Appendix A

Vulnerability and Consequence Profiles

Appendix A contains the Vulnerability and Consequence Profiles, as described in Chapter 05. These profiles provide an exposure assessment of key asset classes in San Francisco and characterize their vulnerability to disruption by hazard events and the potential consequences from their disruption. Subject matter experts were consulted to ensure that the profiles reflect the best available information at the time of the analysis. These profiles can be used by decision makers, departmental staff, and the general public to obtain a more complete understanding of assets within the city, how they relate to each other, and how they may be impacted by hazards. The findings from the profiles informed the strategies found in Chapter 07.

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Vulnerable Populations

While all San Franciscans are vulnerable to the health impacts of hazard events, vulnerability is not evenly distributed. A person, household, or community's resilience depends on an array of interconnected and compounding physical, social, political, environmental, and economic disparities. As one of the goals of the Hazard and Climate Resilience Plan is to "address the inequitable impacts of current and future hazards and promote the just distribution of risk reduction and resilience benefits through implementing policies and programs that address existing racial, economic, and health disparities" , it is necessary to first identify the specific factors that contribute to vulnerability, assess how these factors contribute to a person, household, or community's vulnerability to hazard events, and locate the neighborhoods where these people, households, or communities are concentrated.

A nuanced analysis of the factors that contribute to vulnerability will allow the Hazard and Climate Resilience plan to develop more sophisticated programs and policies that proactively address the disproportionate impacts of hazard events and advance equity through the just distribution of risk reduction and resilience benefits.

This section will divide vulnerability factors into four separate categories that represent a pathway that connects a hazard to health impacts and either modifies the intensity of exposure to the hazard, increases a person's sensitivity to that exposure, or affects the capacity of that person or community to prepare for or respond to that exposure. These categories are:

- socioeconomic and demographic factors,
- housing quality and living conditions,
- community characteristics and social cohesion, and
- pre-existing health conditions.

This section will define each category, detail how some significant factors affects vulnerability, and identify the San Francisco neighborhoods where those vulnerable populations are concentrated. Significance was determined by the availability of research connecting the vulnerability factor to hazard-related health impacts and the availability of data on the local geographic distribution of that vulnerability factor.

TABLE A-1: FACTORS THAT INFLUENCE VULNERABILITY

Socioeconomic and Demographic Factors	Housing and Living Conditions	Community Characteristics and Social Cohesion	Pre-Existing Health Conditions
• Age: o Infants o Children* o Seniors* • Income and Poverty* • Race / Ethnicity* • Educational Attainment • Employment Status • Citizenship Status • Single Parent Families • Outdoor Workers	• Unhoused Populations* • Housing Quality* o Housing Health and Safety Violations o Air Conditioning Ownership o Soft Story buildings • Housing Affordability* o Rent Burden o Home Ownership	• Social Isolation* o Living Alone o Voting Rates o Linguistic Isolation* o Violent Crime o Displacement and No-Fault Evictions* • Community Characteristics o Access to Transportation o Access to Hospitals and Community Health Centers	• Disability and Functional Limitations* • Chronic Disease o Respiratory Illnesses o Cardiovascular Illnesses o Diabetes o Cancer • Behavioral and Mental Health • Preventable Hospitalizations
Significant Factor = *			

Socioeconomic and Demographic Factors

Socioeconomic and demographic factors represent a broad array of physical, economic, and cultural attributes that influence a person or community's sensitivity to a hazard, or ability to prepare for, respond to, or recover from hazard events.

Children

Children are particularly vulnerable to hazards because of both their physiology that impacts their sensitivity to certain hazards, and their adaptive capacity, as children are reliant on adults for emergency preparation and response activities. Children are vulnerable to environmental exposures like poor air quality. A child's respiratory rate can be two-to three times higher than an adult respiratory rate, so children experience the effects of poor air quality to a greater degree than an adult. Children are also vulnerable to extreme heat as children have a higher surface area to body mass ratio compared to adults while having reduced sweating capacity. Children have more sensitive immune systems and are more likely to have physical contact with contaminated water following a storm or flood. In addition, when certain stressors occur earlier in life, especially during critical development periods, they can cause more severe and long-lasting impacts.1 For example, stress associated with hazard events may have lasting impacts into adulthood.

Data available in 2018 is from American Community Survey (ACS) 2012-2016 estimates. There were an estimate 132,330 children (population under age 18) in San Francisco.2 This population is expected to increase by 12 percent to 148,324 by 2030.3 Neighborhoods with the highest proportion of children are Sea Cliff, Presidio, Bayview Hunters Point, Visitacion Valley, Portola, Outer Mission, West of Twin Peaks.4 Refer to Table A-2 for data tabulated by neighborhood.

TABLE A-2: POPULATION UNDER AGE 18 BY NEIGHBORHOOD, 2012-2016 [5]

Neighborhood	Percent of residents under Age 18	Count of residents under Age 18
Bayview Hunters Point	25.0%	9,400
Bernal Heights	17.7%	4,626
Castro/Upper Market	8.3%	1,750
Chinatown	11.9%	1,763
Excelsior	16.6%	6,530
Financial District/South Beach	8.6%	1,501
Glen Park	17.8%	1,461

[1] Mishra, Gita D., Rachel Cooper, and Diana Kuh. "A Life Course Approach to Reproductive Health: Theory and Methods." *Maturitas* 65, no. 2 (February 2010): 92–97. https://doi.org/10.1016/j.maturitas.2009.12.009.
[2] State of California, Department of Finance, "Report P-1 (Age): State and County Population Projections by Major Age Group, 2010-2060 Sacramento, California, January 2018"
[3] State of California, Department of Finance, "Report P-1 (Age): State and County Population Projections by Major Age Group, 2010-2060 Sacramento, California, January 2018" (?)
[4] ACS 2012-2016
[5] ACS 2012-16; *Indicates unstable data

Golden Gate Park	*	*
Haight Ashbury	9.6%	1,733
Hayes Valley	7.1%	1,296
Inner Richmond	13.2%	2,970
Inner Sunset	12.9%	3,757
Japantown	4.7%	172
Lakeshore	7.5%	1,073
Lincoln Park	1.6%	*
Lone Mountain/USF	9.2%	1,663
Marina	11.2%	2,812
McLaren Park	17.5%	*
Mission	12.2%	7,154
Mission Bay	8.7%	916
Nob Hill	5.1%	1,337
Noe Valley	15.2%	3,526
North Beach	9.0%	1,134
Oceanview/Merced/Ingleside	16.8%	4,705
Outer Mission	18.2%	4,418
Outer Richmond	13.5%	6,057
Pacific Heights	8.9%	2,142
Portola	18.5%	3,037
Potrero Hill	16.8%	2,313
Presidio	28.1%	1,076
Presidio Heights	17.5%	1,876
Russian Hill	6.3%	1,123
Seacliff	28.8%	707

South of Market	7.3%	1,400
Sunset/Parkside	15.6%	12,643
Tenderloin	7.8%	2,201
Treasure Island	13.3%	*
Twin Peaks	10.1%	749
Visitacion Valley	21.5%	3,991
West of Twin Peaks	17.9%	6,834
Western Addition	9.9%	2,200
San Francisco	13.5%	114,788

Seniors

Older adults are at increased risk for morbidity and mortality during hazard events because they are more likely to have chronic health conditions, mobility constraints, are more likely to be socially isolated, public transportation dependent, and rely on city and federal resources. Seniors are particularly vulnerable to extreme heat events because they are more likely to have pre-existing cardiovascular, respiratory, and renal conditions. They are at a greater risk for dehydration because of their reduced sense of thirst and higher likelihood of taking medications, such as blood pressure medication, that may cause more frequent urination and perspiration. Older adults are more physically impaired by floodwaters covering walkways and more likely to contract an infection. Older adults are also vulnerable to the health impacts of power disruption associated with many hazard events because they are more likely to have mobility disabilities and be dependent on electronic medical devices. Older adults who live alone experience heightened vulnerability.

ACS 2012-2016 estimates 143,717 senior citizens (residents age 65-plus) in San Francisco. This population is projected to increase to over 200,000 by 2030.[6] Neighborhoods with the highest proportion of seniors are Japantown, Chinatown, Western Addition, and Twin Peaks.[7] Refer to Table A-3 and Figure A-1 for more information.

[6] State of California, Department of Finance, *P-2 County Population Projections by Age, 2010-2060*. Sacramento, California, May 2019.
[7] ACS 2012-16

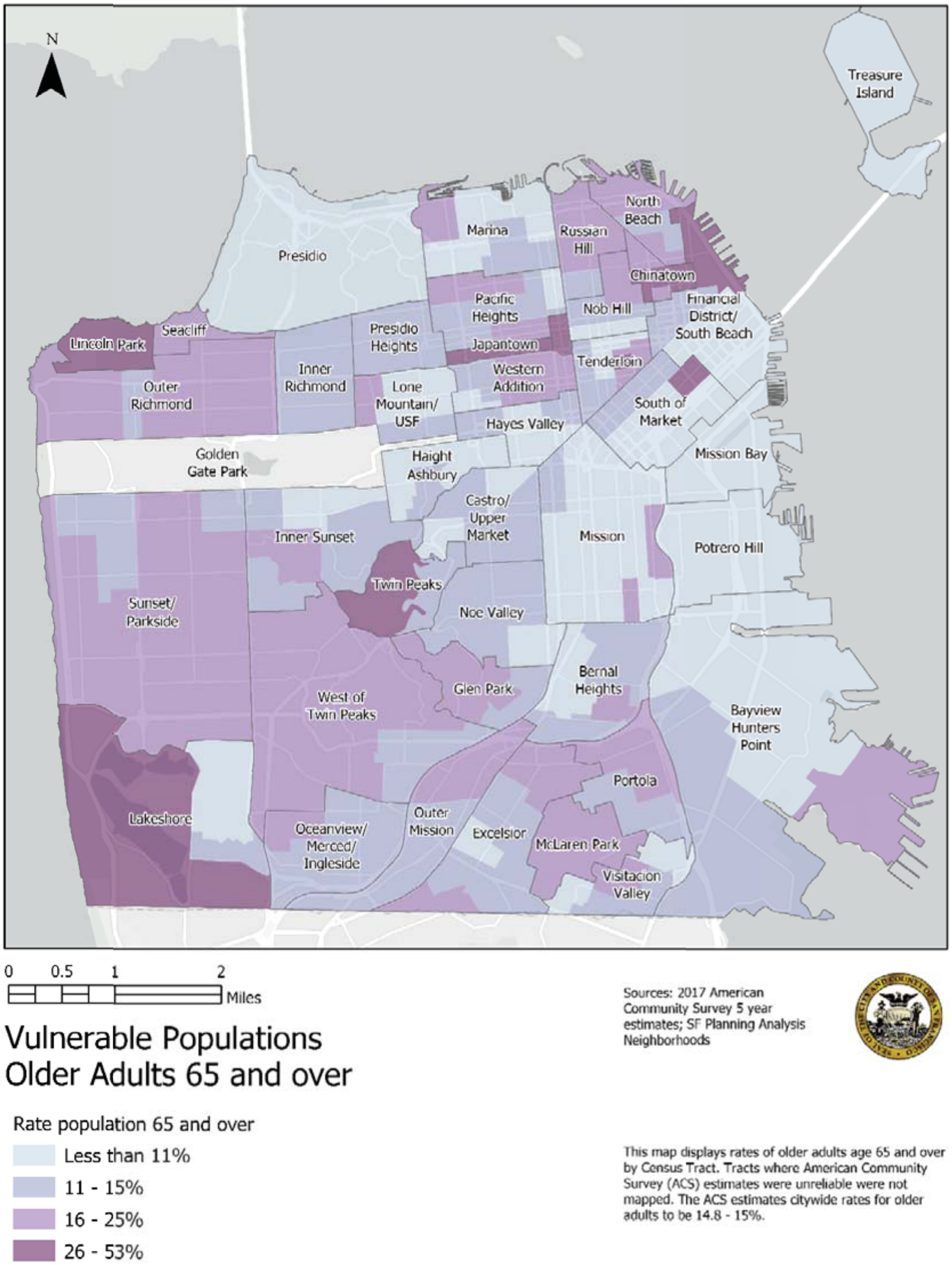
TABLE A-3: POPULATION OVER AGE 65 BY NEIGHBORHOOD, 2012-2016[8]

Neighborhood	Percent of residents age 65+	Count of residents age 65+
Bayview Hunters Point	10.8%	4,061
Bernal Heights	10.7%	2,797
Castro/Upper Market	12.2%	2,573
Chinatown	26.3%	3,897
Excelsior	14.9%	5,862
Financial District/South Beach	9.5%	1,658
Glen Park	17.1%	1,403
Golden Gate Park	*	*
Haight Ashbury	7.5%	1,354
Hayes Valley	9.7%	1,770
Inner Richmond	15.2%	3,420
Inner Sunset	13.4%	3,903
Japantown	35.6%	1,300
Lakeshore	10.5%	1,502
Lincoln Park	*	*
Lone Mountain/USF	10.8%	1,952
Marina	11.4%	2,862
McLaren Park	25.2%	*
Mission	9.5%	5,571
Mission Bay	7.9%	832
Nob Hill	15.8%	4,141
Noe Valley	12.0%	2,784
North Beach	17.4%	2,192

[8] ACS 2012-16; *Indicates unstable data

Oceanview/Merced/Ingleside	13.8%	3,865
Outer Mission	15.4%	3,738
Outer Richmond	17.9%	8,032
Pacific Heights	15.6%	3,754
Portola	16.8%	2,758
Potrero Hill	7.7%	1,060
Presidio	1.4%	54
Presidio Heights	14.0%	1,501
Russian Hill	17.4%	3,102
Seacliff	18.9%	464
South of Market	16.0%	3,068
Sunset/Parkside	17.8%	14,426
Tenderloin	15.5%	4,375
Treasure Island	1.7%	*
Twin Peaks	19.9%	1,475
Visitacion Valley	13.7%	2,543
West of Twin Peaks	19.1%	7,292
Western Addition	20.9%	4,644
San Francisco		122,441

FIGURE A-1: PERCENT POPULATION 65 AND OVER BY CENSUS TRACT



Income and Poverty

While San Francisco has a comparatively high median household income, this wealth is not evenly distributed. While median household income in San Francisco is $96,265 (+/- $1349) this number is stratified by race.[9] The median income for white households is over $116,000 a year, while the median income for Black/African American households is $30,235 a year.[9]

TABLE A-4: MEDIAN HOUSEHOLD INCOME BY RACE/ETHNICITY

Median Household Income by Race/Ethnicity	San Francisco
All Households	$96,265
White	$116,102
Black / African American	$30,235
American Indian / Alaskan Native	$52,276
Asian	$82,445
Native Hawaiian / Pacific Islander	$67,500
Some Other Race	$56,949
Two or More Races	$100,000
Hispanic / Latino (of any race)	$67,282
White alone, not Hispanic / Latino	$121,204

Poverty is correlated with numerous health outcomes including rates of infant mortality, heart disease, cancers, and mental health. During hazard events, income allows households to more quickly respond to stressors and absorb losses. Populations in poverty often experience societal marginalization and have been found less likely to evacuate during a disaster.[10]

9 American Community Survey 2017 5-Year Estimates, Table S1903. https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_5YR/S1903/0500000US06075 (Accessed 2019)
10 Fothergill, A., and L. A. Peek, 2004: Poverty and disasters in the United States: A review of recent sociological findings. Natural Hazards, 32, 89-110. doi:10.1023/B:NHAZ.0000026792.76181.d9

Neighborhoods with the lowest median income are: Chinatown, Tenderloin, Lakeshore and South of Market. Neighborhoods with the highest poverty rate include: Treasure Island, Chinatown, Tenderloin, and Lakeshore. Refer to Tables A-5 and A-6 for more information.

TABLE A-5: MEDIAN HOUSEHOLD INCOME BY NEIGHBORHOOD, 2013-2017[11]

Neighborhood	Median Income
Bayview Hunters Point	$ 57,938.60
Bernal Heights	$ 123,409.58
Castro/Upper Market	$ 138,115.49
Chinatown	$ 23,267.35
Excelsior	$ 75,069.53
Financial District/South Beach	$ 142,830.74
Glen Park	*
Golden Gate Park	$ 135,525.89
Haight Ashbury	$ 143,614.85
Hayes Valley	$ 106,916.39
Inner Richmond	$ 97,054.52
Inner Sunset	$ 117,748.71
Japantown	$ 64,031.99
Lakeshore	$ 45,932.35
Lincoln Park	*
Lone Mountain/USF	$ 110,551.34
Marina	$ 135,626.68
McLaren Park	*
Mission	$ 96,780.65

[11] ACS 2013-17; *Indicates unstable data

Mission Bay	$	143,048.73
Nob Hill	$	79,877.68
Noe Valley	$	143,085.56
North Beach	$	87,205.60
Oceanview/Merced/Ingleside	$	78,865.31
Outer Mission	$	92,552.22
Outer Richmond	$	88,715.73
Pacific Heights	$	134,496.01
Portola	$	85,434.18
Potrero Hill	$	156,694.03
Presidio	$	198,126.79
Presidio Heights	$	127,573.43
Russian Hill	$	123,481.01
Seacliff	$	166,757.91
South of Market	$	48,490.59
Sunset/Parkside	$	96,832.80
Tenderloin	$	29,003.02
Treasure Island	$	53,287.34
Twin Peaks	$	107,627.38
Visitacion Valley	$	58,807.47
West of Twin Peaks	$	142,696.76
Western Addition	$	63,526.79
San Francisco	**$**	**$96,265**

TABLE A-6: PERCENT OF HOUSEHOLDS BELOW 200% OF FPL BY NEIGHBORHOOD, 2012-2016[12]

Neighborhood	Percent of residents below 200% FPL	Count of residents below 200% FPL
Bayview Hunters Point	40.5%	15,228
Bernal Heights	22.3%	5,829
Castro/Upper Market	13.1%	2,762
Chinatown	62.8%	9,306
Excelsior	28.9%	11,369
Financial District/South Beach	19.6%	3,422
Glen Park	12.7%	1,042
Golden Gate Park	*	*
Haight Ashbury	14.6%	2,635
Hayes Valley	22.1%	4,033
Inner Richmond	24.0%	5,401
Inner Sunset	16.0%	4,660
Japantown	30.8%	1,125
Lakeshore	50.9%	7,279
Lincoln Park	*	*
Lone Mountain/USF	20.7%	3,741
Marina	9.6%	2,410
McLaren Park	*	*
Mission	34.0%	19,937
Mission Bay	19.0%	2,001
Nob Hill	28.9%	7,574
Noe Valley	10.1%	2,343

[12] ACS 2012-16; *Indicates unstable data

North Beach	32.6%	4,106
Oceanview/Merced/Ingleside	33.3%	9,326
Outer Mission	24.5%	5,947
Outer Richmond	23.6%	10,589
Pacific Heights	12.2%	2,936
Portola	26.2%	4,300
Potrero Hill	18.0%	2,478
Presidio	10.1%	387
Presidio Heights	14.6%	1,565
Russian Hill	19.9%	3,548
Seacliff	7.5%	184
South of Market	44.2%	8,477
Sunset/Parkside	19.7%	15,966
Tenderloin	58.5%	16,510
Treasure Island	67.8%	*
Twin Peaks	14.5%	1,075
Visitacion Valley	37.4%	6,943
West of Twin Peaks	12.0%	4,581
Western Addition	35.7%	7,932
San Francisco	26.0%	221,073

Race

Race is a societally imposed identity that governs the distribution of risk and opportunities in our race-conscious society.[13] In San Francisco, like across the United States, significant racial inequities exist, such as the income disparities referenced in the previous section, higher instances of adverse health conditions, limited access to the

[13] Jones, Camara Phyllis. "Invited Commentary: 'Race,' Racism, and the Practice of Epidemiology." *American Journal of Epidemiology* 154, no. 4 (August 15, 2001): 299–304. https://doi.org/10.1093/aje/154.4.299.

decision-making process, tenuous relationships with first responders, and more. These inequities point to race as a major indicator of community vulnerability. Because of historic and current impacts of structural racism that have created imbalances in political, cultural, and economic power, many minority groups lack the political access and economic resources to recover from hazard events. Many of these same groups are often concentrated in at-risk neighborhoods of the city, live in vulnerable housing stock, and have greater rates of poverty. For example, rates of preventable hospitalizations among Black/African Americans was nearly four times that of Whites.[14]

While San Francisco is a racially diverse city, many its racial groups are segregated by neighborhood. Much of San Francisco's African American population is concentrated in the Bayview Hunters Point and Western Addition neighborhoods. Chinatown, the Outer Sunset, Outer Richmond, Parkside, Crocker Amazon, and Visitacion Valley are all majority Asian. The Latino population is concentrated in the Mission District and Bernal Heights. The rest of the city is predominately white, with the highest concentrations in the Marina, Pacific Heights, Noe Valley, and the Castro/Upper Market neighborhoods. Refer to Table A-7 and Figure A-2 for more information.

TABLE A-7:
RACIAL COMPOSITION OF SAN FRANCISCO NEIGHBORHOODS, 2012-2016[15]

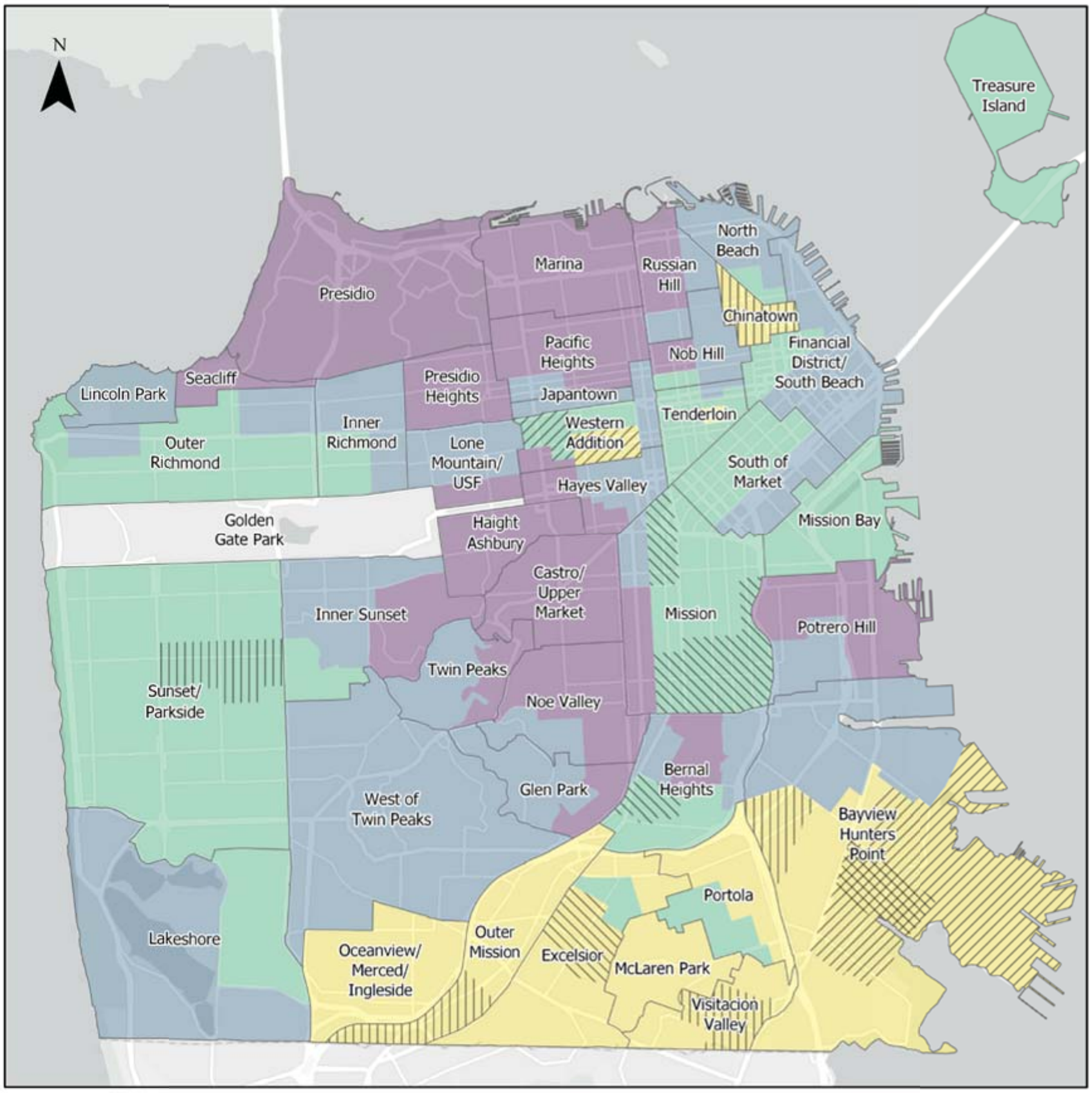
		Not Hispanic or Latina/o/x						
Neighborhood	Percent Hispanic or Latina/o/x	Percent White alone	Percent Black or African American alone	Percent American Indian and Alaska Native alone	Percent Asian alone	Percent Native Hawaiian and Other Pacific Islander alone	Percen t Some other race alone	Percent Two or more races
Bayview Hunters Point	23.2%	7.9%	26.1%	0.0%	36.6%	2.1%	0.4%	3.7%
Bernal Heights	28.7%	46.0%	4.4%	0.3%	15.9%	0.1%	0.6%	4.0%
Castro/Upper Market	7.7%	72.0%	2.4%	0.2%	12.4%	0.4%	0.2%	4.6%
Chinatown	2.6%	13.9%	0.7%	0.3%	81.4%	0.4%	0.1%	0.6%
Excelsior	32.2%	13.7%	1.9%	0.4%	49.3%	0.0%	0.5%	2.0%

[14] San Francisco Health Improvement Partnership. "San Francisco Community Health Needs Assessment 2016: Appendices." San Francisco, CA: San Francisco Department of Public Health, 2016.
[15] ACS 2013-2017

Financial District/South Beach	8.4%	47.4%	3.4%	0.2%	36.5%	0.3%	0.2%	3.7%
Glen Park	13.5%	60.1%	6.4%	0.0%	17.4%	0.0%	0.4%	2.2%
Haight Ashbury	8.0%	73.7%	3.7%	0.1%	9.7%	0.1%	0.1%	4.6%
Hayes Valley	13.1%	58.7%	8.2%	0.3%	15.4%	0.0%	0.2%	4.1%
Inner Richmond	8.0%	48.8%	2.0%	0.0%	36.0%	0.1%	0.4%	4.8%
Inner Sunset	8.6%	49.5%	2.0%	0.1%	33.5%	0.1%	1.4%	4.8%
Japantown	7.8%	51.6%	3.1%	0.0%	34.2%	1.3%	0.0%	2.0%
Lakeshore	20.9%	36.0%	7.4%	0.2%	29.2%	0.2%	1.3%	4.8%
Lincoln Park	3.3%	48.7%	15.8%	0.0%	30.6%	0.0%	0.0%	1.6%
Lone Mountain/USF	12.0%	54.1%	4.2%	0.0%	22.0%	0.3%	1.7%	5.6%
Marina	6.9%	78.2%	1.4%	0.3%	10.0%	0.0%	0.3%	3.0%
McLaren Park	18.8%	0.6%	18.8%	0.0%	43.5%	15.1%	0.0%	3.2%
Mission	37.7%	40.9%	3.0%	0.4%	13.4%	0.2%	0.8%	3.7%
Mission Bay	14.6%	35.5%	6.5%	0.0%	39.5%	0.0%	0.0%	3.8%
Nob Hill	11.1%	51.2%	3.1%	0.0%	30.7%	0.1%	0.3%	3.6%
Noe Valley	13.3%	65.7%	2.4%	0.1%	12.9%	0.2%	1.0%	4.4%
North Beach	7.9%	45.2%	1.5%	0.0%	41.4%	0.0%	0.0%	4.0%
Oceanview/ Merced/ Ingleside	13.4%	14.5%	11.7%	0.2%	55.4%	0.1%	0.6%	4.1%
Outer Mission	27.0%	13.5%	0.9%	0.2%	55.1%	0.1%	0.2%	2.9%
Outer Richmond	5.4%	40.8%	1.9%	0.0%	45.7%	0.4%	0.4%	5.4%
Pacific Heights	6.4%	67.9%	3.3%	0.0%	19.0%	0.2%	0.6%	2.6%
Portola	22.9%	14.6%	4.8%	0.1%	55.8%	0.4%	0.0%	1.5%
Potrero Hill	13.6%	55.9%	6.5%	0.2%	17.2%	0.0%	0.1%	6.4%

Presidio	9.6%	79.1%	0.3%	0.0%	5.0%	0.0%	0.0%	6.0%
Presidio Heights	5.9%	65.8%	1.9%	0.0%	19.5%	1.1%	0.7%	5.3%
Russian Hill	4.8%	64.0%	1.0%	0.0%	28.1%	0.0%	0.1%	1.9%
Seacliff	4.1%	72.2%	0.0%	0.0%	18.1%	0.0%	0.4%	5.1%
South of Market	14.3%	31.4%	9.8%	0.1%	39.4%	0.3%	0.9%	3.8%
Sunset/Parkside	6.7%	31.0%	1.0%	0.1%	56.0%	0.4%	0.3%	4.6%
Tenderloin	24.6%	32.2%	9.2%	0.4%	28.3%	0.4%	1.0%	4.0%
Treasure Island	33.8%	27.7%	17.1%	0.8%	12.2%	0.7%	0.5%	7.2%
Twin Peaks	15.1%	55.2%	5.2%	0.0%	19.7%	0.3%	0.5%	4.1%
Visitacion Valley	27.7%	5.0%	9.4%	0.1%	54.3%	1.6%	0.1%	1.8%
West of Twin Peaks	10.7%	47.8%	2.6%	0.1%	33.2%	0.2%	0.7%	4.7%
Western Addition	8.8%	40.0%	17.7%	0.3%	27.2%	0.1%	0.5%	5.5%
San Francisco	15.3%	40.8%	5.1%	0.2%	33.9%	0.3%	0.5%	3.9%

FIGURE A-2: RACE AND ETHNICITY BY CENSUS TRACT



0 0.5 1 2 Miles

Sources: 2017 American Community Survey 5 year estimates; SF Planning Analysis Neighborhoods

Vulnerable Populations
Race and Ethnicity

Rate People of Color

- Less than 40%
- 40 - 58%
- 59 - 78%
- More than 78%

- Over 66% Asian
- Over 33% Black
- Over 42% Latinx
- Neighborhood Boundary

This map displays racial and ethnic composition by Census Tract. Tracts where population and/or household estimates are less than 100 are not mapped. People of Color includes all populations who do not identify as White—not Hispanic or Latino. Rates displayed for Asian, Black, and Latinx populations represent concentrations in the 95th percentile.

Housing Quality and Living Conditions

Housing has the ability to either contribute to, or protect against the health impacts, especially during or after hazard events. Housing can reduce a residents' exposure to hazard events. For example, residents living buildings without earthquake retrofits are significantly more vulnerable to geologic events while residents living in housing that has been properly protected against in-home dampness during precipitation events are more likely to be protected against flooding and mold exposure.

Housing Quality

Housing quality refers to a building's physical ability to protect the residents from exposure. Older, poorly maintained buildings are often substandard, and not fully safe for habitation. In addition housing attributes such as ventilation, cool systems, and status can impact occupants' vulnerability to a hazard. For example:

- **Housing without air conditioning** or other cooling mechanisms may more easily overheat during extreme heat events. San Francisco has one of the lowest rates of air conditioning ownership in the United States.
- **Soft-story buildings** that have not undergone seismic retrofit are more vulnerable to severe damage during an earthquake.
- **Housing without adequate ventilation or sealing** may be vulnerable to smoke from urban conflagration due to inability to filter respiratory irritants. Similar to air conditioning prevalence in homes, San Francisco housing predominantly relies on passive cooling strategies, bringing cooler, outside air to cool down indoor temperatures. Poor air quality are more likely to occur during warmer temperature days, making it difficult to cool down indoor temperatures and maintain health air quality

Unhoused Population

Unhoused populations are among the most vulnerable San Franciscans. Without stable shelter options, this population is often more exposed to hazard events. During hazard events, this population has limited resources to evacuate, communicate, and shelter in place. This population is more likely to be impoverished, have lower educational attainment levels, and have higher rates of access and functional needs, all of which contribute to vulnerability. For example, during a heavy rainfall event in December of 2014, San Francisco's homeless population experienced a significant spike in Shigella cases. Heavy precipitation likely worsened poor sanitary conditions and increased crowding, contributing to shigellosis transmission among homeless persons.

In 2017, there were an estimated 4,353 unsheltered homeless residents in San Francisco.[16] This population is has remained relatively stable since 2013, growing by only 38 individuals. Unsheltered homeless are concentrated in Supervisorial District Six (SOMA, Rincon Hill, Civic Center) and Ten (Potrero Hill, Bayview Hunters Point, Visitacion Valley). Refer to Table A-8 for more information.

