans for nearly 16 million square feet for new housing and jobs, bringing over $2 billion in public benefits, including 33 percent affordable housing, $500 million for transit, substantial improvements to open space, streets, and environmental sustainability, and funding for cultural preservation and community services to the neighborhood. The Plan includes policies and funding to address SLR.

The Mission Bay redevelopment area includes 303 acres of land between the San Francisco Bay and Interstate-280. The Board of Supervisors established the Mission Bay North and South Redevelopment Project Areas in November 1998. The area will support up to 6,404 housing units, with 1,806 (~30%) affordable to moderate, low, and very low-income

1 Office of Community Investment and Infrastructure (OCII). Mission Bay. Available at https://sfocii.org/mission-bay.

2 Single Room Occupancy hotels.

3 San Francisco Department of Public Health. 2016. Climate and Health: Understanding the Risk: An Assessment of San Francisco's Vulnerability to Flooding and Extreme Storms.

4 SOMA Pilipinas. Welcome to Our Neighborhood. Available at https://www.somapilipinas.org/.

4th and King Caltrain station. Rahul Nair (CC BY-NC 2.0)

Giants ballpark. Tehani Schroeder (CC BY 2.0)

households, 4.4 million square feet of commercial use, the UCSF Mission Bay campus, and 41 acres of new public open space. The Mission Bay development requirements from the 1990s required properties to raise their foundations by one to two feet to address SLR in response to best known science at the time.

A portion of the shoreline for the SoMa neighborhood is included within the Port's Embarcadero Seawall Program, a separate but coordinated effort to create a more sustainable and resilient waterfront. Port assets within the Embarcadero Seawall Program area were not included within this assessment, although they have been identified within this profile for informational purposes. This area is also contained with the Port and U.S. Army Corps of Engineers Flood Study, which will study flood risk along San Francisco's bayside shoreline.

The Shoreline

The SoMa/Mission Bay neighborhood has 5.3 miles of Bay shoreline, including 2 miles of direct shoreline and 3.4 miles of shoreline created by the large piers that dominate the Bayfront.

Without the protection of the piers, most of the SoMa/Mission Bay shoreline would be in a wave hazard zone. Winter storms with large waves have damaged the piers and shoreline, and under existing conditions the wave hazards are greatest between the Bay Bridge and the Pier 40 breakwater.[5] [6]

Most of the Bay facing shoreline is not overtopped until Scenario 7; however, if the piers are damaged due to storm or wave hazards, overtopping and inland inundation could occur earlier.

The Mission Bay area has an additional 1.7 miles of shoreline created by the Mission Creek inlet (west of the Third Street bridge) and in McCovey cove (east of the Third Street Bridge). McCovey Cove includes a ferry dock, a houseboat community along the south side, and a public access walkway along the north side. Wave hazards are minimal within McCovey Cove and Mission Creek.

Most of the overtopping and subsequent flooding in the SoMa/Mission Bay neighborhood occurs along the low-lying inlet shorelines. Under Scenario 4, a third of the Mission Creek/McCovey Cove shoreline is overtopped. This includes the shoreline that contains the houseboat community and the southern side of the 4th Street Bridge, which has a large Muni light rail vehicle track interchange. Under Scenario 5, the northern shoreline of Mission Creek is also overtopped, including a public access sidewalk that is less than 30 feet in front of apartment buildings. By Scenario 6, most of the Mission Creek/McCovey shoreline is overtopped, causing widespread flooding.[7]

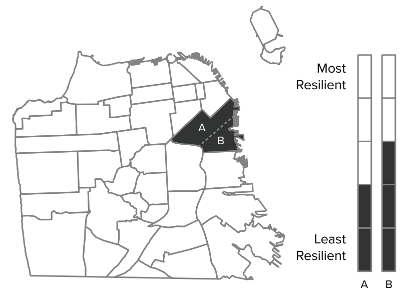
5 Federal Emergency Management Agency, Preliminary Flood Insurance Rate Maps.

6 South Beach Harbor has a 0.4-mile breakwater protecting the Bay facing harbor, the McCovey cove side to the south, and a large Pier 40 building structure to the north. The breakwater and the structures protect the shoreline from wave hazards.

7 The ART Bay Shoreline Flood Explorer allows for interactive exploration and download of the Bay Area SLR and shoreline analysis maps. These maps depict areas at risk of temporary or permanent flooding due to SLR and extreme tides as well as shoreline overtopping. Available at https://explorer.adaptingtorisingtides.org/explorer.


Inundation at 52" Sea Level Rise
Low Lying Land (at risk of inundation at 52")
Overtopping
No Overtopping
PINE ST
BUSH ST
SUTTER ST
GEARY BLVD
OFARRELL ST
TURK ST
GOLDEN GATE AVE
MCALLISTER ST
GROVE ST
HAYES ST
FELL ST
OAK ST
FRANKLIN ST
VAN NESS AVE
LARKIN ST
HYDE ST
LEAVENWORTH ST
JONES ST
MASON ST
POWELL ST
STOCKTON ST
GRANT AVE
KEARNY ST
MONTGOMERY ST
BATTERY ST
MARKET ST
1ST ST
FREMONT ST
MAIN ST
2ND ST
3RD ST
4TH ST
5TH ST
6TH ST
7TH ST
8TH ST
9TH ST
10TH ST
11TH ST
12TH ST
13TH ST
MISSION ST
HOWARD ST
FOLSOM ST
HARRISON ST
BRYANT ST
BRANNAN ST
DIVISION ST
SOUTH VAN NESS AVE
GOUGH ST
DUBOCE AVE
OWENS ST
VALENCIA ST
POTRERO AVE
VERMONT ST
DE HARO ST
16TH ST
17TH ST
Union Square
Civic Center Plaza
Gene Friend Rec Center
Howard & Langton Mini Park
Victoria Manalo Draves Park
South Park
Franklin Square
Jackson Playground
80
101
280

South of Market Mission Bay



NEIGHBORHOOD RESILIENCY SCORE: A **2** B **3**

Hazard Score: A 1 B 1
Environmental Score: A 1 B 1
Transportation Score: A 5 B 4
Community Score: A 1 B 1
Public Realm Score: A 4 B 3
Housing Score: A 2 B 5
Economy Score: A 4 B 5
Health Score: A 4 B 5
Demographics Score: A 3 B 4

Source: San Francisco Climate & Health Program Neighborhood Summary
https://sfclimatehealth.org/neighborhoods/

PUBLIC SAFETY

1 Bureau of Fire Investigation
2 Southern District Fire Station
3 Fire Station #4
4 Public Safety Building
5 Fire Station #35 - Fireboat Headquarters
6 Fifth Street Homeless Center
7 Fire Station #8
8 Contaminated Land
9 Police Headquarters
10 Public Defenders Office
11 Hall of Justice
12 County Jail #4
13 Fireboat Pump Station / Fire Suction Connection
14 Fireboat Manifold

TRANSPORTATION

15 Lefty O'Doul Bridge
16 Fourth Street Bridge
17 Giants Stadium Ferry Terminal

WATER

18 Bay Bridge Pump Station

WASTE WATER

19 Merlin MorrisPump Station
20 Berry Street Pump Station
21 Harriet-Lucerne Pump Station
22 Channel Pump Station
23 Combined Sewer Discharge (CSD)

OPEN SPACE

24 Pier 52
25 China Basin Park
26 Boat Launch
27 Rincon Park
28 Shoreline Park
29 Mission Creek Garden
30 South Beach Park
31 South Beach Harbor
32 Giant's Promenade
33 Brannan Street Wharf

PORT

34 South Beach Marina
35 Pier 62/McCovey Cove and China Basin
36 The Promenade
37 Seawall Lot 337
38 Mission Creek Marina
39 Giants Ballpark
40 Embarcadero Promenade (Bay Trail)
41 WETA, Golden Gate Ferries

Extreme Tide and SLR Flooding Vulnerabilities and Consequences

The scenarios below describe the progression of potential extreme tide and SLR flooding, along with a brief discussion of the City-owned assets that will be impacted, within the SoMa/Mission Bay neighborhoods. Additional details on the exposure, vulnerability, and consequences of extreme tide and SLR flooding on City-owned assets can be found within the respective sector-based chapters. The relevant chapters are referenced below, as appropriate.

Scenario	Sector	Vulnerabilities and Consequences
Scenario 1 (12 inches of SLR or a high tide with a 1-year recurrence interval)	Public Safety	**Public Safety:** Three fire suction connections (part of the emergency firefighting water system, Chapter 9) at the shoreline will experience inundation. The suction connections become unusable when inundated, largely due to limitations in fire engine access.
Scenario 2 (24 inches of SLR or 12 inches of SLR and a high tide with a 1-year recurrence interval)	Public Safety	**Public Safety:** Twelve additional fire suction connections at the shoreline will experience inundation.
	Wastewater	**Wastewater:** Under Scenario 2, the higher Bay water levels may reduce the gravity-driven flow of excess combined wastewater and stormwater from the transport / storage boxes to the Bay via combined sewer discharge outfalls. This impact is only of concern during intense and prolonged rainfall events that exceed the capacity of the large underground transport / storage boxes that ring the city. This could result in an increase in localized flooding in low-lying areas.
Scenario 3 (36 inches of SLR or 12 inches of SLR and a high tide with a 5-year recurrence interval)	Port	**Port:** The SoMa/Mission Bay neighborhood will first experience inundation when the Mission Creek shoreline is overtopped on the south side under Scenario 3, although overall impacts are limited. The Pier 52 Boat Launch and a portion of China Basin Park will experience inundation. The Pier 52 boat launch is the only public launch point in San Francisco's Bayside waterfront. Under Scenario 3, the boat launch may still be useable, but damage to the boat launch would limit public access to the Bay.
	Public Safety	**Public Safety:** One additional fire suction connections at the shoreline will experience inundation.
	Power	**Power:** Streetlights will experience inundation at Scenario 3.
Scenario 4 (48 inches of SLR or 6 inches of SLR and a 100-year extreme tide)	Public Safety	**Public Safety:** With Scenario 4, over 60 acres of inland area will be inundated, including important community facilities, including the Bureau of Fire Investigation, Southern District Police Station, Fire Station #4, and the Public Safety Building. Fire Station #4 and the Public Safety Building (built in 2015) would be inundated. The public safety campus also contains the San Francisco Police Department headquarters, the Arson Task Force, and a Community Room serving the Mission Bay neighborhood. This could impact emergency response in the neighborhood and beyond, resulting in delays in response time and dangers to public health and safety. One of the city's fireboat manifold connections will be inundated under Scenario 4; however, it can remain in service as long as a fireboat can safely establish a connection.
	Port	**Port:** Under Scenario 4, Rincon Park, which is owned and managed by the Port, could be inundated. Mission Creek Shoreline Park South, running parallel to the southern shore of Mission Creek, would be inundated. The park features walking paths, picnic areas, and community gardens and provides viewing and access to Mission Creek. Although the channel between the two parks has been significantly altered, it is the last remnant of the original Mission Bay formed by Mission Creek, and it still supports wildlife. Bayfront Park is currently a large open lot with parking and a bike path that could be inundated under Scenario 4. The park will be improved and expanded as part of the Mission Bay Redevelopment Plan.

Scenario	Sector	Vulnerabilities and Consequences
Scenario 5 (52 inches SLR or 12 inches SLR and a 100-year extreme tide)	Transportation	**Transportation:** Under Scenario 5, flooding would extend to the north side of Mission Creek, flooding 111 acres in Mission Bay North and SoMa, nearly doubling the area impacted under Scenario 4. This has far reaching effects for local residents and businesses and includes impacts to 4.1 miles of Caltrain train tracks.
	Public Safety	**Public Safety:** Fire Station #35, the fireboat headquarters located on Pier 22 1/2 at Harrison Street, will be inundated under Scenario 5. This fire station is located on Port land and is located within the Embarcadero Seawall Program area discussed in Chapter 4. The three fireboats anchored here, the *Phoenix*, *Guardian*, and *Saint Francis*, can connect directly to the emergency firefighting water distribution system via five manifold connections along the shoreline, and pump saltwater from the Bay into the distribution system for fire suppression. The fireboats provide emergency backup protection in the event of a failure of the reservoirs and/or pump stations. Even though the fireboats are not affected, the headquarters and access to the boats could be impacted. This could result in impacts to this unique emergency response system with consequences for public health and safety.
	Port	**Port:** Mission Creek Harbor, including its community of approximately 20 houseboats moored on docks, would be affected in Scenario 5. Although less than a quarter acre is shown as flooded, support facilities and utilities are sensitive to disruption. The utilities have been designed to accommodate SLR and flooding. However, permanent inundation would eliminate the ability to use the site, and due to its water dependent nature, the harbor would not be easy to relocate. This houseboat community would also be impacted by any loss in the ability to operate the drawbridges (see Chapter 5).
	Wastewater	**Wastewater:** The Berry Street pump station could be exposed to floodwaters under Scenario 5. It is a wet-weather pump station located below grade at the corner of Berry Street and 5th Street adjacent to Mission Creek, approximately 200 feet from the San Francisco Bay shoreline. It serves the Channel drainage basin with a pumping capacity of 9.2 mgd. During wet weather, this pump station conveys combined flows from the Berry Street drainage area to a sewer on 5th Street. Electrical equipment and controls are located at and below grade and can be affected by floodwaters entering through openings at grade. The at-grade electrical controls are also at risk from shallow flooding. Impacts at this pump station could result in localized flooding during wet weather; however, the larger Channel/Mission Creek neighborhood would not be impacted.
Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide)	Transportation	**Transportation:** By Scenario 6, over 14,000 residents and nearly 2,000 businesses could be inundated by SLR and extreme coastal flooding. Both bridges across Mission Creek (Lefty O'Doul and 4th Street Bridges) will be impacted, resulting in cascading consequences to local and through traffic and operation of the T-Third line. Impacts to the T-Third would create cascading consequences throughout the Muni system. Impacts to the draw bridge operations would also impact the local houseboat community.
	Public Safety	**Public Safety:** The Public Defender's Office at 555 7th Street is inundated in Scenario 6. It serves 25,000 people a year and employs over 100 attorneys and 60 staff The 5th Street Homeless Center will be impacted under Scenario 6, as well as an additional Fire Station (Fire Station #8 at 530 Bluxome Street between 4th and 5th Streets).
	Wastewater	**Wastewater:** Channel pump station will be impacted under Scenario 6, which could have widespread consequences for the neighborhood and the city. Channel pump station is located near Mission Bay in a mixed residential and industrial area directly adjacent to the Mission Bay shoreline. This pump station serves both the Channel and Northshore drainage basins with a pumping capacity of 103 mgd and operates continuously in both dry and wet weather. In dry weather, Channel pump station receives, and transports wastewater pumped from the North Shore pump station and flows from the Channel drainage area. The pump station conveys wastewater through the Channel force main to the Southeast Treatment Plant. In wet weather, combined flows are conveyed from the local drainage area to the Southeast Treatment Plant. Two additional smaller wastewater pump stations (Harriet Lucerne and Merlin Morris) will also be impacted under Scenario 6, resulting in localized flooding. Harriet-Lucerne pump station is a belowgrade pump station located on Harriet Street with a pumping capacity of 7.3 mgd, and Merlin Morris pump station is a belowgrade pump station located on Merlin Street (near Harrison Street) with a pumping capacity of 9.2 mgd. Impacts at these pump stations could result in localized flooding; however, the larger Channel/Mission Creek neighborhood would not be impacted.

