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)

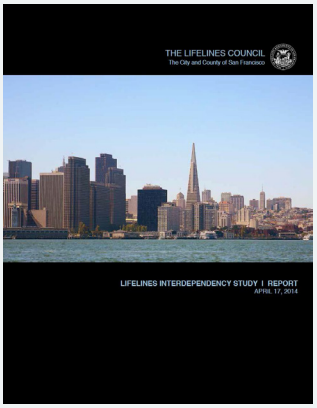
   c. Environment (i.e., environmental values that may be affected, such as water quality, species biodiversity, and ecosystem function and services)

   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

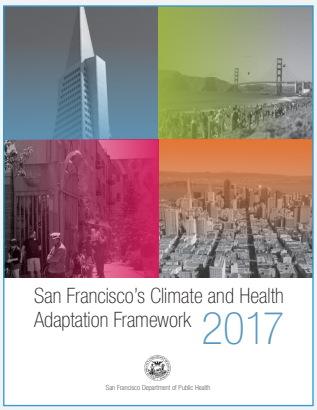
- The Port's multi-hazard risk assessment of the seawall is moving forward under the Seawall Earthquake Safety and Disaster Prevention Program (assessed in Section 8). The multi-hazard risk assessment will analyze vulnerabilities along a 3-mile section of the seawall due to seismic activity, liquefaction, 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



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.

TIMELINE OR STATUS
Completed 2017

AREA
San Francisco, CA

FOCUS
Health impacts of climate change

TARGET AUDIENCE
San Francisco City agencies, San Francisco communities

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.

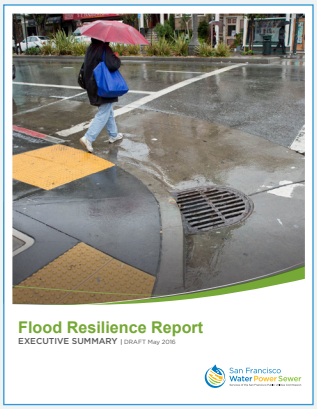
References

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).

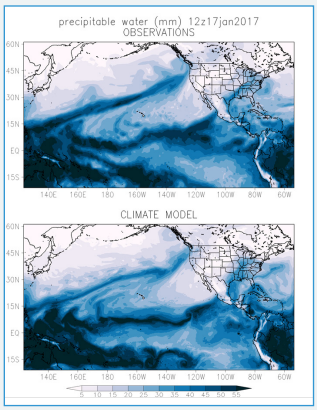
The SFPUC assessment also informs the design of new infrastructure and facilities. The SLR and storm surge inundation mapping informs site selection and helps set critical elevations related to earthwork and grading, first floor elevations, elevations of electrical equipment and control panels, as well 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



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.

TIMELINE OR STATUS
2019

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

FOCUS
Extreme precipitation

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

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