TABLE A-8: UNSHELTERED HOMELESS COUNT IN SAN FRANCISCO, 2013-2017[17]

District	Neighborhood	Unsheltered Homeless Count	
		2013	**2017**
One	Richmond, Laurel Heights	321	57
Two	Marina, Presidio, Cow Hollow, Pacific Heights	24	53
Three	North Beach, Chinatown, Russian Hill, Nob Hill, Downtown	363	293
Four	Outer Sunset, Parkside	136	31
Five	Western Addition, Haight-Ashbury, Cole Valley	284	143
Six	SOMA, Rincon Hill, Civic Center	1,364	1,723
Seven	Merced, Inner Sunset, Forest Hill, Lakeside	19	74
Eight	Castro, Noe Valley, Dolores Heights, Diamond Heights, Duboce Triangle	163	236
Nine	Mission, Bernal Heights	247	281
Ten	Potrero Hill, Bayview Hunters Point, Visitacion Valley	1,278	1,101
Eleven	Excelsior, Mission Terrace, Ingleside, Ocean View, Merced Heights	40	48
	Scattered sites/confidential locations	76	313
	Citywide total	**4,315**	**4,353**

16 Local Homeless Coordinating Board, "Homeless point-in-time count and survey", January 2017
17 Local Homeless Coordinating Board, "Homeless point-in-time count and survey", January 2017

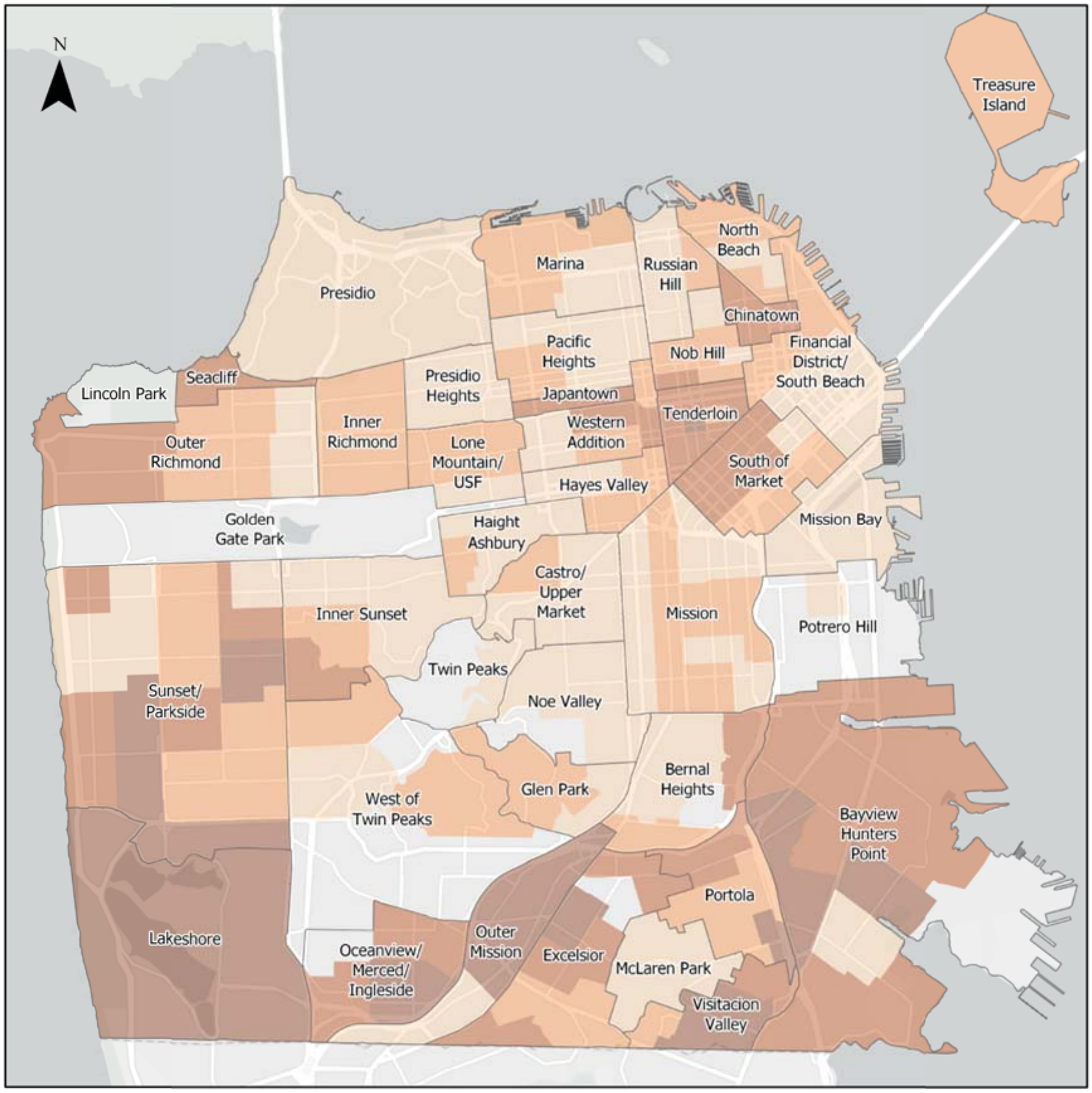
Housing Affordability

Housing affordability is a driver of vulnerability. When housing costs are high, households are less likely to afford necessary expenses such as food, heating, transportation, child care, and healthcare. According to the San Francisco Planning Department's 2018 Housing Needs and Trends Report, San Francisco is "in the midst of a housing affordability crisis unprecedented in [San Francisco's] history".[18]. A household that spends over 30 percent of their pretax income on housing costs is considered burdened while a household that spends over 50 percent of their pretax income on housing costs is considered severely burdened. San Francisco rental prices increased by 22 percent between 2000 and 2012. By 2015, nearly 10 percent of all San Francisco rental households were burdened while about 30 percent of all households between 80-120 percent of area median income were rent burdened. Research demonstrates that low-income households that can afford their housing are able to spend nearly five times as much on healthcare and a third more on food than those severely burdened with housing costs[19].

[18] San Francisco Planning Department, "San Francisco Housing Needs and Trends Report", July 2018

[19] Pew Research "American Families Face a Growing Rent Burden", April 2018. Retrieved from: www.pewtrusts.org/en/research-and-analysis/reports/2018/04/american-families-face-a-growing-rent-burden

FIGURE A-3: SEVERELY RENT BURDENED HOUSEHOLDS RATE BY CENSUS TRACT



0 0.5 1 2 Miles

Vulnerable Populations
Severely Rent Burdened Households

Rate households spending 50% or more on rent

- Less than 16%
- 16 - 23%
- 24 - 35%
- Greater than 35%

Sources: 2017 American Community Survey 5 year estimates; SF Planning Analysis Neighborhoods

This map displays rates of severely housing cost burdened renter occupied households by Census Tract. Severe housing cost burden occurs when housing costs (in this map, gross rent) comprise 50% or more of household income. Tracts where American Community Survey (ACS) estimates were unreliable were not mapped. The ACS estimates rates of severe rent burden to be around 20% citywide.

Community Characteristics and Social Cohesion

A person's ability to prepare for or recover from disaster events is significantly influenced by their relationships with their neighbors, their community and community services, and their government and government services. A community with strong informal networks can work collectively to make sure residents quickly respond to hazard events, access emergency services, and have the resources to recover. The number and strength of community members' formal and informal social networks is often referred to as community and social cohesion. During a "social autopsy" of a 1995 Chicago Heatwave, researchers hypothesized that differences in mortality rates between neighborhoods were correlated with social isolation of senior citizens, access to government services, and neighborhood-level poverty.[20]

A neighborhood with easy access to community services is one that is either walkable or with adequate transportation access, especially to hospitals, health care centers, healthy food, and pharmacies. Social cohesion can enable individuals during a hazard event to draw on preexisting support networks for financial, information, and emotional assistance. When residents of a community are connected to each other through civic and voluntary associations, mobilizing in an emergency happens faster. Research has shown the communities with a higher density of civic organization predating a disaster are better prepared and quicker to recover.

Social Isolation

Social isolation is the experience of diminished social connectedness and typically refers to objective physical separation from other people. It is indicated by situational factors, like a small social network, living alone, infrequent social interaction, and lack of participation in social activities and groups. Social isolation can impact health and quality of life, ability to access adequate support for themselves, and the quality of the environment and community in which they live. Isolation can be a function of poverty that limits access to information technologies. It can be a function of limited literacy and/or linguistic isolation. It may be a function of disability, chronic or mental health conditions. Whatever the cause, when a hazard strikes, social isolation can increase vulnerability. During heat waves for example, one of the most vulnerable populations are elderly, especially those that live by themselves. In the 2003 Paris heat wave, 92% of all hospitalized lived alone. These individuals are less likely to trust their neighbors and have less social ties, resulting in not having someone check-in on them to make sure they're ok, increasing their risk during the event.

[20] . Klinenberg E. "Denaturalizing disaster: A social autopsy of the 1995 Chicago heat wave". Theory and Society. 1999;28:239-95.

Linguistic Isolation

Understand the linguistic environment within a community is essential for hazard planning. Households with limited English proficiency often face barriers to accessing community social services such as appropriate health care. Providing hazard warning and evacuation notices in multiple languages and accessible formats is imperative in ensuring these households are well informed during a hazard event.

Twenty-one percent of San Francisco residents age five and older speak a language other than English at home and speak English less than very well. [21] Geographically, this most common in Chinatown, where 68 percent of the population does not speak English very well. Other neighborhoods with a high percentage of people who speak a language other than English at home and speak English less than very well include Visitacion Valley, Excelsior, Portola, the Outer Mission, and Oceanview/ Merced/Ingleside. However, it is important to note that linguistic isolation data may undercount this population as some undocumented residents and communities that may be less likely to engage with government census agencies. Residents in the undocumented community may be less likely to trust law enforcement which would impact outreach and engagement before, during, and after hazard events.

TABLE A-9: PERCENT OF POPULATION 5 YEARS AND OVER WITH LIMITED ENGLISH PROFICIENCY BY NEIGHBORHOOD, 2013-2017[22]

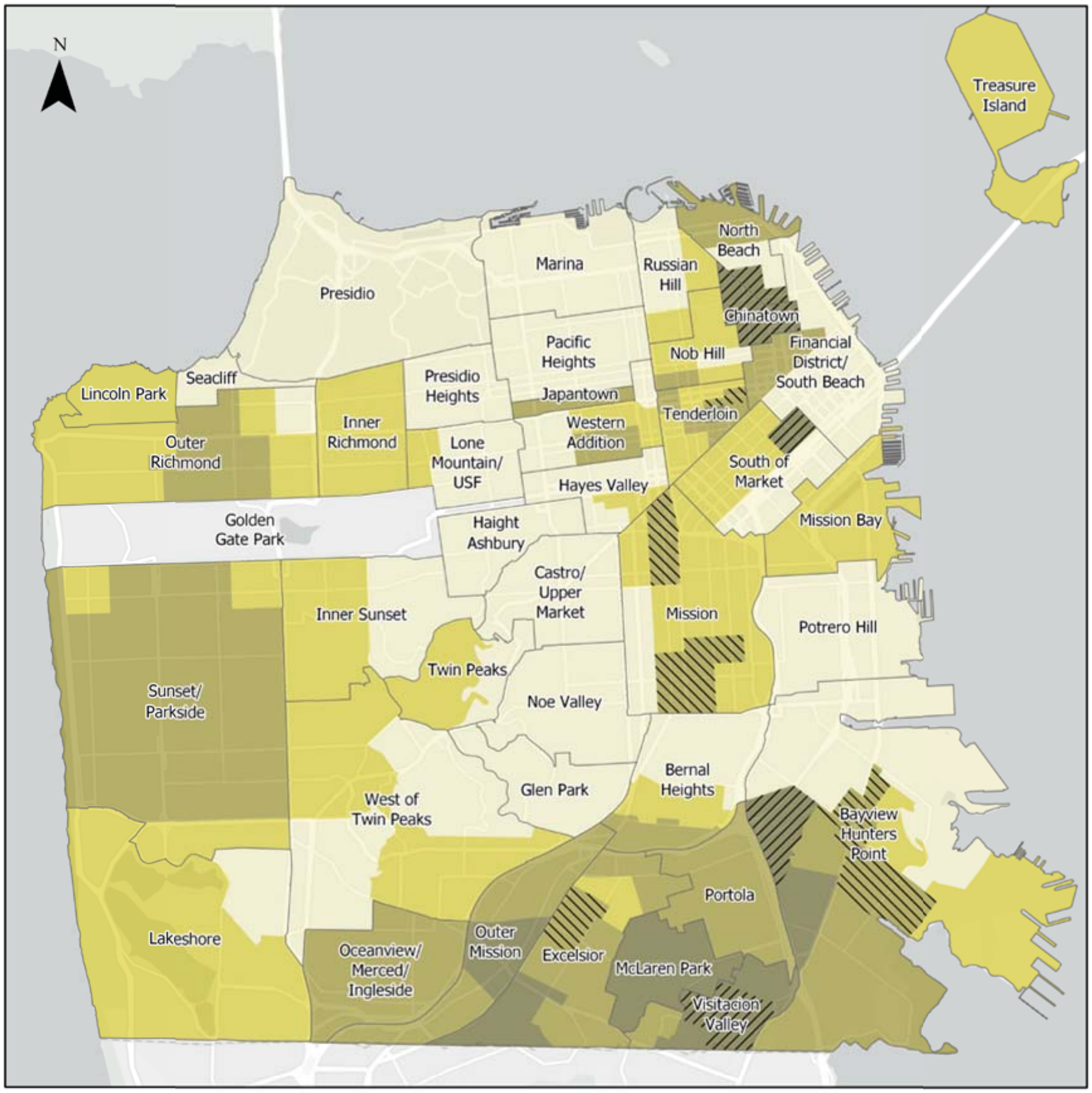
Neighborhood	Percent of residents with Limited English Proficiency	Count of residents with Limited English Proficiency
Bayview Hunters Point	31%	11,110
Bernal Heights	15%	3,612
Castro/Upper Market	3%	584
Chinatown	68%	9,495
Excelsior	38%	14,761
Financial District/South Beach	11%	1,955
Glen Park	6%	481
Golden Gate Park	*	*
Haight Ashbury	3%	470

[21] ACS 2013-2017
[22] ACS 2013-17; *Indicates unstable data

Hayes Valley	8%	1,363
Inner Richmond	18%	3,882
Inner Sunset	12%	3,382
Japantown	29%	1,058
Lakeshore	6%	481
Lincoln Park	*	*
Lone Mountain/USF	9%	1,655
Marina	5%	1,133
McLaren Park	*	*
Mission	20%	10,941
Mission Bay	18%	1,980
Nob Hill	17%	4,368
Noe Valley	5%	1,047
North Beach	26%	3,017
Oceanview/Merced/Ingleside	35%	9,541
Outer Mission	36%	8,427
Outer Richmond	22%	9,658
Pacific Heights	5%	1,160
Portola	34%	5,449
Potrero Hill	6%	802
Presidio	3%	128
Presidio Heights	6%	567
Russian Hill	14%	2,499
Seacliff	8%	179
South of Market	25%	4,833
Sunset/Parkside	27%	21,685

Tenderloin	29%	8,242
Treasure Island	19%	578
Twin Peaks	11%	794
Visitacion Valley	43%	7,747
West of Twin Peaks	12%	4,571
Western Addition	18%	3,945
San Francisco	**21%**	**170,041**

FIGURE A-4: LIMITED ENGLISH PROFICIENCY RATE BY CENSUS TRACT



0 0.5 1 2 Miles

Vulnerable Populations Limited English Proficiency

Rate populations 5 years and over who speak English less than "very well"

- Less than 12%
- 12 - 24%
- 25 - 40%
- Greater than 40%
- Over 31% Chinese-speaking
- Over 17% Spanish-speaking

Sources: 2017 American Community Survey 5 year estimates; SF Planning Analysis Neighborhoods

This map displays rates of populations 5 years and over who speak English less than "very well," referred to as Limited English Proficiency (LEP), by Census Tract. Tracts where American Community Survey (ACS) estimates were unreliable were not mapped. Rates displayed for Chinese- and Spanish-speaking LEP populations represent concentrations in the 95th percentile. The ACS estimates LEP rates to be between 20.3 - 20.9% citywide.

Evictions

Higher levels of housing unaffordability correspond with increasing levels of displacement (i.e. landlords increase evictions to try to free up their property for sale or secure new tenants who can pay higher rents), resulting in neighborhood turnover. This turnover impacts resiliency by weakening informal social networks as households that are displaced often experience loss of social relationships within a community. Additionally, as the cost of good quality housing rises relative to income, specific conditions that contribute to poor health are magnified. Conditions such as overcrowding, substandard construction and maintenance, the concentration of low-income households in neighborhoods, and homelessness are impacted. In 2017, the eviction rate per 1,000 rent controlled housing units was 8.3. Neighborhoods with the highest eviction rate were Mission Bay, Outer Mission, and Bayview Hunter Point.

TABLE A-10: EVICTION RATE (PER 1,000 RENT CONTROLLED HOUSING UNITS) BY NEIGHBORHOOD, 2017[23]

Neighborhood	Evictions rate (per 1000 Rent Controlled Housing Units)
San Francisco	8.3
Bayview Hunters Point	19.9
Bernal Heights	15
Castro/Upper Market	7.6
Chinatown	4
Excelsior	17.4
Financial District/South Beach	1.5
Glen Park	8.6
Golden Gate Park	0
Haight Ashbury	6.5
Hayes Valley	6
Inner Richmond	9.1
Inner Sunset	6.4

[23] SFRB, 2017

Japantown	1.3
Lakeshore	24
Lincoln Park	0
Lone Mountain/USF	6.7
Marina	4.3
McLaren Park	0
Mission	9
Mission Bay	29.9
Nob Hill	4.1
Noe Valley	8.3
North Beach	6.3
Oceanview/Merced/Ingleside	17.3
Outer Mission	27.2
Outer Richmond	8.7
Pacific Heights	3.9
Portola	17.1
Potrero Hill	6.6
Presidio	0
Presidio Heights	9.6
Russian Hill	8.2
Seacliff	0
South of Market	13.8
Sunset/Parkside	12.3
Tenderloin	4.6
Treasure Island	2.1
Twin Peaks	5.1

Visitacion Valley	13.2
West of Twin Peaks	12
Western Addition	3.8

Pre-Existing Health Conditions

Populations with pre-existing health conditions are particularly vulnerable to hazard events. Pre-existing health conditions may impact a person's ability to access emergency response services. Hazard events may exacerbate certain pre-existing health conditions, or make pre-existing health conditions more difficult to manage. For example, extreme heat events exacerbate cardiovascular illness as temperature forces the heart to pump faster and harder in order to regulate body temperature.[24] Similarly, people with asthma may be particularly impacted by air quality impacts.

Disability and Functional Limitations

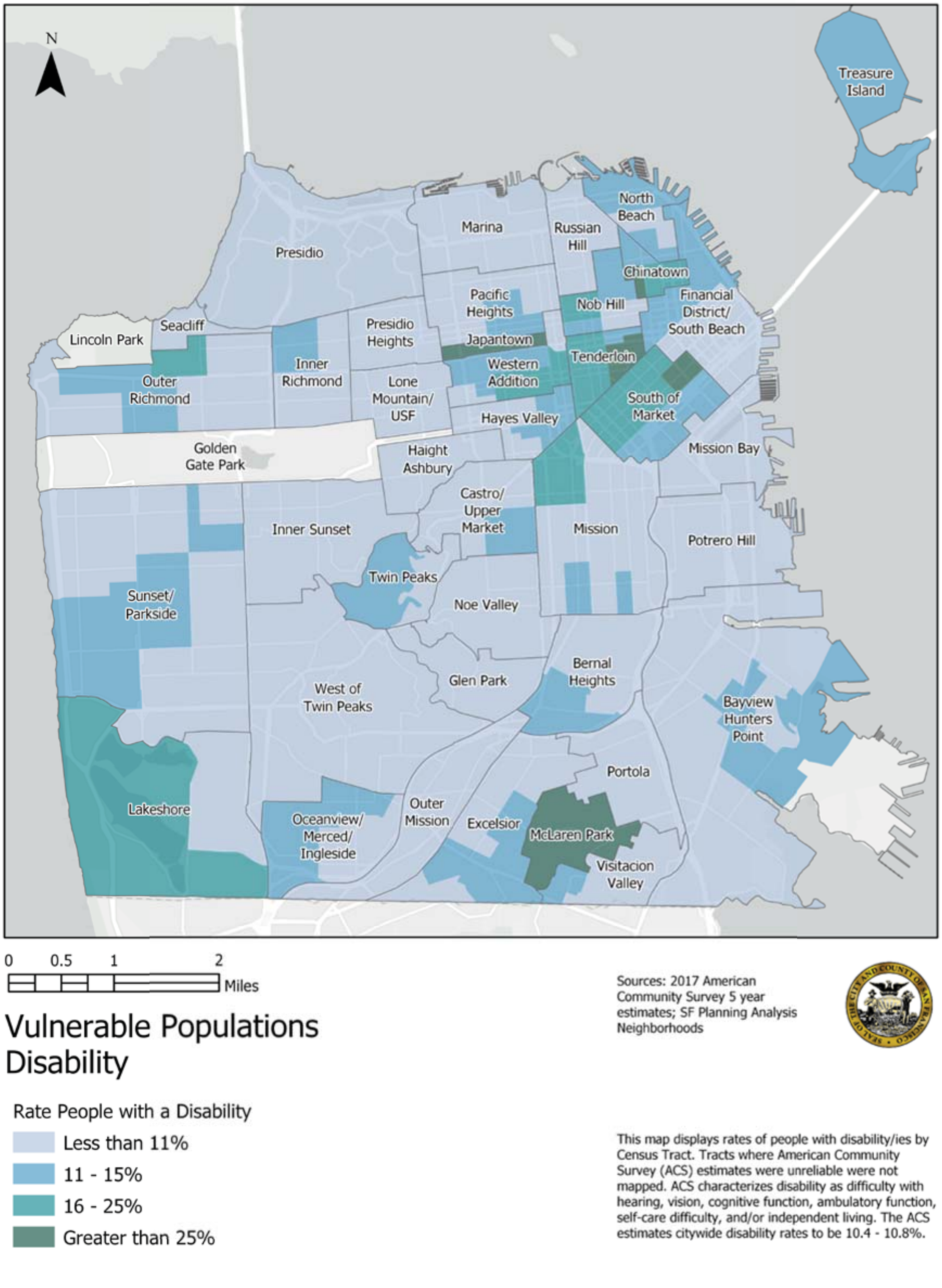
Hazard events such as fires, floods and earthquakes present a real challenge to individual with disabilities. Accommodations and assistance are needed for safe evacuations, including specialized transportation and shelter space. The needs of people with disabilities are often not adequately addressed in disaster relief and recovery plans, if they are addressed at all,[25] and people with disabilities often experience "invisibility" to decision-makers.[26] Communication materials and methods often do not adequately accommodate those with impaired cognitive function, hearing, or vision.[27] The U.S. Census defines six major categories of disabilities:

- **Hearing difficulty** deaf or having serious difficulty hearing
- **Vision difficulty** blind or having serious difficulty seeing, even when wearing glasses
- **Cognitive difficulty** Because of a physical, mental, or emotional problem, having difficulty remembering, concentrating, or making decisions
- **Ambulatory difficulty** Having serious difficulty walking or climbing stairs
- **Self-care difficulty** Having difficulty bathing or dressing
- **Independent living difficulty** Because of a physical, mental, or emotional problem, having difficulty doing errands alone such as visiting a doctor's office or shopping

[24] Skerrett, Patrick J. "Heat is hard on the heart; simple precautions can ease the strain" Harvard Health Blog, 22 July 2011, www.health.harvard.edu/blog/heat-is-hard-on-the-heart-simple-precautions-can-ease-the-strain-201107223180
[25] World Institute on Disability, 2016. *Climate Change and Disability: Existing Resources*
[26] Wolbring, G., and V. Leopatra, 2012: Climate change, water, sanitation and energy insecurity: Invisibility of people with disabilities. *Canadian Journal of Disability Studies*, **1**, 66-90. doi:10.15353/cjds.v1i3.58
[27] Nick, G. A., and others, 2009: Emergency preparedness for vulnerable populations: People with special health-care needs. *Public Health Reports*, **124**, 338-343. PMID: 19320378

Estimates produced by the American Community Survey often undercount disability. According to California Health Interview Survey, an estimated 27 percent of San Francisco adult residents over age 18 self-reported having a disability due to a physical, mental, or emotional condition in 2014.

FIGURE A-5: DISABILITY RATE BY CENSUS TRACT



Importance of Intersectional and Upstream Frameworks

The socioeconomic and demographic, housing quality and living conditions, community characteristics, and pre-existing health factors described throughout this section often co-occur, and cumulatively and interactively work to determine individual and community level vulnerability to hazard events. For example, not only do residents living in poverty have fewer resources to deploy in response to an event, but they are more likely to also have pre-existing health conditions that could make them more susceptible to injury during the event.

The intersectional nature of vulnerability creates deep and seemingly intractable inequities within and across communities. To understand, intervene in, and improve population inequities and vulnerability to hazard events requires more than just a selective list of "vulnerability factors". Even data is not sufficient to comprehensively represent a community. The causes of these factors, and their distribution, should be placed within a framework that identifies their economic and political determinants. Without addressing these structural factors, mitigation, prevention, and recovery activities will be unable to address the root causes on vulnerability, allowing for their continuation and reproduction.

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Critical Response Facilities

Introduction to Asset Class

Critical response facilities are facilities that provide life safety and property and environmental protection services essential to a community during and after an incident such as an emergency or a disaster. For purposes of the Hazard and Climate Resilience Plan (HCRP), critical response facilities include:

- 11 San Francisco Police Department (SFPD) facilities in San Francisco: 10 District Stations (including the Police Headquarters at the new Public Safety Building) and the Regional Training Facility (the Academy).
- 50 San Francisco Fire Department (SFFD) facilities inside the city, including Fire Department Headquarters, and the Division of Training.
- The San Francisco Emergency Operations Center (EOC) and 9-1-1 Dispatch Center[28]; and
- 17 Primary Department Operations Centers (DOCs)[29]
- For facilities at the San Francisco International Airport, please see the Airport profile.

SFPD District Stations are locations where police personnel prepare for their shifts; manage investigations; securely store evidence; maintain weapons, ammunition, and other department resources; and temporarily house suspects. The stations also provide parking and maintenance for vehicle fleets. Police Headquarters houses department leaders who oversee the day-to-day operations of SFPD, and also serves as the home of the Police DOC, Special Operations, and the Forensic, Fiscal, Planning, and Crime Information Services Divisions. The Academy provides training to prepare recruit officers to perform the duties of a peace officer in our community, and also provides training to members of the public.

SFFD stations serve as homes for firefighters and paramedics while they are on duty, and thus include living, sleeping, and eating areas. Fire stations also store apparatus such as fire engines, fire trucks, ambulances, and related vehicles; personal protective equipment; fire hoses; and other specialized equipment and supplies. The headquarters building houses department leaders who oversee the day-to-day operations of the SFFD, and also serves as the location for the Fire DOC, the Bureau of Fire Prevention,

[28] And 1 alternative EOC, included in exposure analysis
[29] And 17 alternative DOCs, included in exposure analysis. 1 DOC and 1 ALTDOC not included in exposure assessment.

and Pump Station 1. The Division of Training (DOT) develops and provides fire suppression and emergency medical service instruction to all members of the Department. DOT is also home to the Neighborhood Emergency Response Team (NERT) Office and is a training site for NERT volunteers and members of the SFFD Fire Reserves.

The San Francisco EOC is a multi-agency coordination center that is used during incidents to coordinate response and initial recovery efforts above the field level. Common functions of the EOC include information gathering, analysis, and dissemination; incident priority determination; critical resource acquisition and allocation; policy making; and coordination with local, regional, state, and federal officials. DOCs are operated by city departments during incidents to manage their field response and recovery activities and resources, and to maintain continuity of operations for their departments. DOCs are also responsible for sharing information with the EOC regarding the status of their operations and resources. The 9-1-1 Dispatch Center is co-located with the EOC and acts as the communications hub for emergency services in San Francisco. Dispatchers answer calls from the public for emergency assistance and dispatch Police, Fire, and ambulance services to the scene of crimes, fires, accidents, and other types of incidents.

With the exception of Police and Fire facilities at the Airport, which is located in San Mateo County, critical response facilities are positioned throughout the City and County of San Francisco (CCSF). The facilities are owned by CCSF and are managed by their respective departments.

Issue Statement

Critical response facilities provide life safety and property and environmental protection during and after a hazard event. A number of police and fire stations are located in hazard areas with fire stations facing greater potential exposure to coastal flooding as sea level rises. Though the EOC, Police DOC, and several additional DOCs are located in seismically-advanced or retrofitted buildings, a number of DOCs are located in facilities that have not been recently retrofitted. Information on building type, build date, condition, retrofitting, air cooling, filtering, sensitive below grade components, back-up measures for utility outages, access to food and water, fuel for generators for all facilities is not easily accessible.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In Table A-11, on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data originates from datasets maintained by SF Department of Emergency Management (2018).

TABLE A-11: EXPOSURE

Hazard	Police Assets 11 Total		Firefighting Assets 50 Total		EOC/DOC Assets 34 Total	
	#	%	#	%	#	%
Geologic						
San Andreas 7.8 - Violent	2	18%	12	24%	2	6%
San Andreas 7.8 - Very Strong	9	82%	38	76%	32	94%
Hayward 7.0 - Very Strong	0	0%	6	12%	4	12%
Hayward 7.0 - Strong	8	73%	34	68%	30	88%
Liquefaction Zone	3	27%	13	26%	18	53%
Flooding						
100-Year Coastal Flood Zone	0	0%	1	2%	0	0%
100-year storm + 24 inches SLR	1	11%	7	14%	1	3%
100-year storm + 66 inches SLR	1	11%	11	22%	3	8%
100-year stormwater flood	1	11%	4	8%	3	8%
Wildfire						
High	0	0%	0	0%	0	0%
Moderate	1	11%	0	0%	0	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

Exposure Summary

Geologic: All of San Francisco would be exposed to violent or very violent shaking in a 7.9 earthquake on the San Andreas Fault, Including all critical response facilities. 38 firefighting assets and 36 EOC/DOC assets would be exposed to very strong shaking in a 7.0 Hayward fault event. Half of EOC/DOC assets are exposed to liquefaction hazard zones.

Flood: Few police facilities are exposed to flooding. However, the Public Safety Building that features the Police Headquarters, the Southern District Station, and Fire Station #4 may be exposed to coastal flooding during a 100-year storm with 24 inches of sea level rise. Compared to police, more fire facilities may be exposed to flooding. With 24 inches of sea level rise, 11 firefighting facilities may be exposed to flooding.

Fire: The only critical response facility exposed to moderate wildfire hazard is the Police Academy Building.

FIGURE A-6: CRITICAL RESPONSE AND LIQUEFACTION HAZARD

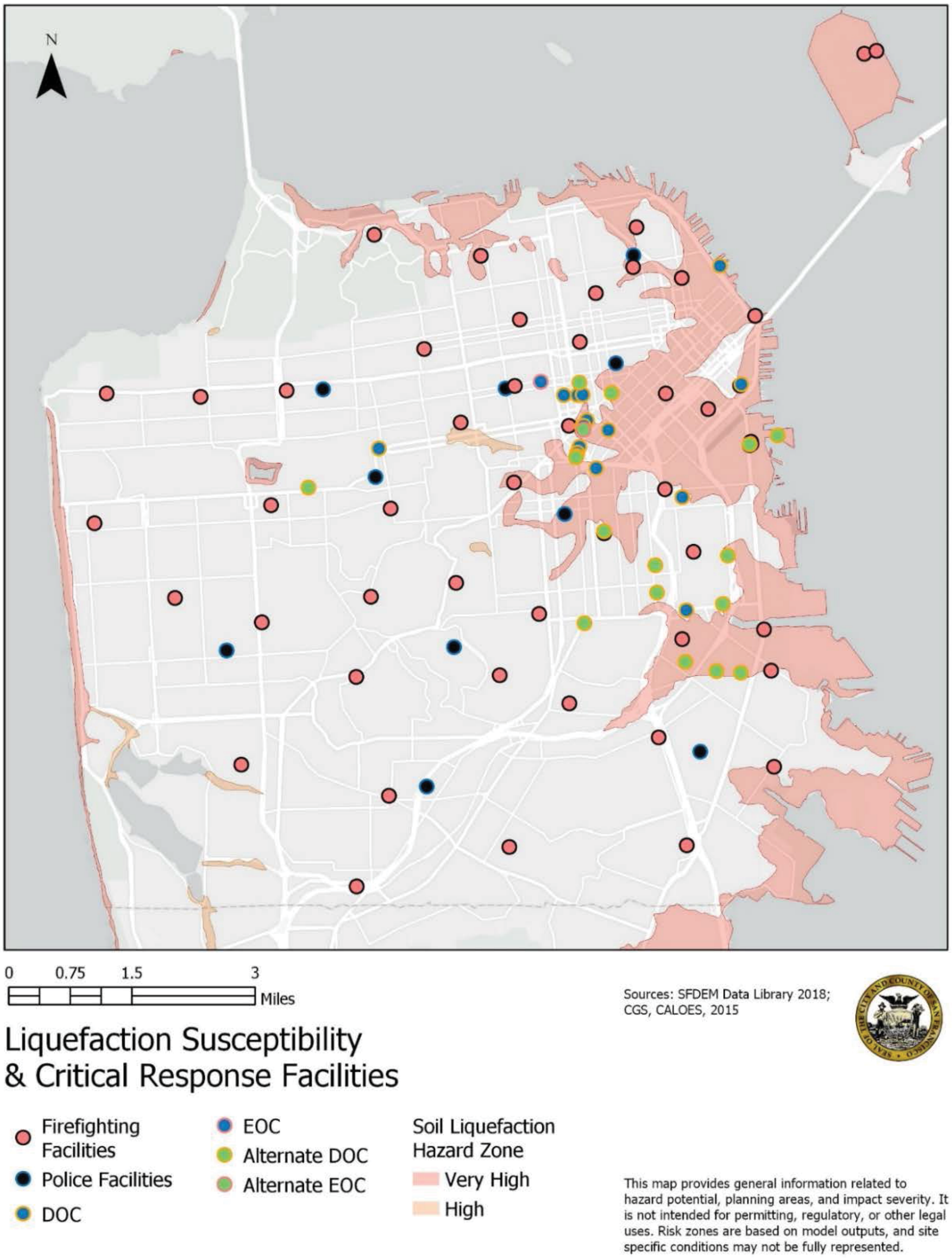
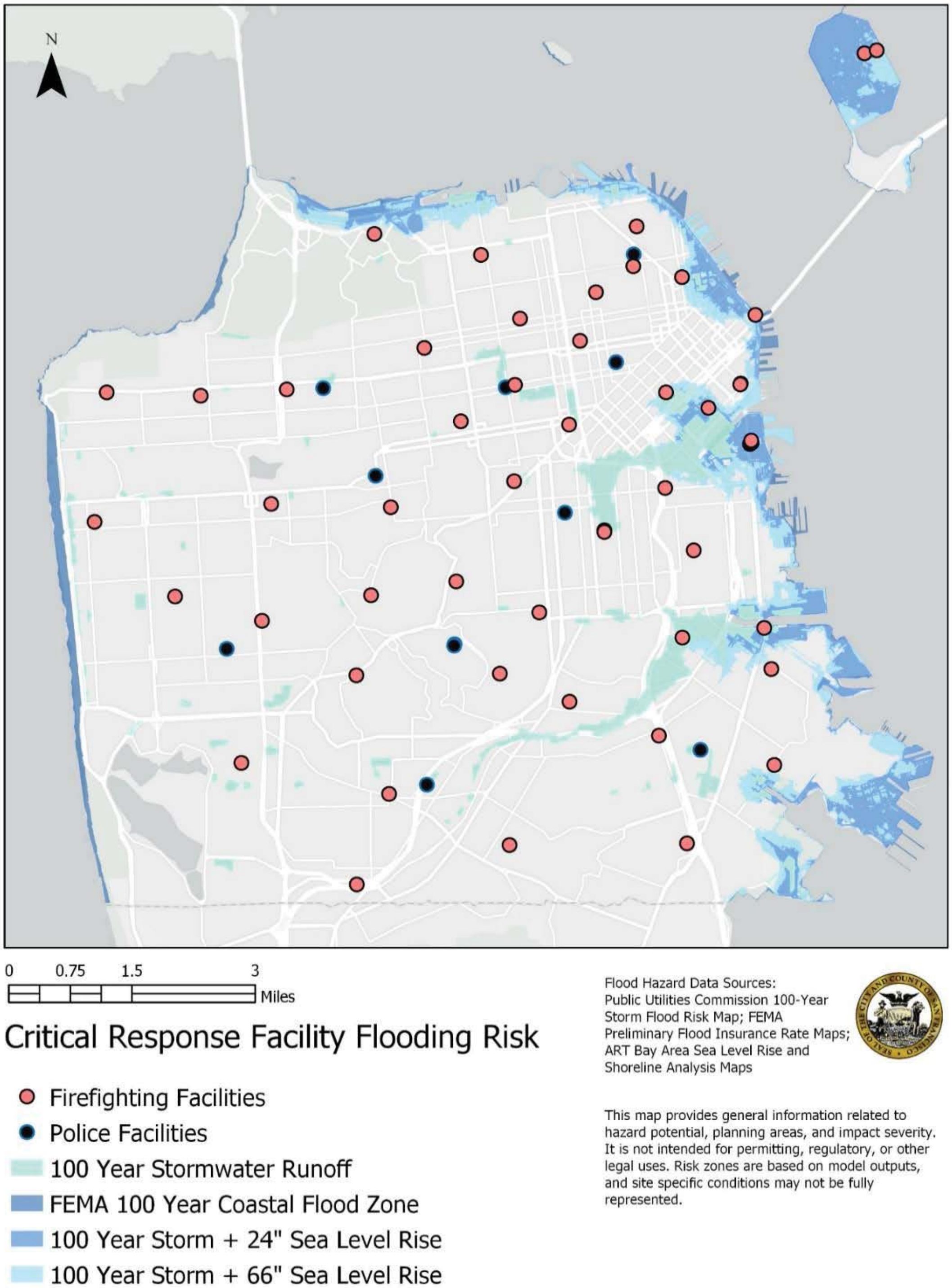