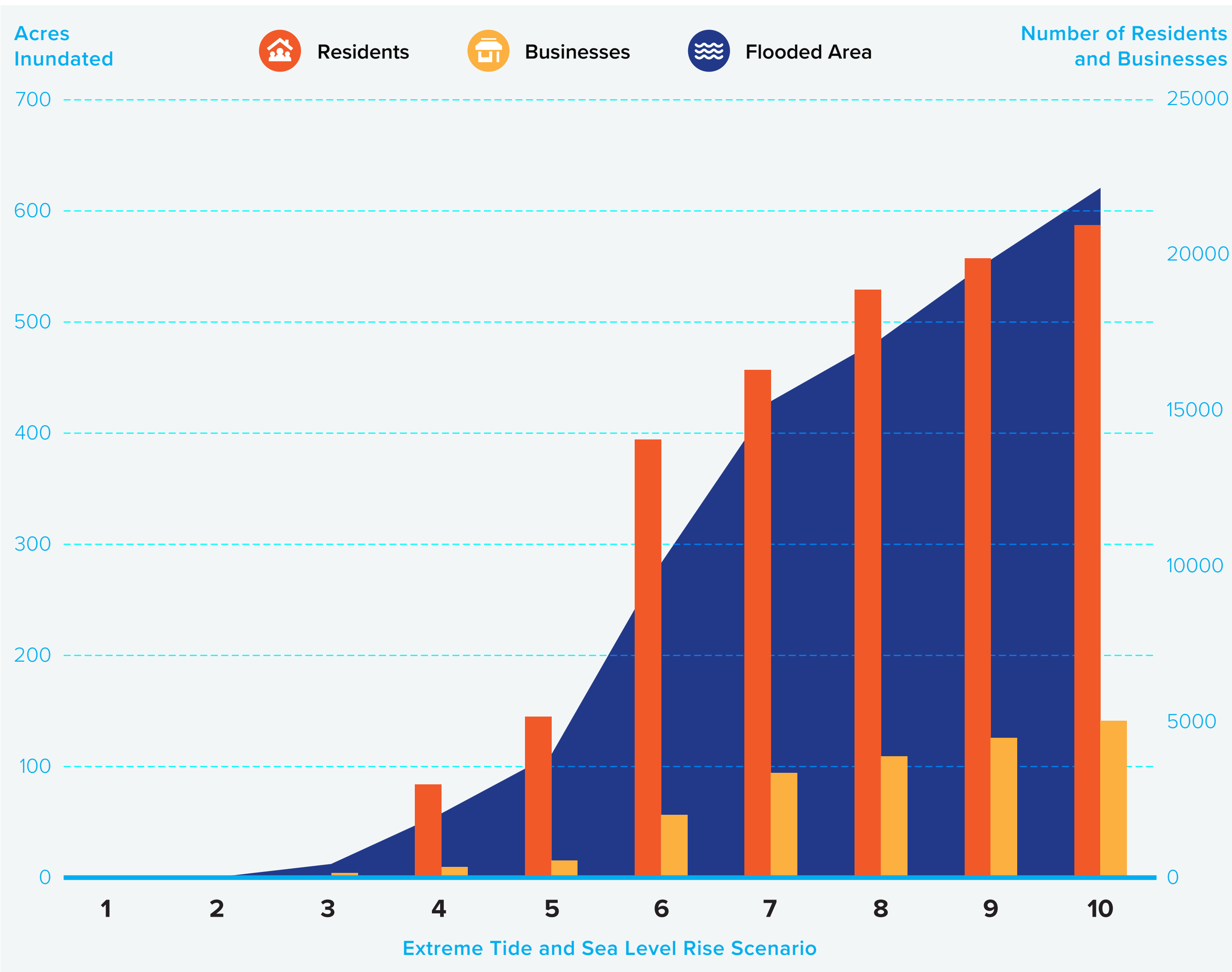
Scenario	Sector	Vulnerabilities and Consequences
		Power: Under Scenario 6, underground transmission lines, overhead lines, and utility poles are exposed and vulnerable to flooding.
		Port: Mission Creek Garden is located onshore in the southwestern corner of Mission Creek near the Houseboat Marina and could be inundated under Scenario 6.
Scenario 7 (36 inches of SLR and a 100-year extreme tide)		**Transportation:** At Scenario 7, the Ferry Terminal serving Oracle Park for games could be inundated, as well as the Giant's Promenade. The majority of Oracle Park itself will also be inundated under this scenario.
Scenario 8 (48 inches of SLR and a 100-year extreme tide)		**Water:** At Scenario 8, Bay Bridge pump station could be impacted, preventing the delivery of potable water to Treasure Island.
		Public Safety: The San Francisco County Jail #4 and the Hall of Justice at 850 Bryant St. will be partially inundated. Although the jail facility is located on the 7th floor, the building could be rendered inaccessible.
Scenario 10 (66 inches of SLR and a 100-year extreme tide)		**Public Safety:** Fire Station #1, located at 935 Folsom at 5th Street, would be inundated and inaccessible at Scenario 10.
		Open Space: Gene Friend Recration Center would not be directly inundated until Scenario 10. However, this facility is located in the historic Hayes Creek bed and it has drainage issues that could worsen as sea levels and the groundwater table rise. The building includes mechanical and electrical equipment that is at grade and sensitive to saltwater flooding. This is the only public recreation center in the SoMa neighborhood, and the center serves a large elderly population and provides services for at-risk youth. There are no nearby City-owned assets that could provide the same services and accessibility for the users of this facility. The 2-acre Victoria Manalo Draves Park, located at Sherman and Folsom Streets, would be affected by coastal flooding and SLR at Scenario 10. It is also located within the historic Hayes Creek bed and hydrology and drainage issues could occur as sea levels and the groundwater table rise. Most of the park areas could recover after inundation subsides. However, the community garden, and lower-lying grassy areas and park vegetation, may be impacted from rising groundwater and eventual saltwater inundation. Other San Francisco parks could provide similar services and amenities if this park is temporarily impacted; however, there are few alternative recreational spaces in the South of Market area.

Residents and Businesses Exposed to Extreme Tide and SLR Flooding

As extreme tides and SLR overtop the Bay shoreline and flood the city's critical infrastructure, residents and businesses in the path of the floodwaters will be affected. The areas with the most affected residents and businesses initially include the Mission Bay area southwest of the Mission Creek Channel. Starting with Scenario 5, areas north of the channel north to Brannan Street, covering the entire area around the Caltrain King Street station and associated tracks, would be affected.

Residents would lose access to the shoreline, park and open spaces, transportation and eventually their homes and places of work if these areas are damaged or disrupted. These impacts would disproportionally impact vulnerable members of the community for whom the loss could be considerable, as they may not have the ability to easily retrofit or relocate to locations not impacted.

For more information about particular properties and buildings are affected under different scenarios, use the *Adapting to Rising Tides Bay Shoreline Flood Explorer*.[1]



1 https://explorer.adaptingtorisingtides.org/home

San Francisco downtown skyline. Photo by Sergio Ruiz

NEIGHBORHOOD PROFILE

FINANCIAL DISTRICT

The Financial District, located on the eastern edge of San Francisco, is comprised of mixed-use, high-density neighborhoods near The Embarcadero and the foot of Market Street. The Financial District includes the Bay Area's largest and densest job center, significant amounts of housing and commercial space, and iconic regional destinations including the Ferry Building, Embarcadero Promenade, and the Central Embarcadero Piers Historic District.

The shoreline of this neighborhood is constructed on a series of aging seawalls referred to as the Embarcadero Seawall. (See Chapter 4.8. *San Francisco Seawall Earthquake Safety and Disaster Prevention Program* for more detailed information on seismic risks and current hazard mitigation planning efforts.) The Financial District also includes significant city and regional transportation infrastructure, including BART, Muni Metro, Muni bus lines, historic streetcars, cable cars, and ferry terminals.

The Financial District is one of the region's densest areas in terms of residents and daytime workers. The Financial District is critical to the San Francisco and regional economy. The Ferry Building and scenic Embarcadero Promenade attract high levels of tourists. Loss of historic piers and buildings, such as the Ferry Building, would impact the historic district and affect tourism and potentially lead to the loss of tax credits. Significant disruption to this area could lead to loss of jobs, tourism, and tax revenues, causing significant economic disruption to the entire Bay Area. Service workers and those who cannot work remotely would be impacted the most.

The Financial District shoreline also plays a critical role in emergency response and disaster recovery. Fire Station #13, Embarcadero Promenade, various recreational plazas, and the ferry terminals serve critical disaster response functions, such as staging areas and evacuation points. In addition to evacuating people from San Francisco to other parts of the Bay Area, the ferry terminals can also transport supplies and personnel to assist with disaster response and recovery within San Francisco. The loss of access to the fire station, ferry terminals, or the inundation of staging areas would delay evacuation and increase emergency response times following a disaster, such as a large earthquake.

The Financial District shoreline is included within the Port's Embarcadero Seawall Program, a separate but coordinated effort to create a more sustainable and resilient waterfront. More information related to the Embarcadero Seawall Program is included in Section 4.8. Port assets within the Embarcadero Seawall Program area were not included within this assessment, although they have been identified within this profile for informational purposes. This area is also contained with the Port and U.S. Army Corps of Engineers Flood Study, which will study flood risk along San Francisco's bayside shoreline.

Giants ballpark. Photo by Tehani Schroeder (CC BY 2.0)


Financial District and downtown skyline. Photo by Flickr user gags9999 (CC BY 2.0)

The Shoreline

The shoreline of the Financial District is one mile long and entirely engineered, including seawalls and piers. Located at the southern end of the Financial District shoreline and extending over 600 feet into the Bay, Pier 14 serves as a breakwater to protect the Downtown Ferry Terminal from wave and tidal forces. Pier 14 includes several informational markers that denote projected elevations of sea levels over time.

Currently, the Downtown San Francisco Ferry Terminal Expansion Project is being constructed next to Pier 14. The new ferry gates will be built to accommodate approximately 3 to 4 feet of anticipated SLR above a 100-year extreme tide event. Pier 1 ½, located north of the Ferry Building, is a public access dock. Pier 7 is a popular public fishing pier located at the northernmost end of the Financial District's shoreline. Pier 7 is a long, thin pier, lined with benches, with panoramic views of both the Bay and the city. Pier 7 is a popular location for crab fishing, mainly at night, and for shark and perch fishing. The Bay Trail, a 500-mile long pedestrian and bicycle path around the Bay, runs along the Financial District shoreline along the Embarcadero.[1]

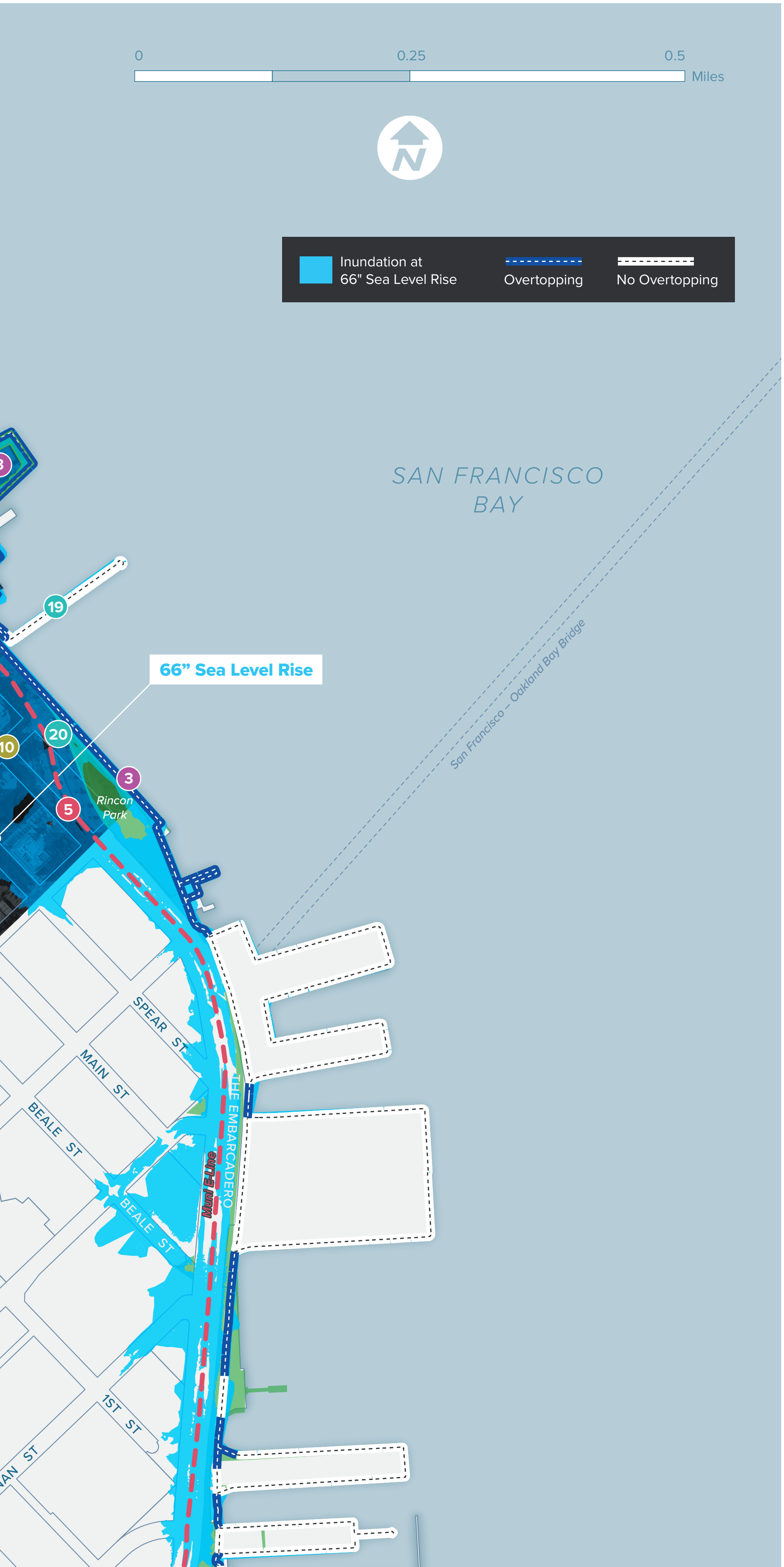
Along approximately half of the shoreline, the wave hazard can reach 3 feet in height, creating the potential for wave damage to the Ferry Building and Ferry landing area.[2] Water levels already overtop the shoreline under existing conditions during extreme high tides. The shoreline overtopping reaches a tipping point at Scenario 4 (48 inches of SLR or 6 inches of SLR and a 100-year extreme tide) when over 60 percent of the Financial District shoreline is overtopped, and widespread flooding of the Embarcadero Roadway is expected.[3] Inundation of this scale would significantly impact mobility, including ground traffic, public transportation, and the regional transportation network.

1 The San Francisco Bay Trail. Available at http://baytrail.org/.

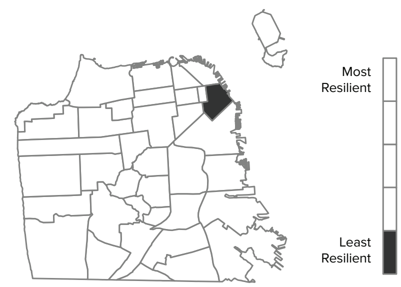
2 Federal Emergency Management Agency, Preliminary Flood Insurance Rate Maps.

3 The ART Bay Shoreline Flood Explorer allows for interactive exploration and download of the Bay Area SLR and shoreline analysis maps. These maps depict areas at risk of temporary or permanent flooding due to SLR and extreme tides as well as shoreline overtopping. Available at https://explorer.adaptingtorisingtides.org/explorer.


Washington Square
UNION ST
SANSOME ST
GREEN ST
COLUMBUS AVE
VALLEJO ST
BROADWAY
KEARNY ST
MONTGOMERY ST
Muni E-Line
PACIFIC AVE
JACKSON ST
DRUMM ST
Sue Bierman Park
THE EMBARCADERO
Wo Hei Yuen
Maritime Plaza
Embarcadero Plaza
Ferry Plaza
WASHINGTON ST
Portsmouth Square
CLAY ST
BATTERY ST
FRONT ST
DAVIS ST
Willie "Woo Woo" Wong Playground
SACRAMENTO ST
California Street Historic Cable Car
CALIFORNIA ST
SPEAR ST
STEUART ST
MAIN ST
Huntington Park
St Mary's Square
MASON ST
POWELL ST
STOCKTON ST
PINE ST
BEALE ST
FREMONT ST
BUSH ST
1ST ST
GRANT ST
SUTTER ST
2ND ST
NEW MONTGOMERY ST
MISSION ST
POST ST
Union Square
MARKET ST
HOWARD ST
GEARY ST
O'FARRELL ST
FOLSOM ST
Jessie Square
3RD ST
ELLIS ST
Yerba Buena Gardens
80
HARRISON ST
Boeddeker Park
EDDY ST
4TH ST
5TH ST
TURK ST
BRYANT ST
JONES ST
6TH ST
South Park



Financial District



NEIGHBORHOOD RESILIENCY SCORE: 1

Hazard Score: 1
Environmental Score: 1
Transportation Score: 5
Community Score: 1
Public Realm Score: 5
Housing Score: 1
Economy Score: 2
Health Score: 2
Demographics Score: 1

Source: San Francisco Climate & Health Program Neighborhood Summary
https://sfclimatehealth.org/neighborhoods/

PUBLIC SAFETY

1. Fire Station #13
2. Contaminated Lands
3. Fireboat Pump Station / Fire Suction Connection

TRANSPORTATION

4. The Embarcadero
5. Streetcar (E-Line)
6. Embarcadero BART
7. Ferry Terminal
8. Cable Car
9. Regional bus routes (Temporary Transbay Terminal)

WASTEWATER

10. Combined Sewage Discharge (CSD)

OPEN SPACE

11. Embarcadero Plaza
12. Ferry Park/Plaza
13. Harry Bridge's Plaza
14. Maritime Plaza

PORT

15. Pier 7: Public pier and fishing
16. Pier 3: Restaurants, offices, water taxi, Hornblower, parking (H)
17. Pier 1: Office (H)
18. Ferry Building: Offices, public serving, restaurants, retail, inconic (H)
19. Pier 14: Public pier and fishing
20. Embarcadero Promenade (Bay Trail)
21. WETA, Golden Gate Ferries

Extreme Tide and SLR Flooding Vulnerabilities and Consequences

The scenarios below highlight the progression of potential extreme tide and SLR flooding, along with a brief discussion of the City-owned assets that will be impacted within the Financial District neighborhood. Additional details on the exposure, vulnerability, and consequences of extreme tide and SLR flooding on City-owned assets can be found within the respective sector-based chapters. The relevant chapters are referenced below, as appropriate.

Scenario	Sector	Vulnerabilities and Consequences
Scenario 1 (12 inches of SLR or a high tide with a 1-year recurrence interval)	Transportation	**Transportation:** Flooding of The Embarcadero is currently observed when Bay water levels are high. This causes minor disruption to the pedestrian and bike path on Embarcadero Promenade between the Ferry Building and Pier 14.
	Public Safety	**Public Safety:** One fire suction connection (part of the emergency firefighting water system) that allows fire engines to draw water from the Bay for fire suppression is inundated. Suction connections become unusable if they are inundated, primarily due to limitations related to fire truck access.
Scenario 2 (24 inches of SLR or 12 inches of SLR and a high tide with a 1-year recurrence interval)	Wastewater	**Wastewater:** Under Scenario 2, the higher Bay water levels may reduce the gravity-driven flow of excess combined wastewater and stormwater from the transport / storage boxes to the Bay via combined sewer discharge outfalls (Chapter 7). This impact is only of concern during intense and prolonged rainfall events that exceed the capacity of the large underground transport / storage boxes that ring the city. This could result in an increase in localized flooding in low-lying areas.
	Public Safety	**Public Safety:** One additional fire suction connection would be inundated under Scenario 2.
Scenario 3 (36 inches of SLR or 12 inches of SLR and a high tide with a 5-year recurrence interval)	Port / Transportation	**Port / Transportation:** At Scenario 3, flooding of the shoreline between the Ferry Building and Pier 14 would cause limited inundation of the Embarcadero Promenade and roadway.
	Power	**Power:** Streetlights would experience inundation at Scenario 3.
Scenario 4 (48 inches of SLR or 6 inches of SLR and a 100-year extreme tide)	Transportation	**Transportation:** At Scenario 4, the westbound lanes of The Embarcadero will be inundated, causing cascading impacts to local and through traffic, bike routes, truck traffic, bus routes, pedestrian access to the shoreline, tourism, and the historic streetcar E-Line service. Although the first pedestrian entrances to the underground Embarcadero Muni/BART Station will not be directly inundated until Scenario 5, floodwaters could enter the underground station through other potential flood pathways, such as manholes, vents, and access hatches, under an earlier scenario.
	Public Safety	**Public Safety:** One additional fire suction connection would be inundated under Scenario 4.
Scenario 5 (52 inches SLR or 12 inches SLR and a 100-year extreme tide)	Transportation	**Transportation:** Impacts to the Embarcadero Station would cause significant citywide and regional impacts to transportation. The Embarcadero station is the last San Francisco BART stop before connecting to Oakland via the Transbay Tube. Impacts to the Embarcadero BART station would cause systemwide impacts for the BART and Muni Metro systems, significant delays, and impact the ability for travelers to make trips between San Francisco and the East Bay, impacting hundreds of thousands of riders each day. Disruption of the Embarcadero Station would lead to congestion of other modes of transportation such as buses, personal vehicles, and ferries. Flooding of the station would cause more traffic congestion throughout the city, and would impact people's ability to get to work, school, or other destinations.

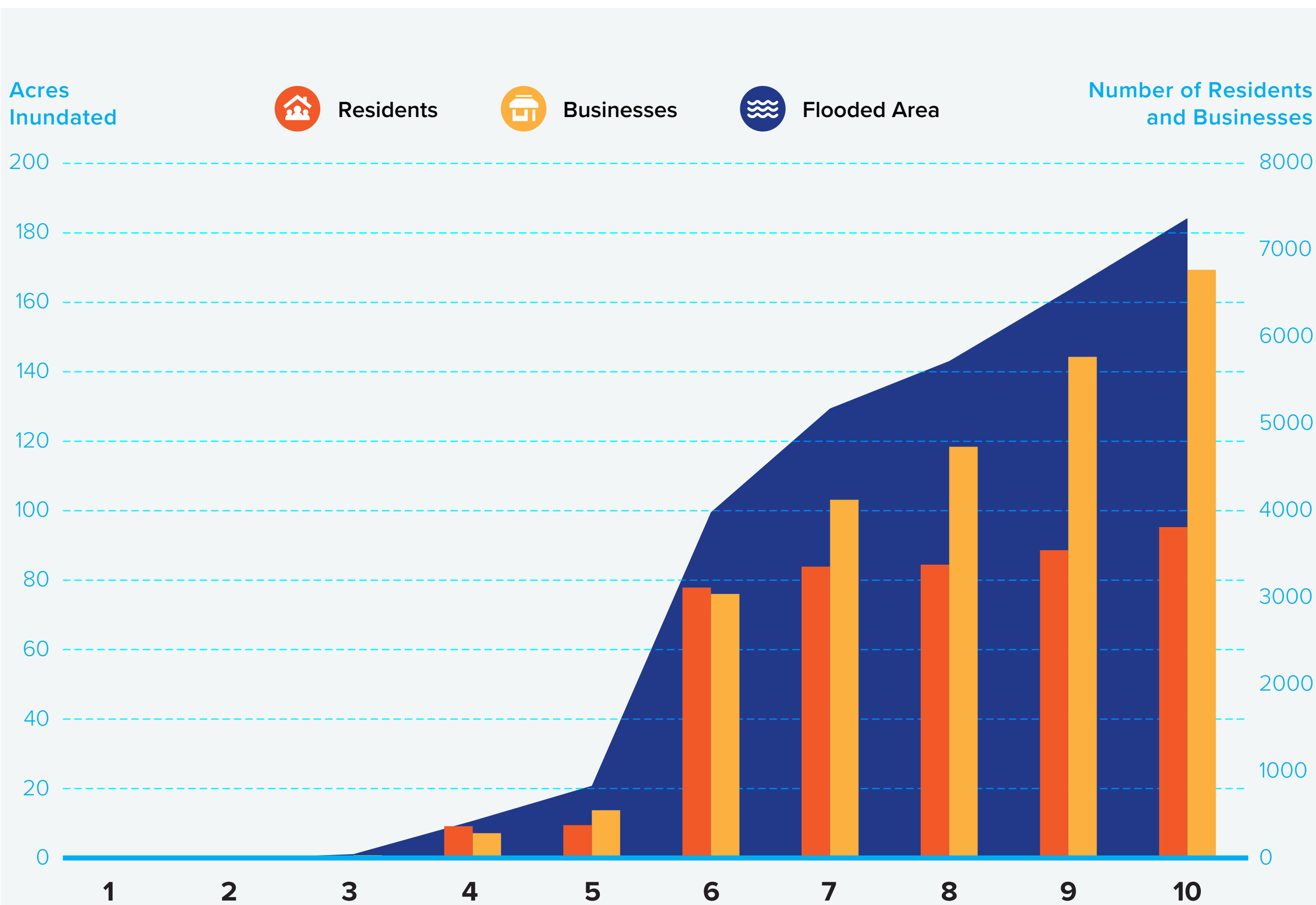
Scenario	Sector	Vulnerabilities and Consequences
		Port / Open Space: Although the Ferry Terminal would be operational under Scenario 5, pedestrian access for boarding and offloading would be affected. Open space would also be impacted as three City recreational plazas could flood along The Embarcadero shoreline, including Embarcadero Plaza, Sue Bierman Park , and Harry Bridge's Plaza. Approximately 2 miles of the San Francisco Bay Trail will be inaccessible. The length of shoreline overtopped under Scenarios 3, 4, and 5 will be minimal (less than 0.1 mile). However, while the length of the shoreline overtopped is minimal, many assets would still be at risk of inundation due to the low-lying of the topography of the area and the ability of floodwaters to spread quickly. Alternatively, a small shoreline improvement project to prevent overtopping could provide widespread benefits.
Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide)		**Transportation:** Under Scenario 6, the potential inundation could become widespread. More than 3,100 residents and 3,000 business will be impacted and there will be significant impacts to city streets and public transportation. Three entrances to the Embarcadero Muni/BART station, 10 miles of bus routes, the Historic streetcar E-Line, and the terminus of the California Street cable car line will all be impacted. The Ferry Building, a historical landmark and part of the Central Embarcadero Piers Historic District, would become inundated and the Ferry Terminal would become non-operational. Regional transit bus routes will be flooded, including SamTrans, Golden Gate Transit, and Amtrak. The Port of San Francisco's headquarters located at Pier 1 could also be flooded under Scenario 6. Pier 7 would be overtopped and public access for fishing would be limited.
		Open Space: Maritime Plaza, located just inland of Sue Bierman Park, could also be inundated under Scenario 6. However, Maritime Plaza is elevated from street level and only access to the park is anticipated to be impacted.
		Public Safety: One additional fire suction connection would be inundated under Scenario 6.
Scenario 7 (36 inches of SLR and a 100-year extreme tide)		**Power:** There are 3.7 megawatts of PG&E solar energy panels on a building that is inundated at Scenario 7. The electrical infrastructure connecting the solar panels to the power grid could be vulnerable to flooding.
Scenario 9 (52 inches of SLR and a 100-year extreme tide)		**Public Safety:** At Scenario 9, Fire Station #13 is impacted. Impacts from SLR and coastal flooding could compromise emergency and fire response times throughout the Financial District.
		Wastewater: Although SFPUC has underground water and combined sewer infrastructure in the Financial District, the infrastructure is not expected to be vulnerable to flooding. However, the large transport / storage box under The Embarcadero may not function as intended when Bay water levels are high. The box may not be able to discharge excess stormwater directly to the Bay during a heavy rainfall event when the city's three treatments plants exceed their capacity. This could lead to localized flooding resulting in environmental and public health hazards.
Scenario 10 (66 inches of SLR and a 100-year extreme tide)		**Port:** Widespread flooding extending into the center of the Financial District would occur under Scenario 10. While inaccessible beginning around Scenario 4, Pier 14 – which provides pedestrian access for scenic vistas and fishing – becomes inundated at Scenario 10.

Residents and Businesses Exposed to Extreme Tide and SLR Flooding

As extreme tides and SLR overtop the Bay shoreline and flood the city's critical infrastructure, residents and businesses in the path of the floodwaters will be affected. Few residents and businesses are affected until Scenario 4, when approximately 11 acres of the Financial District become inundated and approximately 300 businesses and nearly 400 residents are impacted. The level of impact reaches a tipping point at Scenario 6, when the shoreline is overtopped and flooding extends inland to Front Street. At this scenario, the number of residents and businesses impacted both exceed 3,000. Due to the highly dense commercial nature of the Financial District, thousands of additional businesses would be impacted under future SLR scenarios, with the total number exceeding 7,000 businesses under Scenario 10.

The Financial District is a heavily populated area and the populations at risk include residents, tourists, commuters, and vendors. Although over 3,100 residents are impacted under Scenario 6, most of the population impacted is not classified as vulnerable populations by the Department of Public Health. However, many of the people affected by inundation under later scenarios are classified as vulnerable.

For more information about particular properties and buildings are affected under different scenarios, use the *Adapting to Rising Tides Bay Shoreline Flood Explorer*.[4]



4 https://explorer.adaptingtorisingtides.org/home

NEIGHBORHOOD PROFILE

NORTH BEACH & FISHERMAN'S WHARF

Fisherman's Wharf and Russian Hill. Photo by Daniel Pouliot (CC BY-NC-ND 2.0)

The North Beach and Fisherman's Wharf neighborhoods are located on the northeastern edge of San Francisco and include primarily commercial land use along the waterfront with some residential buildings. The neighborhood includes significant tourist attractions like the Exploratorium, Pier 39, Fisherman's Wharf, historic piers and buildings, and many hotels and restaurants. The shoreline is largely human-made and includes historic piers. Ongoing commercial fishing at Fisherman's Wharf provides an important link to San Francisco's maritime history.

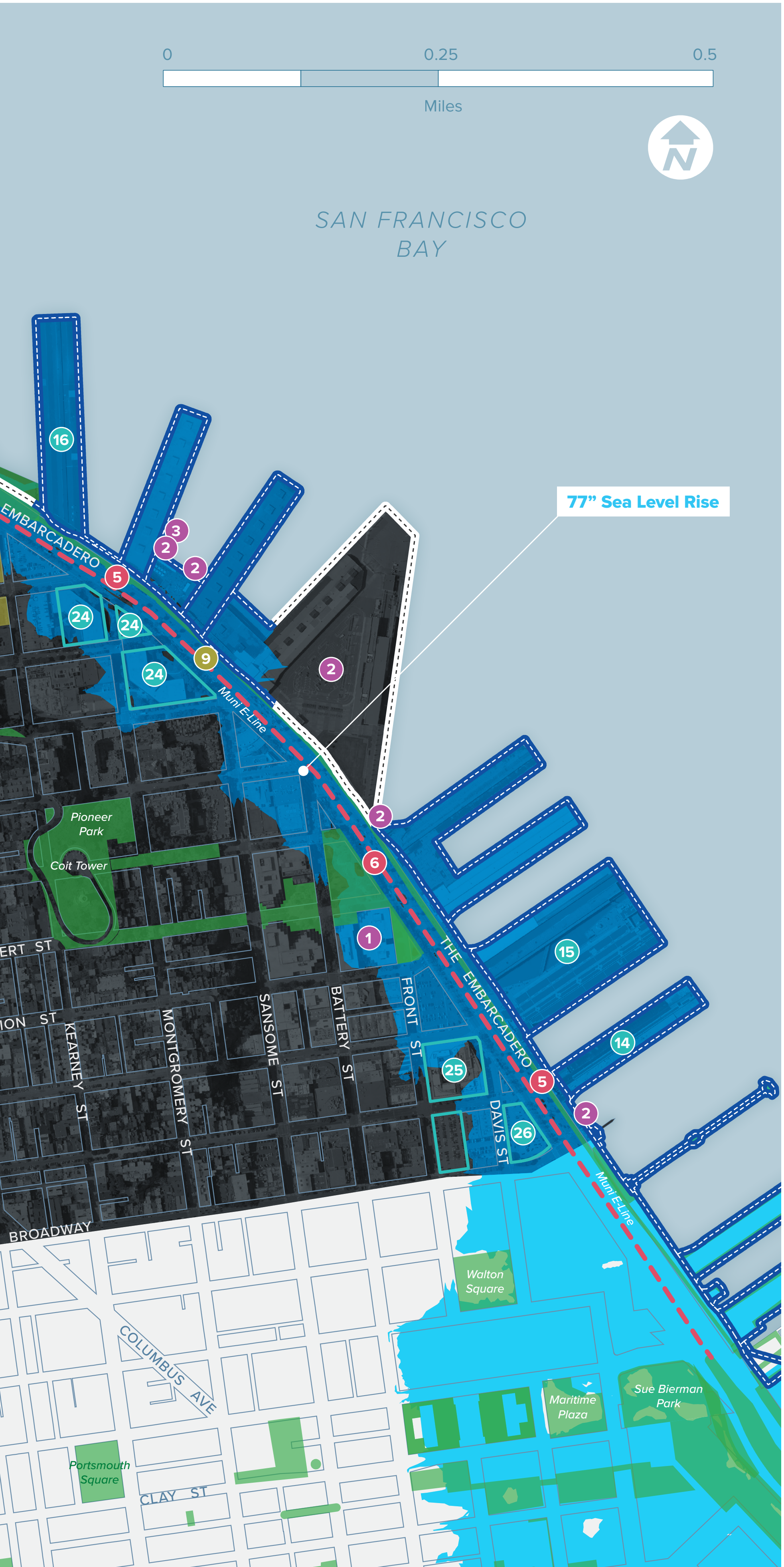
North Beach is one of the City's densest daytime neighborhoods.[1] Fisherman's Wharf is San Francisco's most visited tourist attraction; more than 10 million people visit this neighborhood each year.[2] West of Fisherman's Wharf along the shoreline is Aquatic Park. Adjacent to the San Francisco Maritime Museum and Ghirardelli Square, Aquatic Cove is a sheltered cove that is popular place for open-water swimming.