FIGURE A-7: CRITICAL RESPONSE AND FLOOD HAZARDS



VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Most of the facilities in this asset class were built or have been retrofitted to withstand strong earthquake shaking. Additional seismic improvements are prioritized based on HAZUS and Seismic Hazard Ratings, described in greater detail in the informational section below. The current ambulance deployment facility is a tilt-up construction warehouse that is vulnerable to seismic damage, but a new facility is currently under construction. The bureau of equipment is another important facility housing the fire departments complete inventory of rescue tools and other important equipment. The building was built in 1907 with a brick foundation and is vulnerable to seismic damage. **Flood:** Several facilities in this class may be vulnerable to coastal flooding due to their location. These include Fire Station 35 on the Embarcadero in South Beach, Fire Station 48 and SFFD Training Center on Treasure Island, and the Police Headquarters/ Southern District Police Station in Mission Rock. The Southern District Police Station has sensitive equipment in the basement and first floor **Extreme Heat:** Though some of the newer facilities in this class have air conditioning, such as the EOC, most do not. **Fire:** Though some of the newer facilities in this class, such as the EOC, have air filtering, most do not.
Functional	**Networks:** Fire and police stations are “networked” in the sense of each station having distinct assignments and areas of responsibilities that combine to provide protection to the city as a whole. Thus, damage to one or more of these facilities will impact non-damaged facilities as they may need to assume responsibility for areas or assignments that would otherwise have been covered by damaged stations. If the EOC is damaged, citywide coordination of information and resources may suffer in a disaster. If a DOC is damaged, management of a department's continuity and field personnel may be adversely affected. The EOC and DOCs have alternate facilities that may be used if the primary facility is damaged. **External Services:**

	The facilities in this asset class rely on power, water, the 800 MHz public safety radio system, and internet services. The facilities also rely on outside fuel needs to power vehicles and generators. In addition, the departments with responsibility for these assets rely on the transportation network, including public transit, to bring personnel to their respective facilities. These facilities have the ability to run on generator power if needed, and most have short-term back-up water and food supplies (3 days to one week). The EOC, DOCs, and police and fire facilities have access to the Mayor's Emergency Telephone System, a hard-wired phone system that is expected to work when other phones do not. The EOC also has access to satellite phones and to amateur radio operators who can provide communication as needed. **Populations Served:** Police and Fire Stations provide assistance to anyone in their area of responsibility in need of life safety, incident stabilization, or property protection services. This includes services to people with disabilities or access and functional needs, including providing medical attention, search and rescue, and other protective care. The EOC and DOCs provide indirect services to all CCSF residents, day workers, and visitors by supporting field personnel with information and needed resources. **Unique or Critical Function:** Fire stations house personnel and apparatus used to provide fire suppression, emergency medical services to the community that are essential every day, and especially in a disaster. Police stations house personnel and resources to provide community safety and other protective services that are essential every day, and especially in a disaster. The EOC provides critical information, communications, and resource coordination services in support of first responders and other field personnel. DOCs provide support to field personnel and maintain their department's continuity of operations that are critical to maintain in a disaster.
Informational	**All-Hazard:** Francisco uses the HAZUS methodology at the individual building level, run first in 2013 and updated in 2017, to understand potential damage and losses in an earthquake. Seismic Hazard Ratings are used to assess risk and prioritize seismic-strengthening improvements for over 200 public buildings. Data on building type, build date, condition, retrofitting, air cooling, filtering, sensitive below grade components, back-up measures for

	utility outages, access to food and water, fuel for generators for all facilities is not easily accessible.
Governance	**Geologic:** The Earthquake Safety and Emergency Response (ESER) bond program continues to make improvements to firehouses and police district stations, including seismic improvements.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Significant emergencies or disasters may result in the loss of facilities in this asset class as well as human casualties from building damage. This, in turn, would result in reduced ability to provide life safety, incident stabilization, and protection of property and the environment, which will prolong response and recovery times, leading to increased damage, casualties, and economic hardship. **Geologic:** Significant ground shaking and liquefaction may result in failure of facilities in this asset class as well as human casualties from building damage. This is turn would result in reduced ability to provide life safety, incident stabilization, and protection of property and the environment. **Flood:** Significant coastal or storm water flooding may result in building damage for facilities in this asset class as well as human casualties. This is turn would result in reduced ability to provide life safety, incident stabilization, and protection of property and the environment. **Extreme Heat:** Extreme heat may result in the need to close and relocate DOC facilities without air conditioning. This is turn may result in delayed or reduced ability to provide life safety, incident stabilization, and protection of property and the environment. **Fire:** Fire may cause damage or destruction of facilities in this asset class. Poor air quality from fires in CCSF or in the Bay Area may result in the need to close DOCs and other facilities in this asset class that do not have air filtering capability. This is turn would result in reduced

	ability to provide life safety, incident stabilization, and protection of property and the environment.
Economy	**All-hazards:** Without the life safety and protective services provided by Fire and Police in CCSF, one can assume the impacts to CCSF in terms of lost lives, infrastructure damage, loss or revenue, and interruption of economic activity would be substantial if not catastrophic. Losing the EOC and DOCs would also have substantial impacts, as these facilities provide incident coordination and management services, respectively. The loss of any of these facilities would result in longer response and recovery times, which in turn will negatively impact the city's economy. Cost to repair these facilities could be in the millions. Cost to replace would be in the billions. **Fire:** Without fire suppression abilities, fire could destroy large parts of the city (direct fire) or could cripple city functions (severe smoke impacts).
Environment	**All-hazards:** Police and Fire personnel may be among the first to learn of environmental impacts during an incident. Fire is the lead department with regard to land-based hazardous materials incidents in CCSF. Police take the lead in providing evacuation and protective services needed in an incident that impacts the environment. DOCs and EOC provide support to the field personnel in terms of information and resources needed to combat environmental impacts. The loss of this asset class would make containment and removal far harder, resulting in longer response and recovery times. **Geologic:** Earthquakes may result in hazardous debris and hazardous material spills. Loss of this asset class would make containment and removal of such hazardous materials far harder, resulting in longer response and recovery times. **Flood:** Floods may result in hazardous debris and hazardous material spills. Loss of this asset class would make containment and removal of such hazardous materials far harder, resulting in longer response and recovery times. **Extreme Heat:** Extreme heat events may result in heightened numbers of people seeking medical assistance and to infrastructure damage leading to power grid, traffic, and other types of disruptions. Fire is the lead

	provider of emergency medical assistance in CCSF. Police play an important role in resolving power, traffic, and other technological disruptions. DOCs and EOC provide support to the field personnel in terms of information and resources needed to address heat impacts. The loss of this asset class would result in longer response and recovery times. **Fire:** Fires result in toxic ash and other dangerous debris. Smoke events may result in heightened numbers of people seeking medical assistance. Fire is the lead provider of emergency medical assistance in CCSF. Police play an important role in limiting access to burn areas until toxic debris can be contained and removed. DOCs and EOC provide support to the field personnel in terms of information and resources needed to address fire impacts. The loss of this asset class would result in longer response and recovery times and increased danger to the public from potential exposure.

Hospitals

Introduction to Asset Class

Hospitals are institutions that provide life-saving and life-sustaining services to protect the health and wellbeing of all San Franciscans. They also play a critical role in responding to disaster events and providing medical surge capacity[30] to address the resulting influx of patients following an event. San Francisco's hospitals are licensed by the California Department of Public Health, and are required to provide 24-hour inpatient care, and include at the minimum the following eight basic services: medical, nursing, surgical, anesthesia, laboratory, radiology, pharmacy, and dietary services.[31] In addition to providing critical health care services, hospitals are also major employers and tend to be located on medical campuses with multiple other buildings housing related health care services, from pharmacies to doctors' offices.

San Francisco has 15 hospital facilities comprised of 56 buildings that are located across the city.[32] These facilities are concentrated in the city's northeast quadrant, which are also the city's most densely populated areas. For a map of hospital locations, refer to Figure A-8, on the following page. *Hospitals are often located in large, technically complex, multi-story buildings* that are comprised of a diverse set of services. In San Francisco, hospital buildings range from 1-15 stories tall, with the average building being five stories. In San Francisco, the three largest hospitals systems are UCSF, Dignity Health, and Sutter Health, accounting for 81% of the hospital beds in the City. Zuckerberg San Francisco General Hospital (ZSFG) is the city's primary safety-net hospital and the only Trauma Level I hospital in the county. ZSFGH and Laguna Honda hospital (primarily serves a long-term care facility, but is licensed as a hospital and skilled nursing facility) are owned and operated by the San Francisco Department of Public Health. Other hospitals in the City are either privately owned or owned by other public institutions, such as the University of California.

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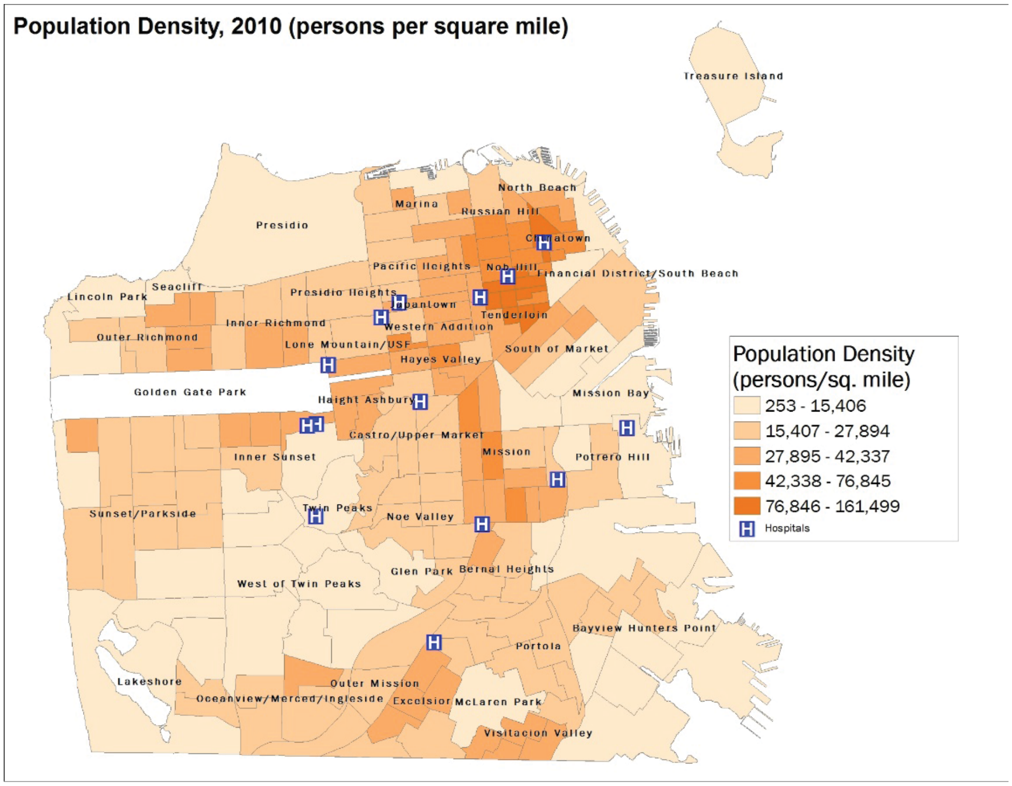
[30] Medical surge is defined as "the ability to provide adequate medical evaluation and care during events that exceed the limits of the normal medical infrastructure of an affected community" (e.g. a natural disaster or pandemic outbreak). US Department of Health and Human Services. Assistant Secretary for Preparedness and Response. Hospital Preparedness Program (HPP) Measure Manual: Implementation Guidance for the BP3 HPP Program Measurement Activities. July 1, 2014 – June 30, 2015. Retrieved from: http://www.phe.gov/Preparedness/planning/sharper/Documents/bp3-hpp-implementation-guide.pdf

[31] 22 CCR § 70005. General Acute Care Hospital.

[32] OSHPD/Facilities Development Division, Healthcare Construction Cost Data. September 2018

FIGURE A-8: SAN FRANCISCO HOSPITALS AND POPULATION DENSITY, 2016



GENERAL ACUTE CARE HOSPITAL SYSTEMS:

- Chinese Hospital
- California Pacific Medical Center (CPMC; Davies, Mission Bernal, and Van Ness Campuses)
- Kaiser Permanente San Francisco Medical Center
- Zuckerberg San Francisco General Hospital & Trauma Center (ZGSF)
- Saint Francis Memorial Hospital
- St. Mary's Medical Center
- University of California, San Francisco (UCSF; Mission Bay, Mount Zion, and Parnassus Campuses)

OTHER HOSPITALS:

- Jewish Home (long-term care facility & acute psychiatric hospital)
- Laguna Honda Hospital (a long-term care facility)
- Langley Porter Psychiatric Hospital
- Kentfield Hospital San Francisco (long-term care)

- Laguna Honda Hospital (a long-term care facility)

Issue Statement

Hospitals provide life-saving and life-sustaining services to protect the health and wellbeing of all San Franciscans, and play a critical role in responding to disaster events. They are highly regulated entities governed by local, state, and federal level rules on building standards and operations, emergency preparedness, and assortment of other resilience focused standards. Hospital are especially vulnerable to impact from hazard events given the population they serve (medically and socially vulnerable community members), the complexity of services they provide, and their reliance on outside resources to function, including power, communications, food, fuel, routine shipments of equipment, and transportation access. Any significant damage or disruption to a hospital facility would have severe and cascading impacts to health, especially for San Franciscans without the means to find alternate care. Failure of a hospital facility could also impact surrounding hospitals during a hazard event and create a surge in patients that stress their medical capacity.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In Table A-12, on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Data was sourced from the SF Department of Public Health (SF DPH, 2019). Hospitals are broken into three sub-types based on specialization: Hospitals, Hospitals-Nursing, and Hospitals-Psychiatry.

TABLE A-12: EXPOSURE

Hazard	Hospitals 20 Total	
	#	%
Geologic		
San Andreas 7.8 - Violent	1	5%
San Andreas 7.8 - Very Strong	19	95%
Hayward 7.0 - Very Strong	0	0%
Hayward 7.0 - Strong	15	75%
Liquefaction Zone	2	10%
Flooding		
100-Year Coastal Flood Zone	0	0%
100-year storm + 24 inches SLR	0	0%
100-year storm + 66 inches SLR	0	0%
100-year stormwater flood	0	0%
Wildfire		
High	0	0%
Moderate	0	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

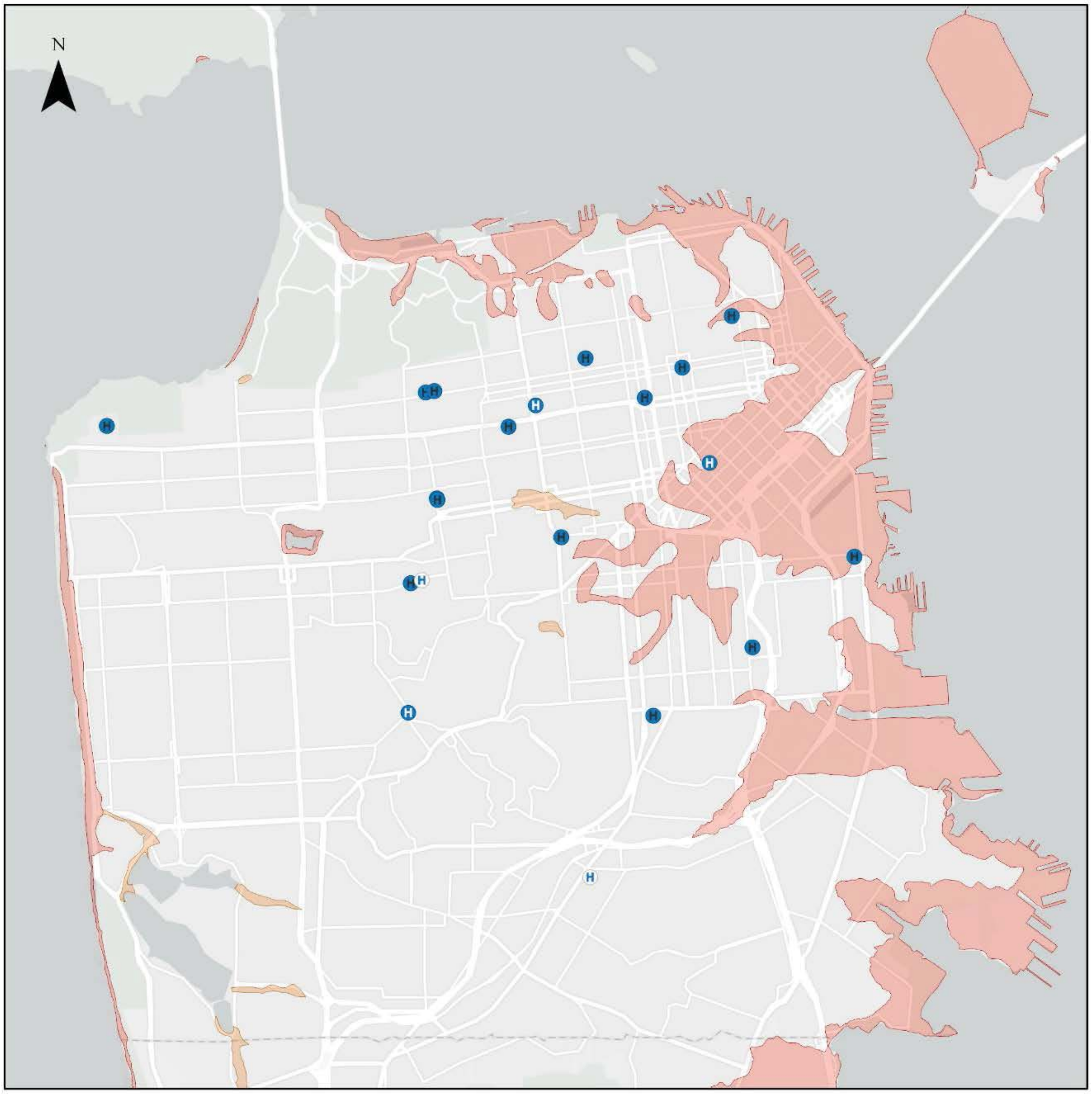
Exposure Summary

Geologic: All of San Francisco would be exposed to violent or very violent shaking in a 7.9 earthquake on the San Andreas fault, including all of the hospitals. 14 hospitals would be exposed to violent shaking in a 7.0 earthquake on the Hayward fault. The San Francisco Sobering Center is the only hospital exposed to liquefaction hazard.

Flood: None of San Francisco's hospitals are exposed to current and projected future coastal flooding. None of the hospitals are in the stormwater flood risk zone.

Fire: None of San Francisco's hospitals are located in high or moderate wildfire zones.

FIGURE A-9: HOSPITALS AND LIQUEFACTION HAZARD



0 0.75 1.5 3 Miles

Sources: SFDEM Data Library 2018; CGS, CALOES, 2015

Liquefaction Susceptibility & Hospitals

Hospitals

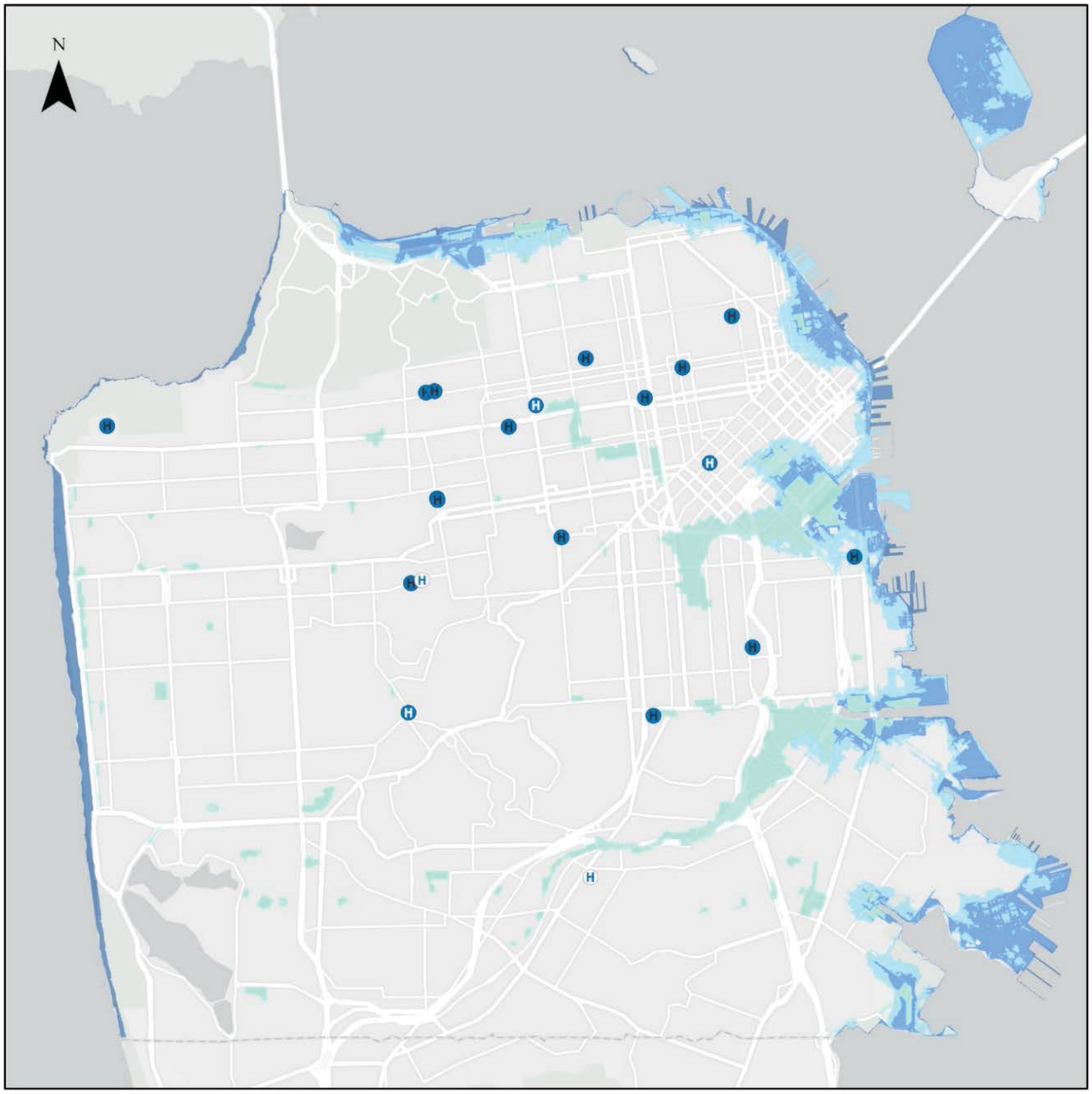
- Hospitals
- Hospitals - Nursing
- Hospitals - Psychiatric

Soil Liquefaction Hazard Zone

- Very High
- High

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

FIGURE A-10: HOSPITALS AND FLOOD HAZARDS



0 0.75 1.5 3 Miles

Hospital Flooding Risk

Hospitals

- Hospitals
- Hospitals - Nursing
- Hospitals - Psychiatric
- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Flood Hazard Data Sources:
Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Hospital buildings that are older (pre-1973) and non-retrofitted to meet current seismic standards are most at risk of serious damage during an earthquake. Under California law SB 1953, existing hospital acute care buildings must be retrofitted to adhere to certain seismic standards (or removed from general acute care service) by 2030. In San Francisco, 5 out of 15 facilities (33%) have met the 2030 deadline. **Flood:** Hospitals can experience site damage, structural and nonstructural building damage, destruction or impairment of utility service equipment, and damage to contents due to flooding. Hospitals without elevated generators may be vulnerable to power disruption in the event of flooding. Generators, or their supporting infrastructure (e.g. fuel tanks) are often below grade and are vulnerable if floodwater breaches the containment wall. **Extreme Heat:** Depending on the age of the building, the facility may have limited or substandard cooling systems. These cooling systems may not be sufficient during extreme heat events and place patients at increased risk of health impacts. Sensitive medical equipment stored in clinical labs are vulnerable to extreme temperatures. Additionally, older facilities may not have capacity (i.e. outlets) for temporary cooling equipment such as portable coolers. **Fire:** Hospitals are required to adhere to strict air filtration standards based on each area of the hospital's function.[33] Operating rooms, pharmacies, and sterile processing departments are required to meet stricter filtration requirements. In addition to filtration requirements, hospitals in California are required to use only outside air for ventilation, and cannot recirculate air. Therefore many buildings do not have the capacity to switch ventilations systems from bringing outside air in to recirculating inside air in the event of poor air quality due to smoke.
Functional	**Networks:** Damage or disruption at one hospital will significantly increase demand for services at other area hospitals as patients are rerouted. However, hospital networks have processes in place if one hospital is

[33] California Building Standards Code (California Code of Regulations/2016 California Mechanical Code/Title 24/Part 4/Chapter 3

	unavailable in order to mitigate disruption to the system. Hospitals also have the ability to expand their capacity to treat patients during hazard events through "medical surge." Zuckerberg San Francisco General Hospital is the only trauma center in the City, so any impact to ZSFG would have significant impacts in the ability to provide health services post-hazard in the City. **<u>External Services:</u>** Hospitals rely on power, communications, food, fuel, routine shipments of equipment, and transportation access to function. Hospitals are required to have a backup power generator on site with automatic restoration of power within 10 seconds. Current code requires existing acute care hospitals to have fuel supply on premises that is sufficient to provide 24 hours of full demand operation. [34] By 2030, acute care hospitals are required to have a minimum of 72 hours of fuel storage (newly constructed acute care hospital buildings must meet these requirements now).[35] Similar to power requirements, new acute care hospital facilities are required maintain an on-site water supply to support 72 hours of emergency operation (both potable and non-potable uses).[36] Existing buildings will need to comply with this requirement by 2030. Additionally, hospitals are required to have at least seven days' supply of staple foods (non-perishable) and two days' supply of perishable food on premises.[37] There is only one blood bank in the City, but each hospital has a cache of blood onsite. **<u>Populations Served:</u>** Hospitals provides life-saving and life-sustaining services to protect the health and wellbeing of all San Franciscans, regardless of citizenship or ability to pay. San Francisco hospitals are an integral public resource for vulnerable populations that may be disproportionately impacted during hazard events, including older adults during extreme heat events and unhoused populations or populations experiencing homelessness during extreme storm events. Hospitals serve those with access and functional needs, including those with pre-existing health conditions, medically dependent and mobility challenged individuals, and residents of all ages including pregnant women and young children. San Francisco hospitals serve San Francisco's ethnically and culturally diverse populations. As a

[34] According to 22 CCR § 70841 (b) "…The [emergency electrical system] shall serve all lighting, signals, alarms and equipment required to permit continued operation of all necessary functions of the hospital for a minimum of 24 hours.
[35] California Administrative Code, Chapter 6 and California Electrical Code Sections 517.25 and 700.12 (B))
[36] *California Plumbing Code Section 615.4* Emergency Water Supply
[37] *Title 22 – Section 70277*

	result, hospitals must tailor services to respond to multiple and simultaneous needs. **Unique or Critical Function:** Hospitals are a core component of the City emergency response apparatus and are expected to provide emergency medical services during and after disaster events. These facilities need to ensure continuity and quality of care for community members, even during emergency events. Hospitals can serve as a "teaching hospital", which provide medical education and training to future and current health professionals, and conduct medically-focused research. Teaching hospitals provide a unique educational role in our health care services system and would be difficult to replace.
Informational	**All-hazards:** All hospitals are required to submit data on health care financing and utilization to the Office of Statewide Health Planning and Development (OSHPD) on an annual basis. This information is publicly available for each facility. Information regarding building age, height, seismic risk, and compliance with state seismic rules is also collected and made publicly available. Hospitals are also required to develop hazards emergency operations plan and conduct an all-hazard risk assessment. Information developed through this planning document can be used to inform facilities planning for and response to hazard event. This plans are not hazard specific, and may leave gaps in understand facilities vulnerabilities to specific events.
Governance	**All-hazards:** Hospitals must comply with strict local, state, and federal laws and standards that govern building code, operation/maintenance, retrofit, and emergency preparedness requirements. California Department of Public Health (CDPH) is responsible for the licensure, regulation, inspection, and certification of general acute care hospitals. Office of Statewide Health Planning and Development (OSHPD) monitors the construction, renovation, and seismic safety of hospitals. In addition to state requirements, federal rules promulgated in 2016 by Center for Medicare & Medicaid Services (CMS) requires that all hospitals participating in Medicare and Medicaid develop an Emergency Operations Plan (EOP) which describes how a facility will respond to and recover from all hazards. Hospital revenue streams are varied and complex, and are often restricted in how they can be appropriated to address and prepare

	facilities for hazard events. Financing upgrades to meet the state's seismic safety requirements is especially hard for smaller and independent hospitals, some of which don't even have the credit to qualify for loans. The state mandate came with no state or federal money, so the cost has completely borne by the hospitals. For some, the only way to comply with the state requirement is to consolidate with larger hospitals.[38] Public hospitals in San Francisco have been successful in obtaining bond funding for complying state required seismic retrofits and other safety standards. In 2008, 84 percent of San Francisco voters approved Proposition A, which appropriated $887.4 million in general obligation bonds for the building of a new, seismically compliant, acute care hospital and trauma center at San Francisco General Hospital. In June 2016, 79 percent of San Francisco voters approved the $350 million Public Health and Safety bond to fund seismic upgrades in public health facilities (including hospital buildings) across the city.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Any significant damage or disruption to a hospital facility would have severe and cascading impacts to health. Damage or disruption to a San Francisco hospital facility may directly increase morbidity and mortality, especially for San Franciscans without the means to find alternate care. If a hospital facility were to fail, the capacity surge on surrounding hospitals would impact care. Also as major employment centers, a disruption to a hospital would impact the workforce, particularly hourly workers who would lose wages. If a hospital is temporarily without power, it will rely on backup generation and must, at a minimum have fuel to provide power for the continued operation of all necessary functions of the hospital for at least 24 hours. Any power disruption would mandate the relocation of vulnerable patients. **Extreme Heat:** High temperatures in hospital facilities without adequate cooling capacity may impact patients that are vulnerable to the health impacts of extreme heat, including children, the elderly, and people

[38] Ana B. Ibarra. "For California Hospitals That Don't Pass Quake Test, Money's Mostly At Fault." *California Healthline*. May 26, 2017. https://californiahealthline.org/news/for-california-hospitals-that-dont-pass-quake-test-moneys-mostly-at-fault/.

	with pre-existing cardiovascular conditions or diabetes. Extreme heat may damage sensitive technological equipment which may either stall or slow certain medical processes. The surge in hospitalizations associated with extreme heat events may strain hospital capacity. **Fire:** Smoke from fires may impact facilities without adequate ventilation. Patients with respiratory illnesses would be especially impacted by impaired indoor air quality.
Economy	**All-hazards:** Significant damage to a hospital would require the immediate expenditure of resources to relocate vulnerable patients and medical equipment and would strain regional health care infrastructure. Hospitals have high capital requirements and house expensive medical equipment with high replacement costs. Any power disruption would mandate the relocation of vulnerable patients at moderate economic impact. Additionally, hospitals are important employment centers so disruption could affect related economic activity. **Extreme Heat:** An extreme heat event would not cause significant physical damage, but would increase power usage and utility costs and may damage sensitive equipment in buildings that haven't been adequately weatherized. If a heat event were severe enough to cause a hospital's temperature to be dangerously high, there would be economic costs associated with the relocation of vulnerable patients. **Fire:** If a smoke event were severe enough, there would be economic costs associated with the relocation of vulnerable patients and potential damage to medical equipment.
Environment	**All-hazards:** Hospitals store hazardous materials. Damage from an earthquake, flood, or fire could result in the release of hazardous materials.

Other Emergency Facilities

Introduction to Asset Class

Other emergency facilities are facilities or sites that provide supportive services essential to a community during and after an incident. They are located throughout San Francisco. For purposes of this assessment, other emergency facilities include:

- 102 indoor facilities and 5 outdoor sites that the City and County of San Francisco (CCSF) may rely on to provide sheltering services for people who are displaced or otherwise impacted in an incident. These sites include Moscone Center North, South, and West buildings.
- The San Francisco Animal Care and Control animal shelter, which would provide care and other services to displaced pets, service animals, and wild or exotic animals following an incident.
- 25 sites currently identified for use as potential resource staging areas following an incident impacting the city.

Potential shelter facilities included in this asset class are located primarily at public schools owned and operated by the San Francisco Unified School District (SFUSD), recreation centers owned and operated by the Recreation and Parks Department (RPD), and privately-owned places of worship. Each of these facilities is used during non-disaster periods to provide educational, recreational, religious, and other services to the community. Most of the facilities are open to the public, though some are privately owned and thus are typically available during daily operations to a more limited clientele. In general, before any of these facilities may be used as shelters following an incident, they must be inspected to ensure they are safe for use.

The San Francisco Department of Animal Care and Control (ACC) animal shelter is a taxpayer-funded, open-admission animal shelter. In its daily operations, the shelter provides housing, care, and medical treatment to domestic stray, lost, abandoned, sick, injured, and surrendered animals; and to wild and exotic animals. The shelter also serves as a headquarters for personnel who enforce state and local animal control and welfare laws in CCSF and act as first responders for animals during incidents. The ACC shelter is owned and operated by the San Francisco General Services Agency. The city has plans to thoroughly renovate an existing building in a different location for use as a new animal shelter, with relocation scheduled for the end of 2020.

Potential staging areas included in this asset class include vacant lots, parking lots attached to schools or recreation facilities, and playgrounds. Accordingly, most of the sites included in this category serve a daily function as a parking or recreational area. As with shelter facilities, before a staging area can be selected for service following an incident, it must be inspected to ensure it is safe for use.

Issue Statement

Other emergency sites play a critical role during and after a disaster for sheltering displaced persons, pets, and staging materials. Staging areas tend to be located in areas susceptible to liquefaction and coastal flooding. Disruption of lifelines, such as water, power, sewer, and communications would require that backup systems or supplies such as generators, portable toilets, or bottled water be brought onsite. The city lacks up-to-date data on privately-owned shelter facilities in terms of their vulnerability or resilience, such as retrofitting or air cooling and filtering. Loss of functionality of facilities in this asset class would increase response and recovery time

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In Table A-13, on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Data was sourced from the SF Department of Emergency Management (SF DEM, 2019). The staging areas are mostly port properties along the Bay Shore, with the care and shelter locations being a mix of public/private buildings.