The shoreline for the North Beach neighborhood is included within the Port's Embarcadero Seawall Program, a separate but coordinated effort to create a more sustainable and resilient waterfront. More information related to the Embarcadero Seawall Program is included in Section 4.8. This area is also contained with the Port and U.S. Army Corps of Engineers Flood Study, which will study flood risk along San Francisco's bayside shoreline.

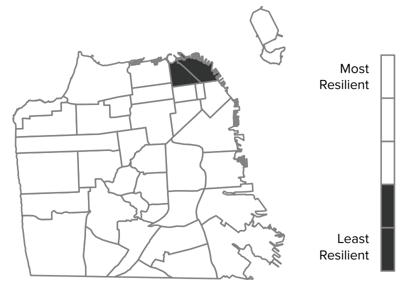
1 San Francisco Department of Public Health. 2014. San Francisco Climate and Health Profile. Available at https://sfclimatehealth.org/wp-content/uploads/2018/12/SFDPH_ClimateHealthProfile_FinalDraft.pdf.

2 Fisherman's Wharf Community Benefit District. Annual Report 2014-2015. Available at http://static1.squarespace.com/static/565080eee4b03de1ac9f6805/t/5651da4ce4b037d305df7db4/1448206308220/FWCBD+14-15+Annual_Report.pdf.


77" Sea Level Rise
Fishermans Wharf
Aquatic Cove
Aquatic Park Pier
Dolphin Swim & Boat Club
San Francisco Maritime National Historic Park
Fort Mason
Pier 39
Muni E-Line
Joseph Conrad Mini Park
Russian Hill Park
Francisco Park
Fay Park
George Sterling Park
Michelangelo Playground
Joe DiMaggio Playground
Washington Square
Ina Coolbrith Park
Allyne Park
Helen Wills Park
Betty Ong Rec Center
JEFFERSON ST
BEACH ST
NORTH POINT ST
BAY ST
FRANCISCO ST
CHESTNUT ST
LOMBARD ST
GREENWICH ST
UNION ST
GREEN ST
VALLEJO ST
BROADWAY
PACIFIC AVE
JACKSON ST
WASHINGTON ST
VAN NESS AVE
FRANKLIN ST
GOUGH ST
POLK ST
LARKIN ST
HYDE ST
LEAVENWORTH ST
JONES ST
TAYLOR ST
MASON ST
POWELL ST
STOCKTON ST
GRANT AVE
COLUMBUS AVE
Inundation at 77" Sea Level Rise
Overtopping
No Overtopping



North Beach Fishermans Wharf



NEIGHBORHOOD RESILIENCY SCORE: 2

Hazard Score: 1
Environmental Score: 3
Transportation Score: 5
Community Score: 2
Public Realm Score: 4
Housing Score: 1
Economy Score: 3
Health Score: 3
Demographics Score: 2

Source: San Francisco Climate & Health Program Neighborhood Summary
https://sfclimatehealth.org/neighborhoods/

PUBLIC SAFETY

1. Contaminated Land
2. Fireboat Pump Station / Fire Suction Connection
3. Fireboat Manifold

TRANSPORTATION

4. Kirkland Division
5. The Embarcadero
6. Streetcar (E-Line)

WASTE WATER

7. North Point Wet-Weather Treatment Plant
8. Northshore Pump Station
9. Combined Sewage Discharge (CSD)

OPEN SPACE

10. Aquatic Park
11. Dolphin Club
12. South End Rowing Club

PORT

13. Fisherman's Wharf
14. Pier 9 *Offices, bar pilots, WETA offices*
15. Piers 15-17 *Exploratorium, public spaces, offices, iconic*
16. Pier 35 *Cruise Ship Terminal and public serving*
17. Pier 39 Marina
18. Pier 39 *Public serving, restaurants, retail, aquarium, iconic*
19. Pier 41 *Ferries, offices*
20. Pier 43 *Ferries*
21. Pier 45 *Public spaces, entertainment, fish processing*
22. Pier 47 *Restaurants, Fisherman's Wharf, retail, public serving*
23. Hyde Street Harbor *Commercial fishing, fish processing, historic vessels, recreational boating, fuel dock*
24. Seawall 315-317: Waterfront Plaza *(offices and restaurants)*
25. Seawall 322: 88 Broadway *(future affordable housing)*
26. Seawall 324 *Hotel Teatro Zinzani and open space*

Ships along Marina Blvd. John Menard (CC BY-SA 2.0)

Pier 39. Wally Gobetz (CC BY-NC-ND 2.0)

The Shoreline

The North Beach and Fisherman's Wharf shoreline is 2.6 miles long and is an entirely hardened and engineered shoreline, including piers, seawalls, and wharves. Originally, the city's northeast shoreline extended to what is today Taylor and Francisco streets. North Beach was an actual beach and was filled in to allow for additional development around the late 19th century.

The Exploratorium, a popular participatory science museum for all ages, relocated from the Palace of Fine Arts to Piers 15 and 17 in April 2013. In 2014, the James R. Herman Cruise Terminal opened at Pier 27. The terminal can handle ships with up to 4,000 passengers, and the associated plaza provides 2.5 acres of dedicated public open space.

Further north along the shoreline is Hyde Street Pier. This pier houses a fuel dock, as well as the historic vessels, including the USS *Pampanito*, a decommissioned World War II era submarine, and the *Balclutha*, a 19th-century cargo ship. West of Fisherman's Wharf is the Aquatic Park Historic District, a National Historic Landmark and building complex located within the San Francisco Maritime National Historical Park. The sheltered Aquatic Cove includes a small sandy beach with a stepped concrete seawall. To the west is the horseshoe-shaped Municipal Pier, popular for fishing.

Along the Bay shoreline, the wave hazards can exceed 4 feet in height,[3] creating the potential for coastal erosion of natural shorelines and wave damage to engineered shorelines. With SLR, the potential for wave hazards will increase because deeper Bay waters allow for the generation of larger waves. The breakwater wall surrounding Aquatic Park and Fisherman's Wharf provide significant shelter from wave hazards.

The shoreline is first overtopped in Scenario 3 (36 inches); however, the inundation impacts are localized to a relatively small area along Aquatic Park. The tipping point for North Beach and Russian Hill occurs in Scenario 6 (66 inches of SLR, or 24 inches of SLR coupled with a 100-year extreme tide) when large stretches of the shoreline are overtopped and significant impacts to the neighborhood, especially its business districts, could occur.[4]

3 Federal Emergency Management Agency, Preliminary Flood Insurance Rate Maps.

4 The ART Bay Shoreline Flood Explorer allows for interactive exploration and download of the Bay Area SLR and shoreline analysis maps. These maps depict areas at risk of temporary or permanent flooding due to SLR and extreme tides as well as shoreline overtopping. Available at https://explorer.adaptingtorisingtides.org/explorer.

Extreme Tide and SLR Flooding Vulnerabilities and Consequences

The scenarios below describe the progression of potential extreme tide and SLR flooding, along with a brief discussion of the City-owned assets that will be impacted, within the North Beach and Russian Hill neighborhoods. Additional details on the exposure, vulnerability, and consequences of extreme tide and SLR flooding on City-owned assets can be found within the respective sector-based chapters. The relevant chapters are referenced below, as appropriate.

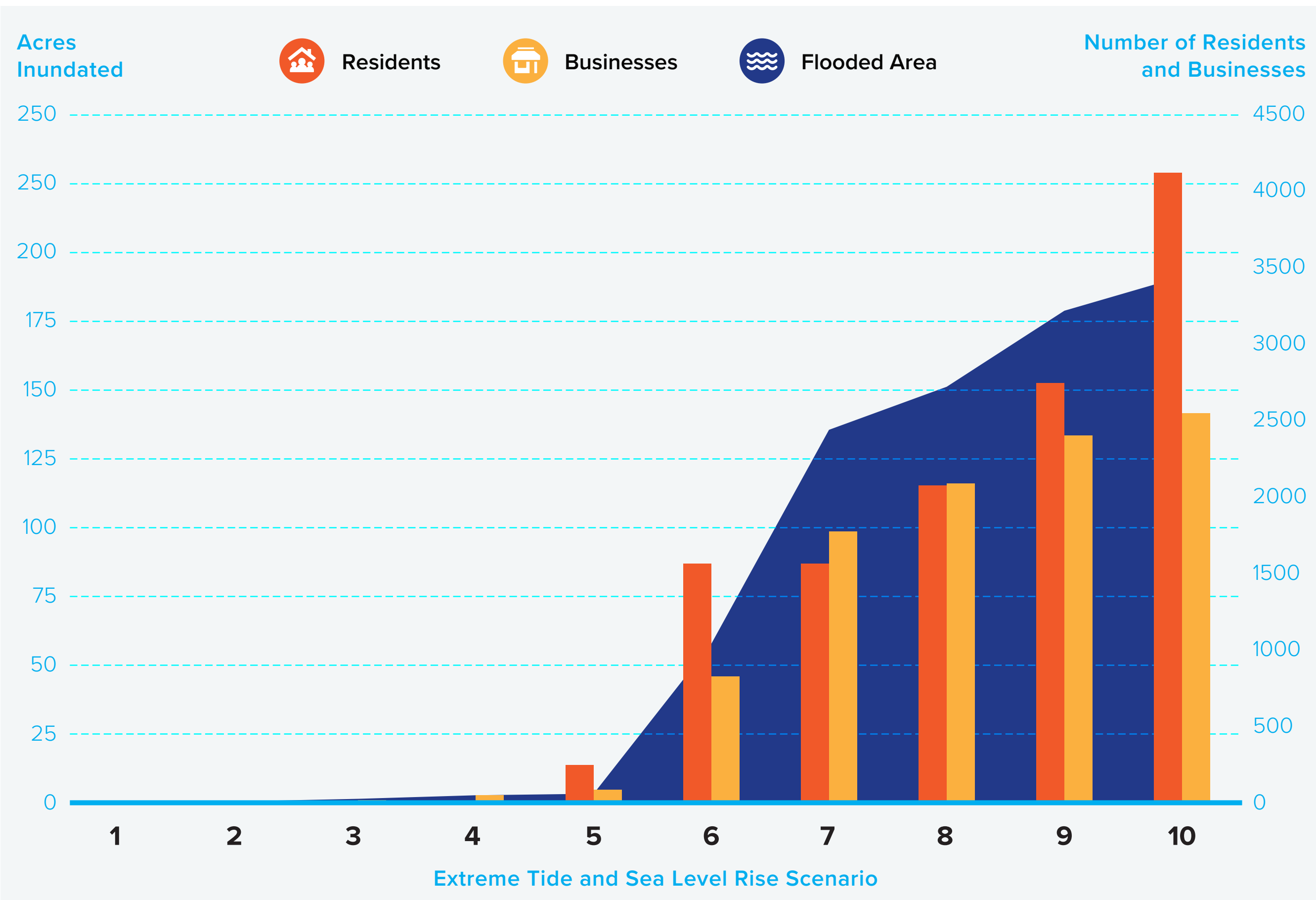
Scenario	Sector	Vulnerabilities and Consequences
Scenario 1 (12 inches of SLR or a high tide with a 1-year recurrence interval)	Public Safety	**Public Safety:** Under Scenario 1, five fire suction connections (part of the emergency firefighting water system) that allow fire engines to draw water from the Bay for fire suppression are inundated. Suction connections become unusable if they are inundated.
Scenario 2 (24 inches of SLR or 12 inches of SLR and a high tide with a 1-year recurrence interval)	Wastewater	**Wastewater:** Under Scenario 2, the higher Bay water levels may reduce the gravity-driven flow of excess combined wastewater and stormwater from the transport / storage boxes to the Bay. This impact is only of concern during intense and prolonged rainfall events that exceed the capacity of the large underground transport / storage boxes that ring the city. This could result in an increase in localized flooding in low-lying areas.
	Public Safety	**Public Safety:** Under Scenario 2, four additional fire suction connections are inundated, further reducing emergency firefighting response potential.
Scenario 3 (36 inches of SLR or 12 inches of SLR and a high tide with a 5-year recurrence interval)	Open Space	**Open Space:** Although the sandy beach in Aquatic Park will experience increasing inundation under Scenarios 1 and 2, significant loss of beach access occurs under Scenario 3. The beach and aquatic facilities (the access point for the beach and storage sheds for the boats and recreational gear used in the park) for the South End and Dolphin rowing clubs are all impacted to some degree under this scenario.
Scenario 4 (48 inches of SLR or 6 inches of SLR and a 100-year extreme tide)	Public Safety	**Public Safety:** Two fire boat manifolds (part of the emergency firefighting water system) will be inundated at this scenario. Fire boats may still be able to make a secure connection to the manifold even if it is inundated. If the fire boats cannot make a connection, and the emergency firefighting water system loses pressure, the system may become unusable.
	Power	**Power:** At Scenario 4, streetlights are inundated in North Beach.
Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide)	Wastewater	**Wastewater:** At Scenario 6, North Point wet weather treatment plant is exposed to flooding along its northern edge. However, because the potential for flooding is limited, the treatment plant is likely to retain most of its operational capacity during a flood event that occurs when this facility is in operation.
	Power	**Power:** At Scenario 6, streetlights are inundated in Russian Hill.
	Port	**Port:** At Scenario 6, Hyde Street Pier and the harbor that houses San Francisco's commercial fishing fleet and fuel dock could be inundated. This pier is also located behind a breakwater wall that if overtopped could expose the city shoreline to high wave activity. Pier 39, Fisherman's Wharf, and the surrounding open space areas could also be inundated causing significant impacts to the regional economy through lost tourism and visitors. The new site of the Hotel Teatro ZinZanni within the Port's Historic District, across the Embarcadero from the Exploratorium and between Broadway and Green Streets, could also be inundated under Scenario 6. Under existing conditions, the site serves as a parking lot.

Scenario	Sector	Vulnerabilities and Consequences
		Transportation: Kirkland Division is a SFMTA facility is located on a 2.6-acre site between North Point, Beach, Stockton, and Powell streets. This facility provides bus storage, operations, and limited maintenance for 135 40-foot hybrid buses. The site includes mostly flat, paved surfaces with small operations and maintenance structures and underground storage tanks. If this facility is flooded, water can enter the underground storage tank through openings such as fill pipes, vent pipes, gaskets, loose fittings, covers, and sumps.
		Public Safety: Fire Department Pump Station No. 2 is located at the foot of Van Ness Avenue near Fort Mason. This pump station contains four diesel-driven pumps, each with a pumping capacity of 2,700 gpm at 300 psi. An approximately 160-foot concrete intake tunnel located underneath the pump station floor conveys seawater from the Bay to the pumps. This Bay connection will impact the pump station by Scenario 6. The pump station includes sensitive electrical equipment that is at and below grade and sensitive to any inundation.
Scenario 7 (36 inches of SLR and a 100-year extreme tide)		**Wastewater:** The Northshore pump station is inundated under Scenario 7. Northshore is an abovegrade 30-mgd dry-weather pump station that serves the Northshore drainage basin, conveying wastewater to Channel pump station. Northshore pump station is located at 2001 Kearney Street, at the intersection of Kearney Street and Bay Street. During wet weather, the North Point Wet Weather Facility can treat up to 150 mgd of combined flows. Impacts at this pump station could result in localized flooding; however, the larger North Beach/Russian Hill neighborhood would not be impacted.
		Port: Under Scenario 7, Pier 9 (part of the Historic District and home to the Water Emergency Transportation Authority and the Bar Pilot Association) could be inundated, creating cascasing impacts to ferry traffic and water-based response to regional emergencies, and container ship traffic to the Ports of Oakland and Stockton. Pier 15/17 (part of the Historic District and home to the Exploratorium) could also be inundated, impacting tourism and a local destination for science-based educational entertainment and learning opportunities for children.
Scenario 8 (48 inches of SLR and a 100-year extreme tide)		**Port:** The James R. Herman Cruise Terminal Cruise ship terminal is inundated at Scenario 8. This will reduce the capacity of the city to serve cruise ships and impact the tourism industry. If cruise ships are temporarily located at an alternate terminal, they may not be able to plug into shore power, which can lead to local air and water quality impacts associated with running the ship's engine to maintain onboard power.
Scenario 9 (52 inches of SLR and a 100-year extreme tide)		**Public Safety:** Fire Department Pump Station No. 2 (Chapter 6) will be inundated by floodwaters by Scenario 9.

Residents and Businesses Exposed to Extreme Tide and SLR Flooding

As extreme tides and SLR overtop the Bay shoreline and flood the city's critical infrastructure, residents and businesses in the path of the floodwaters will be affected. Few residents and businesses are affected until Scenario 6 when over 800 businesses and 1,500 residents are impacted. The areas with the most affected businesses are around Fisherman's Wharf and Pier 39. The impacted residents are located near the Embarcadero in North Beach.

For more information about particular properties and buildings are affected under different scenarios, use the *Adapting to Rising Tides Bay Shoreline Flood Explorer*.[5]



5 https://explorer.adaptingtorisingtides.org/home

NEIGHBORHOOD PROFILE

MARINA & PRESIDIO

Aerial of the San Francisco Marina. Photo by Jill Clardy (CC BY-NC-SA 2.0)

The Marina neighborhood is located on the northern edge of San Francisco between the Presidio and Aquatic Cove. The Presidio, one of the county's most famous former U.S. Army forts, is now a 1,500-acre national park in the Golden Gate National Recreation Area. The Golden Gate Bridge, the only direct ground transportation link between San Francisco and Marin County to the north, touches down in the Presidio.

The Marina District is largely residential, with over 16,000 housing units.[1] The neighborhood also features several neighborhood commercial corridors along Chestnut, Fillmore, and Union streets, and recreational features, such as the Moscone Softball Fields, the Fort Mason Center for Arts and Culture, and Marina Greens. The waterfront includes two marinas for small watercraft. The Palace of Fine Arts, a dramatic neoclassical monument that remains from the 1915 Panama-Pacific Exhibition, is a major landmark and tourist attraction. Residents in this neighborhood tend to be highly educated and experience low rates of poverty relative to other neighborhoods.

The Presidio, including Baker Beach and Crissy Field, is owned and managed by the National Park Service. A detailed vulnerability assessment of National Park Service assets was not completed for this report.

1 American Community Survey (ACS). 2016. Social Explorer. Available at https://www.socialexplorer.com/a9676d974c/explore.

Fort Mason. Adam Fagen (CC BY-NC-SA 2.0)


Marina Green. Daniel Hoherd (CC BY-NC 2.0)


Palace of Fine Arts. Elizabeth K. Joseph (CC BY 2.0)

The Shoreline

The Marina and Presidio neighborhoods Bay shoreline is 6.6 miles long. Over half of the shoreline includes engineered shoreline structures and the remainder of the shoreline is natural (i.e., cliffs and beaches). The natural shoreline areas are primarily located in the Presidio. The neighborhoods' shoreline stretches from Aquatic Park in the east to the Golden Gate Bridge along the city's northern shore and along the west coast south to the southern part of Baker Beach.

The natural low-lying beach shorelines are the most vulnerable to SLR, wave hazards, and coastal erosion, including Chrissy Field on the Bay side and Marshall and Baker Beaches on the ocean side, both important recreational areas. The Presidio also includes high cliffs fronted by small pockets of beach. Due to its proximity and direct frontage to dynamic ocean wave hazards, these neighborhoods can experience higher wave hazards than the more sheltered Bayside neighborhoods. Wave hazards can be 6 feet or greater in some areas.[2] Breakwaters currently reduce the wave hazards for the from Gas House Cove to north of the Saint Francis yacht club. As sea levels rise, the breakwaters will become less effective at reducing wave hazards.

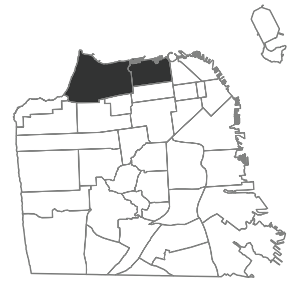
The tipping point in these neighborhoods occurs in Scenario 6, when the roads and assets (such as the Palace of Fine Arts) could be inundated. In Scenario 5, the breakwater area near the Golden Gate and Saint Francis yacht clubs is overtopped, and by Scenario 6, the Marina Green area could also be flooded.[3]

2 Federal Emergency Management Agency, Preliminary Flood Insurance Rate Maps.

3 The ART Bay Shoreline Flood Explorer allows for interactive exploration and download of the Bay Area SLR and shoreline analysis maps. These maps depict areas at risk of temporary or permanent flooding due to SLR and extreme tides as well as shoreline overtopping. Available at https://explorer.adaptingtorisingtides.org/explorer.


Inundation at 66" Sea Level Rise
Low Lying Land (at risk of inundation at 66")
Overtopping
No Overtopping
66" Sea Level Rise
PACIFIC OCEAN
South Harbor
Golden Gate Bridge
101
Crissy Field
MASON ST
STOREY AVE
LINCOLN BLVD
VETERENS BLVD
MONTGOMERY ST
FUNSTON AVE
ARGUELLO BLVD
WASHINGTON BLVD
W PACIFIC AVE
RICHARDSON
BAKER ST
LYON ST
Palace of Fine Arts
Julius Kahn Playground
Mountain Lake
Mountain Lake Park
PARK PRESIDIO BLVD
7TH AVE
LAKE ST
CALIFORNIA ST
Richmond Playground
CHERRY ST
SPRUCE ST
LAUREL ST
PRESIDIO AVE
Presidio Heights Playground
EUCLID AVE
Laurel Hill

Marina and Presidio



TRANSPORTATION

1. Marina Boulevard Arterial
2. Mason Street
3. Highway 101 / Richardson Ave

WASTEWATER

4. Palace of Fine Arts Pump Station
5. Combined Sewer Discharge (CSD)

PUBLIC SAFETY

6. Fireboat Pump Station
7. Fireboat Pump Station / Fire Suction Connection
8. Fireboat Manifold

OPEN SPACE

9. Crissy Field
10. Yacht Harbor and Marina Green
11. Palace of Fine Arts
12. Marina Green Three Lawns
13. Golden Gate Yacht Club
14. Saint Francis Yacht Club

Extreme Tide and SLR Flooding Vulnerabilities and Consequences

The scenarios below describe the progression of potential extreme tide and SLR flooding, along with a brief discussion of the City-owned assets that will be impacted, within the Bayview North Islais Creek neighborhood. Additional details on the exposure, vulnerability, and consequences of extreme tide and SLR flooding on City-owned assets can be found within the respective sector-based chapters. The relevant chapters are referenced below, as appropriate.

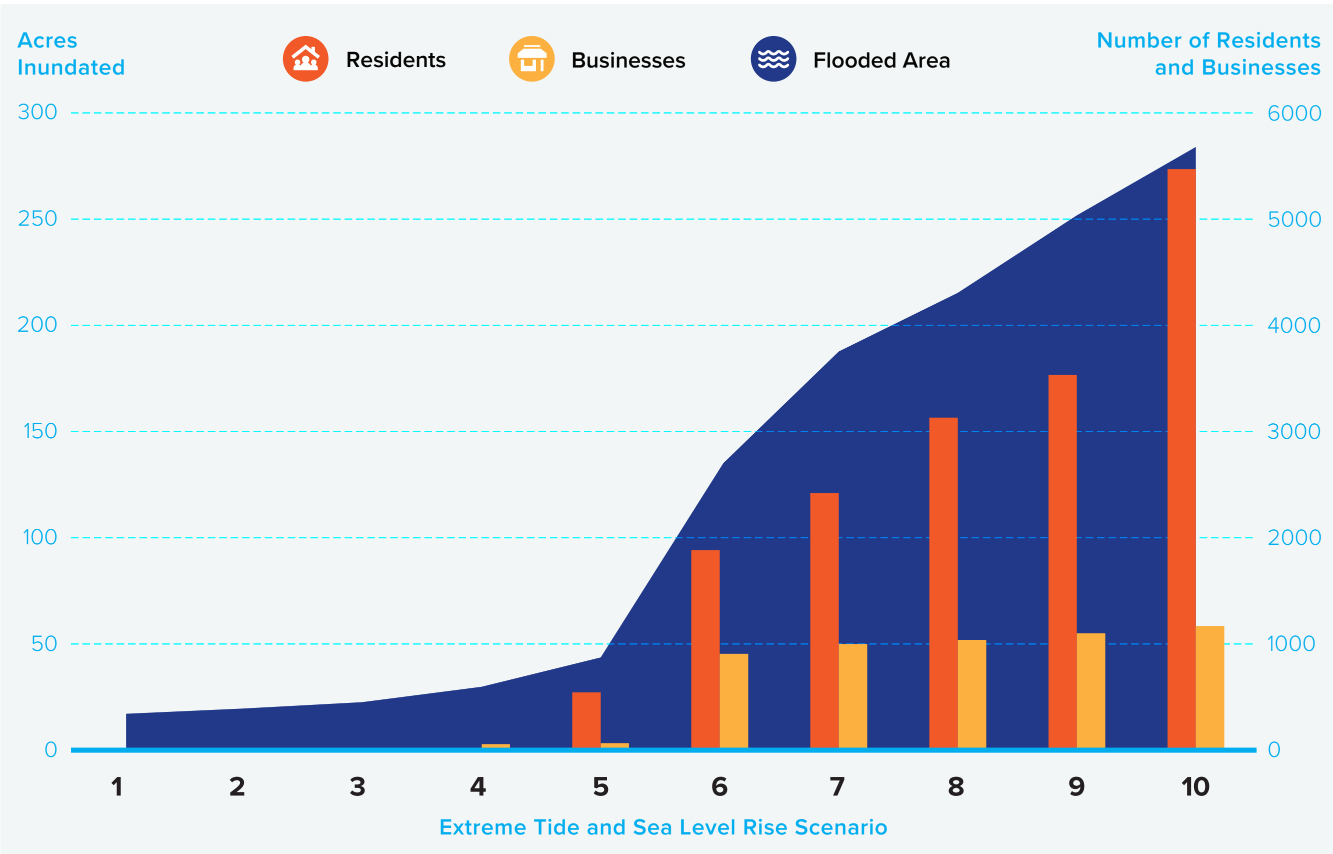
Scenario	Sector	Vulnerabilities and Consequences
Scenario 1 (12 inches of SLR or a high tide with a 1-year recurrence interval)	Open Space	**Open Space:** The Crissy Field wetlands already experience regular inundation during high tides today. As sea levels rise, the wetlands may keep pace with SLR and continue to provide valuable habitat, or they may be submerged. The wetlands are expected to keep pace with SLR until mid-century; however, as SLR accelerates after mid-century, the wetlands may be lost if sediment doesn't accumulate fast enough to support wetland growth (due to deeper Bay levels).
	Public Safety	**Public Safety:** One fire suction connection (part of the emergency firefighting water system) that allows fire engines to draw water from the Bay for fire suppression is inundated. The suction connections become unusable when inundated, largely due to limitations in fire engine access.
Scenario 2 (24 inches of SLR or 12 inches of SLR and a high tide with a 1-year recurrence interval)	Open Space	**Open Space:** The Marina neighborhood with its variety of high-quality aquatic recreation and shoreline access, is expected to be adversely impacted before Scenario 2, mostly due to impacts to the Marina Green seawall. The historic internal marina seawalls in the west are in poor condition and continue to fail. The northern marina shoreline adjacent is also subject to erosion, primarily due to waves generated by passing ship traffic. Approximately 75 percent of the site is subject to tidal, wind, and wave hazards. The West Harbor has more substantial wave protection than the East Harbor. The Marina Shop's lower level floods during very high tides, and the floodwaters can impact mechanical equipment, including pumps, motors, and valves. At-grade utilities, including water and power, are connected to the docks. The Golden Gate Yacht Club will also be impacted at this scenario. Located at 1 Yacht Road in the protected harbor, the structure is built on pilings over water and could be inundated by temporary floodwaters as early as Scenario 2. Wave action is already causing erosion issues for the access road/ jetty to the Golden Gate Yacht Club. Impacts to some of the historic seawall and shoreline fortifications will become worse, eventually cutting off access to the yacht clubs and marina facilities.
	Public Safety	**Public Safety:** Six additional fire suction connections are inundated under Scenario 2. The suction connections become unusable when inundated, largely due to limitations in fire engine access.
	Wastewater	**Wastewater:** Under Scenario 2, the higher Bay water levels may reduce the gravity-driven flow of excess combined wastewater and stormwater from the transport / storage boxes to the Bay through combined sewer discharge outfalls (Chapter 7). This impact is only of concern during intense and prolonged rainfall events that exceed the capacity of the large underground transport / storage boxes that ring the city. This could result in an increase in localized flooding in low-lying areas.
Scenario 4 (48 inches of SLR or 6 inches of SLR and a 100-year extreme tide)	Transportation	**Transportation:** A major roadway, Marina Boulevard, could be impacted at Scenario 4, near Divisadero, affecting access and thru-traffic for residents and commuters.
	Public Safety	**Public Safety:** One fire boat manifold (part of the emergency firefighting water system) will be inundated at this scenario. Fire boats may still be able to make a secure connection to the manifold even if it is inundated. If the fireboats cannot make a connection, and the emergency firefighting water system loses pressure, the system may become unusable.
	Power	**Power:** Under Scenario 4, streetlights are impacted by flooding.