TABLE A-13: EXPOSURE

Hazard	Staging 25 Total		Care and Shelter 107 Total		Animal Care and Control 1 Total	
	#	%	#	%	#	%
Geologic						
San Andreas 7.8 - Violent or Very Strong	3	12%	80	75%	0	0%
San Andreas 7.8 - Very Strong	22	85%	22	21%	1	100%
Hayward 7.0 - Very Strong	23	88%	5	5%	0	0%
Hayward 7.0 - Strong	2	8%	82	77%	1	100%
Liquefaction Zone	25	96%	24	22%	1	100%
Flooding						
100-Year Coastal Flood Zone	8	31%	2	2%	0	0%
100-year storm + 24 inches SLR	8	31%	3	3%	0	0%
100-year storm + 66 inches SLR	24	92%	5	5%	0	0%
100-year stormwater flood	0	0%	6	6%	1	100%
Wildfire						
High	0	0%	0	0%	0	0%
Moderate	0	0%	3	3%	0	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

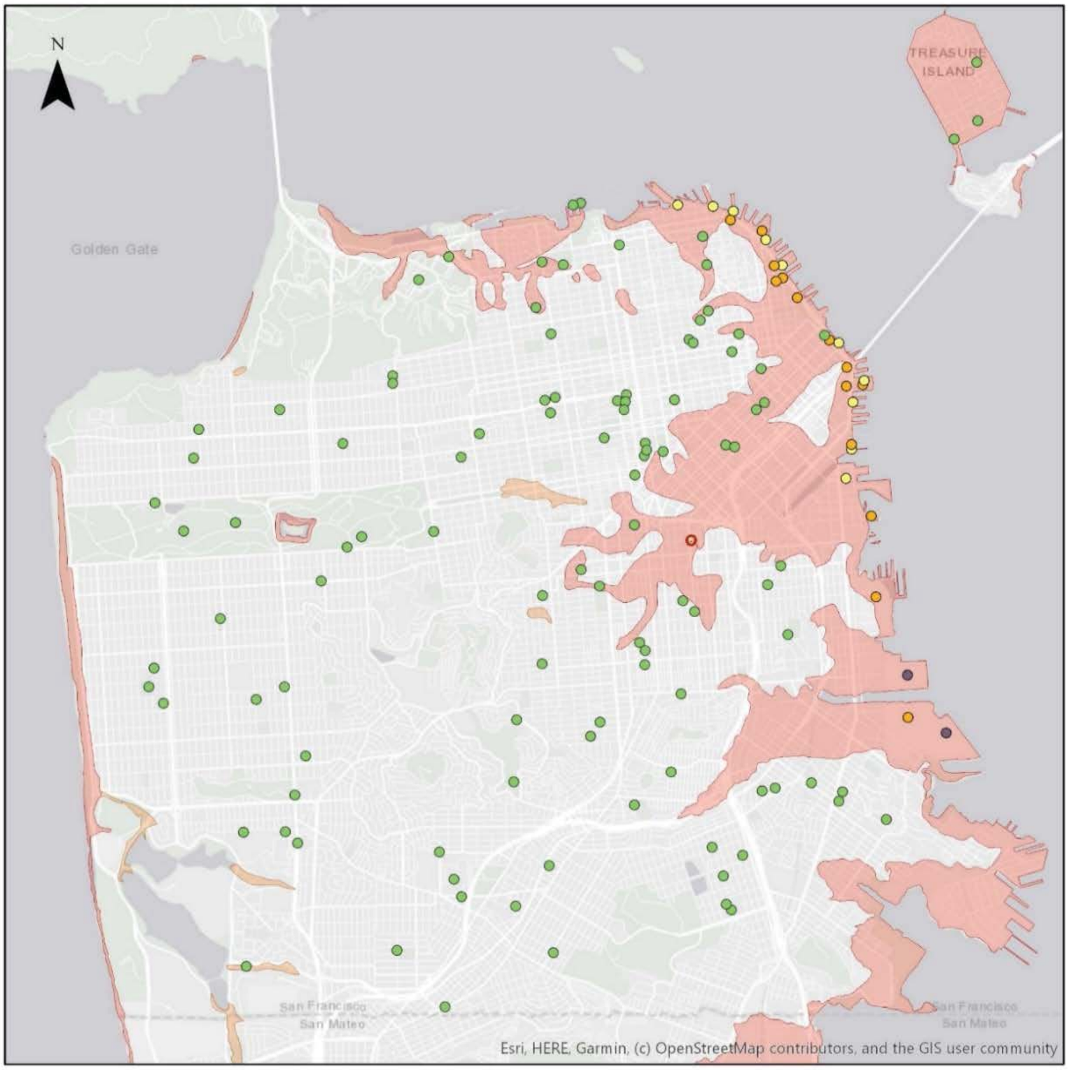
Exposure Summary

Geologic: All of San Francisco would be exposed to violent or very violent shaking in a 7.9 earthquake on the San Andreas Fault, including all other emergency facilities. A significant proportion of staging areas and the current Animal Care and Control Center are exposed to liquefaction hazard zones.

Flood: Given the location of staging areas along eastern waterfront, they may potentially be exposed to flooding hazards. Eight staging sites are currently exposed to coastal flooding during a 100-year storm, and this increase to 24 sites with 66 inches of sea level rise. In addition, 25 staging sites are in the liquefaction zone. Notably, the current Animal Care and Control Center, the only facility of its kind, may be to be exposed to 100-Year stormwater flooding. Care and Shelter Facilities have limited exposure to potential flooding, however, the two Fort Mason Center Pavilions and one Treasure Island facility listed as possible shelters are located within the current 100-year coastal flood zone.

Fire: Three shelters are exposed to moderate wildfire hazard zones. However, in relation to the total number of shelters, this does not represent a significant amount of exposure.

FIGURE A-11: OTHER EMERGENCY SITES AND LIQUEFACTION HAZARD



0 0.75 1.5 3 Miles

Sources: SFDEM Data Library 2018; CGS, CALOES, 2015

Liquefaction Susceptibility & Other Emergency Sites

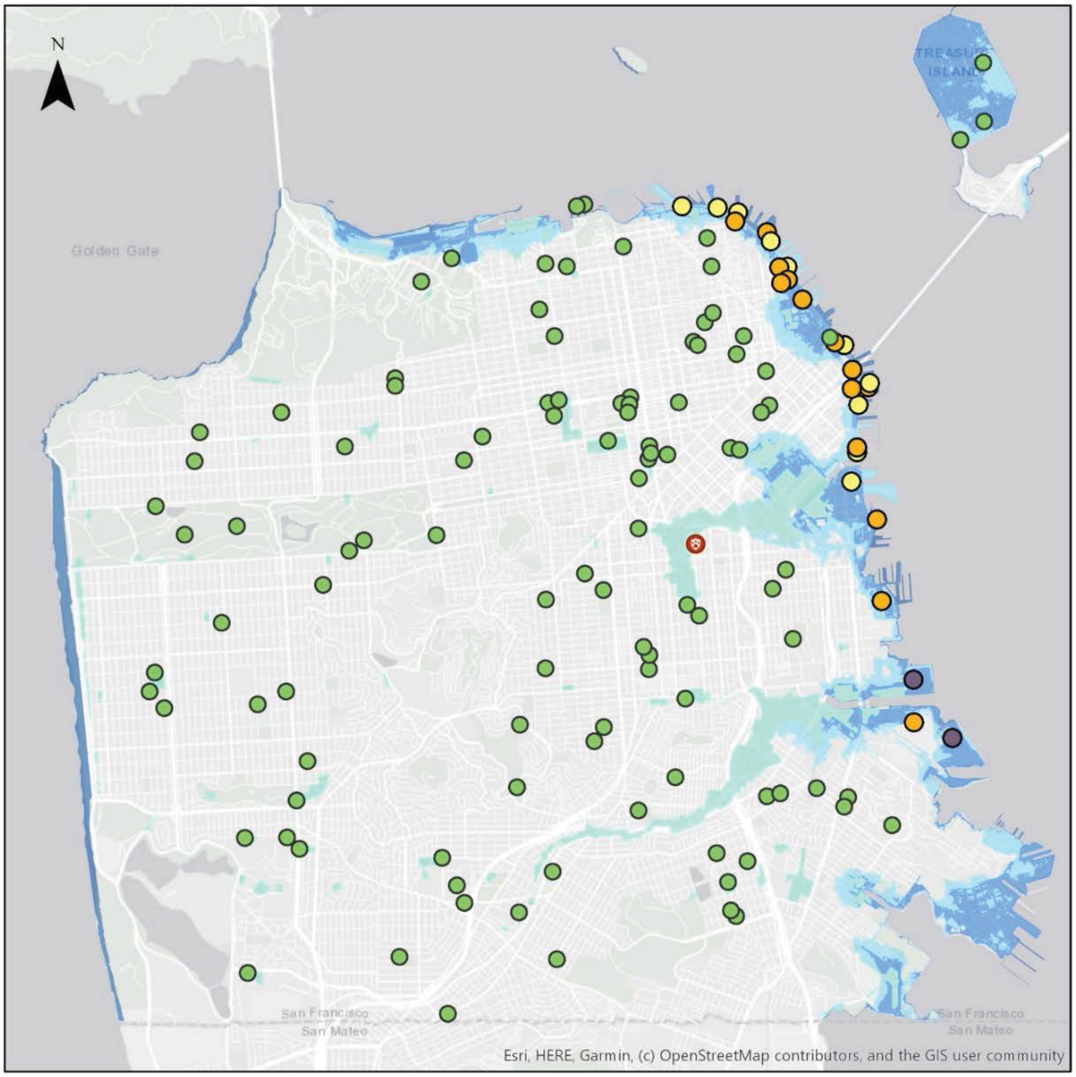
- Animal Care and Control
- Emergency Shelters
- Staging - FEMA
- Staging - Mixed Use
- Staging - People

Soil Liquefaction Hazard Zone

- Very High
- High

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

FIGURE A-12: OTHER EMERGENCY SITES AND FLOOD HAZARDS



0 0.75 1.5 3 Miles

Other Emergency Site Flooding Risk

- Animal Care and Control
- Emergency Shelters
- Staging - FEMA
- Staging - Mixed Use
- Staging - People
- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Flood Hazard Data Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** At least 42 of the potential shelter facilities included in this asset class have received some retrofitting. Of these, 13 Recreation and Parks facilities have completed seismic renovations within the last ten years; these facilities would become operational first following a large earthquake. In addition, the City is planning to build a new ACC shelter facility, which is scheduled to open in 2020. The new facility is also located in the liquefaction area but has been designed to withstand strong earthquake shaking. Many of the staging areas are located on older piers that were not built to modern seismic standards and would be susceptible to damage in an earthquake. The piers in the northern waterfront are being studied as part of the Seawall Program. The piers in the southern waterfront need to be evaluated individually to better understand their vulnerability and consequence of damage and identify specific work that is needed to improve their performance. **Flood:** Several facilities and sites in this asset class may be vulnerable to coastal flooding due to their location. Many of the piers in the southern waterfront are vulnerable to flooding, particularly where utilities exist under the piers, there is a need for space under the piers to maintain them, the condition of the pier aprons and fenders are already compromised, or where there is a need for access connections between the water and the land. The newly-renovated ACC shelter facility, scheduled to open in 2020, is located outside the 100-year storm risk zone. **Extreme Heat:** Though most of the newer facilities in this asset class have air conditioning, older facilities do not. For example, six recently-renovated shelter sites have upgraded HVAC systems providing a climate-controlled environment. In contrast, the current ACC shelter facility has no air conditioning. Resource staging areas included in this asset class are all located outside, which would potentially place personnel working in these areas at risk for heat-related complications during extreme-heat events. The renovated ACC shelter facility will have an electrically-powered air conditioning system. **Fire:**

	None of the facilities or sites included in this asset class are located in areas of very high or high fire risk as determined by the California Department of Forestry and Fire Protection (CAL FIRE). However, potential shelter facilities in Fort Mason are located in an area of moderate fire risk according to CAL FIRE. Most public schools and recreation centers included as potential shelter sites in this asset class have fire sprinkler systems installed. However, 15 of the possible shelter sites are wood-framed structures, which potentially increases their fire risk. In addition, all sites and facilities in this asset class may be susceptible to poor or unhealthy air quality stemming from fires located outside San Francisco. Though some of the newer facilities in this class have air filtering, most do not. Only three of the potential shelter facilities have filtered air. Both current and proposed ACC shelter facilities are designed to use 100-percent outside air circulation for disease control. During a fire or external smoke event, all ventilation would be shut down to minimize the spread of smoke into the building. In addition, both the current and renovated ACC facilities have older, historic windows that do not perform as well in preventing outside air infiltration. All of the resource staging areas included in this asset class are located outdoors, leaving personnel and other resources in these areas susceptible to impacts from smoke.
Functional	**Networks:** Potential shelter facilities are not networked in the sense of having discrete areas of responsibility. However, loss of a number of shelters would certainly impact the city's capability to provide shelter to displaced persons. Though the ACC animal shelter facility is a "stand-alone" facility, ACC's ability to respond in a disaster will heavily impact the city's human shelters, as ACC provides support for service animals in shelters serving humans, and provides emergency sheltering for household pets co-located with or within a short distance of human shelters. Similarly, the loss of multiple staging areas will impact the city's ability to locate needed resources close to areas where they are needed or near transportation routes for efficient dispersal. Thus, if one or more of these sites or facilities are unavailable, this will impact available sites or facilities, which may need to assume greater responsibility for unmet needs. **External Services:** Other emergency sites depend on water, sewer, gas, electricity, and telecommunications. Disruption of such lifelines would require that backup systems or supplies such as generators, portable toilets, or

	bottled water be brought onsite. Interruption of the sewer system also would present disease control challenges. ACC currently has no emergency water storage onsite, so a water tanker or hook-up to nearby fire hydrants may be required during an incident. A lack of electrical power could affect refrigeration capabilities, which may result in a loss of critical medical supplies such as vaccines. This, in turn, could impact the health of animals in ACC's care and potentially lead to disease outbreak. Shelters rely on transportations systems as they require a high volume of commodities being delivered for effective operations, including food, cots, blankets, toiletries, and first aid supplies. As commodities become depleted locally, the city will depend on aid from other sources. If transportation corridors are temporarily unavailable or are damaged, this will further impact provisioning of these facilities. ACC also relies on outside agencies for assistance with towing emergency trailers from storage location to a temporary shelter site or sites. Shelter sites depend on trained building and health inspectors. Before any of the potential shelter sites can be occupied following an earthquake event, a safety assessment of the facilities must be conducted by trained building inspectors. Because CCSF has a large number of critical facilities that require similar inspections, and because the supply of local, trained building inspectors is limited, inspections of shelter facilities will need to be prioritized. Similarly, the Department of Public Health must conduct inspections of shelter facilities to ensure that they meet health and sanitation standards. **Populations Served:** Shelters provide temporary housing for displaced persons, though typically they serve a disproportionate number of people with fewer resources. This includes people who—because of age, disability, language barriers, or income—have limited housing options and require additional assistance to recover from an incident. For example, the city anticipates that a larger percentage of renters will seek shelter, as homeowners are more likely to remain with their property or have insurance to cover housing alternatives. The ACC shelter is tasked with serving all populations within San Francisco, including people with disabilities, lower incomes, or people who are displaced. A major incident will result in an increase in the number of animals that need to be housed, fed, and cared for, including those needing medical attention. ACC is limited in its ability

	to support additional physical sheltering for stray animals without an owner or guardian, but is exploring obtaining additional equipment for this type of facility in austere conditions. Resource staging areas may be used to locate personnel, equipment, and supplies needed in an incident. These resources, in turn, support response and recovery personnel and the general population. **Unique or Critical Function:** Emergency shelters provide temporary accommodations to persons displaced from their homes by an incident. The ultimate goal of shelter operations is to help people to find the resources needed to leave the shelter. Shelters remain open until occupants can return home or find alternate housing. Because people often arrive at shelters without daily necessities, shelter staff work to identify and connect individuals with services or resources to meet basic needs. This includes access and functional needs such as obtaining personal care assistance, durable medical equipment, or needed medication. ACC is charged with providing rescue, emergency care, housing, and reunification services for animals that are lost, missing, or injured. ACC also provides support for service animals in human shelters and emergency household pet sheltering co-located with or near shelters for people. Staging areas serve as locations for emergency personnel waiting to be deployed, or for the storage of emergency supplies and equipment.
Informational	**All-hazards:** The city lacks up-to-date data on privately-owned shelter facilities in terms of retrofitting, air cooling and filtering, installation of sprinkler systems, sensitive below grade components, back-up measures for utility outages, access to food and water, and fuel for generators for all facilities. ACC is in the process of negotiating memoranda of understanding with other city agencies for assistance; however, options for trailering, water supply, and temporary shelter site locations remain unclear.
Governance	**All-hazards:** The Americans With Disabilities Act (ADA), 42 U.S. Code §§ 12101 et seq., requires shelters to provide equal access to benefits provided, including modifying "no pets" policies to allow people with disabilities to be accompanied by their service animals. See 28 C.F.R. § 35.130(b)(7)(i). Under the ADA, service animal means any dog that is individually trained to do work or perform tasks for the benefit of an

	individual with a disability. The work or tasks performed by a service animal must be directly related to the individual's disability. The Pets Evacuation and Transportation Standards (PETS) Act, P.L. 109-308 (H.R. 3858), requires FEMA to ensure that local and state emergency operations plans address the needs of individuals with household pets and service animals before, during, and after a major disaster or emergency. The PETS Act also authorizes FEMA to provide funding to local and state governments for animal emergency preparedness, including procurement, construction, leasing, or renovating of emergency shelter facilities and materials that would accommodate people with their pets and service animals following an evacuation. The Post-Katrina Emergency Response Act (PKEMRA), P.L. 109-295 (H.R. 5441), amended the Stafford Act to authorize search, rescue, care, and shelter of pets and service animals as a type of essential assistance to be provided after a major disaster declaration. All CCSF departments must abide by San Francisco Administrative Code Chapter 6, which governs public works or improvement contracting policies and procedures, including the procurement of professional design, consulting, and construction management services for public work or Improvement projects.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Significant incidents may result in the loss of facilities in this asset class as well as human casualties from building damage. This would result in reduced ability to provide shelter for people and animals. It may also prevent or delay the use of certain staging areas, requiring the use of alternate sites. This, in turn, may increase response and recovery times. **Geologic:** Significant ground shaking and liquefaction may result in failure of facilities in this asset class as well as human casualties from building damage. This in turn would result in reduced ability to provide shelter for people and animals. Seismic impacts may also prevent or delay the use of certain staging areas, requiring the use of alternate sites. Collectively, such consequences may lengthen response and recovery times. **Flood:**

	Significant coastal or storm water flooding may result in building damage for facilities in this asset class as well as human casualties. This is turn would result in reduced ability to provide shelter for people and animals. Flooding may also prevent or delay the use of certain staging areas, requiring the use of alternate sites. Collectively, such consequences may lengthen response and recovery times. **Extreme Heat:** Extreme heat may result in the need to avoid using or to lessen reliance on shelter facilities without air conditioning. It may also require moving some outdoor staging sites to indoor facilities where the climate can be controlled, or to reducing the pace of work in outdoor staging area to lessen heat impacts to personnel at the site. Collectively, such consequences may result in reduced ability to provide shelter for people and animals, and to a reduction in the efficiency of staging areas, lengthening response and recovery times. **Fire:** Fire may damage or destroy facilities in this asset class. Poor air quality from fires in CCSF or in the Bay Area may result in a need to close shelter and ACC facilities that do not have air filtering capability, or to purchase filtering equipment, masks, and other supplies to lessen smoke impacts. This may result in reduced ability to provide shelter for people and animals and may prevent or delay the use of certain staging areas, requiring the use of alternate sites. Collectively, such consequences may increase response and recovery times.
Economy	**All-hazards:** The loss of, or delayed access to, the facilities or sites in this asset class would result in longer response and recovery times, which in turn will negatively impact the city's economy and ability to quickly recover. Costs to repair the facilities in this asset class could be in the millions or billions. Cost to replace would be in the trillions.
Environment	**All-hazards:** Staging areas provide support to department or field personnel by storing resources needed to combat environmental impacts, and by serving as locations where personnel may gather to prepare for deployment.

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Municipal Buildings

Introduction to Asset Class

This section includes municipal offices, jails, and publicly owned arts venues. Other types of public buildings are covered in different sectors of the assessment, such as emergency response facilities (e.g. police and fire stations), educational facilities, and health facilities (e.g. hospitals and clinics). The locations of buildings and exposure analysis calculations were made using data from the City's Facility System of Record.

- **Municipal offices**: Buildings where City employees work, members of the public receive services, and/or the combination of these two. Some City services focus on the unique needs of low-income and other sub-populations. For example, the Human Service Agency (HSA) administers many of these programs at its nine service center locations. Most municipal offices are clustered around City Hall, and several are located in the southeast. This analysis classifies 48 buildings as municipal office. Twenty-eight of these buildings house city departments, but are not owned by the City. Three private buildings which hold city departments are 240 feet or taller and therefore classified as a "Tall Building" in the City's Tall Building Inventory initial database.[39]
- **Correctional facilities**: There are three active County Jails at two facilities within San Francisco proper: County Jails #1 (Intake and Release) and #2 (Administrative Areas, Kitchen, Jail Pods and Medical/Psychology Ward) at 425 7th Street, and County Jail #4 at the Hall of Justice. The Hall of Justice also houses other justice-related staff offices, as well as San Francisco's criminal and traffic courts. There is also one active jail, County Jail #5, located in San Bruno (San Mateo County), which is mapped in Appendix B. There is a locked ward at Zuckerberg San Francisco General Hospital and two additional wards in the original San Francisco General Hospital building for inmates requiring hospitalization. The Juvenile Justice Center campus is located in the center of the city near Twin Peaks; that campus has a variety of on-site services, including a court, gymnasium, and administrative offices. The Log Cabin Ranch, a Santa Cruz Mountains facility for

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[39] Tall Buildings Safety Strategy acknowledges that the 240-foot height criterion for the initial database was somewhat arbitrary. To the extent that the *San Francisco Building Code* imposes elevator, fire safety, and other requirements on high-rise buildings defined as those taller than 75 feet, it would be useful to expand the database to include at least all buildings above this height.

juveniles with violent or chronic offenses, had its operations suspended in June 2018 following repeated residents running away.

- **City-owned cultural centers, museums, and performance halls**: There are four major museums in the City's portfolio: The Asian Art Museum on Civic Center Plaza, the de Young Museum and the California Academy of Sciences in Golden Gate Park, and the Legion of Honor near Land's End lookout. The de Young and Legion of Honor are both managed by the city's Fine Arts Museums Department, which also maintains a warehouse in the Bayview neighborhood. The City's Arts Commission owns four cultural centers: Bayview Opera House, Mission Cultural Center for Latino Arts, SOMArts, and the African American Art and Culture Complex—located in the historic Fillmore Jazz District. The War Memorial Department holds three performance halls and one rehearsal hall, and the Real Estate Division owns one performance hall (Bill Graham Civic Auditorium); all five of these performance venues are located within one block of City Hall. There are many other museums in San Francisco which are privately owned and managed.

Issue Statement

Municipal buildings have diverse roles and needs. Municipal offices and service centers provide functions critical to the well-being and safety of San Francisco residents and visitors. Museums, performance halls, and historic buildings have unique cultural and economic value. These buildings range in their seismic safety and resilience to other hazards. Community members rely on services provided by the City and may not be able to locate replacement services. The consequences of municipal building disruption are more severe for residents who require public assistance to meet their basic needs, who are resource-constrained and experience other social vulnerabilities, including incarcerated populations.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In Table A-14, on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data originates from the facility system of Record (FSR) dataset maintained by the Office of Resilience and Capital Planning and available through the San Francisco Open Data Portal.

TABLE A-14: EXPOSURE

Hazard	Municipal Office 42 Total		City-Owned Arts Institution 9 Total		Jail/Juvenile Detention Facilities 3 Total	
	#	%	#	%	#	%
Geologic						
San Andreas 7.8 - Violent	0	0%	3	33%	0	0%
San Andreas 7.8 - Very Strong	42	100%	6	67%	3	100%
Hayward 7.0 - Very Strong	4	10%	0	0%	0	0%
Hayward 7.0 - Strong	38	90%	9	100%	2	67%
Liquefaction Zone	23	55%	2	50%	2	67%
Flooding						
100-Year Coastal Flood Zone	1	2%	0	0%	0	0%
100-year storm + 24 inches SLR	2	5%	0	0%	0	0%
100-year storm + 66 inches SLR	8	19%	0	0%	2	67%
100-year stormwater flood	4	10%	4	44%	0	0%
Wildfire						
High	0	0%	0	0%	0	0%
Moderate	0	0%	1	11%	0	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

Exposure Summary

Geologic: All municipal buildings would be exposed to Violent or Very Strong shaking during a 7.8 earthquake on the San Andreas Fault. All municipal buildings except the juvenile detention facility would be exposed to Very Strong or Strong shaking during a 7.0 earthquake on the Hayward fault. The two County jail facilities in San Francisco, the Asian Art Museum, Bill Graham Civic Auditorium, and 23 municipal buildings are in the liquefaction zone.

Flood: The two County jail facilities in San Francisco and 8 municipal offices are in the 66" sea level rise zone. All War Memorial buildings and four municipal office buildings are in the 100-year stormwater flood zone.

Fire: The Legion of Honor is the only municipal building in a wildland-urban interface fire risk zone (Moderate).

FIGURE A-13: MUNICIPAL BUILDINGS AND LIQUEFACTION HAZARD

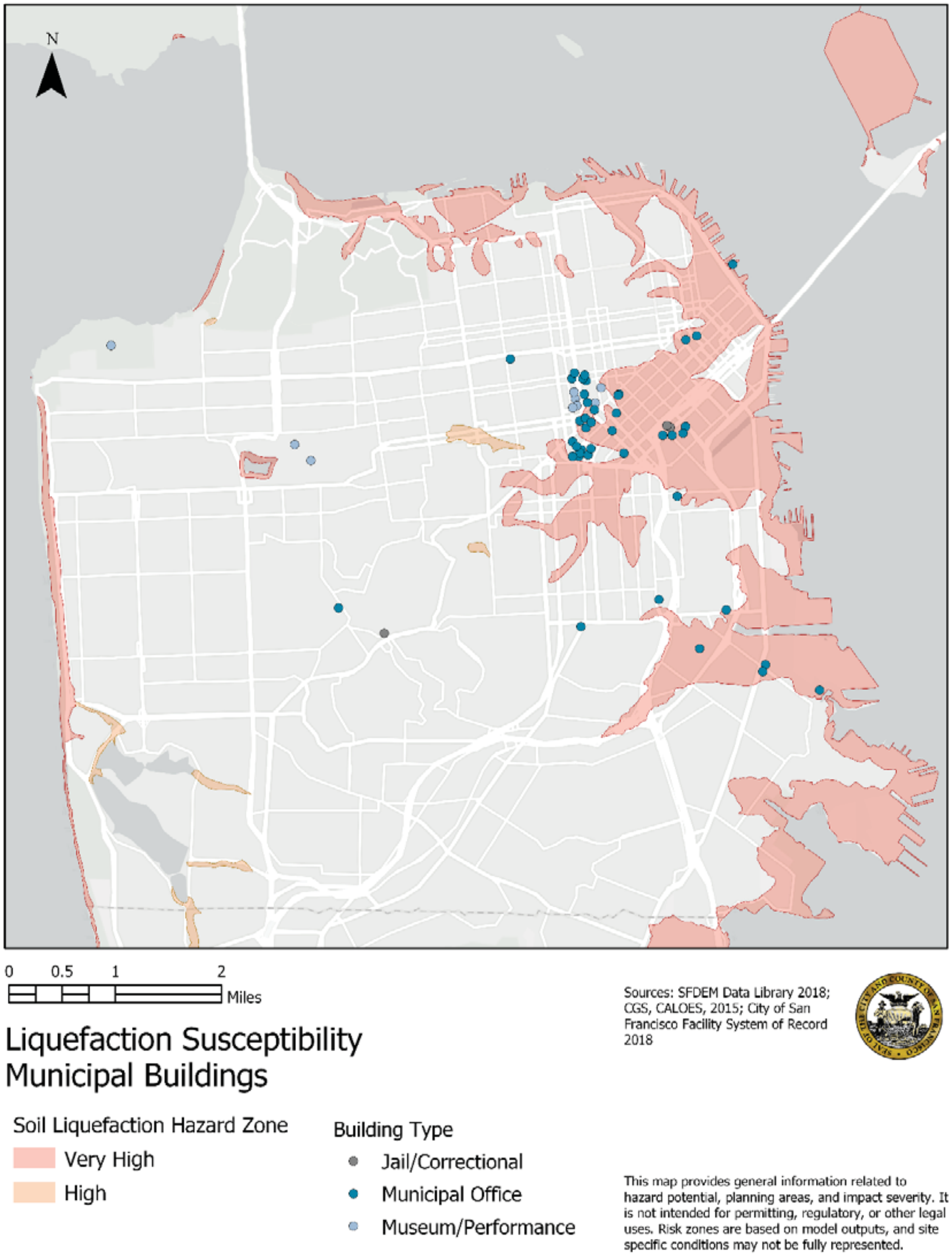
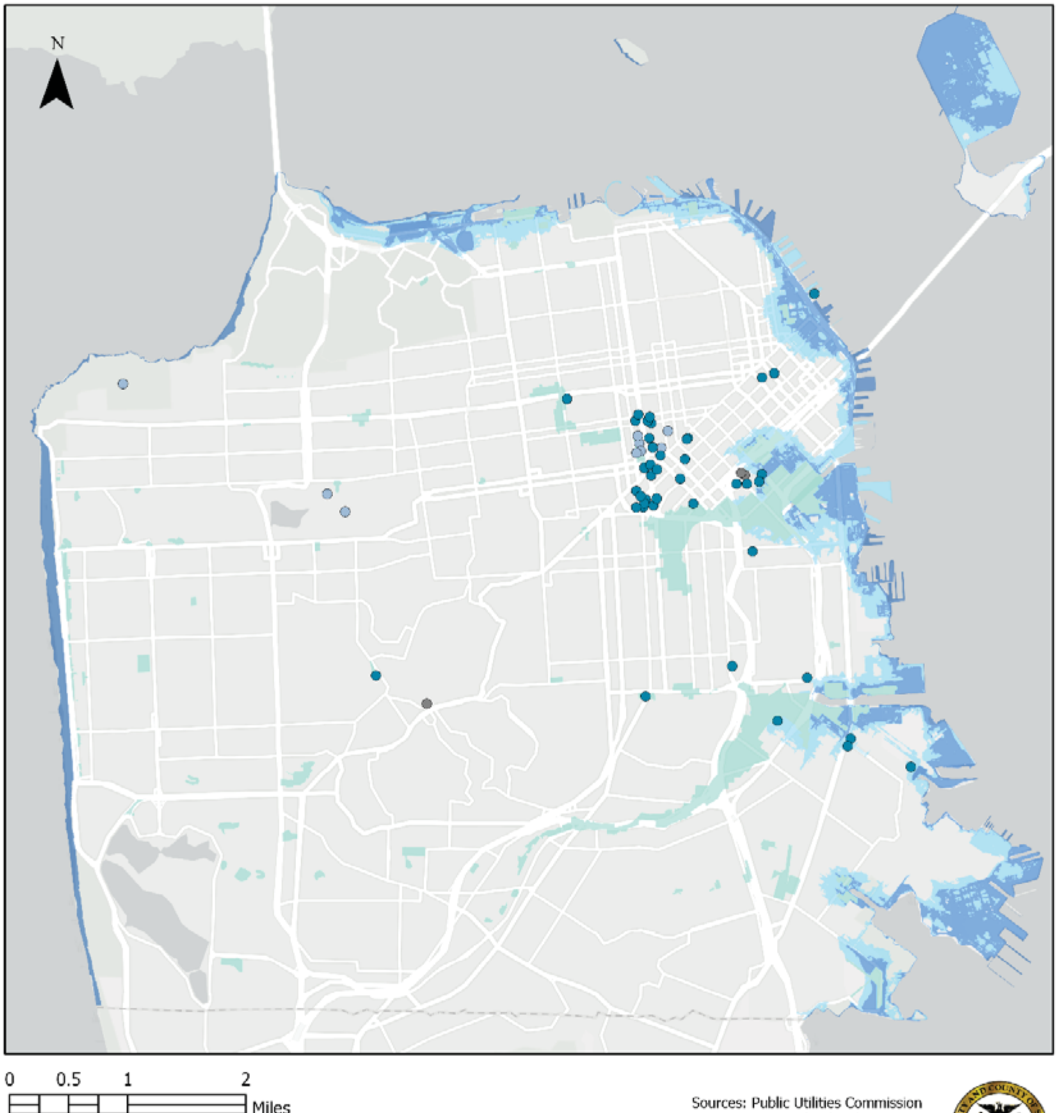


FIGURE A-14: MUNICIPAL BUILDINGS AND FLOOD HAZARDS



Flood Risk and Municipal Buildings

Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps; City of San Francisco Facility System of Record 2018

Flood Hazards

- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Building Type

- Jail/Correctional
- Municipal Office
- Museum/Performance

This map is intended for planning-level analysis and should not be used for permitting, regulatory, or other legal uses. Flooding is possible in areas outside of those displayed on this map. The risk zones are based on model outputs and relied on LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and structures, site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Municipal buildings vary in their seismic soundness. Some have completed retrofits; in others the tenants have been partially or completely relocated. San Francisco uses seismic hazard ratings (SHRs) to assess risk and prioritize seismic-strengthening capital improvements. At present, the City has developed mitigation strategies for many of the buildings identified as SHR4 (worst performing), but resources are needed in order to deliver those mitigations. A top priority of the City's Capital Plan is to vacate, demolish, and rebuild the Hall of Justice. Though it is not an SHR4, a 2012 seismic evaluation of the Hall of Justice determined that "damage would be very severe and pose appreciable life hazards to occupants."[40] Some departments have been permanently relocated from the building, and additional mitigations are underway. There are certain building types in the municipal buildings asset category with structural vulnerabilities that make them high-priority for the City. Pre-1980 non-ductile concrete frame buildings are brittle and vulnerable to extensive damage with significant life safety risk.[41] Approximately 3,400 such buildings exist in San Francisco (residential and nonresidential), but it is not yet known which small percentage of these pose a collapse risk in an earthquake. Steel frame structures built between 1960 and 1994 are vulnerable to earthquakes if they use a welded steel construction method.[42] San Francisco's Earthquake Safety Implementation Program and Tall Buildings Safety Strategy recommend non-ductile concrete buildings and welded steel frame buildings be evaluated starting in 2020. **Flood:** Most buildings are not built to withstand any amount of flooding, as construction materials, siting and design standards do not require consideration of potential exposure to either water or salt. Buildings with at- or below-grade mechanical systems or equipment are vulnerable to flooding and groundwater intrusion.

[40] City Services Auditor 2013 Hall of Justice Replacement Jail http://www.sfsheriff.com/files/sf_jail_needs_8_2013.pdf
[41] "Guide to Earthquake Vulnerable Commercial Building Types," Association of Bay Area Governments Resilience Program, September 2016, http://resilience.abag.ca.gov/commercial-building-types/
[42] Detweiler, S.T., and Wein, A.M., eds., 2018, The HayWired earthquake scenario—Engineering implications: U.S. Geological Survey Scientific Investigations Report 2017–5013–I–Q, 429 p., https://doi.org/10.3133/sir20175013v2

	Extreme Heat: Older buildings with limited or substandard cooling systems are more vulnerable during extreme heat events. **Fire:** Buildings made with wood are highly susceptible to fire. Steel and concrete buildings are less vulnerable to fire damage, and steel buildings contain fire proofing materials to resist fire damage. Emergency plans and evacuation procedures are required by federal law. Populations with limited mobility or medical conditions are particularly at risk during evacuation. The *San Francisco Building Code* requires many buildings to have an in-building secondary water supply to operate the sprinkler system for 30 minutes. The Tall Buildings Safety Strategy recommends a study to evaluate whether (1) the in-building secondary water supply for automatic fire suppression in tall buildings is sufficient to inhibit fire spread and allow safe evacuation, and (2) the building code provisions that rely on elevators for evacuation during a fire emergency will be effective following an earthquake. Older buildings that do not have adequate HVAC and filtration technology may be more vulnerable to air quality impacts.
Functional	**Networks:** Municipal Buildings rely on each other in implementing programs, sharing data and information, and operating city services. Cross-department collaboration is highly dependent on functioning internet and telephones, and city IT systems are networked. The CCSF IT-focused Disaster Preparedness, Response, Recovery and Resiliency (DPR3) requires all departments to develop, test, and maintain departmental IT-focused Continuity of Operations plan (IT COOP) to meet the needs of critical system operations in the event of a disruption.[43] The War Memorial Veterans Building and Opera House share mechanical systems, as do the Hall of Justice and 425 7th Street, and Moscone Center North and South.[44] **External Services:** Municipal buildings rely on electricity delivery through PG&E's transmission and distribution system and all buildings have back up power sources to run emergency lighting and critical equipment. Municipal Buildings that house critical functions in the event of a power failure are equipped with backup generators to support those functions. Most of the solar installations on municipal buildings are tied to the grid without backup storage systems and the solar installation will not be able to be used in the event of a power failure:

[43] https://sfcoit.org/dpr3
[44] SFPUC 2017 Energy Benchmarking Report https://sfwater.org/Modules/ShowDocument.aspx?documentID=13356

	buildings with local storage systems can add to resilience if power from the grid is lost. Municipal buildings also rely on communications infrastructure, adequate air ventilation, potable water, and sewer to function normally. The functionality of municipal buildings is highly dependent on transportation access. The majority of City employees commute by transit, and resource-constrained residents are more likely to rely on transit to access city services. **Populations Served:** San Francisco's municipal buildings serve all San Franciscans and must be prepared to meet the needs of anyone who walks through the doors. American Community Survey 2017 estimates 20.3-20.9% of populations 5 years and older speak English less than "very well"[45] and 10.4-10.8% of noninstitutionalized population is with a disability.[46] Individual departments and facilities may also have particular service populations to consider. The Human Services Agency provides cash assistance, food and nutritional support, health insurance, employment training, child care, and specialized supportive care for low-income residents, who may have limited English proficiency or experience disability or homelessness. Forty percent of County Jail inmates seek mental health services at some point during their residency, and 53% of jail population is Black, which is almost 10 times higher than rates of Black population citywide.[47] Museums and performance halls attract visitors from all over the world, who may not speak English or may not know how to respond during an emergency. **Unique or Critical Function:** Municipal offices and service centers provide functions critical to the well-being and safety of San Francisco residents and visitors. Museums, performance halls, and historic buildings have unique cultural and economic value. Jails and juvenile detention facilities have specific design and staff requirements that cannot be replaced by other buildings. City workers are designated Disaster Service Workers and may be called upon to support emergency response and recovery efforts.
Informational	**All-hazards:** While information about municipal building systems, components, and structure does exist, it is very high-level and of limited use for hazard mitigation planning. Building structural data and building occupancy are included as inputs in the City's HAZUS analysis, and

[45] 2013-2017 American Community Survey 5-Year Estimates S1601: Language Spoken at Home
[46] 2013-2017 American Community Survey 5-Year Estimates S1810: Disability Characteristics
[47] https://www.sfdph.org/dph/files/jrp/BOS-Committee-Presentation-October-24-%202018.pdf

	the Public Utility Commission reports out information about certain components of buildings in their yearly Energy Benchmarking Reports. There is a directive to identify municipal facilities that can serve as locations of respite during poor air quality incidents.
Governance	**<u>All-hazards:</u>** The Real Estate Division is responsible for the management of municipal office buildings for General Fund Departments. Enterprise Departments have their own real estate management teams. For City departments occupying private buildings, the San Francisco Building Code regulates commercial building safety requirements. This includes soft story and masonry retrofit requirements, as well as HVAC, filtration, and fire requirements. San Francisco's Building Code also contains requirements for post-earthquake repair and retrofit of earthquake-damaged buildings. City Hall and surrounding buildings are contained in the Civic Center Historic District, and most of the Port's waterfront property is listed in the National Register of Historic Places.[48] Buildings in historic preservation districts have unique management needs and are subject to rigorous processes to make changes. New municipal buildings and major renovation projects that are 10,000 gross square feet or more are required to meet the Municipal Green Building Code, which in addition to requiring the building project to achieve a LEED Gold certification or higher, requires that an analysis be conducted to evaluate the costs and benefits of incorporating onsite batteries that store electricity from onsite solar photovoltaic systems that can be temporarily separated from the electricity grid to supply the community with electricity in the event of disaster.

Consequences

Category	Consequence
Society/Equity	**<u>All-hazards:</u>** Damage and disruption to municipal buildings impacts services provided to San Francisco residents. This is particularly impactful to residents who are resource-constrained or experience other social vulnerabilities. Persons housed at San Francisco's correctional facilities and rely on on-site services would likewise experience disproportionately strong impacts from facility disruption.

[48] https://sfport.com/historic-preservation

	Damage and disruption to municipal buildings impacts City employees' quality and timeliness of work, workplace social networks, and can even prompt short-term unemployment. This is particularly impactful to the lives of those who are non-salaried, who are low-income, and who are transportation- and housing-burdened. Museums, performance spaces, historical areas, and other buildings can provide cultural identity and their disruption could impact community identity. Tourists of these cultural areas may be limited English proficiency or have limited information available to them about emergency services. **Geologic:** Significant groundshaking and liquefaction can result in human casualties from building damage and significant property loss that would be difficult or impossible to redress. Persons with limited mobility could have difficulty evacuating. **Flood:** Significant flooding may result in human casualties if there is no second story. Populations with limited mobility or medical conditions are particularly at risk when coming into contact with even a small amount of floodwaters. **Extreme Heat:** Extreme heat may cause closures in non-weatherized buildings without cooling capabilities. Heat waves increase health risk for certain populations, such as the elderly, pregnant women, and those with medical conditions. **Fire:** Significant fire can result in human death or injury, especially in high rises. **Poor air quality:** Fire smoke in unfiltered buildings can result in increased rates of asthma attacks and other health risks. This is especially true for under-resourced communities and communities of color, which have significantly higher rates of bronchial disease.
Economy	**All-hazards:** Damages to buildings will require property owners to fund repairs, replacement, and interim facilities. Non-salaried employees face greater consequences, and will lose wages for each day of closure. Residents who rely on public assistance for their basic needs face greater consequences than the general public. City-owned

	properties that are leased to private tenants may lose sources of revenue if buildings are damaged or disrupted. **Geologic:** Depending on severity and building type, damage can lead to short- or long-term closure. **Flood:** Areas in coastal and storm water flood zones will see the most damage and economic impact. **Extreme Heat:** Depending on severity, heat events can lead to short term closure in older buildings that do not have adequate HVAC, which may be accompanied by relocation costs. Those with adequate HVAC will increase power use and see associated financial impact. This hazard will not cause permanent or indefinite closure. **Fire:** Damage from fire can lead to short to long term closure, which may be accompanied by relocation costs.
Environment	**Geologic:** Air quality could be temporarily impacted by the production of particulate matter from building damage. Reconstruction of damaged buildings may be material and energy-intensive, including emissions and air quality reduction from equipment and impacts from trucks supplying construction materials. Debris management and removal may have impacts, including truck traffic and exposure to harmful chemicals if not properly managed. **Flood:** Floods could mobilize debris and soil to move into and potentially degrade waterways. Floods could also mobilize hazardous waste that is improperly stored. **Extreme Heat:** Increased use of HVAC systems could increase GHG emissions if these are not efficient and using a clean energy source. **Fire:** Air quality would be temporarily reduced in the neighborhood, potentially regionally, if buildings are directly impacted by fire. Debris management and removal may have impacts, including truck traffic and exposure to harmful chemicals if not properly managed.

Municipal Maintenance and Operations Yards

Introduction to Asset Class

Some City departments have specialized storage and maintenance needs that require the use of municipal maintenance and operations yards. Municipal yards contain facilities necessary to sustain essential city services, including public transit and parks. This profile covers yards of the following departments:

- San Francisco Public Works (SFPW): one operations yard contains all the department's equipment and vehicle fleet
- San Francisco Municipal Transportation Agency (MTA): yards where vehicles and/or equipment are stored and/or are serviced. These include facilities for light rail vehicles, buses (electric trolley and motor coaches), cable cars, and historic streetcars
- Port of San Francisco: two maintenance facilities at Pier 50, Shed D and Pier 90
- Recreation and Park Department (RPD): two maintenance facilities in Golden Gate Park

Issue Statement

In addition to routine work, yards play an important role in disaster response. During and after an emergency, departments must work together to inspect city and private property, look for safety hazards, and clear debris. Most yards contain old buildings that are unsafe during an earthquake and unhealthy during an extreme heat or poor air quality event. Improving yards has been challenging. There is no horizontal space available for expansion and securing financing has proven difficult.

Inoperable or inefficient yards can disrupt city services. Disruptions in city services and delays in disaster response have the potential to exacerbate existing access, health, and mobility inequities.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In Table A-15, on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data originates from the Facility System of Records maintained by the Office of Resilience and Capital Planning and available through the San Francisco Open Data Portal (2018).

TABLE A-15: EXPOSURE

Hazard	SFPW 1 Total		MTA 19 Total		Port 2 Total		PUC 1 Total		RPD 4 Total	
	#	%	#	%	#	%	#	%	#	%
Geologic										
San Andreas 7.8 - Violent	0	0%	0	0%	1	50%	0	0%	2	50%
San Andreas 7.8 - Very Strong	1	100%	19	100%	1	50%	1	100%	2	50%
Hayward 7.0 - Very Strong	0	0%	3	16%	2	100%	0	0%	0	0%
Hayward 7.0 - Strong	1	100%	13	68%	2	100%	1	100%	3	75%
Liquefaction Zone	1	100%	11	58%	2	100%	0	0%	0	0%
Flooding										
100-Year Coastal Flood Zone	0	0%	0	0%	1	50%	0	0%	0	0%
100-year storm + 24 inches SLR	0	0%	3	16%	1	50%	0	0%	0	0%
100-year storm + 66 inches SLR	0	0%	7	37%	2	100%	0	0%	0	0%
100-year stormwater flood	0	0%	2	11%	1	50%	0	0%	0	0%
Wildfire										
High	0	0%	0	0%	0	0%	0	0%	0	0%
Moderate	0	0%	0	0%	0	0%	0	0%	0	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

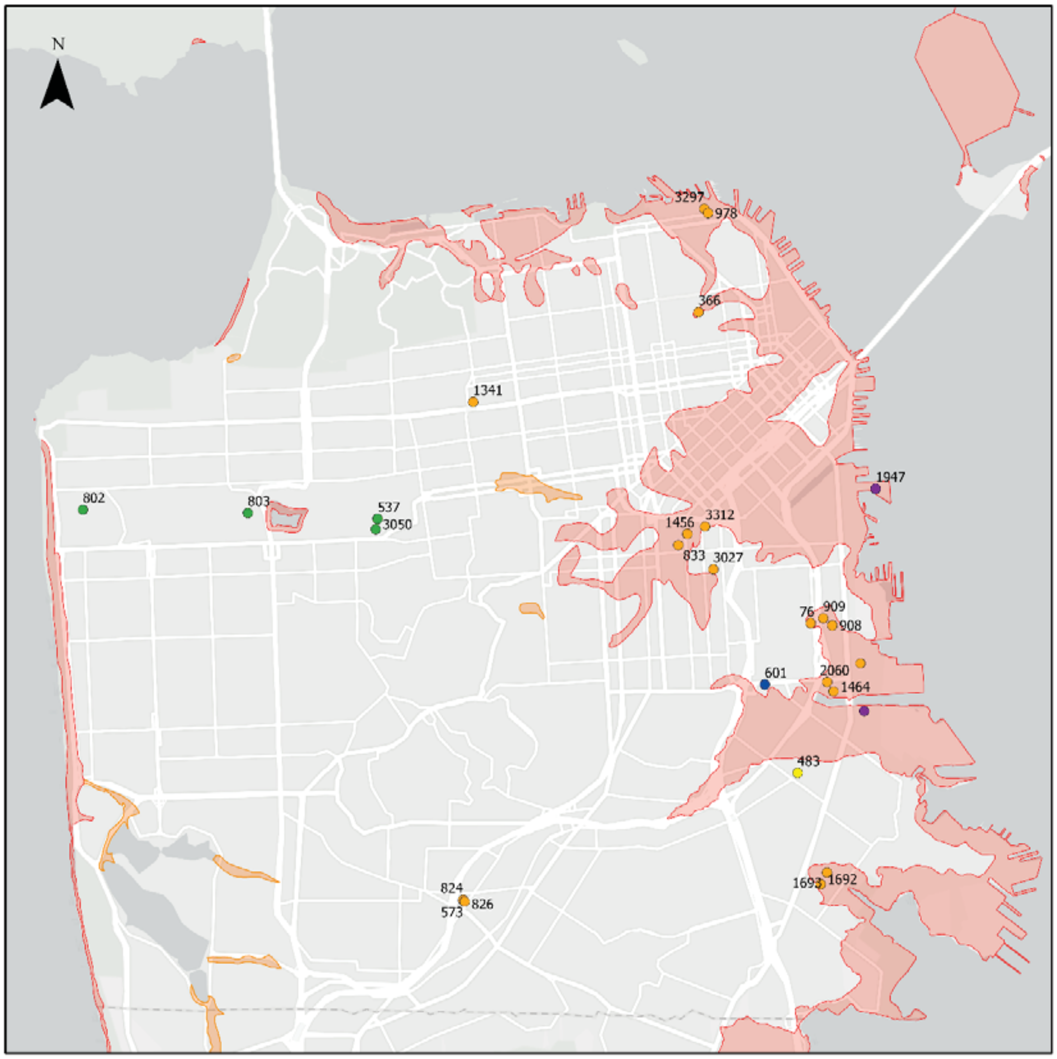
Exposure Summary

Geologic: Around 90% of municipal yards will experience Very Strong or Strong ground shaking during an M7.0 earthquake on the Hayward fault. SFPW, Port, and MTA yards are in the liquefaction zone.

Flood: Only Port and MTA yards are in any flood zone, with about 40% of MTA yards in the 66" sea level rise zone.

Fire: No municipal yards are in a wildfire risk zone.

FIGURE A-15: MUNICIPAL YARDS AND LIQUEFACTION HAZARD



0 0.5 1 2
Miles

Sources: SFDEM Data Library 2018; CGS, CALOES, 2015; City of San Francisco Facility System of Record 2018

Liquefaction Susceptibility Service and Repair Yards

Soil Liquefaction Hazard Zone

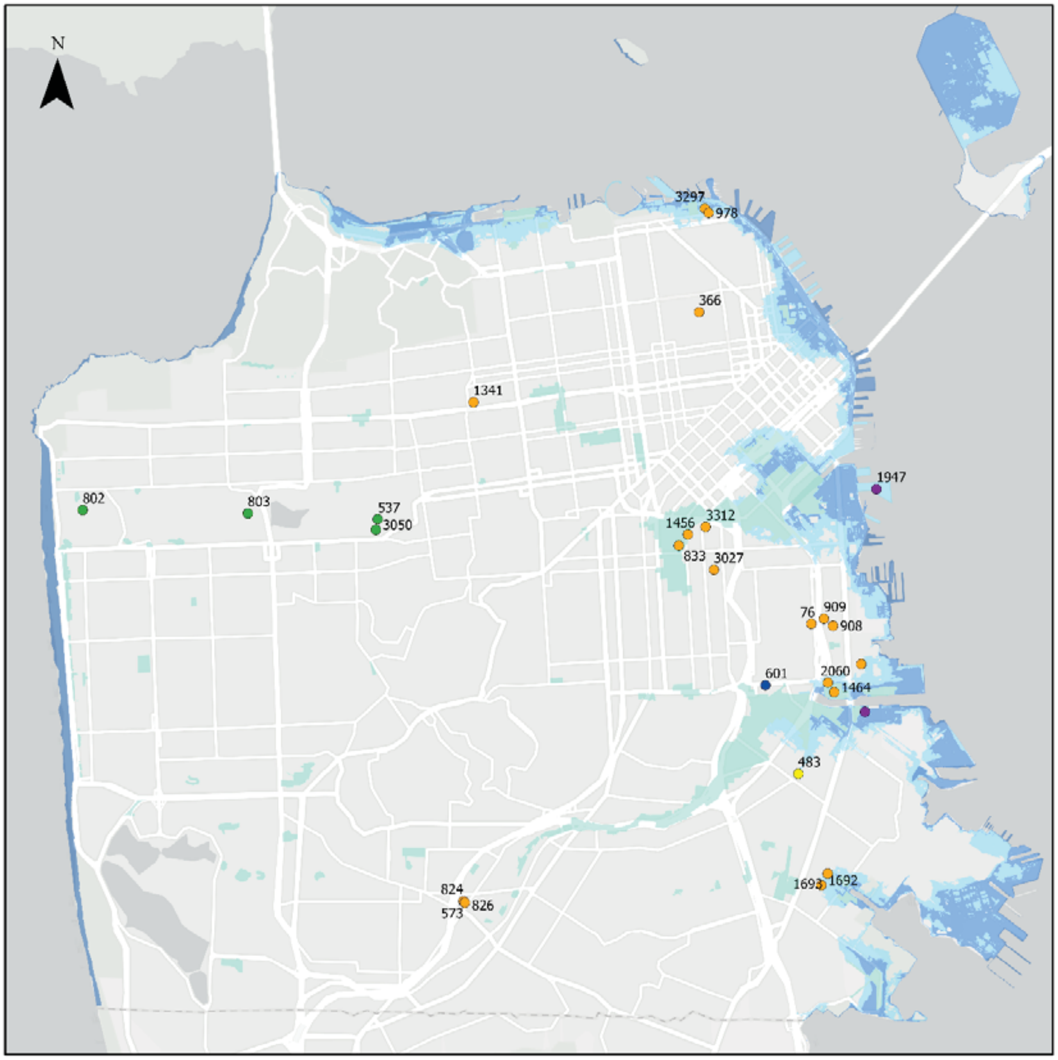
- Very High
- High

Department

- DPW
- MTA
- Port
- PUC
- RPD

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

FIGURE A-16: MUNICIPAL YARDS AND FLOOD HAZARDS



0 0.5 1 2
Miles

Flood Risk
Service and Repair Yards

Flood Hazards

- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Department

- DPW
- MTA
- Port
- PUC
- RPD

Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps; City of San Francisco Facility System of Record 2018

This map is intended for planning-level analysis and should not be used for permitting, regulatory, or other legal uses. Flooding is possible in areas outside of those displayed on this map. The risk zones are based on model outputs and relied on LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and structures, site specific conditions may not be fully represented.

VULNERABILITIES[49]

Category	Vulnerability
Physical	**Geologic:** The majority of buildings in municipal yards are un-retrofitted, and many structures were built during the 1940's and 50's. The MTA yard at Islais Creek was rebuilt in 2014, and MTA facilities at Bancroft, Burke, and Woods locations have also been retrofitted. Underground components at facilities could be damaged by liquefaction. Due to variances in topography, MTA yards at Presidio and Potrero locations were built into hills and have below-ground components. But these two facilities are not in a high liquefaction risk zone. **Flood:** Port yards at Pier 50 and Pier 90 are vulnerable to coastal flooding, and inundation of Bay waters into force main pipes affects functionality of restrooms at the piers. MTA yards at 1399 Marin and Islais currently experience flooding, and electrical exposure to flooding poses a safety hazard at these sites. RPD yards do have equipment on the ground, but are not located in areas with flood risk. **Extreme Heat:** Many buildings in municipal yards are open air, with no climate control. Many closed buildings take the form of garages, which may have overhead heaters but no cooling. Buildings at the SFPW yard do have central air conditioning but need upgrades. Facilities may not have capacity for temporary cooling equipment such as portable coolers. **Fire:** Many buildings are open air, or simple shed-like structures without filtration. Some facilities have HVAC systems are substandard or not operational and financing is not available to make improvements. In the SFPW buildings which do have filtration, air circulation was a problem during high smoke days in Fall 2018. Facilities may not have capacity for temporary equipment such as air scrubbers. Most RPD facilities are wood and therefore highly flammable, although not located in areas with wildland-urban interface fire risk. Sprinkler systems help mitigate fire risk.
Functional	**Networks:** Yards are formally linked during disaster response through Incident Command System (ICS). Debris clearance equipment is located at SFPW, RPD, PUC, and the Port. At other times, yards support each other's operations in ad hoc and informal ways. Services provided at yards are not redundant; if one yard becomes inoperable, the services

[49] Information collected during meeting with staff from SFPW, RPD, Port, MTA on February 6, 2019

	cannot be replicated at another yard. SFPW yard is currently over capacity, and MTA yards cannot move due to lack of space in the city to accommodate transit vehicle storage. Citywide, there is no room for horizontal growth. **External Services:** Yards rely on electrical power, water, sewage, internet, fuel, and some gas. Electricity is particularly critical for MTA functions. RPD vehicles require fuel, which are co-located at its central gas station in Golden Gate Park. Not all yards have emergency backup power. Two MTA motor coach facilities have backup power, and all motor coach facilities have underground storage tanks for fuel. However, the duration of the fuel supply is currently unknown.[50] The only RPD emergency backup power is located at its Department Operations Center (DOC). The Port's entire facility has backup generator power. Staff rely on regional transportation, as many workers at municipal yards live outside city limits. **Populations Served:** Municipal maintenance and operations yards sustain San Francisco's public transit, roads, and open spaces, which serve the city's diverse populations. Some sub-populations would be more impacted by a disruption in services (e.g. low-income and mobility challenged individuals are especially dependent on public transportation). City staff working at municipal yards may face greater risks to hazard events as many positions require outdoor labor. **Unique or Critical Function:** Yards play essential roles in City emergency response. After the Police and Fire Departments, SFPW is third in line for response following a disaster event. SFPW has a responsibility for road clearance and structure assessment. The SFPW yard becomes a DOC, and other departments follow ICS protocols to support SFPW's operations. RPD operates its own DOC. SFPW logistics requests are submitted to the citywide Emergency Operations Center (EOC), which forwards these logistic requests to the RPD DOC for support. Crews inspect for damaged overhead lines, which pose immediate safety hazard. All SFPW vehicles are in one location, and satellite yards could help improve response. Most of DPW vehicle fleet is Priuses, which are low to the ground and will be difficult to drive on streets with debris. SFPW fleet does not include bulldozers and will rely on contractors to complete debris removal.[51] MTA fleet vehicles are used in inspection, and yards must be accessible for the fleet to be

[50] Interviews with MTA staff for the Lifelines Restoration Performance Project, October 9, 2018
[51] Interviews with SFPW staff for the Lifelines Restoration Performance Project, August 23, 2018

	deployed. Before the Port supports citywide operations, it conducts its own facility inspection with staff engineers.
Informational	**All-hazards:** Historically, information collected for MTA yards is based on service requests, but the department plans to shift to a more proactive approach over the next few years. To meet Federal Transit Administration Transit Asset Management compliance, MTA completes a 10-year asset management plan that contains condition assessment on all yards and replacement costs. SFPW recently changed their work order program so that outstanding tasks are stored with an estimated cost, for use in funding requests in the Capital Plan. RPD has completed a conditions assessment for use in preventative maintenance planning, containing indices on all facilities to monitor when replacements are needed. Port uses the citywide capital management tool for work orders and management.
Governance	**All-hazards:** Very few city policies exist to prompt repairs and improvement. Financing repairs and improvements is also a challenge. SFPW has made requests in the Capital Plan to improve its yard improvements—which needs a major renovation. MTA resilience improvements occur when other major capital work must be conducted at a facility, and there is no specific fund to do this. The Port received Homeland Security funding to establish backup generator power for its entire facility. **Flood:** MTA uses SLR capital planning checklist when designing or upgrading a facility. MTA is the lead department in implementing transportation strategies to reduce citywide greenhouse gas emissions[52] and is conducting an assessment on sea level rise vulnerabilities and consequences.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Disruptions to roads and public transit operations impact residents and visitors to San Francisco, and have the potential to exacerbate existing access/mobility inequities. Disruptions to park maintenance is most detrimental in RPD-designated equity zones where park access is limited, and for residents without private outdoor space and/or air-conditioning.

[52] https://www.sfmta.com/sites/default/files/reports-and-documents/2017/12/cap_draft_full_document-final1.pdf

	Geologic: Un-retrofitted structures at yards are dangerous for onsite workers. **Flood:** Floodwater contact with electrical components is dangerous for onsite workers. **Extreme Heat:** Absent cooling systems at municipal yards will increase health risks for onsite workers during extreme heat events. Outdoor workers will be particularly vulnerable. **Fire:** Absent filtration systems at municipal yards will increase health risks for onsite workers during poor air quality events. Outdoor workers will be particularly vulnerable.
Economy	**All-hazards:** Damages to facilities will require funding repairs, replacement, and/or interim alternatives. If yard damage leads to service disruption, economic impacts would disproportionately impact communities who rely on transit for mobility. If the transit system is impacted, MTA could lose substantial funds from missing fares. Non-salaried employees face greater consequences, and will lose wages for each day of closure.
Environment	**All-hazards:** Disruptions to transit service may cause an increase in private vehicle use and greenhouse gas emissions. Road closures and re-routing may increase traffic and congestion. **Geologic:** Air quality could be temporarily impacted by the production of particulate matter from structure damage. **Flood:** Floods could mobilize debris, soil, or wastewater to move into and potentially degrade waterways. Floods could also mobilize hazardous waste that is improperly stored, including leaking underground storage tanks. **Extreme Heat:** Increased use of cooling systems could increase GHG emissions if not efficient and using a clean energy source. **Air Quality:**

	Air quality could be temporarily reduced in the neighborhood, potentially regionally, if structures are directly impacted by fire.

Health Care Facilities

Introduction to Asset Class

Health care facilities provide life-saving and life-sustaining services. All health care facilities are important resources for disaster response. For the purpose of this assessment, the 'Health Care Facilities' asset class is defined as any of the following medical or nonmedical use facilities.

- **Primary Care Clinics**, or community and free clinics/sites, offer a range of primary care services to uninsured and underinsured populations. The majority of primary care clinics in California are operated by public agencies, including public hospitals and health systems, health care districts, or nonprofit corporations. Primary care clinics operate in a wide variety of building types, including as part of a large hospital or school campus, or as a multi-story commercial building. There are 64 primary care clinics in San Francisco, which predominantly located in the city's northeast and southeast quadrants, mirroring population density.
- **Skilled-Nursing Facilities** provide supportive medical care on an extended basis.46 In San Francisco, skilled nursing facilities vary by both building type, neighborhood location, and size. Standalone skilled nursing facilities can range from 30 to 180 beds and operate in both high density and low-density neighborhoods. Skilled nursing facilities may be on the same campus as a Residential Care Facility for the Elderly (RCFE). There are 15 standalone skilled nursing facilities in San Francisco, and facilities at San Francisco General, CPMC, and the Veteran's Administration Community Living Center.
- **Pharmacies** are defined by the California State Board of Pharmacies as a licensed place where "controlled substances, dangerous drugs, or dangerous devices are stored, possessed, prepared, manufactured, derived, compounded, or repackaged, and from which the controlled substances, dangerous drugs, or dangerous devices are furnished, sold, or dispensed at retail".[53] According to the Department of Consumer Affairs, there are 201 pharmacies in San Francisco. Pharmacies operate as both part of larger hospital complexes, as the first floor of a commercial building, or as a standalone building. Pharmacies provide medicine that can reduce morbidity and mortality in the aftermath of disaster events. Pharmacies are required to have a detailed plan for disasters and other disruption of normal business operations.[3]

[53] California State Board of Pharmacy Business and Professions Code 4015

- **Residential Care Facilities for the Elderly (RCFEs)** are non-medical facilities that offer important supportive residential living for individuals age 60 and over who are no longer able to live safely independently. They provide room, meals, housekeeping, supervision, storage and distribution of medication, and personal care assistance with basic activities like hygiene, dressing, eating, bathing and moving. There are 64 RCFEs in San Francisco, and 4 RCFEs as continuing care at retirement communities. These facilities may be adjacent to skilled nursing facilities and vary by both building type and size. Many RCFEs are single family homes in primarily residential neighborhoods with fewer residents, while other RCFEs are in larger complexes with many beds and employees. While not technically a medical facility, RCFE house very vulnerable older adults.
- **End Stage Renal Disease (ESRD)** facilities, or dialysis facilities, are "a free-standing specialty clinics, which provides less than 24-hour care for the treatment of patients with ESRD."[54] The free-standing component of California's definition makes it more restrictive than the federal definition, which includes hospital-based dialysis".[55] These facilities part of a larger hospital, in a larger commercial building or office complex, or a standalone facility. There are 14 dialysis clinics in San Francisco.

Note that there are several other types of health care facilities that operate in San Francscico, including an array of behavioral health specific service sites. These sites have similar attributes to facilties outlined above, provide services to similar populations, and have similar distributions across the city.

Issue Statement

Health care facilities provide vulnerable populations with life-saving and life-sustaining services. All health care facilities have important roles in disaster response and recovery. For example, primary care clinics can scale to provide urgent care services in an event with a significant medical surge, while skilled nursing facilities and residential care facilities may be tasked with administering services during shelter-in-place events. The continuity of these services is important, and any disruption to health facilities would

[54] CA Health and Safety Code (HCS). Division 2: LICENSING PROVISIONS; CHAPTER 1. Clinics; ARTICLE 1. Definitions and General Provisions

[55] "A Review of Regulatory Standards, Quality of Care Concerns, and Oversight of Ambulatory Surgery Clinics, Comprehensive Outpatient Rehabilitation Facilities, and End-State Reginal Disease Facilities" California Department of Public Health, June 2017. https://www.cdph.ca.gov/Programs/CHCQ/LCP/Pages/ReviewofRegulatoryStandards.aspx

strain the services they provide and disproportionately impact populations without access to alternate forms of care or who are unable to travel to an alternate facility. Exposure to groundshaking from the Hayward fault affects 90% of the city's clinics, skilled nursing facilities, and dialysis facilities, and the entire city of San Francisco is exposed to groundshaking from the San Andreas Fault. Skilled nursing facilities and residential care facilities provide 24/7 residential and medical care for vulnerable populations. Any disruption to these facilities from a hazard would require evacuation and additional medical and housing resources.

TABLE A-16: EXPOSURE

Hazard	Clinics 97 Total		Skilled Nursing Facilities 18 Total		Pharmacies 201 Total		RCFEs 63 Total		Dialysis Facilities 14 Total	
	#	%	#	%	#	%	#	%	#	%
Geologic										
San Andreas 7.8 - Violent	12	12%	2	11%	25	12%	28	42%	1	7%
San Andreas 7.8 - Very Strong	85	88%	16	89%	176	88%	38	57%	13	93%
Hayward 7.0 - Very Strong	3	3%	0	0%	12	6%	0	0%	0	0%
Hayward 7.0 - Strong	84	87%	16	89%	153	76%	45	67%	13	93%
Liquefaction Zone	23	24%	0	0%	50	25%	1	1%	1	7%
Flooding										
100-Year Coastal Flood Zone	0	0%	0	0%	0	0%	0	0%	0	0%
100-year storm + 24 inches SLR	2	2%	0	0%	7	3%	0	0%	0	0%
100-year storm + 66 inches SLR	2	2%	0	0%	11	5%	0	0%	1	7%
100-year stormwater flood	2	2%	0	0%	5	2%	0	0%	0	0%
Wildfire										
High	0	0%	0	0%	0	0%	0	0%	0	0%
Moderate	1	1%	1	6%	0	0%	0	0%	0	0%

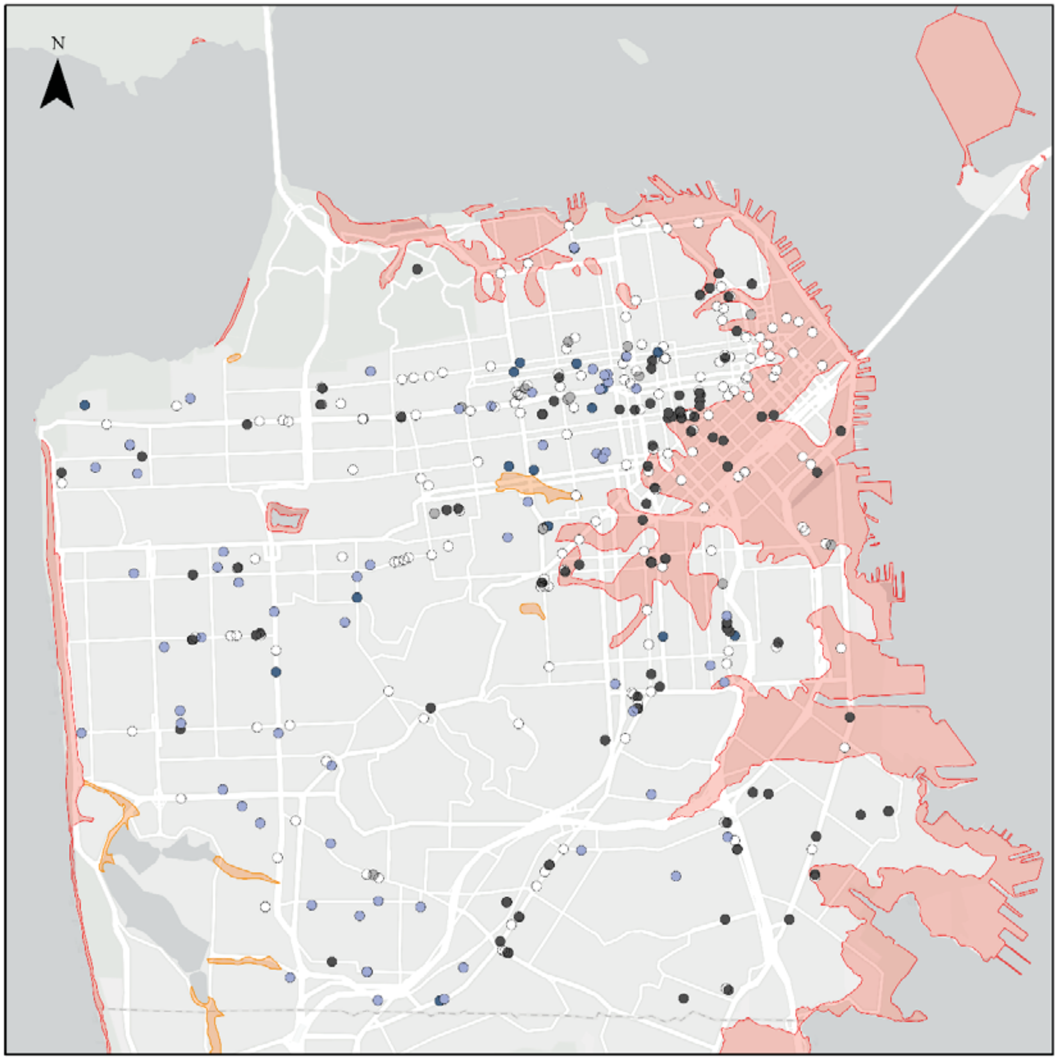
Exposure Summary

Geologic: All health care facilities would be exposed to violent or very strong shaking during a 7.8 earthquake on the San Andreas fault. Around 90% of the city's clinics, skilled nursing facilities, and dialysis facilities would be exposed to very strong or strong shaking during a 7.0 earthquake on the Hayward fault. Liquefaction exposure is lower than groundshaking, around one quarter of the city's clinics and pharmacies are in the liquefaction zone; other health care facilities have minimal liquefaction risk.