Scenario	Sector	Vulnerabilities and Consequences
Scenario 5 (54 inches SLR or 12 inches SLR and a 100-year extreme tide)		**Transportation:** Marina Boulevard will be increasingly inundated under Scenario 5 between Broderick and Scott streets, affecting access and thru-traffic for residents and commuters. Mason Street, which serves as an alternate route to and from the Golden Gate Bridge and US 101 during commute hours, would also be inundated under Scenario 5.
Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide)		**Wastewater:** The Palace of Fine Arts Pump Station, consisting of two facilities that serve a two-acre drainage area, could be inundated under Scenario 6. The pump station serves a small area in the North Shore drainage basin during dry and wet weather with a pumping capacity of 0.43 mgd. The pump station receives wastewater from the Palace of Fine Arts building, and stormwater runoff and drainage from the adjacent lagoon. Dry- and wet-weather flow is transported to the Marina transport / storage box.
		Transportation: The primary impacts to transportation occur under Scenario 6 when US 101/ Richardson Avenue is flooded, impacting local traffic and through traffic to the Golden Gate Bridge. This roadway is also a designated truck route. The inundation will impact public transportation, in particular the Golden Gate Transit bus connections to Marin County. Under Scenario 6, Marina Boulevard, and its adjacent residences and the Marina Green, will be inaccessible between Webster and Baker streets and the US 101 on-ramp. Large portions of Mason Street and many of the adjacent businesses will also be inaccessible.
		Open Space: Under Scenario 6, floodwaters could inundate the shoreline park and public access areas, including the entire Marina Green area, the yacht harbor, and the Saint Francis and Golden Gate yacht clubs. The Palace of Fine Arts is first inundated under Scenario 6, with 75 percent of the grounds and structures impacted by temporary flooding. However, high groundwater levels and drainage issues are present today, and SLR is likely to exacerbate these issues before overland coastal flooding occurs. The Marina Green and yacht harbors, as well as Crissy Field, provide key access and unique views of the San Francisco Bay to residents and visitors and are important for San Francisco's tourism and sailors. The marinas (the physical structures, supporting buildings, and electricity supply) could be damaged and/or become inaccessible due to flooding and secondary hazards, such as wave impacts, creating potentially long-lasting and costly impacts.

Residents and Businesses Exposed to Extreme Tide and SLR Flooding

As extreme tides and SLR overtop the Bay shoreline and flood the city's critical infrastructure, residents and businesses in the path of the floodwaters will be affected. Under Scenario 6, the flooded area increases tenfold from about 5 to 50 acres, impacting thousands of residents and approximately 1,000 businesses. In the Marina, thousands of residents and several hundred business are impacted, while in the Presidio, less than 50 residents and less than 350 businesses are affected. The area with the most affected residents and businesses is concentrated along the waterfront, Marina Green, Marina Boulevard, and Mason Street.

For more information about particular properties and buildings are affected under different scenarios, use the *Adapting to Rising Tides Bay Shoreline Flood Explorer*.[4]



4 https://explorer.adaptingtorisingtides.org/home

NEIGHBORHOOD PROFILE

WESTSIDE OCEAN BEACH

The Great Highway along Ocean Beach. Photo by Daniel Austin Hoherd (CC BY-NC 2.0)

The Westside neighborhoods border Ocean Beach and the Pacific Ocean between the San Mateo County border and the Golden Gate Bridge, including the Seacliff, Outer Richmond, Outer Sunset, Parkside, and Lakeshore neighborhoods. These neighborhoods are primarily residential, with Outer Richmond and Outer Sunset as two of the most heavily populated neighborhoods in the city. The Westside also features many important recreational areas, including Land's End, Sutro Baths, Golden Gate Park, Ocean Beach, the San Francisco Zoo, Fort Funston, and Lake Merced. These neighborhoods are generally set back from the ocean, with the Great Highway between them running parallel to the Pacific Ocean. The Great Highway includes a separated bicycle and pedestrian pathway. San Francisco State University and the Oceanside Treatment Plant are both located in the Lakeshore neighborhood.

The Westside neighborhoods include residents across a wide range of income and racial and ethnic groups. Richmond, Sunset, and Lakeshore have large Asian communities, with linguistic isolation for about 15 percent of households. In Lakeshore, census tracts around San Francisco State University have high rates of poverty and housing burden. Portions of the Lakeshore neighborhood are included in MTC's Communities of Concern [1]

The Shoreline

The Westside shoreline is over 5 miles long and includes both coastal bluffs and sandy beaches, including Ocean and Baker beaches. Baker Beach is a 1-mile-long beach that includes recreational picnic areas and views of Golden Gate Bridge and the Marin Headlands.[2] Ocean Beach, a 3.5-mile stretch of sand, draws a diverse population of more than 300,000 visitors each year and part of the Golden Gate National Recreation Area.

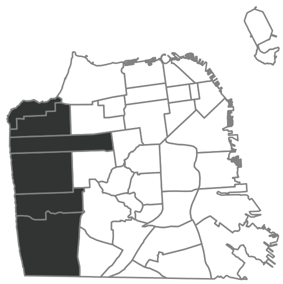
Ocean Beach has a long history of modifications, beginning with dune stabilization efforts in the 1860s, followed by construction of the Great Highway,

1 http://opendata.mtc.ca.gov/datasets/mtc-communities-of-concern-in-2018-acs-2012-2016?fullScreen=true&geometry=-122.686%2C37.629%2C-122.338%2C37.766

2 National Park Service. Presidio of San Francisco Baker Beach. Available at https://www.nps.gov/prsf/planyourvisit/baker-beach.htm.


66" Sea Level Rise
66" Sea Level Rise
66" Sea Level Rise
PACIFIC OCEAN
Ocean Beach
Funston Beach
Coastal Trail
Golden Gate Park
San Francisco Zoo
Oceanside Treatment Facility
Lake Merced
Lake Merced Park
West Sunset Playground
Sunset Playground
Sunset Recreation Center
McCoppin Square
Parkside Square
Pine Lake Park
Stern Grove
Larsen Park
Grandview Park
Golden Gate Heights Park
BALBOA ST
CABRILLO ST
FULTON ST
LINCOLN WAY
IRVING ST
JUDAH ST
KIRKHAM ST
LAWTON ST
MORAGA ST
NORIEGA ST
ORTEGA ST
PACHECO ST
QUINTARA ST
RIVERA ST
SANTIAGO ST
TARAVAL ST
ULLOA ST
VICENTE ST
SLOAT BLVD
OCEAN AVE
EUCALYPTUS DR
GREAT HIGHWAY
SUNSET BLVD
JOHN MUIR DR
SKYLINE BLVD
LAKE MERCED BLVD
FONT BLVD
BROTHERHOOD WAY
JUNIPERO SERRA BLVD
HOLLOWAY
LAKEVIEW
48TH AVE
45TH AVE
41ST AVE
40TH AVE
32ND AVE
30TH AVE
28TH AVE
26TH AVE
24TH AVE
22ND AVE
19TH AVE
17TH AVE
14TH AVE
12TH AVE
0
0.5
1
Miles

Westside / Ocean Beach



WASTE WATER

1. Lake Merced Transport/Storage Box
2. Vicente Transport/Storage Box
3. Lincoln Transport/Storage Box
4. Combined Sewer Discharge (CSD)

OPEN SPACE

5. Coastal Trail

Sea Cliff. Wayne Hsieh (CC BY-NC 2.0)

Dragon boats on Lake Merced. Michael Ocampo (CC BY 2.0)

Esplanade, and O'Shaughnessy seawall in 1929, the Taraval seawall in 1941, and the Noriega seawall in the 1980s. Ocean Beach has experienced significant erosion south of Sloat Boulevard over the past two decades. Temporary measures such as rip rap have not mitigated the problem. The erosion has damaged the Great Highway, parking areas, and is threatening the most seaward component of the city's combined wastewater system — the Lake Merced Tunnel, a 14-foot-diameter pipe under the Great Highway. Since 2010, there has been an extensive interagency and public process to develop the Ocean Beach Master Plan, a comprehensive long-term vision to address SLR, protect infrastructure, restore coastal ecosystems, and improve public access.

The Westside shoreline, including Ocean Beach, is also covered by a Local Coastal Program that guides development, conservation, and the protection of coastal resources in partnership with the Coastal Commission.[3] Originally certified in 1986, San Francisco's Local Coastal Program was amended in May 2018 to include recommendations from the Ocean Beach Master Plan.[4]

City and federal agencies are working together to implement short- and long-term adaptation measures at South Ocean Beach, following the recommendations of the Ocean Beach Master Plan. Current implementation efforts include annual sand replenishment, roadway narrowing, and wastewater pump station improvements. Long-term improvements include road narrowing and realignment, an improved recreation trail, and the Ocean Beach Long-Term Improvements Project. See Chapter 12. *A Changing Shoreline* for more information.

The wave hazards along the Pacific Ocean shoreline are much larger than within the sheltered Bay, with wave heights exceeding 20 feet along some stretches of shoreline. As sea levels rise, the potential for wave hazards and coastal erosion will increase, because deeper ocean waters allow for the generation of larger waves. Coastal erosion of the oceanfront beaches and bluffs will continue to change the Westside shoreline over the coming century.

Extreme Tide and SLR Flooding Vulnerabilities and Consequences

The scenarios below describe the progression of potential extreme tide and SLR flooding, along with a brief discussion of the City-owned assets that will be impacted, within the Westside neighborhoods.

For the Westside, vulnerability was evaluated relative to the 100-year dynamic water level, which includes both the 100-year extreme tide level and the increase in the mean water level due to the presence of waves often referred to as wave setup. The wave dynamics

3 California Coastal Commission. 2019. Public Resources Code Division 20: California Coastal Act. https://www.coastal.ca.gov/coastact.pdf.

4 City and County of San Francisco Planning Department. 2016. Local Coastal Program Amendment – Sea Level Rise Existing Data and Analyses Technical Memorandum. http://default.sfplanning.org/plans-and-programs/local_coastal_prgm/20160506.SFLCP_SLR_Tech_Memo.FINAL.pdf.

along the Westside shoreline are very different from those observed within the more sheltered San Francisco Bay; therefore, it is important to consider the impact of the waves along the Westside shoreline. For each of comparison with the Bayside assets, the Westside SLR and 100-year dynamic water levels are presented relative to the 10 SLR scenarios. However, the Westside shoreline analysis only evaluated the 100-year dynamic water level plus 12, 24, 36, 48, and 66 inches of SLR (Scenarios 5, 6, 7, 8, and 10, respectively).

Additional details on the exposure, vulnerability, and consequences of extreme tide and SLR flooding on City-owned assets can be found within the respective sector-based chapters. The relevant chapters are referenced below, as appropriate.

Scenario	Sector	Vulnerabilities and Consequences
Scenario 5 (54 inches SLR or 12 inches SLR and a 100-year extreme tide)	Wastewater	**Wastewater:** Under Scenario 5, the higher Pacific Ocean water levels may reduce the gravity-driven flow of excess combined wastewater and stormwater from the Lake Merced and Vicente Street transport / storage boxes via the combined sewer discharge outfalls. This impact is only of concern during intense and prolonged rainfall events that exceed the capacity of the large underground transport / storage boxes that ring the city. This could result in an increase in localized flooding in low-lying areas.
	Open Space	**Open Space:** Several of the trails that comprise the Coastal Trail could experience inundation under Scenario 5. Almost 100 percent of the Ocean Beach / Fort Funston Shoreline trail is inundated at this scenario, and the Baker Beach trail is approximately 90 percent inundated. Both trails run adjacent to the Pacific Ocean and can be subjected to erosion during large coastal storms with high winds and large waves.
Scenario 6 (66 inches of SLR or 24 inches of SLR and a 100-year extreme tide)	Wastewater	**Wastewater:** Under Scenario 6, the higher Pacific Ocean water levels may reduce the gravity-driven flow of excess combined wastewater and stormwater from the Lincoln transport / storage boxes via the combined sewer discharge outfalls. This impact is only of concern during intense and prolonged rainfall events that exceed the capacity of the large underground transport / storage boxes that ring the city. This could result in an increase in localized flooding in low-lying areas.

Residents and Businesses Exposed to Extreme Tide and SLR Flooding

Along the Westside shoreline, residential developments and businesses are generally located outside of the SLR Vulnerability Zone. However, the SLR Vulnerability Zone does not consider how the Westside shoreline could change if the ongoing coastal erosion hazards were allowed proceed without intervention. Currently, the implementation of the Ocean Beach Master Plan should address the most pressing erosion problems, providing protection for the city's critical infrastructure and its residents. As sea levels rise and the climate continues to change, the wave hazards may also change, placing additional areas at risk of erosion and flooding. The City is committed to monitoring long-term change along the Westside shoreline, particularly after large coastal storm events.

Ocean Beach and the Great Highway.
Photo by Martin Eckert (CC BY-NC-ND 2.0)

CHAPTER 13

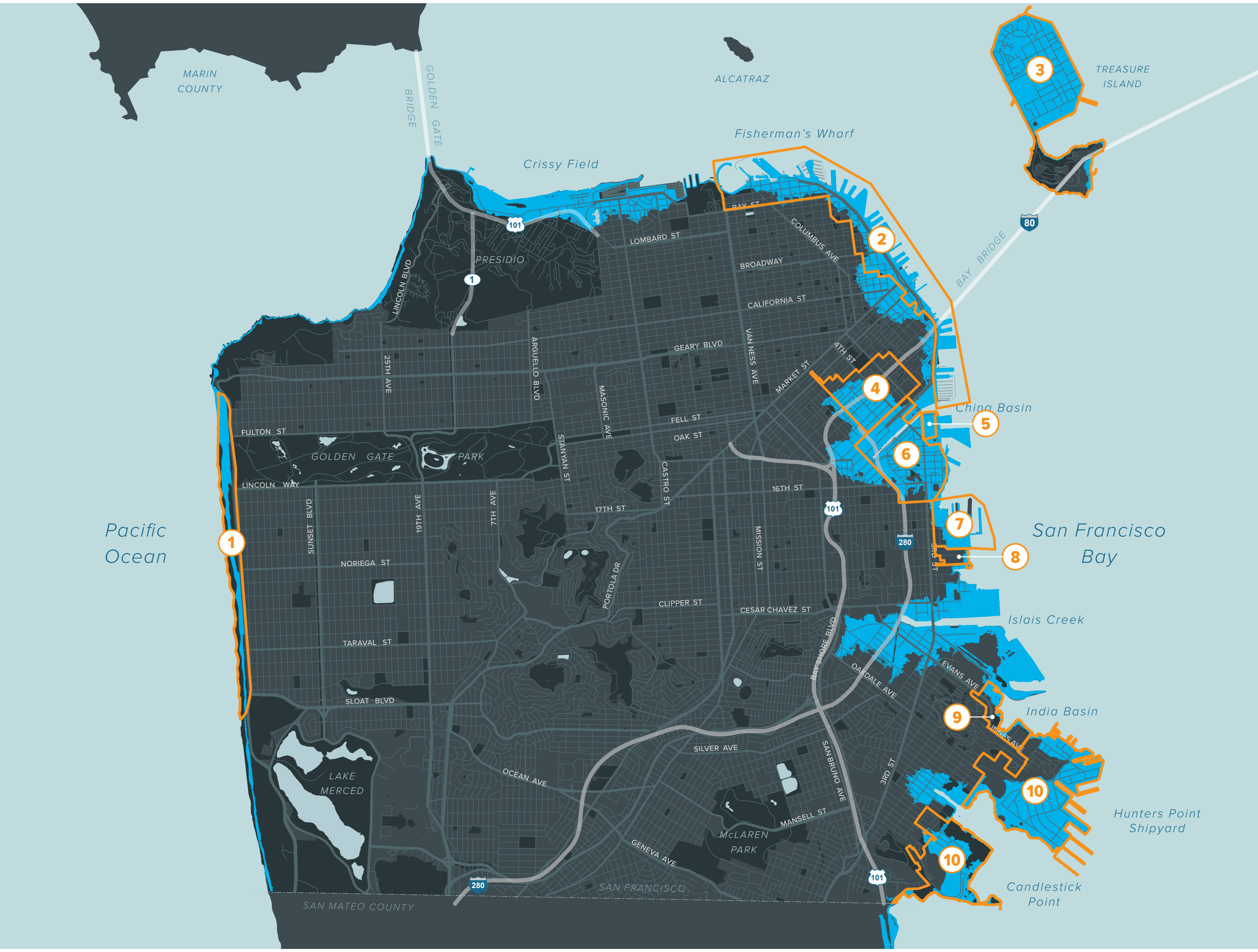
A CHANGING SHORELINE

Planned public and private development at San Francisco's edge

San Francisco's shoreline is a dynamic place. New mixed-use neighborhoods are being built in formerly industrial areas, the City is creating significant new open spaces for all to use, and new transportation and other infrastructure is being built to serve new residents, workers, and visitors. These uses co-exist with ongoing Port, maritime, and industrial operations that continue to serve a vital function on the waterfront.