Flood: Eleven pharmacies, two clinics, and one dialysis clinic are in the 66" sea level rise zone. Five pharmacies and two clinics are in the 100 year stormwater zone. Altogether, only around 5% of all health care facilities are in any flood zone.

Fire: One clinic and one skilled nursing facility have moderate wildfire risk.

FIGURE A-17: HEALTH CARE FACILITIES AND LIQUEFACTION HAZARD



0 0.5 1 2
Miles

Sources: SFDEM Data Library 2018; CGS, CALOES, 2015; OSHPD, CHHS, SF Health Network, Veterans Affairs, DCA compiled by SFDEM 2018

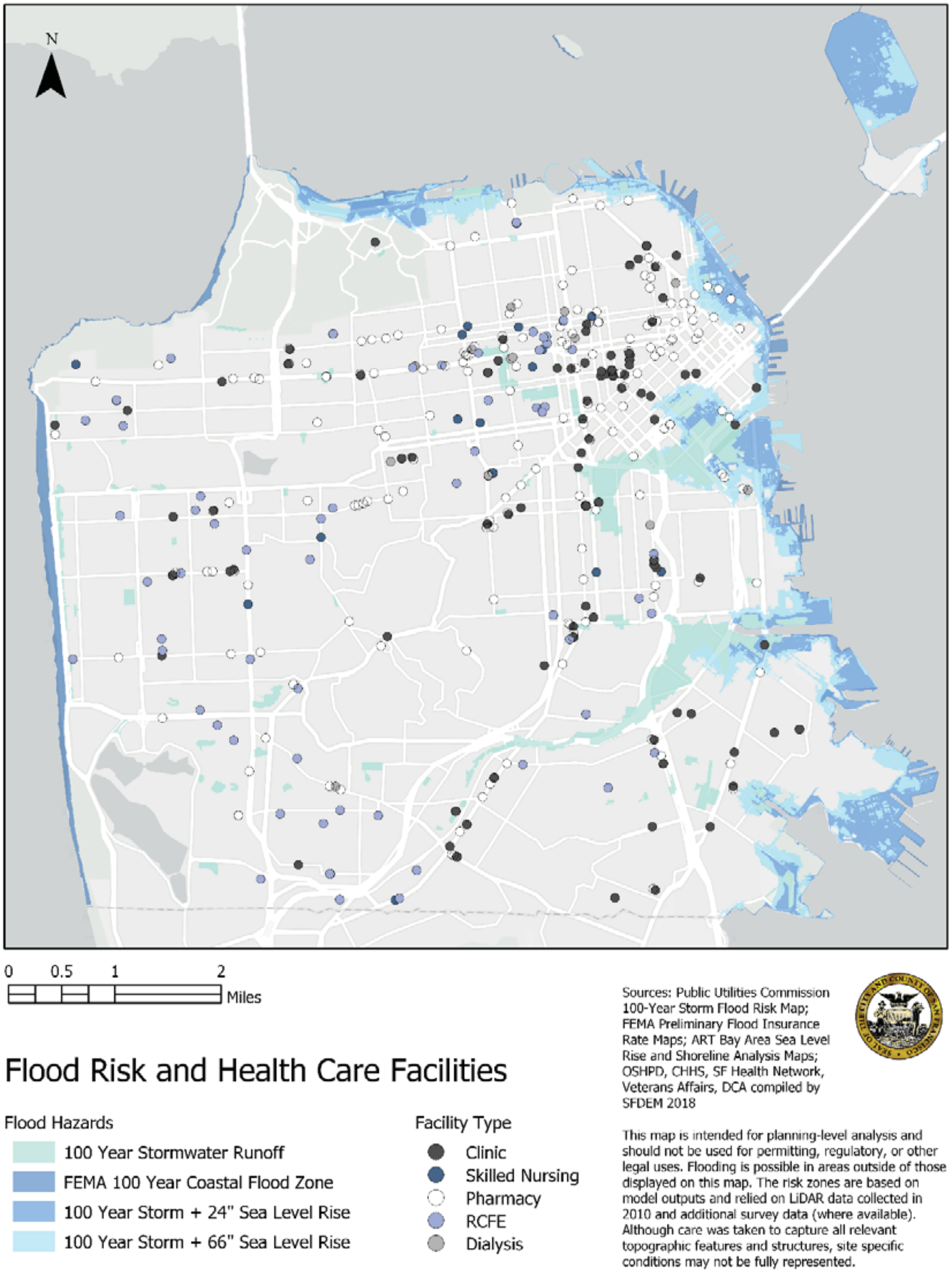
Liquefaction Susceptibility
Health Care Facilities

Soil Liquefaction Hazard Zone
- Very High
- High

Facility Type
- Clinic
- Skilled Nursing
- Pharmacy
- RCFE
- Dialysis

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

FIGURE A-18: HEALTH CARE FACILITIES AND FLOOD HAZARDS



VULNERABILITIES

Category	Vulnerabilities
Physical	**All Hazards:** The diversity of health care facilities creates a wide variety of physical vulnerabilities dependent on the building type, density, equipment stored in the building, and the specific regulations of the body that governs it. **Geologic:** There is significant overlap in the physical attributes between health care facilities and residential and commercial buildings. Please refer to the Housing and Commercial Vulnerability and Consequence Profiles for details for seismic vulnerability. Of note, skilled nursing facilities and RCFEs are not required to meet the same safety seismic standards as hospitals as outlined in California SB 1953.[56] **Flood:** Depending on building design, facilities may be vulnerable to flood events. Facilities either located at or below grade or with equipment stored on the ground floor adjacent to entryways may be impacted by flood events and experience building damage, destruction of equipment or other materials, or disruption of power and other utility services. **Extreme Heat:** Depending on building age and structural design, the facility may have limited or substandard cooling systems. These cooling systems may not be sufficient during extreme heat events and residents most vulnerable to the health impacts of extreme heat may be at increased risk of morbidity and mortality. **Fire:** Buildings made with wood are highly susceptible to fire. Steel and concrete buildings are less vulnerable to fire damage and steel buildings contain fire proofing materials to resist fire damage.
Functional	**Networks:** Primary care facilities are indirectly and directly networked (e.g. San Francisco Health Network, DPH Healthcare Coalition, Community Clinic Consortium). If a primary care were to shut down, it may impact patient access to other facilities (e.g. longer wait times for appointments), as they become the health home for more patients.

[56] Office of Statewide Health and Planning Department (OSHPD)

	Any disruption to skilled nursing facilities, RCFEs, or ESRDs would necessitate the relocation of vulnerable patients to other available facilities. **External Services:** All health care facilities rely on power, natural gas, water, communications, and transportation access to function. Primary care facilities are likely to have some backup power. Because skilled nursing facilities and RCFEs house populations are likely to have access and functional needs, access to medical equipment and adequate transportation are especially important in hazard events. RCFEs are required to plan for self-reliance for up to 72 hours. Pharmacies depend on temperature control for certain medications. **Populations Served:** Health care facilities provide public life-sustaining services. Primary care facilities serve all San Franciscans regardless of citizenship or the ability to pay. Skilled nursing facilities and RCFEs house populations with access and functional needs, including those with pre-existing health conditions, medically dependent and mobility challenged individuals, and elderly populations. ESRDs serve populations with end stage renal disease. **Unique or Critical Function:** **Primary Care:** These facilities will respond to the medical surge immediately post hazard event and are located in neighborhoods with limited access to other urgent health care services. **Skilled Nursing Facilities and RCFEs**: These facilities provide a unique and critical service by providing 24/7 residential care and in the case of Skilled Nursing Facilities – medical care for vulnerable populations. These facilities need to ensure quality of care in emergency events. **Pharmacies**: These facilities provide life-sustaining medications for residents across the city. **ESRDs**: For patients with end stage renal disease and on dialysis, ESRDs are critical life-sustaining services. Patients must visit ESRDs multiple times a week and any disruption in service would require patients to find alternative services.
Informational	**Primary Care and Skilled Nursing Facilities:** All primary care clinics and skilled nursing facilities are required to submit data on health care financing and utilization to Office of Statewide Health Planning and Development (OSHPD) on an annual basis. This information is publicly available for each facility.

	Pharmacy: Pharmacy facilities must obtain a license through the California Board of Pharmacy. Contact information for all licensed facilities is publicly available online. **RCFEs**: Data on RCFEs are collected by the California Department of Social Services and includes contact information, capacity, and inspections and citations.
Governance	**Primary Care:** The OSHPD regulates structural development primary care clinics. The California Department of Public Health regulates the operation of community clinics and free clinics. **Skilled Nursing Facilities:** OSHPD regulates structural development of skilled nursing facilities. The California Department of Public Health (CDPH), Health and Human Services (HHS), and Centers for Medicare and Medicaid Services (CMS) regulates emergency preparedness in skilled nursing facilities. These facilities are required to have an emergency plan based on an established risk assessment that addresses the special needs of client populations.[57] **RCFE:** In 2008, California passed AB 479, which addressed emergency preparedness in RCFEs and added a section to the California Health and Safety Code that mandates RCFEs have evacuation procedures, plans for the community to be self-reliant for at least 72 hours, an emergency transportation plan, emergency power, a communication plan, an emergency plan for the storage of medications, and an emergency plan for electronically dependent populations.[58] **Pharmacies:** Pharmacies are regulated by the California State Board of Pharmacy. The California State Board of Pharmacy and the California Business and Professions Code adopted a policy to "encourage and permit emergency provision of care to affected patients and areas by waiver of requirements that it may be implausible to meet under these circumstances, such as prescription requirements, record-keeping requirements, labeling requirements, employee ratio requirements, consultation requirements, or other standard pharmacy practices and duties that may interfere with the most efficient response to those affected."[59]

[57] CMS Code of Federal Regulations https://www.cdph.ca.gov/Programs/CHCQ/LCP/Pages/EPRR.aspx#
[58] California Assembly Bill 479
https://leginfo.legislature.ca.gov/faces/billCompareClient.xhtml?bill_id=201720180AB3098
[59] Disaster Response Policy Statement, California Board of Pharmacy
http://www.pharmacy.ca.gov/publications/disaster_policy.pdf

	ESRDs: ESRDs are regulated by the Centers for Medicare and Medicaid Services (CMS). These regulations require that ESRDs develop emergency preparedness procedures and review these procedures annually.[60]

CONSEQUENCES

Category	Consequence
Society/Equity	**All Hazards:** Any significant impact to health care facilities will have cascading impacts on society and equity and the populations served by these facilities. These impacts could be as significant as loss of life as health care facilities often serve some of San Francisco's most vulnerable populations. **Primary Care:** Any disruption to primary care clinics would have inequitable impacts as it would most severely affect populations without access to alternative sources of health care. Residents that live far away from transit corridors and are served by neighborhood primary care clinics may have difficulty accessing a different clinic. **Skilled Nursing Facilities and RCFEs:** Any significant structural damage that disrupts these facilities would have significant impacts. Damage to skilled nursing facilities and RCFEs would mandate permanent relocation of many vulnerable residents. Residents without other support systems may have a difficult time finding the same level of care. **Pharmacies:** Any disruption in services would have inequitable impacts for populations with access or functional needs or without access to transportation, who would have more difficulty obtaining medications. **ESRDs:** Geographic distribution of ESRD incidence indicates that social determinants influence which populations suffer from ESRD.[61] In San Francisco, the underlying causes of renal disease, like Type 2 Diabetes and High Blood Pressure, disproportionately impact low-income communities, and communities of color.[62] Data indicates that these communities are therefore more likely to have higher incidences of ESRDs. Any impact to dialysis facilities would increase this unequal health burden. Populations without adequate medical

[60] Centers for Medicare and Medicaid Services https://www.cms.gov/Regulations-and-Guidance/Legislation/CFCsAndCoPs/ESRD.html
[61] Nicholas SB, Kalantar-Zadeh K, Norris KC. Socioeconomic disparities in chronic kidney disease. *Adv Chronic Kidney Dis.* 2015;22(1):6-15.
[62] San Francisco Health Improvement Partnership. "San Francisco Community Health Needs Assessment 2016: Appendices." San Francisco, CA: San Francisco Department of Public Health, 2016.

	care or alternative resources would be especially impacted by any disruption in dialysis services. **Geologic:** Seismic impacts are more widespread and can result in more permanent health, society, and equity impacts. Any significant structural damage that results in the permanent disruption of service by health care facilities would have significant impacts. **Flood:** Flood impacts would be geographically limited, but could impact society and equity if there were significant disruption of transportation, power, or health care services. **Extreme Heat:** The health impacts of extreme heat is influenced by social determinants. Populations most vulnerable to extreme heat events include elderly populations and patients with renal disease. These populations rely heavily on healthcare facilities. **Fire:** Fire could disproportionately burden residents in residential care facilities with access or functional needs who need assistance in evacuations.
Economy	**All Hazards:** **All Types:** Medical facilities are employment centers and any impact could affect economic activity. There may be economic costs associated with any building repairs or replacement of damaged or destroyed equipment or supplies. **Primary Care:** Depending on the severity of the event, and subsequent disruption to primary care clinics, economic impacts could demand the immediate expenditure of resources to relocate patients and medical supplies. **Skilled Nursing Facilities and RCFEs:** Depending on the severity of the hazard, impacts could include displacement from skilled nursing facilities or RCFEs. Reduction in the number of available beds in these facilities could increase cost and price new tenants out of the market. Beds in these facilities are already in high demand. **ESRDs:** Depending on the severity of the hazard, there could be economic costs for patients forced to find new ways to receive treatment. There could also be economic costs for the facilities from building repairs or damaged or destroyed medical equipment. **Geologic:**

	Geologic impacts are more widespread and can result in more significant economic impacts. **Flood:** Although flood impacts are geographically limited in scope, any water damaged equipment or medicine would have to be replaced. In a power outage, pharmacies must have backup power to refrigerate medicine that must be chilled. **Extreme Heat:** Although an extreme heat event would not cause significant structural damage, it could increase power and utility costs. If a residential facility is not prepared for an extreme heat event, relocation of residents may be necessary at additional costs. **Fire:** If smoke from a fire impacts vulnerable residents at a residential facility, relocation of residents may accrue additional costs.
Environment	**All Hazards**: Many health facilities store hazardous materials that may be released in an earthquake, flood, or fire event.

Food Distribution

Introduction to Asset Class

Food distribution assets include wholesale suppliers, grocery stores, and charitable food distribution. Wholesale food distribution companies provide fresh and processed food products to grocery stores and restaurants that serve local communities. Charitable food distribution centers serve a number of functions. Many centers offer hot and cold meals on site, while others act as a food pantry site. Both provide meals and groceries for those who are low income, elderly, disabled, and/or critically ill. Many organizations provide food delivery services that additionally offer wellness checks and referrals specifically for the elderly and critically ill. The SF-Marin Food Bank is a critical networked distribution asset for these charitable organizations, supplying food to nearly 400 non-profit partners, including 278 local food pantries.[63]

Grocery stores and corner stores are spread widely throughout the city, though the Bayview Hunters Point area was designated by the USDA as a food desert in 2011[64], and continues to have few high quality grocery options. Wholesale distributions centers and the SF-Marin Food Bank are largely located in the industrial sections of the southeast quadrant of the city. The Real Estate Division owns the property for the San Francisco Wholesale Produce Market as well as several wholesale produce market buildings and facilities in Bayview Hunters Point and Bernal Heights areas. Many other food distributors have clustered near that facility.

Food distribution centers have a variety of build forms. Corner stores are small commercial storefronts while grocery stores are typically large commercial buildings that rely on temperature control and loading infrastructure for trucks. Wholesale suppliers are housed in industrial warehouses and similarly rely on temperature control and loading infrastructure. Farmers markets are open air temporary marketplaces. The SF-Marin Food Bank has a large modern warehouse in the Potrero Hill neighborhood that services City of SF. Centers that provide full meal services are larger buildings with commercial kitchens and large areas for dining. Other food distribution centers have a variety of built forms that are not consistent across this asset class. Centers vary in property ownership status, but typically manage their own facilities.

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[63] "Community Partners," SF-Marin Food Bank, 2018, https://www.sfmfoodbank.org/programs/community-partners/.
[64] "Food Access Research – Go to the Atlas," United States Department of Agriculture Economic Research Service, 2017, https://www.ers.usda.gov/data-products/food-access-research-atlas/go-to-the-atlas/.

Issue Statement

Food distribution centers are critical, life sustaining resources for all community members. Charitable food distribution centers are especially important for highly vulnerable populations. While city regulations require that certain building types are retrofitted, there continue to be numerous types of built forms that are vulnerable in a Geologic event and it is unclear how many of these are food distribution centers. Access to power supply is important for centers to keep their perishable food supply fresh and safe to eat. It is unclear how many centers have contingency plans for power outages that can be caused by geologic, storm, and heat events. Transportation access is another point of vulnerability for food distribution centers. Losing transportation roadways or vehicles due to geologic, flood, or fire can have detrimental impacts to food supply, especially those who rely on mobile food deliveries. In emergency scenarios, detailed contingency food supply plans are enacted by the Department of Emergency Management in partnership with a number of charitable food distribution centers.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In Table A-17, on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data is originates from the Dunn and Bradstreet (2017) dataset obtained from SFGIS.

TABLE A-17: EXPOSURE

Hazard	Grocery Stores 761 Total		Wholesale Merchants 101 Total	
	#	%	#	%
Geologic				
San Andreas 7.8 - Violent	113	15%	9	9%
San Andreas 7.8 - Very Strong	648	85%	92	91%
Hayward 7.0 - Very Strong	51	7%	52	51%
Hayward 7.0 - Strong	613	81%	45	45%
Liquefaction Zone	196	26%	68	67%
Flooding				
100-Year Coastal Flood Zone	10	1%	20	20%
100-year storm + 24 inches SLR	26	3%	26	26%
100-year storm + 66 inches SLR	43	6%	50	50%
100-year stormwater flood	24	3%	8	8%
Wildfire				
High	0	0%	0	0%
Moderate	4	1%	0	0%

Note: For an exposure table with additional hazards, please see Appendix X.

Exposure Summary

Geologic: All food distribution assets are at risk of either Violent or Very Strong groundshaking during a M7.8 earthquake along the San Andreas Fault. 90% of both grocery stores and wholesale merchants are at risk of Very Strong or Strong groundshaking during a Hayward M7.0 earthquake. Two thirds of the city's wholesale merchants are in either Very High or High liquefaction zones. Chinatown, Mission, and South of Market neighborhoods have several grocery stores in liquefaction zones.

Flood: Wholesale merchants experience greater exposure than grocery stores to flood zones, particularly coastal flooding, with many located along the waterfront. A quarter of the city's wholesale merchants are within the 24" sea level rise zone, and half within 66" sea level rise.

Fire: Food distribution has low exposure, with virtually no assets in the wildland-urban risk zones

FIGURE A-20: FOOD DISTRIBUTION AND LIQUEFACTION HAZARD

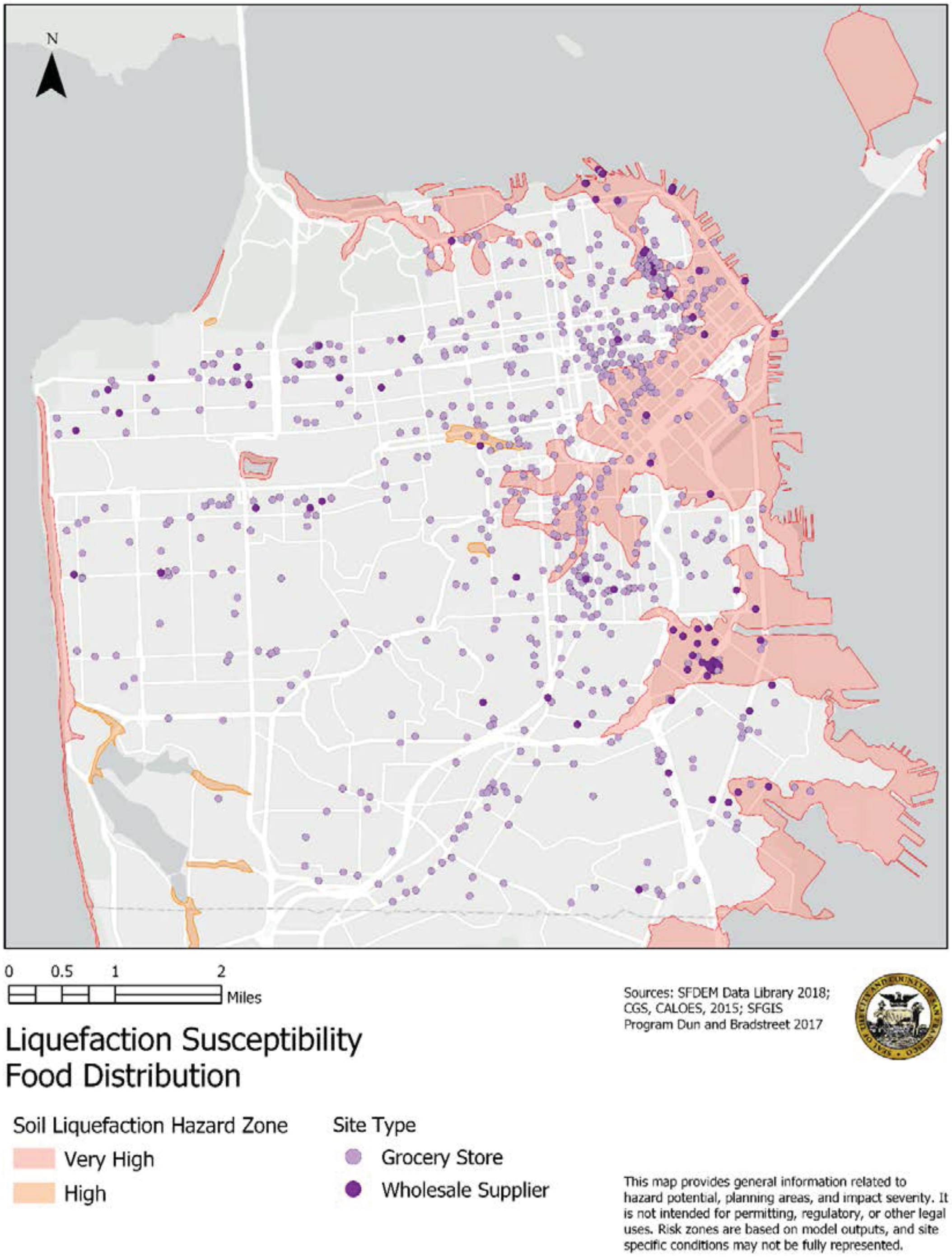
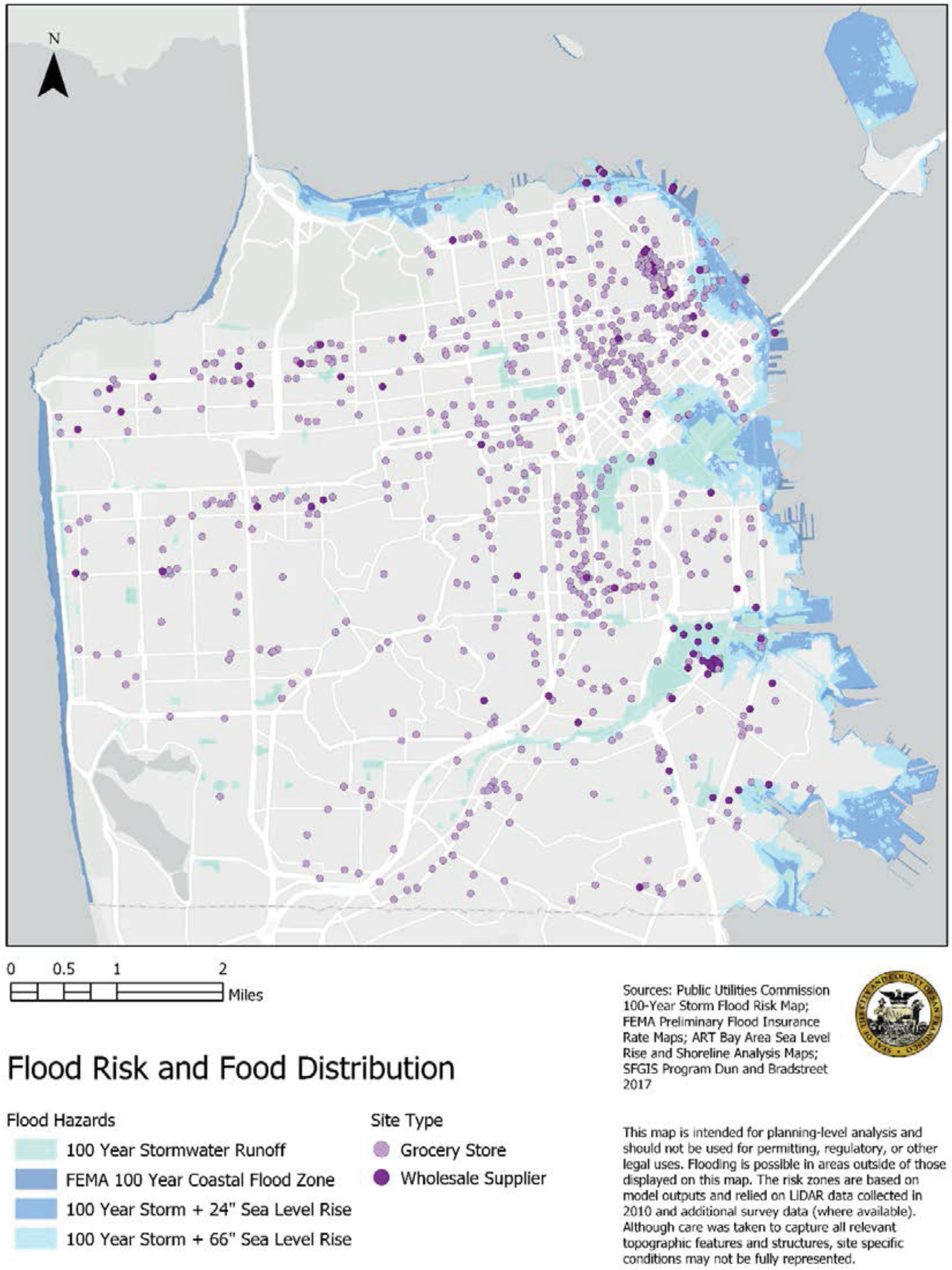


FIGURE A-21: FOOD DISTRIBUTION AND FLOOD HAZARDS



VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Pre-1978 soft story buildings are vulnerable to extensive damage. This impacts centers that are housed in store fronts underneath multi-unit residential buildings. Regulation requires these buildings (with 5+ units, and with 2+ stories over a soft story) to be retrofitted by 2020. Unreinforced masonry buildings that have not been retrofitted are more vulnerable to damage. Regulation required non-residential buildings (<5 units) to be retrofitted by 2006, so these should be rare. Pre-1995 tilt-up industrial buildings and pre-1980 non-ductile concrete frame buildings are vulnerable to extensive damage. Which building types are prevalent among food distribution centers is not readily available. Many older and legacy food distribution businesses are in buildings that are not very resilient (e.g. out of date and leaky refrigeration systems, few upgrades over time, inefficient energy/water use). The San Francisco Wholesale Produce Market and the nearby cluster of food distribution related business are located in an area that is susceptible to liquefaction in an earthquake as well as flooding. **Flood:** Flooding above the finished floor causes damage to the building materials and contents. Distribution centers may experience structural or nonstructural building damage, and impairment or destruction of utility service equipment. **Extreme Heat:** The building itself would have low vulnerability to heat. In non-weatherized buildings without cooling capabilities (e.g. air conditioning), services could shut down during high heat events. High heat events can cause power outages, which could spoil refrigerated food products. Many older and legacy food distribution businesses are in buildings that are not very resilient (e.g. out of date and leaky refrigeration systems, few upgrades over time, inefficient energy/water use). These facilities likely struggle during extreme heat days. **Fire:** Food distribution buildings may be more or less vulnerable to fire due to exposure based on proximity to hazard areas/zones. Buildings with metal frames are especially vulnerable to building collapse in the event of fire. Reduced air quality due to fire smoke causes increased

	health risks for employees and customers in buildings that do not have proper air filtration.
Functional	**<u>Networks:</u>** Grocery stores are not directly networked to each other, but damaged grocery stores can lead strained functioning of other nearby grocery stores, which may not have resources needed to meet extra demand. In an emergency event, grocery stores are hit hard and food shortages are possible. Damage to wholesale suppliers can exacerbate food shortages. The SF-Marin Food Bank is a food supplier to nearly 400 non-profit partners, including 278 local food pantries.[65] This building appears to be recently built and is not a seismically vulnerable commercial building type. It is outside of the 100 year flood plain. Most charitable food distribution centers are not networked with each other. However, if a building is too damaged to be used, the users of the center may redistribute to other centers while the building is repaired. This may strain functionality of these services. While impacts on the emergency/charitable food network are critical, longer-term impacts on the overall food distribution supply and networks are important since everyone (food banks included) relies on these facilities. In an emergency situation, there are numerous plans in place for mass feeding. The Tenderloin Hunger Task Force successfully conducted an emergency mass feeding drill and created a mutual assistance agreement between CBOs and the government, requiring food distributors to share information with each other in an emergency.[66] The SF Emergency Plan contains operations for mass feeding, including mobile operations. MREs and other similar shelf stable meals are available in widespread emergency situations from military bases.[67] **<u>External Services:</u>** Transportation is critical for food distributors, especially for suppliers and for delivery services. Impacts to transportation can leave food supply chains vulnerable to disruption. Power is necessary to maintain temperature control in food storage facilities, and to refrigerate and prepare food. Pantries have increased

[65] "Community Partners," SF-Marin Food Bank, 2018, https://www.sfmfoodbank.org/programs/community-partners/.
[66] Cissie Bonini, "San Francisco Disaster Good System Report," Walter and Elise Haas Fund, September 2014, http://www.haassr.org/wp-content/uploads/2014/10/wehfDisasterFoodSystems.pdf.
[67] "Emergency Support Function #6 Mass Care, Housing, and Human Services Annex," City and County of San Francisco Department of Emergency Management, May 2017, https://sfdem.org/sites/default/files/FileCenter/Documents/837-ESF%206%20-%20Mass%20Care%2C%20Housing%2C%20and%20Human%20Services%20Annex.pdf.

	the proportion of fresh food and reduced the proportion of canned foods, creating more reliance on power. **Populations Served:** Grocery stores are the primary food distribution centers for most people. These stores accept SNAP/CalFresh and WIC, important monetary supplements that enable food access to those who are low income, pregnant/nursing, and very young. Charitable food distribution centers provide meals and groceries for those who are low income, elderly, isolated, mobility challenged, health impaired/medically dependent, and housing insecure/burdened. On site services provide meals and social bonding for these groups. Delivery services are especially important for the elderly, mobility impaired, and critically ill. These services often provide daily wellness checks, nutrition counseling, social work, and home safety and urgent needs services. **Unique or Critical Function:** The asset class is critical in its function as a provider of food, a basic necessity, especially in emergency situations. Charitable food distribution services provide important free social services, such as food provision/delivery, wellness checks, social services referrals, and social events. These centers can also function as nodes of community based political power, advocating for food access among vulnerable populations. In major emergencies, food pantries and meal service centers may function as emergency staging and distribution centers. This is arranged through SF Community Agencies Responding to Disaster (SF CARD), the SF Fire Dept's Neighborhood Emergency Response Team (NERT), and/or SF Voluntary Organizations Active in Disasters (SF VOAD).
Informational	**All-hazards:** A draft vulnerability and consequence assessment exists for sea level rise threat. DEM has detailed emergency response protocol that includes how non-profits contribute their services to mass care. However, data on building type/condition, retrofitting, air cooling, filtering, sensitive below grade components, back-up measures for utility outages, and contingency/emergency plans for all food distribution centers is not easily accessible.
Governance	**All-hazards:** AB 903 requires reimbursement of emergency response costs to nonprofits. SF CARD, NERT, and SF VOAD regulate emergency response coordination among participating community centers.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Significant damage to charitable food distribution structures can create long term disruptions to the normal social structures and supports of community members, especially those who are highly vulnerable and who receive targeted social, health, and wellness services. These populations would have to find other means of obtaining food, and for some this could mean a reduction in food quality and caloric intake. Damage to wholesale distribution centers and grocery stores can result in disruption to food supply, from days to months. This is impactful for all community members. Long term disruptions of grocery stores may reduce the accessibility of fresh food in neighborhoods. There may be equity impacts if groceries within low income/highly diverse neighborhoods have more vulnerable building types or are within more hazard vulnerable zones. Food distribution and retail businesses tend to provide jobs for people with lower educational attainment, and the distribution sector in particular can provide a pathway to more skilled / better paid jobs (this is less true of food retail jobs, as well as other low-skilled sectors like retail, hospitality, etc.). Disruptions to this sector would have a negative impact on our economic diversity. **Geologic:** Significant groundshaking can result in human casualties from building damage, and can result in the reduction of food supplies citywide **Flood:** Significant stormwater flooding may result in human casualties if there is no 2nd story. **Extreme Heat:** Extreme heat increases health risk for employees and customers who are elderly, pregnant, children, and/or have medical conditions. **Fire:** Significant fire can result in human casualties. Reduced air quality in unfiltered buildings can result in increased rates of asthma attacks. This is especially true in under-resourced communities and communities of color, which have significantly higher rates of bronchial disease.

Economy	**<u>All-hazards:</u>** Any damage to the facility will require centers to fund repairs or replacement. Additionally, non-salaried employees will lose wages for each day of closure and permanent closures will result in loss of employment. Wholesale suppliers, grocery stores and farmers markets receive revenue from the services they provide. Each day of closure or limited facility use will reduce or eliminate daily revenue. As for customers, populations that rely on free and subsidized meal/grocery services may have to utilize traditional grocery stores, reducing available personal income. **<u>Geologic:</u>** Neighborhoods with un-retrofitted buildings will see the most damage and economic impact. **<u>Flood:</u>** Neighborhoods in coastal and storm water flood zones will see the most damage and economic impact. **<u>Extreme Heat:</u>** This hazard will not cause permanent or indefinite closure. **<u>Air Quality:</u>** Air quality reduction from fire will not cause permanent or indefinite closure.
Environment	**<u>Geologic:</u>** Air quality could be impacted by the production of particulate matter from building damage. **<u>Flood:</u>** If food distribution facilities are near to the coast, flooding may cause debris from the building and soil from around the building to move into waterways. **<u>Fire:</u>** Air quality would be reduced in the neighborhood, and potentially citywide, if the building is directly impacted by fire.

Education Institutions

Introduction to Asset Class

Educational institutions include public and private K-12 schools, as well as public and private colleges and universities. K-12 institutions provide education, nutrition, and basic health care to children and youth, including those who may be more vulnerable to climate impacts because of existing disparities (see Vulnerable Populations profile). Higher education institutions provide career services, confer degrees, and foster research, in addition to providing nutrition, housing, and health services to many of their students. Education institutions are major employers, especially large universities.

Educational facilities are dispersed widely throughout the City. Analysis was conducted on 124 public K-12 San Francisco Unified School District schools, 127 private K-12 schools, and 50 higher education institutions, including colleges, universities, and community colleges. City College of San Francisco operates on 11 sites, UCSF operates education services in two main locations (the Parnassus campus and Mission Bay), UC Hastings and SFSU each operate on central campuses, and there are 21 private universities and colleges. Private schools provide services to a third of K-12 students in San Francisco[68].

Educational facilities are generally situated on a campus, with one or several buildings and open/recreational space. K-12 education facilities generally include classrooms, gymnasium/cafeteria, library, and recreational space. SFUSD owns and manages K-12 public facilities, while private schools operate independent of each other unless they are part of a larger religious or nonprofit network. College facilities are typically campuses with multiple buildings dedicated to specific disciplines. UCSF is a medical university that operates facilities dedicated to medical care and biotech research, in addition to classroom functions. College facilities also often include residential units in addition to medical, retail, cultural, recreational, and dining services for its students. Colleges and universities own or rent and manage their own facilities.

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[68] *Earthquake Risk and San Francisco's Private Schools*, December 31, 2013

Issue Statement

Educational institutions provide important services in addition to the provision of basic and continuing education, including housing, medical care, employment, child care, nutrition, social services, and emergency shelter. They serve a large population, and tailor services specific to the needs of many disadvantaged and sensitive groups. K-12 school populations are particularly sensitive to health risks from heat and smoke from fire, though many facilities do not have air cooling or filtration technology. Public K-12 school buildings are required to be resistant to earthquakes by the Division of State Architects, but this policy does not apply to private schools (which serve approximately 33% of the City's school-aged children). Private schools are likely to perform significantly worse in earthquakes than public school buildings.[69] Structural damages to K-12 buildings from earthquake, flooding, or fire can cause citywide social and economic impacts if students need to be redistributed to other schools. Short term closures can impact facility employee and parent wages, and can impact a child's performance in school.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In Table A-11, on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data originates from DEM, DataSF Open Data Portal, and National Center of Education Statistics.

[69] *Earthquake Risk and San Francisco's Private Schools*, December 31, 2013

TABLE A-18: EXPOSURE

Hazard	Public K-12 124 Total		Private K-12 127 Total		University/College /Community College 50 Total	
	#	%	#	%	#	%
Geologic						
San Andreas 7.8 – Violent	29	23%	31	24%	4	8%
San Andreas 7.8 - Very Strong	95	77%	96	76%	46	92%
Hayward 7.0 - Very Strong	1	1%	3	2%	7	14%
Hayward 7.0 - Strong	95	76%	98	77%	40	80%
Liquefaction Zone	14	11%	29	23%	27	54%
Flooding						
100-Year Coastal Flood Zone	0	0%	0	0%	1	2%
100-year storm + 24 inches SLR	1	1%	2	2%	5	10%
100-year storm + 66 inches SLR	4	3%	6	5%	9	18%
100-year stormwater flood	7	6%	3	2%	4	8%
Wildfire						
High	0	0%	0	0%	0	0%
Moderate	3	2%	4	3%	3	6%

Note: For an exposure table with additional hazards, please see Chapter 5

Exposure Summary

Geologic: All of San Francisco would be exposed to Violent or Very Strong shaking in a 7.8 earthquake on the San Andreas fault, including all educational institutions. 244 institutions would be exposed to Very Strong or Strong shaking in a 7.0 earthquake on the Hayward fault. 70 institutions are in the liquefaction zone, including over half of the city's universities/colleges/community colleges.

Flood: 19 of San Francisco's educational institutions, including five SFUSD schools, are exposed to current and projected future coastal flooding; 13 of the institutions, including seven SFUSD schools, are in the storm water flood risk zone.

Fire: Educational exposure to wildland-urban fire zones is limited to moderate risk, and 10 educational institutions are in this zone.

FIGURE A-22: EDUCATIONAL INSTITUTIONS AND LIQUEFACTION HAZARD

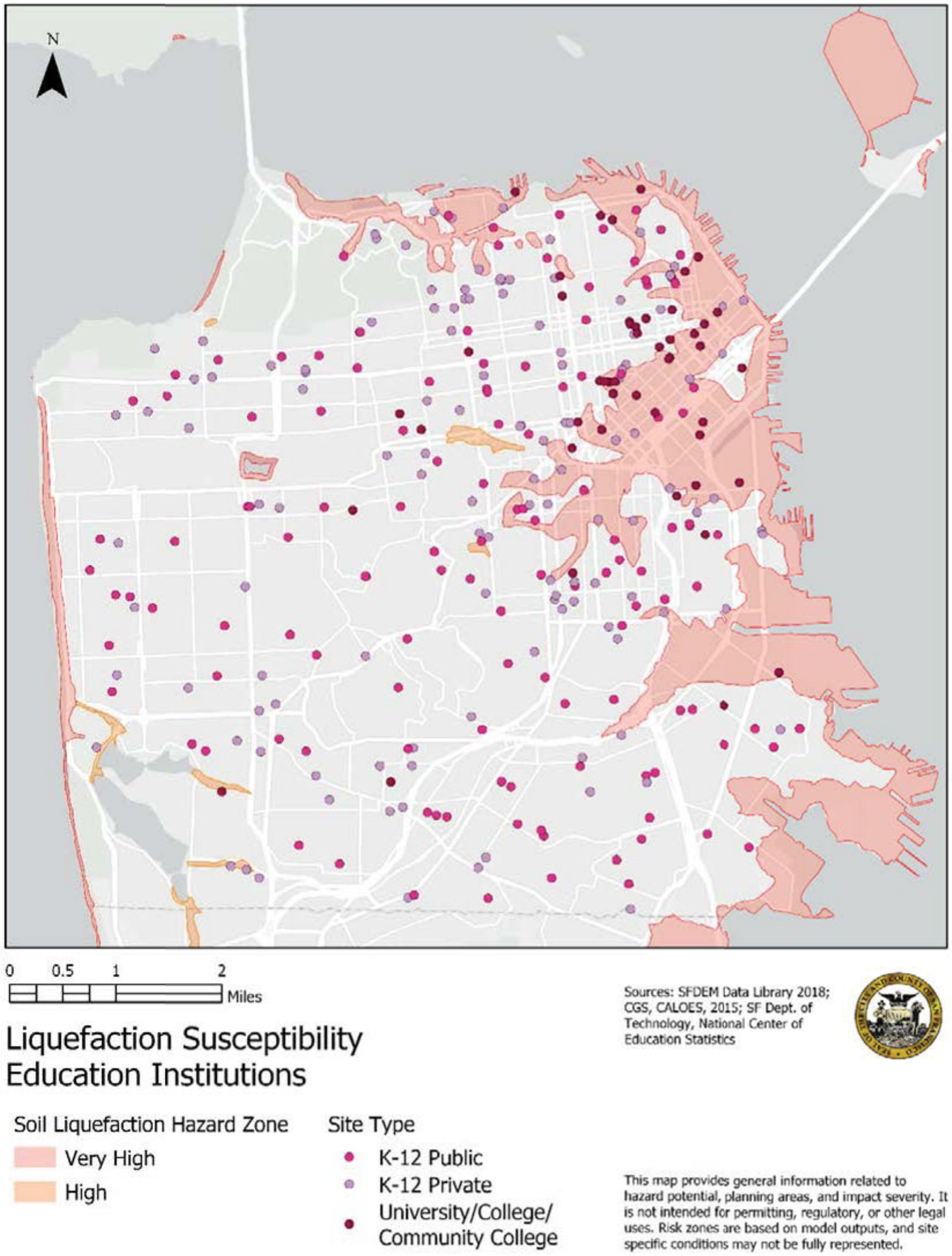
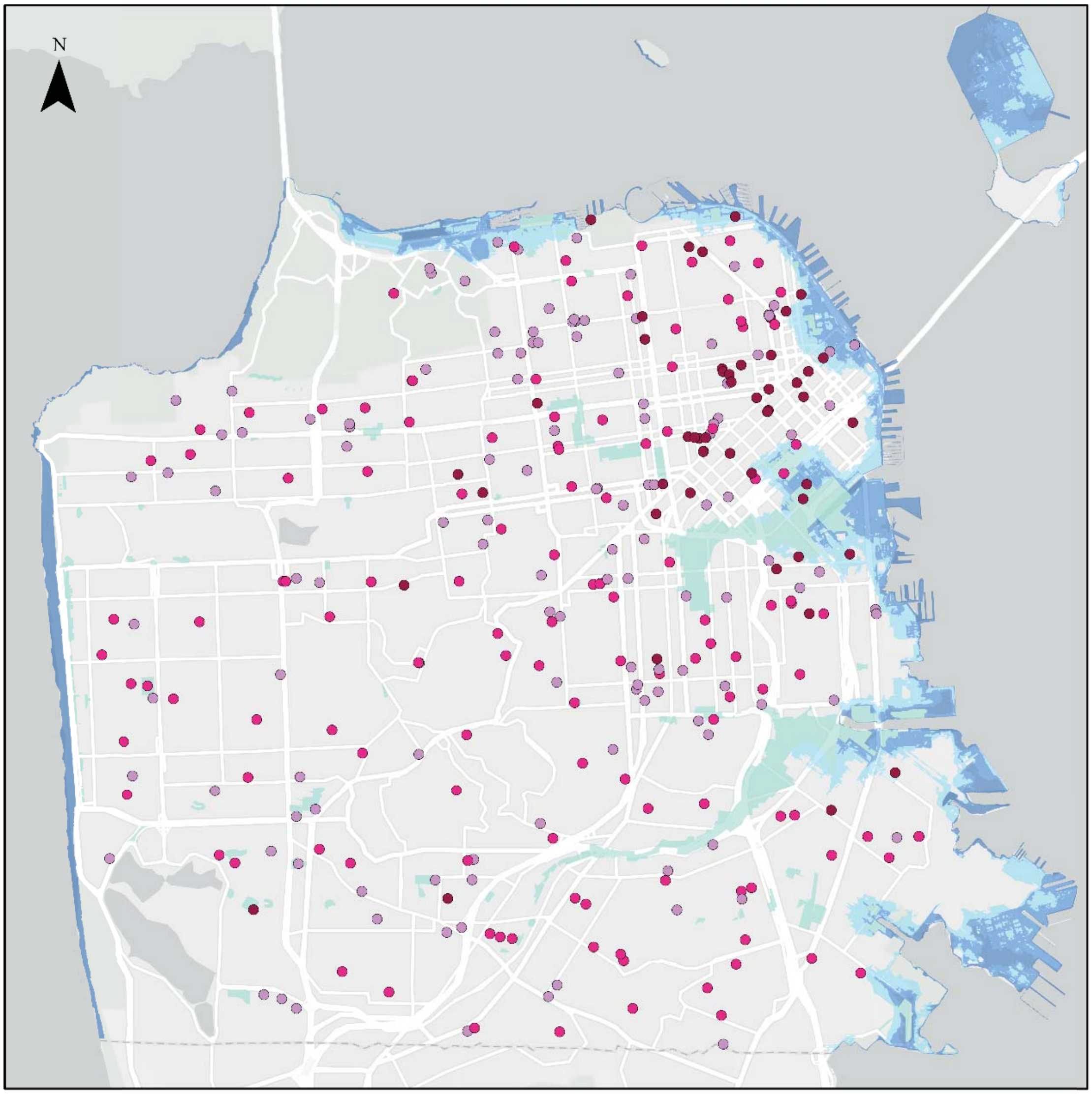


FIGURE A-23: EDUCATIONAL INSTITUTIONS AND FLOOD HAZARDS



0 0.5 1 2
Miles

Flood Risk
Educational Institutions

Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps; SF Dept. of Technology, National Center of Education Statistics

Flood Hazards

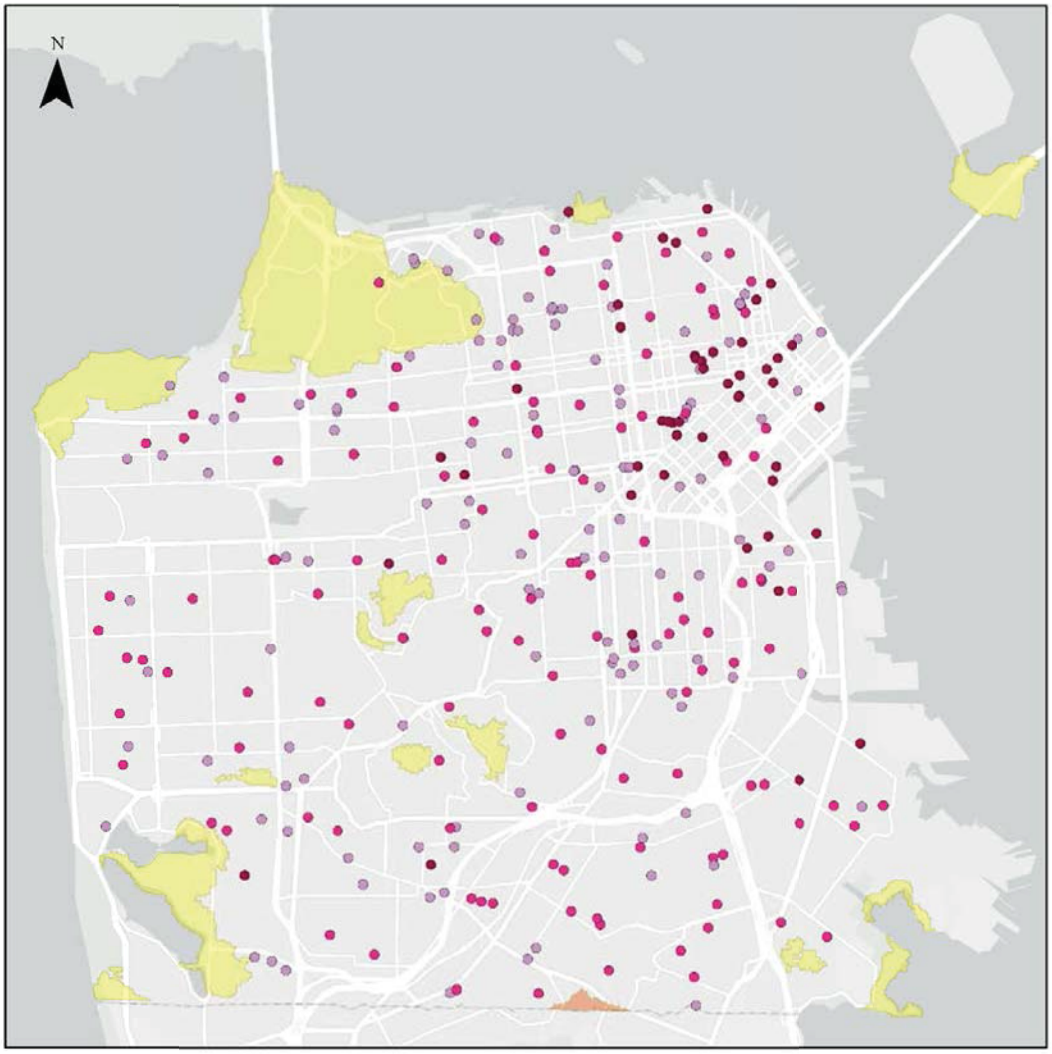
- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Site Type

- K-12 Public
- K-12 Private
- University/College/ Community College

This map is intended for planning-level analysis and should not be used for permitting, regulatory, or other legal uses. Flooding is possible in areas outside of those displayed on this map. The risk zones are based on model outputs and relied on LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and structures, site specific conditions may not be fully represented.

FIGURE A-24: EDUCATIONAL INSTITUTIONS AND WILDLAND URBAN INTERFACE FIRE HAZARD



0 0.5 1 2 Miles

Wildfire Risk
Educational Institutions

Wildfire Hazard Zone
- High
- Moderate

Site Type
- K-12 Public
- K-12 Private
- University/College/ Community College

Sources: SFDEM Data Library 2018; CSF FRAP Data 2008; SF Dept. of Technology, National Center of Education Statistics

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** According to the 2004 Seismic Safety Commission's report on schools in CA, "public schools constructed under the Field Act after 1978 are likely to be among the safest buildings in which to experience a major earthquake."[70] Pre-1978 public school buildings that have not been retrofitted will be vulnerable to damage in the event of a seismic event. SFUSD has identified seismic retrofitting and upgrades as a high priority, and as part of its Prop A Bond Program all schools are assessed for seismic needs. In 2013, 12% of public school buildings and 33% of private school buildings had characteristics that "indicate they might perform poorly in future earthquakes." 24% of private schools did not have enough information to know. This is significant considering that San Francisco has a high private school enrollment (33% in 2013).[71] DBI has a private school seismic program that required private schools to perform an earthquake evaluation of their buildings by 2017 (final report publication, TBD). **Flood:** Flooding above the finished floor of schools damages building materials and contents. Schools may experience structural or nonstructural building damage, and impairment or destruction of utility service equipment. Flooding in SFUSD basements may damage boilers. SFUSD schools that have experienced flooding have sump pumps installed. **Extreme Heat:** Colleges and universities may have sensitive equipment that could be impacted by heat events. SFUSD keeps its IT equipment in actively cooled data closets. In non-weatherized school buildings without adequate cooling systems (e.g. air conditioning), students are at increased risk of health impacts. The vast majority of SFUSD facilities do not have air conditioning, and only certain sites have mechanical ventilation. Schools may shut down in extreme heat events at the discretion of the SFUSD Board of Education.

[70] "Seismic Safety in California Public Schools," California Seismic Safety Commission, 2004, http://ssc.ca.gov/forms_pubs/cssc_2004-04_school_safety.pdf.
[71] Earthquake Risk and San Francisco's Private Schools, December 31, 2013

	Fire: Fire impact to air quality is a concern for educational facilities, especially those serving children. Neither California nor San Francisco has regulations that requires the use of air filtration. Many SFUSD schools do not have mechanical ventilation and air filtration systems. In the event of very poor air quality, schools may shut down at the discretion of the SFUSD Superintendent. The Division of the State Architect oversees a rigorous Fire and Life Safety program governing the design of public schools and community colleges for onsite fire prevention.
Functional	**Networks:** SFUSD has an IT network that is currently supported by backup generators. This is important to maintain communication because Additionally, if a K-12 school building is too damaged to be used, the students will need to be distributed to other area schools while the building is reconstructed or repaired. This may strain the services provided by the receiving schools. **External Services:** Education facilities rely on transportation access, power, water, and food. They also rely on communications (i.e. phone and internet) to maintain safety (communication with parents and emergency services) and for lesson requirements (internet research/media use). SFUSD, UCSF, SFSU, CCSF all have emergency plans. Some SFUSD school sites have backup generators, such as school sites with IT networks. SFUSD has transportation services and radio communication for use in an emergency. SFUSD also requires food and water storage for emergency use. **Populations Served:** Educational institutions serve nearly all school aged children in San Francisco. Public institutions (SFUSD and San Francisco City College) serve young people and adults regardless of income or citizenship status. Public education facilities also provide programming and/or services for those who have physical and intellectual disabilities. Some educational facilities serve significant populations of ethnically/culturally diverse populations. K-12 public schools in particular have English language learner (ELL) programs to accommodate non-native English speakers. SFUSD also provides newcomer program supports, newcomer student linkages, and sanctuary education supports.

	Unique or Critical Function: Public K-12 schools are critical community institutions that provide basic education in addition to social work for highly sensitive, low income, and otherwise disadvantaged populations. Public K-12 schools provide subsidized meals for low income students through the free breakfast and lunch programs, they interface with the foster system and social workers, and they provide sanctuary education supports. Universities and colleges provide unique services to the city in the form of research development, in addition to medical and professional training. These institutions, in particular SFUSD, are critical for emergency services. SFUSD staff members are designated emergency workers, and the School District partners with the Department of Emergency Management to coordinate mass sheltering and feeding at its facilities.
Informational	**All-hazards:** Data on building type/condition, retrofitting, air cooling, filtering, sensitive below grade components, back-up measures for utility outages, and contingency/emergency plans for *all* educational institutions (including private and higher education institutions) is not easily accessible. SFUSD and DEM have detailed emergency response protocols. SFUSD has data on school facilities, and DBI has records on private school facility seismic resilience.
Governance	**All-hazards:** The Field Act and subsequent state legislation requires that public schools are built to be earthquake resistant and older buildings be retrofitted. No such requirements exist for private schools. Private schools in San Francisco were mandated to conduct an earthquake resistance report by 2017. Public schools have mandated earthquake and fire drills to mitigate human casualties. The SFUSD superintendent is responsible for cancelling school services in the event of extreme heat or poor air quality. SFUSD has a detailed School Site Emergency Plan and partners with Department of Emergency Management to coordinate mass housing and care in the case of an emergency. The Division of the State Architect oversees a rigorous Fire and Life Safety program governing the design of public schools and community colleges.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** In the event that students need to be evacuated from a damaged building, families may be unable to immediately reunite with students. SFUSD emergency protocol has a detailed reunification strategy to ensure students are cared for until they are reunited with family. Any significant damage to the facility building may result in indefinite redistribution of students, which separates students from their normal social structures and supports (peers and teachers). Students may also have to travel for long distances to get to their newly assigned school. Significant damage and health hazards can result in the shutdown of school services from days to weeks. This results in students' education being disrupted (with each day lost tied to test score reductions). The scale of impact depends on the time of year (there is low student attendance during the summer months). **Geologic:** Significant ground shaking and liquefaction can result in human casualties from building damage. **Flood:** Significant storm water flooding may result in human casualties if there is no second story. **Extreme Heat:** Extreme heat may cause facilities without air conditioning to close, keeping students at home, though most SF homes also do not have cooling capabilities. Students and schools in urban heat island areas (such as Chinatown, Potrero Hill-Dogpatch, and Bayview neighborhoods) will be particularly vulnerable. **Fire:** Building fires can result in human casualties, though this is mitigated by emergency protocols (e.g. fire drills). Poor air quality from fire may cause school closures. If schools do not close and do not have filtering technology, poor air quality will increase health risks to students. Air quality reduction from fire will not result in building damage or redistribution of students, although it can impede learning if schools must close.
Economy	

	All-hazards: Any damage to the facility will require schools to fund repairs or replacement. In the event of major damage, schools will also have to fund interim costs during rebuilding such as portable classrooms and transportation. Additionally, non-salaried facilities employees will lose wages for each day of closure. Parents of young children will lose wages for each day they need to stay home for child care purposes. This may be mitigated by employee protections (e.g. use of sick days). Hourly employees and single parent households, which are also likely to be low income, are most impacted. Indefinite closures will result in loss of employment. Short-term construction employment will gain jobs. The scale of impact depends on the time of year (there is low student attendance during the summer months). **Flood:** This hazard can cause indefinite closure in coastal and storm water flood zones. **Geologic:** Neighborhoods with un-retrofitted school buildings (mostly private school buildings) will see the most damage and impact. **Extreme Heat:** This hazard will not cause indefinite closure. **Fire:** Air quality reduction from fire will not cause indefinite closure.
Environment	**Geologic:** Air quality could be temporarily impacted by the production of particulate matter from building damage. **Flood:** If school facilities are near to the coast, flooding may cause debris from the building and soil from around the building to move into waterways. **Fire:** Air quality would be reduced in the neighborhood, and potentially citywide, if the building is directly impacted by fire or from smoke from regional fires.

Community Centers

Introduction to Asset Class

Community centers provide a location where community members can obtain resources and information, and participate in spiritual, educational, recreational, and/or political activity. These include libraries, recreation centers, senior centers, youth centers, neighborhood centers, and faith-based centers. SF Human Services Agency outlines more than 40 centers that offer services for the elderly across the city.[1] A 2010 list from the Office of Assessor-Recorder identifies 530 spiritual centers citywide.[2] It is challenging to find specific data on youth and neighborhood centers. Community centers are run by the City, NGOs and places of worship, and many are a part of organizational networks, such as the YMCA.

Community centers vary in form. Some are large facilities that contain fitness, open space, and kitchen amenities. Others operate in small to medium sized commercial properties or in traditional building types for places of worship. The building age, materials, and forms are not consistent across this asset class. Centers vary in property ownership status, but typically manage their own facilities.

Issue Statement

Community centers are critical in their function as a community convener that enables social networking and bonding, as well as the provision of important free or low cost social services. Centers also may function as shelters, air quality respite centers, and cooling centers during emergency events. The services these institutions provide are especially important to vulnerable populations. However, data on how vulnerable community centers are to climate and seismic hazards is not well understood. In addition, community centers rely on power and communication, but how many centers have contingency plans for power outages that can be caused by seismic, storm, and heat events is unknown. This is especially important for centers that play a role as an emergency shelter or cooling center.

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[1] "Senior Centers and Activity Centers," City and County of San Francisco Human Services Agency, 2018, https://www.sfhsa.org/services/connection-community/senior-centers-and-activity-centers.
[2] SF Planning GIS data library (2018)

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data originates from the San Francisco Facilities System of Record (2018). Although there is a wide range of community centers as described above, given data availability, the exposure assessment focuses on three representative community center types found in the City and County of San Francisco's Facility System of Record database: libraries, recreation centers, and other community centers.

Exposure Summary

Geologic: All of San Francisco would be exposed to Violent or Very Strong shaking in a 7.8 earthquake on the San Andreas Fault, including all community centers. 49 centers would be exposed to Very Strong or Strong shaking in a 7.0 earthquake on the Hayward fault. 13 centers are in the liquefaction zone.

Flood: One library in the 24" sea level rise zone represents the extent of community center exposure to current and future coastal flooding. There are 5 community centers in the 100 year stormwater flood zone.

Fire: One recreation center in the Moderate wildland-urban interface fire zone represents the extent of community center exposure to wildfire.

TABLE A-19: EXPOSURE

Hazard	Libraries 29 Total		Recreation Centers 20 Total		Other Community Centers 11 Total	
	#	%	#	%	#	%
Geologic						
San Andreas 7.8 - Violent	9	31%	4	20%	1	9%
San Andreas 7.8 - Very Strong	20	69%	16	80%	10	91%
Hayward 7.0 - Very Strong	0	0%	0	0%	2	18%
Hayward 7.0 - Strong	23	79%	16	80%	8	73%
Liquefaction Zone	6	21%	5	25%	2	18%
Flooding						
100-Year Coastal Flood Zone	0	0%	0	0%	0	0%
100-year storm + 24 inches SLR	1	3%	0	0%	0	0%
100-year storm + 66 inches SLR	1	3%	0	0%	0	0%
100-year stormwater flood	2	7%	2	10%	1	9%
Wildfire						
High	0	0%	0	0%	0	0%
Moderate	0	0%	1	5%	0	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

FIGURE A-25: COMMUNITY CENTERS AND LIQUEFACTION HAZARD

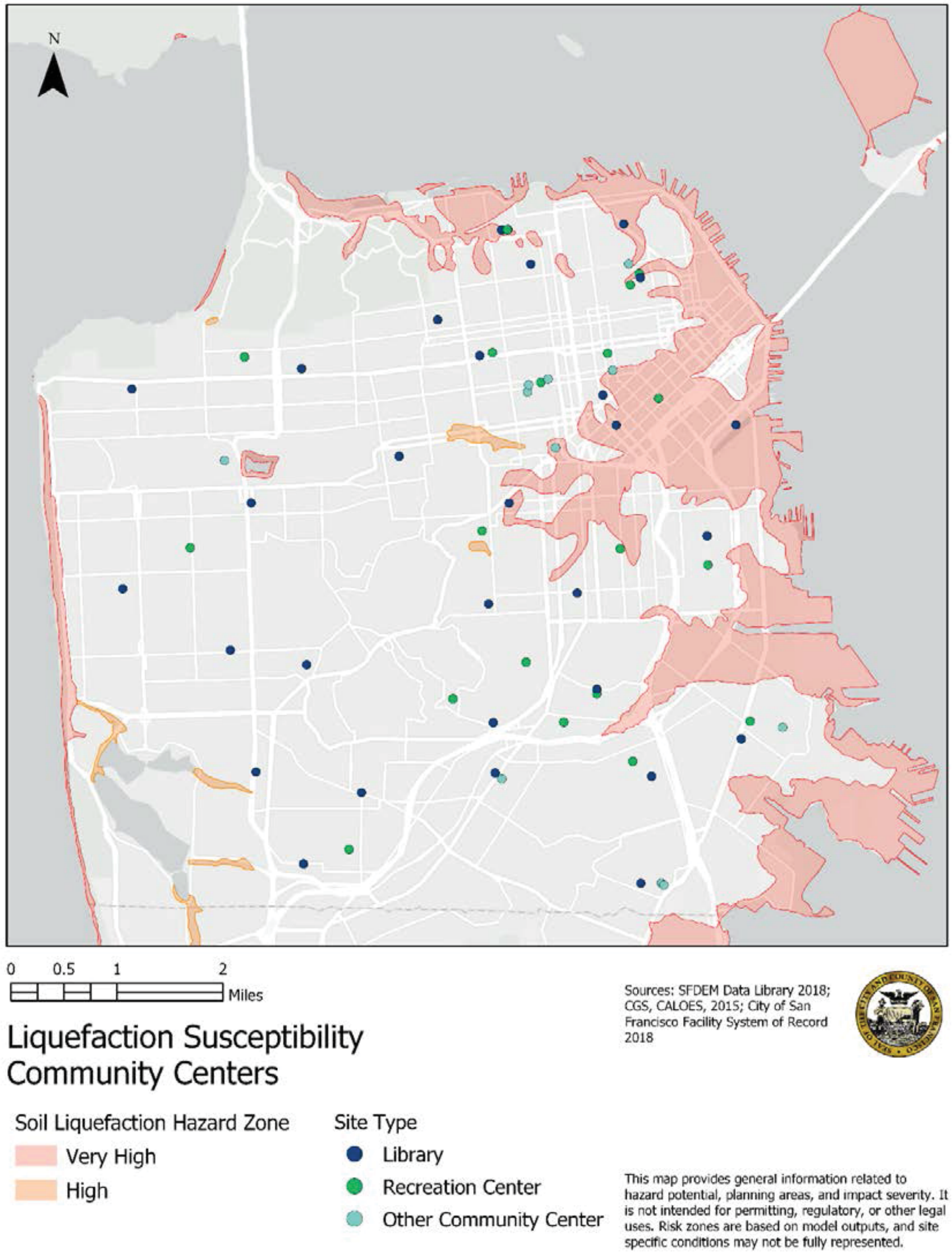
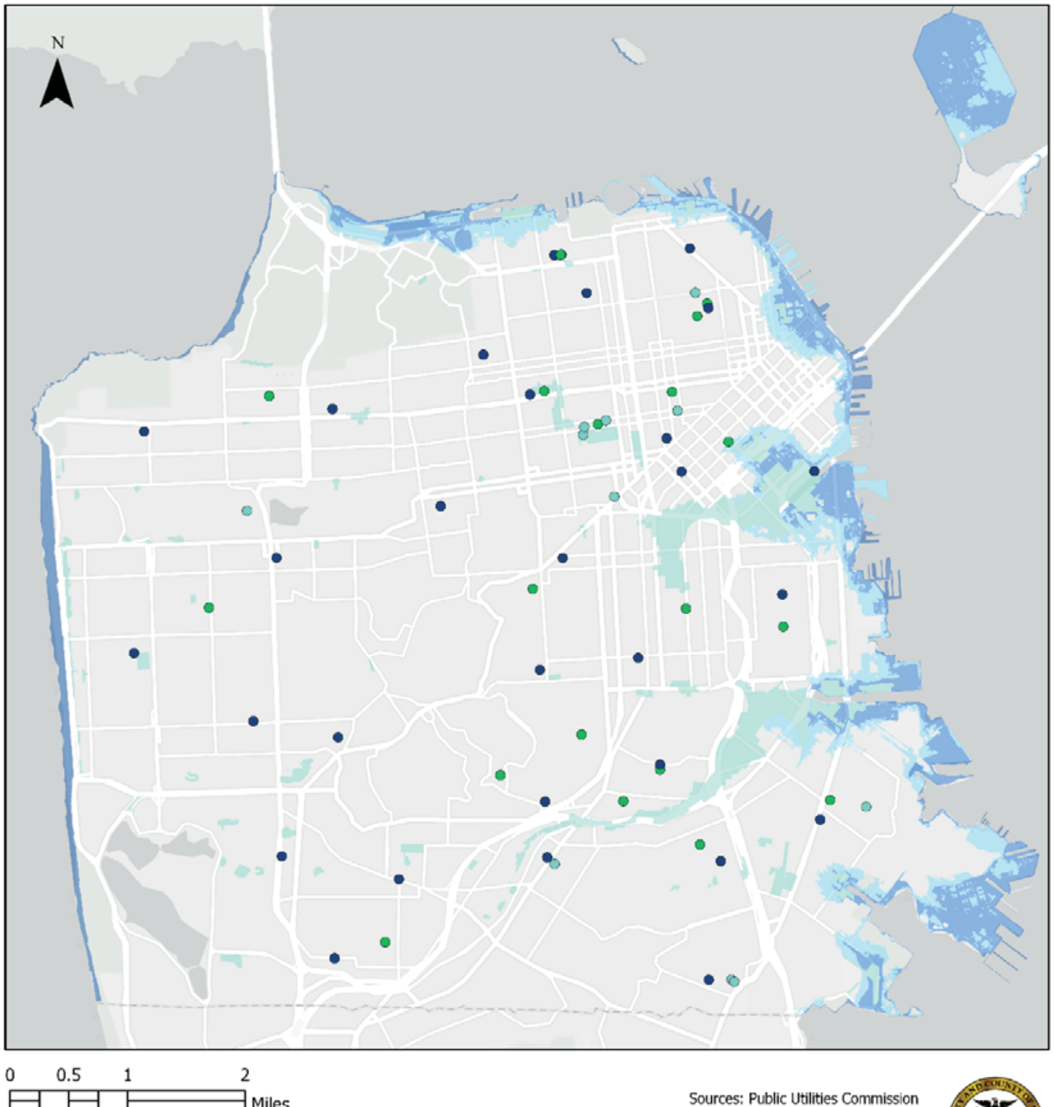


FIGURE A-26: COMMUNITY CENTERS AND FLOOD HAZARDS



Flood Risk and Community Centers

Flood Hazards

- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Site Type

- Library
- Recreation Center
- Other Community Center

Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps; City of San Francisco Facility System of Record 2018

This map is intended for planning-level analysis and should not be used for permitting, regulatory, or other legal uses. Flooding is possible in areas outside of those displayed on this map. The risk zones are based on model outputs and relied on LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and structures, site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Pre-1978 soft story buildings are vulnerable to extensive damage. This impacts centers that are housed in store fronts underneath multi-unit residential buildings. Regulation requires these buildings (with 5+ units, and with 2+ stories over a soft story) to be retrofitted by 2020. Unreinforced masonry buildings that have not been retrofitted are more vulnerable to damage. Regulation required non-residential buildings (<5 units) to be retrofitted by 2006, so these should be rare. Pre-1995 tilt-up industrial buildings and pre-1980 non-ductile concrete frame buildings are vulnerable to extensive damage. Which building types are prevalent among community centers, especially those owned or managed by private entities, is not readily available. **Flood:** Flooding above the finished floor causes damage to the building materials and contents. Distribution centers may experience structural or nonstructural building damage, and impairment or destruction of utility service equipment. **Extreme Heat:** In non-weatherized buildings without cooling capabilities (e.g. air conditioning), services could shut down during high heat events. High heat events can cause power outages for centers without backup power sources. **Fire:** Community center buildings may be more or less vulnerable to fire due to exposure based on proximity to hazard areas/zones. Buildings with metal frames are especially vulnerable to building collapse in the event of fire. Reduced air quality due to fire smoke causes increased health risks for employees and members in buildings that do not have proper air filtration.
Functional	**Networks:** The community centers are not directly networked. All branch libraries are connected to the Main Library data center, some by City Fiber, however, if a building is too damaged to be used, the members of the center may redistribute to other centers while the building is reconstructed/repaired. This may strain functionality of the services provided by the asset class. For example, day care use of a YMCA may be redistributed to other similar centers in the area, or to other YMCAs. Library collections are networked and damage to one or more facilities could impact citywide service.