The rest of the Sea Level Rise Vulnerability and Consequences Assessment studies San Francisco's current land use and infrastructure. This chapter focuses on future proposed changes to San Francisco's waterfront that will be impacted by rising sea levels, and the steps that proposed infrastructure and development projects are taking to address SLR impacts (see Figure 13.1).

Figure 13.1 Planning Efforts Underway



Inundation at 108" Sea Level Rise

1. Ocean Beach Adaptation Projects
2. Port of San Francisco Embarcadero Seawall Program and Flood Study
3. Treasure Island/Yerba Buena Island
4. Central SOMA
5. Mission Rock
6. Mission Bay
7. Pier 70
8. Potrero Power Station
9. India Basin Mixed-Use Project and India Basin Shoreline Park
10. Hunters Point Shipyard and Candlestick Point

Ocean Beach Adaptation Projects [1]

Ocean Beach, a 3.5-mile stretch of sand along San Francisco's rugged Pacific coast, draws a diverse population of more than 300,000 visitors each year and is an important piece of the Golden Gate National Recreation Area. Ocean Beach is also home to major elements of San Francisco's wastewater and stormwater infrastructure.

At Ocean Beach, storm-driven waves contribute to erosion of coastal bluffs. As climate change causes sea levels to rise, erosion is expected to worsen, threatening coastal infrastructure including roads and sewers and causing the beach to narrow.

Along the southern reaches of Ocean Beach, shoreline erosion is threatening the most seaward component of the combined sewer/stormwater system, the Lake Merced Tunnel, a 14-foot-diameter pipe under the Great Highway. Other components of the sewer system are located just behind the tunnel. To address erosion and SLR threats to this critical infrastructure, SFPUC participated along with other agencies and the public, in the development of the Ocean Beach Master Plan. SFPUC subsequently published a Coastal Protection Measures & Management Strategy Report.[2]

City and federal agencies are working together to implement short- and long-term adaptation measures at South Ocean Beach, following the recommendations of the Ocean Beach Master Plan[3]. Current implementation efforts include annual sand replenishment, roadway narrowing, and wastewater pump station improvements. Long-term improvements include road narrowing and realignment, an improved recreation trail, and the Ocean Beach Long-Term Improvements Project.

The Long-Term Improvement Project includes managed retreat (i.e., recontouring the bluffs and removing the Great Highway between Sloat Boulevard and California State Route 35), removal of rubble and rock from the beach and bluffs, continued beach nourishment, and installation of a low-profile wall to protect the Lake Merced Tunnel.

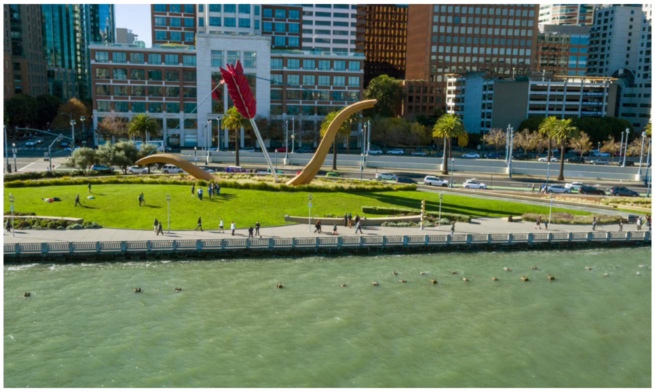
This project will protect vital public wastewater infrastructure and improve access, recreation, and habitat at South Ocean Beach. The Ocean Beach Long-Term Improvements Project, being implemented by SFPUC, is expected to begin construction in 2022.

1 San Francisco Planning. 2019. Ocean Beach Adaptation Efforts. https://sfplanning.org/ocean-beach-adaptation-efforts.

2 San Francisco Public Utilities Commission (SFPUC). 2015. Coastal Protection Measures and Management Strategy for South Ocean Beach. Available at https://www.spur.org/sites/default/files/wysiwyg/OB_Coastal_Protection_Mgmt_Final_20150424.pdf.

3 https://www.spur.org/featured-project/ocean-beach-master-plan?utm_medium=redirect&utm_source=oceanbeach

Port of San Francisco Embarcadero Seawall Program [4] and Flood Study [5]



The Embarcadero Seawall is over 100 years old and was designed and constructed before engineers understood how to build infrastructure to survive earthquakes. Most of the seawall is built over "young bay mud," a weak, saturated, and highly compressible marine clay that tends to amplify earthquake shaking. The seawall has aged and settled, and no longer offers sufficient flood protection.

The Port of San Francisco is leading the Embarcadero Seawall Program, a Citywide effort to create a more sustainable and resilient waterfront. The Program is dedicated to robust community and stakeholder engagement, along with fiscal responsibility, accountability, and transparency. Part of the Port's Waterfront Resilience Program, the Seawall Program will provide the tools to address current and future risks over time. There are three elements to the Program—Strengthen, Adapt and Envision—which allow the Port to respond to risks and conditions. Planning for all three elements is occurring now, implementation for each element will depend upon findings, public input, regulatory input, cost/benefit analysis, and availability of funding and financing.

San Francisco voters passed a $425 million General Obligation Bond for the Program in November 2018. The Port is currently pursuing local, state, federal, and private funding sources to fully fund infrastructure improvements anticipated to cost up to $5 billion. Immediate seismic and flood protection upgrades are targeted for completion by 2026. The Program is currently in the early stages of planning, following an extensive Vulnerability Study. Chapter 4, Supporting Assessments includes further discussion of the Embarcadero Seawall Program.

In addition to the Embarcadero Seawall Program, USACE and the Port are partnering to study flood risk along San Francisco's bayside shoreline. The approximately three- to five-year Flood Study will identify vulnerabilities and recommend strategies to reduce current and future flood risks for consideration by the Assistant Secretary of the Army and the U.S. Congress for federal investment and implementation.

The goals of the Flood Study are to better understand current and future flood risk along San Francisco's bayside shoreline, identify alternatives to reduce flood risk, engage the public and other stakeholders to identify priorities for the Flood Study, and create opportunities for funding for flood risk reduction projects.

The study area includes the Port's entire shoreline ownership from Aquatic Park to Heron's Head Park. The study will result in potential flood risk mitigation projects to protect against flooding through 2080 and consideration of flood risks through 2130.

4 https://www.sfportresilience.com/seawall-program.

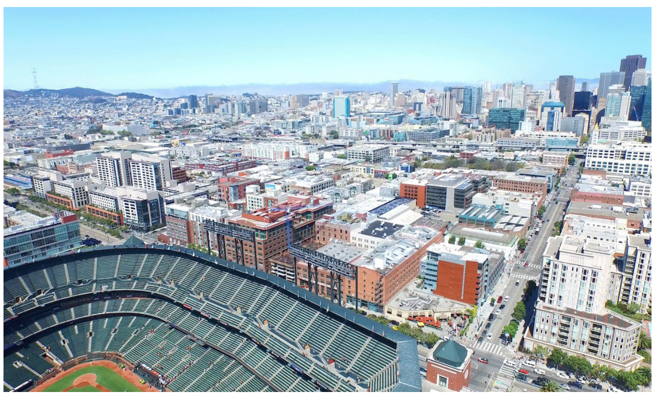
5 https://www.sfportresilience.com/-flood-studyhttps://sfport.com/sites/default/files/Commission/Documents/Item%2013A%20USACE%20Feasibility%20Cost%20Sharing%20Agreement.pdf.

Treasure Island/Yerba Buena Island [6]

The redevelopment of Treasure Island and Yerba Buena Island will produce a new district of up to 8,000 homes, 25 percent of which will be offered at below-market rates, extensive open spaces, three hotels, restaurants, retail, and entertainment venues within San Francisco. Project construction will use grading and shoreline protection features to adapt to estimated 2050 SLR impacts and identifies triggers for future adaptation planning. The development also includes tax increment financing to fund future shoreline adaptation strategies.

6 City and County of San Francisco. Treasure Island Development Authority. Available at https://sftreasureisland.org/.

Central SOMA [7]



The Central SOMA Plan Area, located within the South of Market Area neighborhood, is bounded by Market Street, Townsend Street, 2nd Street, and 6th Street, and enables the development of up to 32,500 jobs and 8,800 housing units in a complete neighborhood. The new development would result in more than $2 billion in public benefits to serve the neighborhood. The Plan Area is largely within the SLR exposure zone. To that end, the plan incorporates policies to protect individual buildings and the neighborhood from flooding. These policies call for the development of a comprehensive SLR and flood management strategy for Central SOMA, the implementation of building and subdivision requirements to reduce flood risk, and the installation of green infrastructure to reduce flood risk. The Central SoMa Plan also includes funding through a Community Facilities (Mello-Roos) District to address long-term SLR.

7 San Francisco Planning. Central SOMA Plan. Available at https://sfplanning.org/project/central-soma-plan.

Mission Rock [8]

8 https://sfport.com/missionrock

Mission Rock, a partnership between the Port and the San Francisco Giants, will convert a 28-acre site consisting primarily of a surface parking lot homes, offices, and open space. The project includes:

- 1,500 rental homes with 40 percent affordable
- 8 acres of parks and open space
- SLR and sustainability strategies
- 1 million to 1.4 million square feet of office space
- Water access

The proposed development will adapt to SLR by grading, elevating its waterfront riprap and seawall, and designing floodable shoreline open space.

Mission Bay [9]

9 https://sfocii.org/mission-bay

San Francisco's Mission Bay North and South Redevelopment Project Areas cover 303 acres of land between the San Francisco Bay and I-280, bounded by portions of Townsend Street to the north and Mariposa Street to the south. The Board of Supervisors adopted the Mission Bay North and South Redevelopment Plans and related controlling documents in November 1998.

As of March 2019, 5,789 housing units (including 1,191 affordable units) of the planned 6,514 units have been constructed in Mission Bay. More than 3.5 million square feet of commercial, office, clinical, and biotechnology laboratory space has been built out of the planned 4.4 million square feet. About 75 percent of the University of California, San Francisco (UCSF) campus will be developed by 2020 when several buildings currently under construction are completed. The campus will include nine research buildings, a campus community center, three parking structures, a university housing development, a childcare center, and the UCSF Health medical center. More than 19 acres of new non-UCSF parks and open space out of the planned 41 acres have also been completed, including a children's park.

Pier 70 [10]

Pier 70 is a Port of San Francisco site that is approximately 69-acres located in the City's Central Waterfront, generally between Mariposa and 22nd Street, east of Illinois Street. This site has been identified as a future National Historic District due to its over 150 years of continuous operations in Ship Building and Repair, the role it has played in the industrialization of the Western United States, the war efforts and architectural and engineering feats.

The Port of San Francisco working with its regulatory partners and through an extensive community planning process recently completed a Pier 70 Preferred Master Plan. The Preferred Master Plan outlines an approach to rehabilitate historic resources, provide new shoreline open space, allow for new infill development, continue the historic ship repair operations and conduct environmental remediation and infrastructure improvements where required.

Pier 70 includes a 25-acre waterfront site that will house new mixed-use development. Following a competitive development solicitation process, in July 2011, the Port entered into an Exclusive Negotiation Agreement (ENA) with Forest City Development.

The Forest City project includes new market-rate and affordable residential uses, commercial use, retail-arts-light industrial uses, parking, shoreline improvements, infrastructure development and street improvements, and public open space. Depending on the uses proposed, the Project would include between 1,645 to 3,025 residential units, 1,102,250 to 2,262,350 gross square feet (gsf) of commercial-office use, and 494,100 to 518,700 gsf of retail-light industrial-arts use.

The proposed development will adapt to SLR through grade changes, floodable open space along the shoreline, and building elevation as necessary. The project will also contribute to a Port-wide resilience fund.

10 https://sfport.com/pier-70-area

Potrero Power Station [11]

The Potrero Power Station is a 28-acre site located in the Central Waterfront District east of the Dogpatch neighborhood and American Industrial Center and directly fronting San Francisco Bay. For over 150 years before being decommissioned as a power plant in 2011 by then-owner Mirant Potrero LLC, the site was host to a range of industrial uses from barrel-making and sugar refining to power generation. While industrial uses will continue to be an important element of the urban fabric in the Central Waterfront, including on this site, the City's Central Waterfront Area Plan identifies the site as a location for additional growth and a wider range of land uses, including residential, commercial, and parks.

In 2016, Associate Capital (Project Sponsor) purchased the Potrero Power Station from then-owner NRG Energy. In 2017, it began an extensive planning process with City agencies and the community to develop a master plan for the site. The proposed project would include approximately 2,400 dwelling units, 1.2-to 1.9 million gsf of commercial uses, and six acres of open space. The proposed development would adapt to SLR by grading, elevating its waterfront riprap and seawall, and designing floodable shoreline open space.

The Potrero Power Station Design for Development Public Review Draft, Draft Infrastructure Plan, and Draft Environmental Impact Report were published on October 3, 2018. These documents remain under review by City agencies and additional opportunities for community input will occur throughout 2019.

11 San Francisco Planning. Potrero Power Station. Available at https://sfplanning.org/project/potrero-power-station.

India Basin Mixed-Use Project and India Basin Shoreline Park [12]

India Basin is located along the San Francisco Bay generally between the PG&E Power Plant site and Hunters Point Shipyard. The proposed India Basin Mixed-use Project consists of two main components, the 700 Innes Avenue Development Project and the India Basin Waterfront Parks and Trails Project.
The 700 Innes Avenue Development Project currently consists of 17.2 acres of mostly Bay-fill vacant land. The project envisions the creation of a mixed-use village with retail shops, apartments, and townhomes intricately linked to a 6-acre park along the shoreline. At completion, 700 Innes will include approximately 1,250 dwelling units, an allowance of up to 270,000 square feet of retail, and 1,800 parking spaces, and public open space.

The India Basin Waterfront Parks and Trails Project would create a new 1.8-acre public park at 900 Innes and rehabilitate two existing open spaces, India Basin Shoreline Park (5.6 acres) and India Basin Open Space. The proposed development will adapt to SLR by grading, elevating its waterfront rip rap and seawall, and designing floodable shoreline open space.

12 India Basin San Francisco. Reimagining Urbanism. Available at http://indiabasinsf.com/. San Francisco Recreation and Park. India Basin Shoreline Park. Available at https://sfrecpark.org/destination/india-basin-shoreline-park/.

Hunters Point Shipyard and Candlestick Point [13]

The Hunters Point Shipyard, a former naval base, is a master-planned community located along the southeastern waterfront of San Francisco. The Board of Supervisors originally adopted the Redevelopment Plan in 1997 and amended it in 2010 to provide for the integrated planning and development of the Shipyard and the Candlestick Point portion of the Bayview Hunters Point Redevelopment Project Area.

Phase I of the Shipyard Project, which includes the Hillside and Hilltop areas, is completing the infrastructure and will ultimately include up to 1,428 homes and 20,000 square feet of commercial space.

Hunters Point Shipyard and Candlestick Point Phase II covers approximately 702 acres in San Francisco's Bayview Hunters Point and Hunters Point Shipyard neighborhoods. The amended plan for the area calls for mixed-use development consisting of up to 10,672 residential units that includes a mix of affordable and market rate units, 1,146,000 square feet of neighborhood and regional retail, 4.4 million square feet of research and development/office, and 328 acres of open space.

The SLR strategy at Candlestick Point is addressed in Volume 1 of OCII's Infrastructure Plan and the Shipyard is addressed in Volume 2. The design criteria of this strategy include: a) raising grades such that finished floor elevations are a minimum of 5.5 feet above the base flood elevation; b) raising the shoreline open space areas around the development perimeter 24 inches above wave-influenced water surfaces, and; c) a new storm drain system designed to operate under gravity at a height 24 inches above water levels, and other design criteria based on the amount of actual SLR.

The Hunters Point Shipyard Project will establish a special assessment district to develop an Adaptive Management Plan, as referenced in the Project's Mitigation Measures. As sea level rises, adaptive management strategies will include storm drain pump stations and shoreline berms to protect the Hunters Point Shipyard-Candlestick Point Project roads, infrastructure, and buildings. The addition of a new pump station at each storm drain outfall will increase the storm drain system capacity. The strategy also calls for identifying a stream of funding to construct future improvements.

13 Office of Community Investment and Infrastructure (OCII). Hunters Point Shipyard and Candlestick Point. Available at https://sfocii.org/hunters-point-shipyard-and-candlestick-point.

Photo by Sergio Ruiz

CHAPTER 14

NEXT STEPS

The earth and its inhabitants are facing a climate emergency. Even as we work to mitigate our contributions to global heating, we are aware that we are already facing many climate-related impacts: prolonged drought, extreme heat, massive wildfires, hazardous air quality, flooding, and severe weather. Combined with new, more severe weather patterns like coastal storms, SLR presents a daunting challenge for waterfront cities like San Francisco.

Following the SLR Action Plan framework, this Assessment lays out detailed information on the City's vulnerabilities to SLR over time, and the consequences of those vulnerabilities. City agencies, decision makers, and the public can use this information to plan, fund, prioritize, and implement adaptation strategies for our shoreline and individual buildings and infrastructure assets.

San Francisco's efforts to adapt to SLR, coastal flooding, and other climate impacts will continue for decades. Major adaptation projects that involve significant changes to the City's shoreline infrastructure will take many years to plan, fund, and build. These projects will involve phasing plans that identify near-term, high-priority actions that address the most imminent flooding concerns. Smaller fixes to individual buildings or other infrastructure may be built into ongoing capital improvement plans and built quickly.

Some areas of the City are already affected by coastal flooding and require near-term solutions. Other areas may be affected within 10 years. Infrastructure solutions and capital investments will take years or decades to plan, engineer, and fund. The City is developing and implementing plans and projects to protect people, buildings, infrastructure, and open space (Table 14.1).

Table 14.1 Sea Level Rise Action Plan Next Steps

Next Step	Status
Review Science & Pursue SLR Research Priorities	**Ongoing.** Ongoing activities include state science update and extreme precipitation study. Other identified needs include research on the overlay of groundwater, contamination, and liquefaction in bay fill areas.
Complete Citywide Vulnerability & Risk Assessments	**Complete.** This report completes this step.
Conduct Comprehensive Economic Risk Analysis	**Ongoing.** Qualitative analysis was performed as part of the consequences assessment in this report. The USACE/Port Flood Study and the Embarcadero Seawall Program multi-hazard risk assessment will include economic impacts.
Develop SLR-Specific Community Education & Engagement Strategy	**Ongoing.** This next step has been integrated into the engagement strategy for the Hazards and Climate Resilience Plan. Individual projects such as Embarcadero Seawall Program and Islais Creek Southeast Mobility Adaptation Strategy include robust community outreach and engagement programs.
Develop Training Program for Capacity Building	**Ongoing.** The City has held individual agency vulnerability workshops, and a multi-agency consequences workshop in 2018. The City is also planning training for agency staff on use of the SLR Capital Planning Guidance
Launch and Complete Bay Area Resilient by Design Challenge	**Complete.** See Resilient by Design[1].
Review Potential Policy and Financing Tools	**Not started.** This work is included in next steps for overall climate resilience planning, scope TBD. Seawall Finance Work Group Report completed as part of Embarcadero Seawall Program (Port of SF). Finance strategies included as part of on-going efforts such as Port/U.S.Army Corps Flood Study and Islais Creek Adaptation Strategy.
Complete Comprehensive Citywide Sea Level Rise Adaptation Plan	**Not Started.** This work is included in next steps for overall climate resilience planning, scope TBD.
Develop Near-Term Adaptation Plans for High-Risk Areas and Assets	**Ongoing.** Adaptation plans are underway through the USACE/Port Flood Study, Embarcadero Seawall Program, Islais Creek Southeast Mobility Adaptation Strategy, Ocean Beach Master Plan implementation, wastewater assets. New shoreline developments and area plans in SLR. zone have built SLR adaptation and funding mechanisms into their approved plans.
Monitor and Investigate Backflow Prevention	**Ongoing.** This work is underway through the Sewer System Improvement Plan (SFPUC)
Develop Interim and Long-Term Airport Shoreline Protection	**Ongoing.** Conceptual designs and cost estimates are complete. Environmental review and permitting are underway.
Coordinate Monitoring and Tracking of Storm Events	**Not Started.**

1 http://www.resilientbayarea.org/

As the City continues to build, operate, and maintain its infrastructure systems, and as we plan for longer-term SLR impacts, we are already taking future SLR into account in our everyday actions, moving forward with long-range multi-phase adaptation plans, and implementing near-term strategies that address our most imminent vulnerabilities.

The City is developing several plans, policies, and projects that help adapt the City to SLR, including:

1. SLR Capital Planning Guidance
2. Ocean Beach Master Plan implementation
3. Embarcadero Seawall Program
4. USACE/Port Flood Study
5. Islais Creek Southeast Mobility Adaptation Strategy
6. SFO Shoreline Protection Program
7. Hazards and Climate Resilience Plan
8. New Shoreline Development and Open Spaces

14.1 SEA LEVEL RISE ACTION PLAN NEXT STEPS

The Sea Level Rise Action Plan identified several next steps for the City to take to adapt to SLR. The City is actively moving forward with several of these. Others are currently being scoped and developed and will follow these initial steps. Some steps will be integrated into a larger climate resilience framework that comprehensively considers how the City will adapt to multiple climate-related impacts.

14.2 ADAPTATION PRINCIPLES

As the City advances adaptation planning efforts, we have identified key considerations to guide adaptation planning and ensure that adaptation strategies are effective, efficient, equitable, and environmentally appropriate.

Successful adaptation planning should:

- Begin with robust community engagement to ensure strategies will meet local needs and build public and political support for action
- Prioritize and include vulnerable neighborhoods that already bear disproportionate environmental burdens and will be most impacted by future flooding
- Include natural solutions where possible to improve the City's environment and provide open space recreation opportunities
- Create a decision-making framework for when and where to implement facility-specific floodproofing versus neighborhood-scale shoreline strategies
- Identify strategies that could be implemented by multiple actors, including individual agencies, private landowners, and the City as a whole
- Adopt adaptation policy for private development and public investment in addition to implementing physical strategies
- Identify potential funding sources and appropriate lead agencies for adaptation projects that cross agency jurisdictions
- Balance uncertainty in long-term climate projections with the need for urgent action
- Integrate SLR and coastal flooding programs with other City resilience efforts

14.3 CURRENT ADAPTATION EFFORTS

14.3.1 Sea Level Rise Capital Planning Guidance

In 2014, the Office of Resilience and Capital Planning created SLR planning guidelines for public projects in the SLR Vulnerability Zone, revised in 2015. This guidance helps the City apply a consistent and comprehensive review, planning, and implementation process to projects with costs of $5 million or more, and ensures that infrastructure projects consider SLR in their planning and design. The SLR capital planning checklist (a portion of the CPC guidance) was updated in 2019 based on updated State science projections.

14.3.2 Hazards and Climate Resilience Plan

The Hazards and Climate Resilience Plan is serving as the 2019 update to the Hazard Mitigation Plan and will underpin the City's next Climate Action Strategy and Community Safety Element update. The Office of Resilience and Capital Planning is leading this effort in partnership with Department of Emergency Management, Department of Public Health, Department of the Environment, and Planning.

This plan incorporates climate change vulnerability analysis and near-, mid- and longer-range resilience actions for SLR and other natural hazards. The draft Plan will be published in 2019 and submitted to the California Governor's Office of Emergency Services and FEMA for review before final adoption.

14.3.3 Ocean Beach Implementation

City and federal agencies are working together to implement short- and long-term adaptation measures at South Ocean Beach, following the recommendations of the Ocean Beach Master Plan[1]. These projects include road narrowing and realignment, an improved recreation trail, and the Ocean Beach Long-Term Improvements Project.

The Long-Term Improvement Project includes managed retreat (i.e., recontouring the bluffs and removing the Great Highway between Sloat Boulevard and California State Route 35), removal of rubble and rock from the beach and bluffs, continued beach nourishment, and installation of a low-profile wall to protect the Lake Merced Tunnel.

This project will protect vital public wastewater infrastructure and improve access, recreation, and habitat at South Ocean Beach. The Ocean Beach Long-Term Improvements Project, being implemented by SFPUC, is expected to begin construction in 2022.

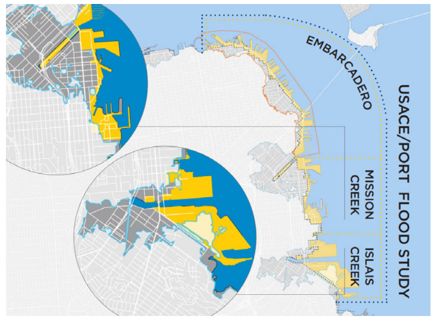
1 https://www.spur.org/featured-project/ocean-beach-master-plan?utm_medium=redirect&utm_source=oceanbeach

14.3.4 Embarcadero Seawall Program

The Port is leading the Embarcadero Seawall Program, a Citywide effort to strengthen the Embarcadero Seawall and create a more sustainable and resilient waterfront.

San Francisco voters passed a $425-million General Obligation Bond for the Program in November 2018. To date, the Port has secured $440 million for urgently needed immediate life safety improvements, and is currently pursuing local, state, federal, and private funding sources to fully subsidize infrastructure improvements anticipated to cost up to $5 billion.

Immediate seismic and flood protection upgrades are targeted for completion by 2026. The Program is currently in the early stages of planning, following an extensive Vulnerability Study.



14.3.4 Port of San Francisco and Army Corps of Engineers Flood Study

USACE and the Port are partnering to study flood risk along San Francisco's bayside shoreline. The approximately three- to five-year Flood Study will identify vulnerabilities and recommend strategies to reduce current and future flood risks for consideration by the Assistant Secretary of the Army and the U.S. Congress for federal investment and implementation.

The goals of the Flood Study are to better understand current and future flood risk along San Francisco's bayside shoreline, identify alternatives to reduce flood risk, engage the public and other stakeholders to identify priorities for the Flood Study, and create opportunities for funding for flood risk reduction projects

The study area includes the Port's entire shoreline ownership from Aquatic Park to Heron's Head Park. The study will result in potential flood risk mitigation projects to protect against flooding through 2080 and consideration of flood risks through 2130.

14.3.5 Islais Creek Southeast Mobility Adaptation Strategy

The Planning Department, in partnership with SFMTA and the Port, is leading the Islais Creek Southeast Mobility Adaptation Strategy. With funding through a Caltrans grant, this 2-year community planning process in the Islais Creek area that will develop actionable strategies that address SLR and coastal flood risk through a robust public engagement process.

Building on the Resilient by Design proposal in coordination with the USACE/Port Flood Study (13.5.2), the Islais Creek Southeast Mobility Adaptation Strategy will develop a long-range vision for the Islais Creek shoreline, asset-specific solutions for public infrastructure, and a prioritized funding and implementation strategy that increases the resilience of the community and provides improved transportation networks and new open space.

The 2-year planning project will begin in early 2019 and conclude in early 2021.

14.3.6 SFO Shoreline Protection Program

SFO is developing a new Shoreline Protection Program to address potential flood risks to address both 100-year storm and SLR out to 2085. Conceptual designs and cost estimates have been developed. Environmental review and permitting are underway in 2020. Early build-out is expected to start in 2025. Project designs are based on the Shoreline Protection Program - Conceptual Design Study.

14.3.7 New Shoreline Development and Open Spaces

In recent years, the City has approved several significant mixed-use development projects along the East Bay shoreline of San Francisco, including Treasure Island, Mission Rock, Pier 70, India Basin, and Candlestick/Hunters Point Shipyard. Other projects are currently under review, including Potrero Power Station. These projects have built SLR adaptation and funding mechanisms into their approved plans. The City has built and planned for new parks along the East Bay shoreline, including Crane Cove Park and India Basin Park, that incorporate SLR adaptation into their designs. See Chapter 13, *A Changing Shoreline*.

14.4 REGIONAL COORDINATION

All nine counties that surround San Francisco Bay are vulnerable to SLR and coastal flooding and are engaged in assessing SLR vulnerabilities and risks or moving forward with SLR adaptation efforts. Several groups are supporting regional coordination and encouraging information sharing as adaptation projects are planned and/or implemented. Regional coordination can help all Bay Area communities become more resilient by sharing lessons learned, discovering and closing data gaps, and developing cross-jurisdictional projects since SLR does not follow traditional jurisdictional boundaries.

San Francisco is currently participating in the following regional groups:

San Francisco Bay Conservation and Development Commission's (BCDC) **Adapting to Rising Tides (ART) Program** has released SLR and coastal flooding inundation layers for the entire Bay Area and developed a portfolio of planning guidance, tools, engagement exercises, and information to support climate change assessments and adaptation. As cities, counties, agencies or localized areas complete assessments using the ART approach, the assessments are typically posted on the ART website to foster lessons learned and transparency across the region. BCDC also hosts Regional Working Groups on a regular basis to encourage regional conversations on adaptation planning and implementation.

The Bay Area Climate Adaptation Network (BayCAN) is a collaborative network of local government staff and partners to help the Bay Area region respond effectively and equitably to the impacts of climate change on human health, infrastructure, and natural systems. BayCAN covers the 9-county San Francisco Bay Area and primarily exists to facilitate connections, information sharing, and best practices development among local governments, develop opportunities for multi-jurisdictional collaboration and program implementation, and help secure greater levels of adaptation funding and resources.

San Francisco Bay Regional Coastal Hazards Adaptation Resiliency Group (CHARG) is an organization of flood control managers and scientists responsible for reducing flood risk in the Bay Area. As a strategic initiative of the Bay Area Flood Protection Agencies Association (BAFPAA), CHARGs goal is to advance the technical, scientific and engineering analysis needed for the region to implement adaptation projects and build resilience to SLR and climate change. CHARG hosts regional workshops, meetings, and presentations to share their findings and encourage collaboration.

14.5 CITYWIDE CLIMATE RESILIENCE PLANNING

As the City continues to study, plan for, and address SLR impacts, we are considering climate resilience comprehensively – both how we continue the City's efforts to mitigate climate emissions and how we adapt our City to become more resilient to climate impacts. San Francisco continues to be a global leader in climate emission reduction. However, even with our best efforts locally, global emissions will continue to occur and we will continue to see climate impacts even if all climate emissions ended today. So, we must plan for climate adaptation as well as climate mitigation.

In addition to the ongoing efforts described in this chapter, the City is developing next steps for climate resilience planning, considering not only SLR but other climate-related hazards as well such as extreme precipitation, drought, poor air quality, extreme heat, and wildfire.

Deliverables for the climate resilience program include:

- **Comprehensive capital planning for climate adaptation**, including shoreline strategies for SLR adaptation
- **Climate resilient codes and standards** for new development that consider climate adaptation, including flood protection and weatherproofing, and climate mitigation such as Zero Net Energy and green roofs
- **General Plan policy updates** to ensure the City's policy integrates and aligns with the need to address climate change and its impacts
- **Funding, legislative, and governance strategies** to reduce our climate emissions and adapting San Francisco to the impacts of climate change.

We are facing a climate emergency. San Francisco is one actor on a global scale. But we can be a leader in working to address the climate crisis and adapting our City to the coming impacts of climate change to improve the lives of people who live and work in San Francisco.

This Assessment provides essential information to help us understand our vulnerabilities to SLR and coastal flooding. It lays the groundwork for the City to work with communities to develop strategies to adapt San Francisco to SLR.


CITY AND COUNTY
OF SAN FRANCISCO