	External Services: Community center facilities rely on transportation access for members and staff. Centers rely on power and water to deliver services within sanitary and functional buildings. They also rely on communications (i.e. phone and internet) to maintain safety (communication with guardians and emergency services) and for service delivery (internet research/media use, emails). Food access becomes important if a community center is turned into an emergency shelter. Some centers have food pantry programs that serve as backup food supplies. Large community service providers, such as YMCA or Girls and Boys Club, have emergency plans and training, but it is unclear if these include contingency plans for back up external services (like off grid power, water/food supply, communications). This is likely highly variable among organizations and dependent on available resources. **Populations Served:** Community centers often primarily serve those with access or functional needs. Senior centers provide specific services to the elderly, who are often medically dependent, transit dependent, require mobility aids, and are low income. Youth centers are important resources for low income families to be able to afford daycare and enrichment for their children. Neighborhood and faith-based centers often provide services that target low income, at-risk community members. In addition, many neighborhood community and faith centers operate in ethnically diverse areas and cater to those populations. These centers offer services in non-English languages, provide ELL courses, and provide important services to members who are linguistically isolated. **Unique or Critical Function:** The asset class is critical in its function as a community convener that enables the development of social networking and bonding, as well as the provision of important free or low cost social services such as daycare, youth enrichment, drug-violence-mental illness prevention/counseling, employment preparation services, and recreation. In major emergencies centers may function as mass care staging centers. Many faith-based and neighborhood organizations have protocols for volunteering their services and buildings for use during emergencies. These protocols are often arranged through SF Community Agencies Responding to Disaster (SF CARD), the SF Fire Dept's Neighborhood Emergency Response Team (NERT), and SF Voluntary Organizations Active in Disasters (SF VOAD). Centers may also function as official and unofficial cooling centers during a heat emergency. These centers especially serve those who are most

	vulnerable and mobility challenged, such as the elderly, low income, and disabled.
Informational	**All-hazards:** A draft vulnerability and consequence assessment exists for sea level rise threat. DEM has detailed emergency response protocol that includes how non-profits contribute their services to mass care. However, data on building type/condition, retrofitting, air cooling, filtering, sensitive below grade components, back-up measures for utility outages, and contingency/emergency plans for all community centers is not easily accessible.
Governance	**All-hazards:** AB 903 requires reimbursement of emergency response costs to nonprofits. SF CARD, NERT, and SF VOAD regulate emergency response coordination among participating community centers.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Significant damage to community centers can create long term disruptions to the normal social structures and supports of community members, especially those who are highly vulnerable and who receive targeted social, health, and wellness services. There may be inequitable impacts if older, fragile, non-retrofitted buildings and buildings without cooling and filtration capabilities are located in or serve disadvantaged communities. A long term closure results in community members having to find other centers that provide similar services at similar prices within a reasonable travel distance. This might be impossible, especially for populations with limited mobility, and for populations with highly specific needs, leaving these members temporarily, and potentially permanently, disconnected from important social, health, wellness, and/or life skills services. Disruption to these facilities could also have ripple impacts on family members who take on caregiving. **Geologic:** Significant groundshaking can result in human casualties from building damage.

	Flood: Significant stormwater flooding may result in human casualties if there is no 2nd story. **Extreme Heat:** Heatwaves may cause closures in non-weatherized buildings without cooling capabilities. For centers providing daycare and education services, this keeps students at home. As SF is typically cool and many residences do not have air conditioning, community centers can act as important places for people to get out of dangerous heat. This is especially important for sensitive populations such as the elderly, disabled, and very young. Should these cooling centers lose power, vulnerable populations may be at greater health risk, especially those who have limited mobility. **Fire:** Significant fire can result in human casualties. Reduced air quality in unfiltered buildings can result in increased rates of asthma attacks. This is especially true in under-resourced communities and communities of color, which have significantly higher rates of bronchial disease.
Economy	**All-hazards:** Any damage to the facility will require centers to fund repairs or replacement. For community centers that receive revenue from the services they provide, each day of closure or limited facility use will reduce or eliminate daily revenue. In addition, non-salaried employees will lose wages for each day of closure. Permanent closures will result in loss of employment. For centers that provide early education and daycare services, guardians of young children will lose wages for each day they need to stay home for childcare purposes. Similarly, disruption to eldercare facilities will impact family members who need to provide the care instead. Hourly employees and single parent households are most impacted-- these are most likely to be low income households. **Geologic:** Neighborhoods with un-retrofitted buildings will see the most damage and economic impact. **Flood:** Neighborhoods in coastal and storm water flood zones will see the most damage and economic impact. **Extreme Heat:** This hazard will not cause permanent or indefinite closure.

	Fire: Air quality reduction from fire will not cause permanent or indefinite closure.
Environment	**Geologic:** Air quality could be impacted by the production of particulate matter from building damage. **Flood:** If facilities are near to the coast, flooding may cause debris from the building and soil from around the building to move into waterways. **Fire:** Air quality would be reduced in the neighborhood, and potentially citywide, if the building is directly impacted by fire.

Housing

Introduction to Asset Class

San Francisco's housing stock, developed and maintained over more than one and a half centuries, includes many building and unit types. The city's housing serves a diverse set of household types—including families with and without children, roommates, single individuals, and multi-generational households—from a wide range of incomes. Some rental units are under rent control, some are restricted to low- and moderate-income households, while others are rented at market rates.

Compared to the rest of the Bay Area, San Franciscans are much more likely to live in multifamily housing, with a fairly even distribution of households living in single family homes and buildings with 2-4 units, 5-19 units and 20 units or more.[3] Housing is distributed across the city with more single family homes in the southern and western portions of the city and more large multifamily housing in the northeastern quadrant of the city. Increasingly, residential high rise towers are being constructed in the northeast portion of the city using new concrete design and construction technologies. 40% of the city's tall buildings have residential occupancies.[4] Homes in San Francisco are constructed with a wide variety of materials. Smaller structures tend to be wood-framed or, less-commonly, constructed with masonry materials. Concrete residential structures tend to be mid-rise buildings. Housing is critical for residents' health and safety. Housing may be resident owned, privately owned and rented, privately-owned subsidized, or publicly-owned and operated public housing.

The continuing high cost of housing in San Francisco amplifies the need for providing affordable housing to all household income levels, especially low and very low income levels. The provision of adequate affordable housing remains a significant challenge for San Francisco. From 1990 to 2015, the number of renter households experiencing severe rent burden (> 50% of income on housing costs) increased from 38,000 to 49,000. Currently, the majority of low income renters and homeowners (< 80% AMI) are cost burdened (> 30% of income on housing costs).[5] Citywide, there are 33,661

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[3] "2017 San Francisco Housing Inventory," San Francisco Planning Department, 2018, http://default.sfplanning.org/publications_reports/2017_Housing_Inventory.pdf.
[4] "SF Tall Buildings Study," San Francisco Office of Resilience and Capital Planning, unpublished.
[5] "San Francisco Housing Needs and Trends Report," San Francisco Planning Department, July 2018, http://default.sfplanning.org/publications_reports/Housing-Needs-and-Trends-Report-2018.pdf

subsidized affordable housing units, restricted for use by individuals and families below certain income thresholds. Sixty percent of these affordable units are located in 5 neighborhoods: Bayview Hunter's Point, Mission, South of Market, Tenderloin, and Western Addition.[6] Of those 33,000 units, approximately 2,250 are in private developments and approximately 31,400 are in public on non-profit developments.

Housing services available to people experiencing or transitioning out of homelessness include shelters, navigation centers, and permanent supportive housing. Temporarily shelters house some of San Francisco's most vulnerable residents, providing a variety of health and case management services; access to laundry facilities and hygiene products; assistance with benefits enrollment; and meals and safety. Homelessness and Supportive Housing Temporary Shelter Capacity is currently 1700 shelter beds for adults and families, 500 Navigation Center beds for adults, 450 transitional housing beds for adults and families, and 100 stabilization units for adults. In addition to HSH facilities, master-leased buildings house some of San Francisco's most vulnerable residents, providing a variety of health and case management services; access to laundry facilities; comfort and safety. The City has master leases with the owners of SROs which house HSH clients. HSH also provides operating funds to third-party service providers that have master leased SRO buildings to house clients. This portfolio in comprised of over 35 buildings and more than 3000 units located throughout the city.

Issue Statement

Housing is a daily necessity for all residents in San Francisco. Depending on the construction type, housing can be severely damaged by hazards and can result in injury, health impacts, or death for residents. Housing supply is limited, particularly for low and moderate income residents. This shortage would be exacerbated by natural hazards and climate change impacts and could lead to significant displacement for vulnerable residents. New models predict that in a M7.8 San Andreas earthquake, 18,300 residential buildings could be damaged in San Francisco, temporarily or permanently displacing 69,600 households (20% of all households).

[6] "San Francisco Housing Needs and Trends Report," San Francisco Planning Department, July 2018, http://default.sfplanning.org/publications_reports/Housing-Needs-and-Trends-Report-2018.pdf

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data is originates from datasets maintained by SF Planning, and SF DEM (2018).

Exposure Summary

Geologic: All housing will experience Violent or Very Strong groundshaking during a 7.8M earthquake on the San Andreas Fault. Around 40% of single family units are in the Violent zone, the highest percentage across all housing assets. Almost 90% of multifamily housing units will experience Very Strong or Strong groundshaking during a 7.0M earthquake on the Hayward fault. The Hayward Very Strong and Strong zones also contain 98% of all subsidized affordable housing units and 99% of all permanent supportive housing sites.

Flood: Single family homes have low exposure to all types of flooding, but around 800 homes are in the 100-year stormwater flood zone. Around 12,000 multifamily units are exposed in both the stormwater and 24” sea level rise zones. The proportion of affordable housing exposed to all types of flooding is higher than rates for other housing types. The 66” sea level rise zone contains over 4,000 affordable units. The MSC South Shelter is within the 24” sea level rise zone, and the Division Circle Navigation Center is within the stormwater risk zone.

Fire: Citywide residential exposure to WUI fire is limited, less than 3,000 housing units are in the Moderate risk zone. Most recently, with the wildfires engulfing Northern California, air quality in San Francisco has been a major concern for residents. Because of the nature of prevailing winds in the region and the proximity to traffic congestion and emissions, notwithstanding the exacerbating impact of the fires, many neighborhoods in the City have air quality levels considered dangerous for vulnerable and low-income communities with multifamily and affordable housing (for example, Bayview/Hunter's Point.) Air quality should play a role in how we build and where we build housing.

TABLE A20: EXPOSURE

Hazard	Single Family Units 95,700 Total		Multi-Family Units 288,800 Total		Subsidized Affordable Units 33,800 Total		Permanent Supportive Housing 122 Total		Navigation Center & Shelter Sites 27 Total	
	#	%	#	%	#	%	#	%	#	%
Geologic										
San Andreas 7.8 - Violent	37500	39%	41000	14%	3100	9%	7	6%	0	0%
San Andreas 7.8 - Very Strong	58200	61%	247800	86%	30700	91%	115	94%	27	100%
Hayward 7.0 - Very Strong	1300	1%	23600	8%	3700	11%	5	4%	3	11%
Hayward 7.0 - Strong	56900	60%	231700	80%	29300	87%	116	95%	23	85%
Liquefaction Zone	1500	2%	73500	25%	13800	41%	47	39%	15	56%
Flooding										
100-Year Coastal Flood Zone	0	0%	1000	0%	400	1%	1	1%	0	0%
100-year storm + 24 inches SLR	100	0%	12100	4%	1800	5%	7	6%	1	4%
100-year storm + 66 inches SLR	400	0%	21800	8%	4300	13%	8	7%	2	7%
100-year stormwater flood	800	1%	11600	4%	2200	7%	6	5%	1	4%
Wildfire										
High	100	0%	100	0%	100	0%	0	0%	0	0%
Moderate	1100	1%	1600	1%	300	1%	0	0%	0	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

FIGURE A-27: RESIDENTIAL PARCELS AND LIQUEFACTION HAZARD

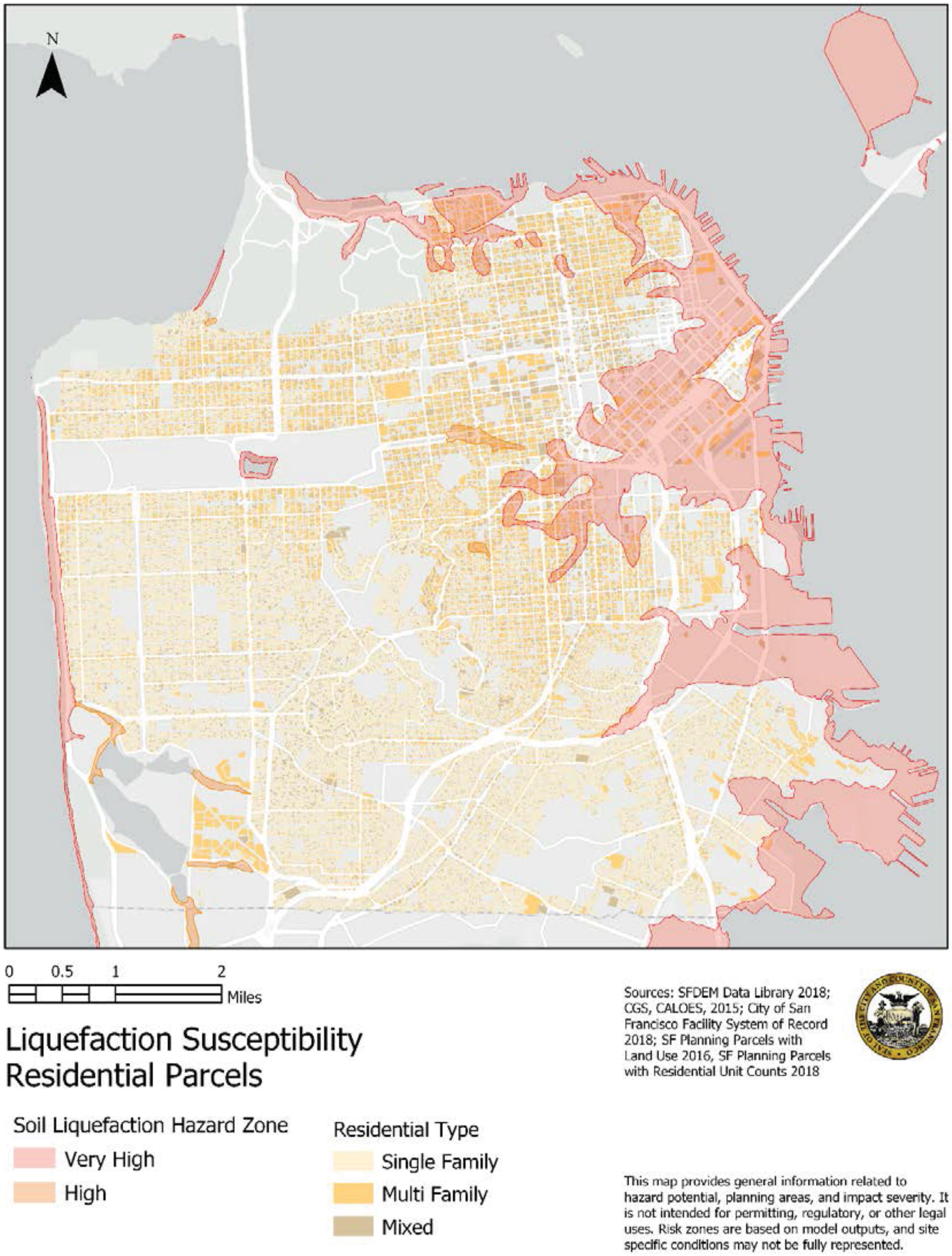
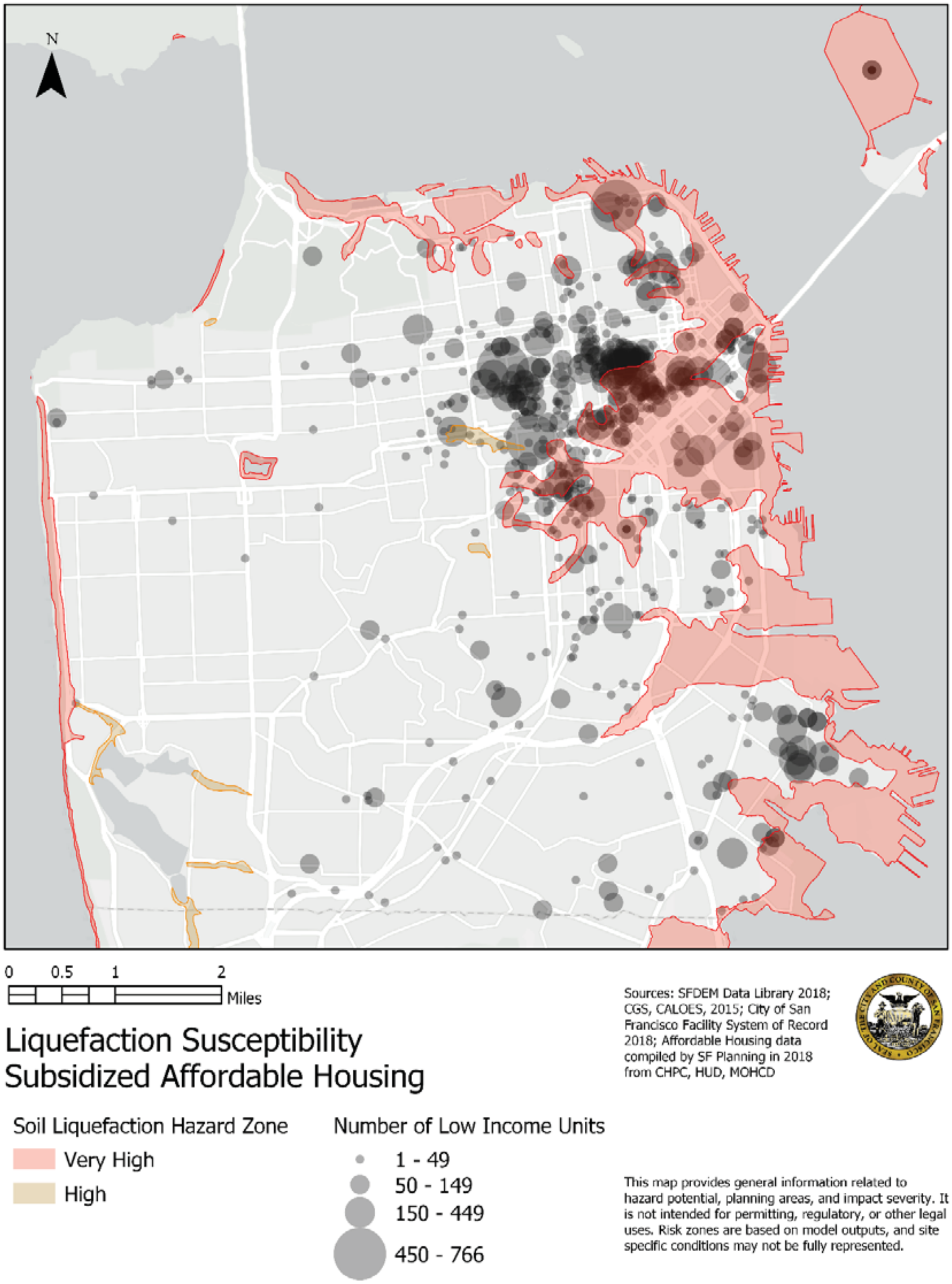


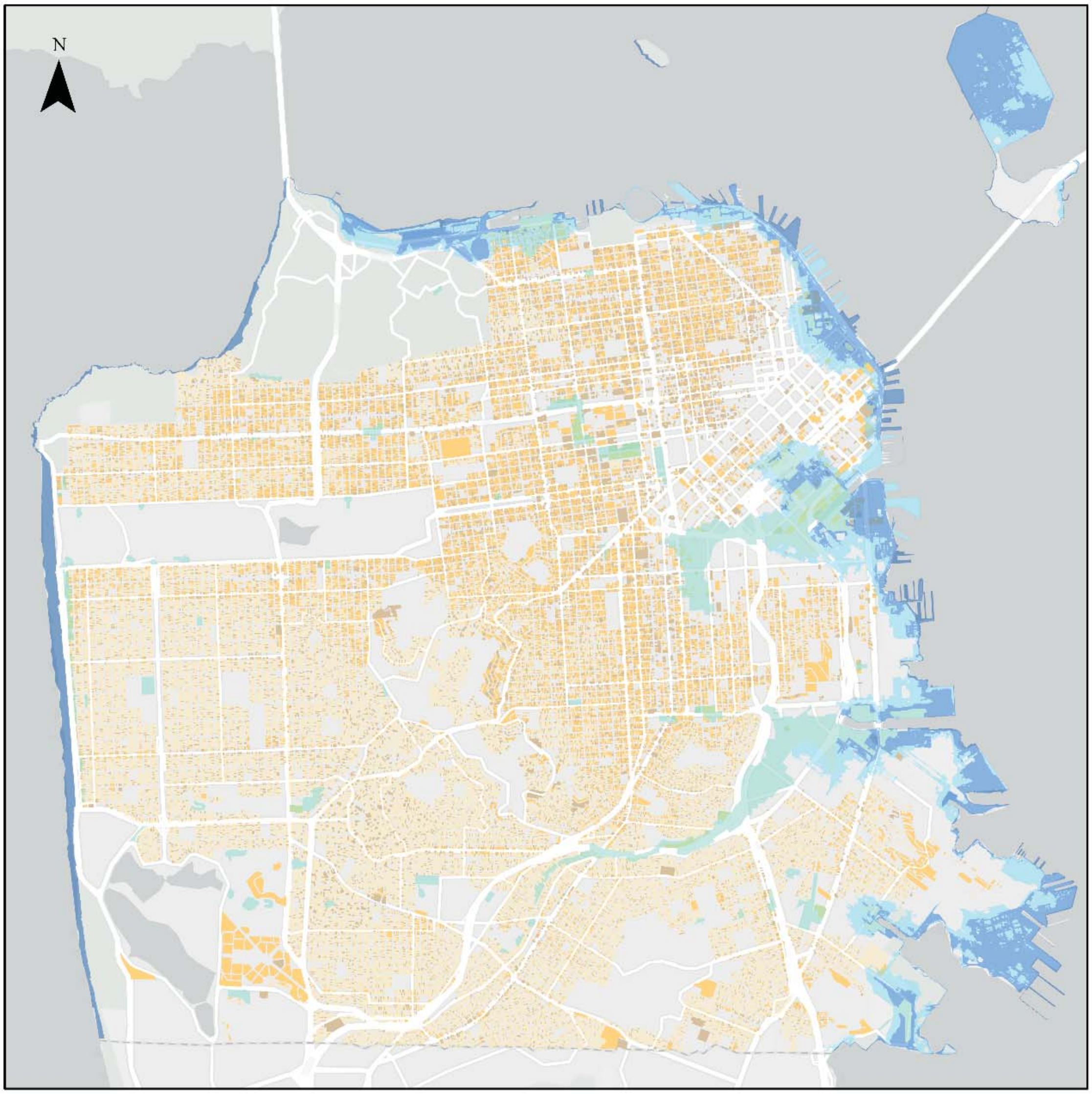
FIGURE A-28: AFFORDABLE HOUSING AND LIQUEFACTION HAZARD



Sources: SFDEM Data Library 2018; CGS, CALOES, 2015; City of San Francisco Facility System of Record 2018; Affordable Housing data compiled by SF Planning in 2018 from CHPC, HUD, MOHCD

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

FIGURE A-29: RESIDENTIAL PARCELS AND FLOOD HAZARD



0 0.5 1 2 Miles

Flood Risk and Residential Parcels

Flood Hazards

- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Residential Type

- Single Family
- Multi Family
- Mixed

Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps; SF Planning Parcels with Land Use 2016, SF Planning Parcels with Residential Unit Counts 2018

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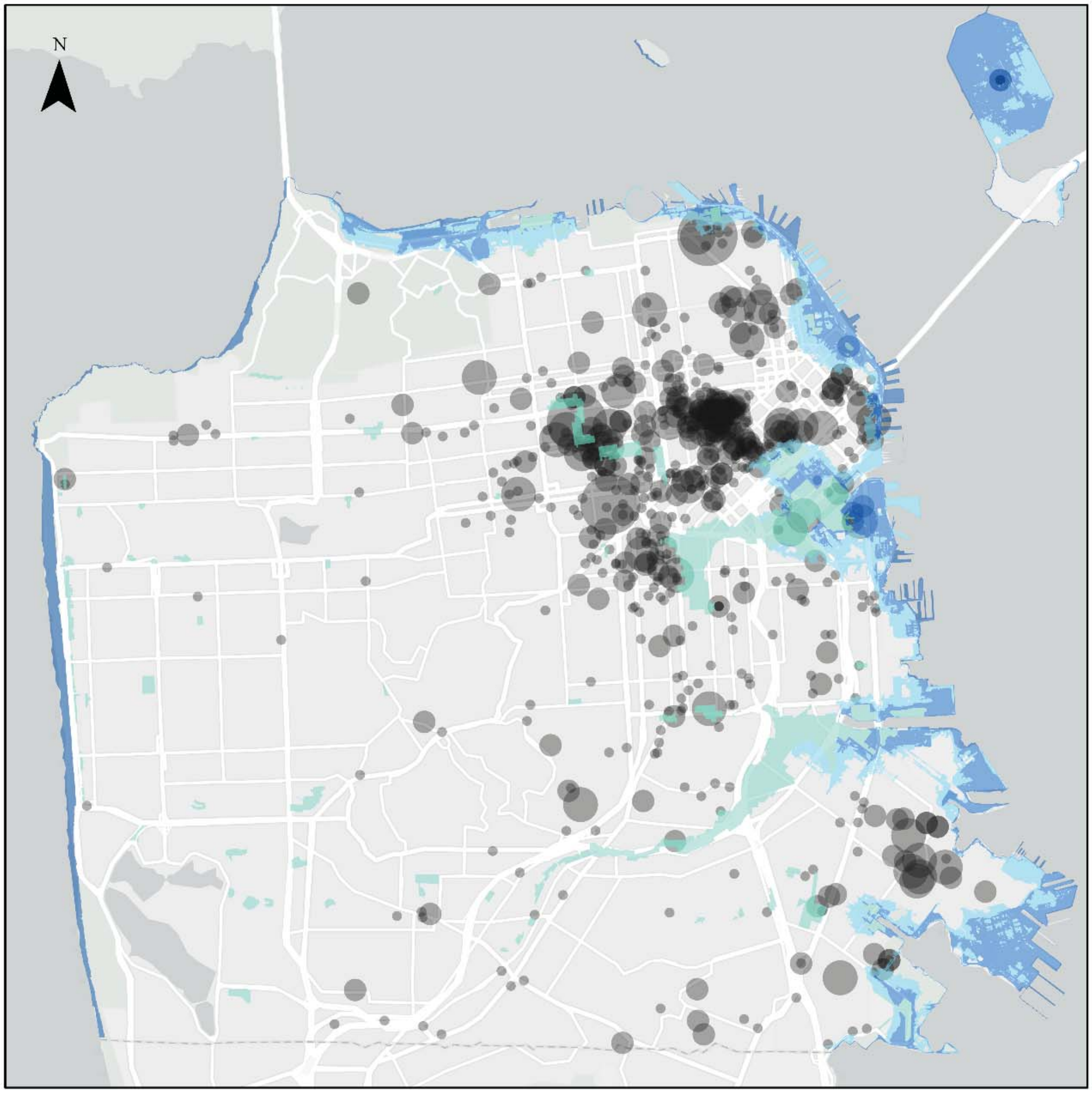
FIGURE A-30: AFFORDABLE HOUSING AND FLOOD HAZARD



0 0.5 1 2 Miles

Flood Risk
Subsidized Affordable Housing

Flood Hazards
- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Number of Low Income Units
- 1 - 49
- 50 - 149
- 150 - 449
- 450 - 766

Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps; Affordable Housing data compiled by SF Planning in 2018 from CHPC, HUD, MOHCD

This map is intended for planning-level analysis and should not be used for permitting, regulatory, or other legal uses. Flooding is possible in areas outside of those displayed on this map. The risk zones are based on model outputs and relied on LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and structures, site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Ground shaking and liquefaction can damage vulnerable housing types:[7] **Older single family homes:** Un-retrofitted older single family homes with cripple walls (short unreinforced walls that raise the first floor 1-5 feet above ground level for a crawl space or above ground basement), that are split level, and that have living spaces over an attached garage. Homes built before the 1940s on flat sites and those built in any year on sloped sites are particularly vulnerable. Homes not bolted to their foundation can slide off and the cripple wall or garage walls can collapse. Hillside homes can collapse down the hill with inadequate anchorage. **Soft-story buildings:** Wood frame multi-family buildings built before 1995 with parking or retail on the ground floor are known to experience ground floor collapse or tilt in an earthquake, as was seen in the Marina District in the Loma Prieta earthquake. More than 2,000 of the city's 4,908 soft-story buildings have been retrofitted to date and work is scheduled to be completed on the remaining buildings by 2020.[8] **Older concrete buildings:** Concrete buildings constructed prior to 1980 are likely to have nonductile detailing and other deficiencies that have resulted in building collapse in previous earthquakes around the world. These buildings tend to be midrise buildings. Approximately 3,300 such buildings exist in San Francisco (residential and nonresidential), but it is not known which percentage of these pose a collapse risk in an earthquake.[9] **Newer construction:** Modern building codes are meant to ensure that buildings have low life-safety risks from falling hazards and collapse. However, modern building codes do not provide minimum requirements for controlling earthquake damage that may require extensive repair with extended downtime.[10] Other less common vulnerable housing types include unreinforced masonry, and mobile or manufactured homes. Nonstructural

[7] "Guide to Earthquake Vulnerable Housing Types," Association of Bay Area Governments Resilience Program, December 2016, http://resilience.abag.ca.gov/housing/vulnerable_types/.

[8] "Mandatory Soft Story Program," San Francisco Department of Building Inspection, 2018, https://sfdbi.org/softstory.

[9] "SF Tall Buildings Study," San Francisco Office of Resilience and Capital Planning, unpublished.

[10] "SF Tall Buildings Study," San Francisco Office of Resilience and Capital Planning, unpublished.

	elements such as water heaters and brick chimneys may also cause damage and injury in an earthquake. New models predict that in a M7.8 San Andreas earthquake, 18,300 residential buildings of any size could be damaged in San Francisco, temporarily or permanently displacing 69,600 households (20% of all households) with 16,500 people seeking privately or publicly provided short term shelter. Residential building losses could top $8 billion in San Francisco alone.[11] Voluntary and mandatory retrofit programs for residential property protects residential investments, keeps residents in their homes and neighborhoods intact. **Flood:** Most homes are not built to withstand any amount of flooding, as current construction materials, siting and design standards do not consider potential exposure to either water or salt. San Francisco does not have an adopted FEMA flood plain with building code requirements but both coastal floodplains (through FEMA) and urban flood zones (through SFPUC) are under development. **Extreme Heat:** Residential buildings are not physically damaged by heat, but older and un-weatherized buildings or those without air conditioning can lead to unhealthy conditions for occupants, particularly the elderly, children, and those with illnesses that make them more sensitive to heat. Given the usually mild conditions in San Francisco, most housing does not have air conditioning. **Fire:** Buildings made with wood are highly susceptible to fire. Steel and concrete buildings are less vulnerable to fire damage, and steel buildings contain fire proofing materials to resist fire damage. Because of varying prevailing winds across San Francisco, and the proximity to freeways and other pollution-producing sources, and as serious fire events increase across Northern California, some neighborhoods and households are more adversely affected by poor air quality than others. Most housing in the City does not have HVAC systems or window insulation to mitigate the risks.
Functional	 **Networks:**

[11] "Expected Housing Losses in an Earthquake," Association of Bay Area Governments Resilience Program, September 2018, http://resilience.abag.ca.gov/housing/losses/.

	Although housing is not networked, housing supply is limited and affordable housing is even more limited[12]. Any damage to housing stock could lead to the displacement of residents from the City or region if they cannot find alternative and affordable housing. **External Services:** Housing relies on power, natural gas, sewer and water systems, and access to food, communications, and transportation for full function. Homes are unlikely to have independent back up power. Many households do not have emergency gas shut-off valves. Residents are encouraged to have earthquake kits including water and food for 72 hours after an event. The Neighborhood Emergency Response Teams (NERTS) and Neighborhood Empowerment Network (NEN) program aim to help empower residents to prepare themselves for disasters. **Populations Served:** Everyone needs housing, but some residents are already in overcrowded or poor condition housing. (Some are also unhoused, see Populations profile). Low income residents are particularly vulnerable to housing damage because they are more likely to rent, more likely to spend a high percentage of their income on housing and may not have the financial resources to find replacement housing. Structural racism and enduring impacts of exclusionary zoning make these vulnerabilities even more acute for communities of color who face displacement pressure under normal conditions. Natural disasters and/or climate change impacts could worsen this pressure and accelerate displacement without proactive strategies from the City and Community Based Organizations. Older housing without adequate HVAC puts residents at higher risk of heat and air quality health impacts from fire. This has a particular impact on sensitive populations, such as children, the elderly, those who are pregnant, and those with medical conditions. This can be particularly acute in Single Room Occupancy buildings (SROs), as well as Skilled Nursing Facilities (SNFs), which both house highly vulnerable populations. **Unique or Critical Function:** Housing is limited in supply and provides a critical function for residents. Loss of housing could lead to permanent displacement of residents given low vacancy rates and high rents and property values.
Informational	

[12] "Housing Needs and Trends Report" San Francisco Planning Department, July 2018, https://sfplanning.org/resource/san-francisco-housing-needs-and-trends-report

	All-hazards: ABAG has resources on seismic vulnerable housing types, as well as expected housing losses during a seismic event. The SF Department of Building Inspection maintains data on mandated seismic reporting and retrofitting. The SF Office of Resilience and Capital Planning will soon publish a report on tall buildings and their vulnerability in a seismic event. The USGS HayWired report also outlines SF high rise vulnerabilities during a seismic event. Additionally, a draft vulnerability and consequence assessment exists for sea level rise
Governance	**All-hazards:** Housing has many individual, private and public owners so hazard mitigation and adaptation action require many different implementation and funding mechanisms. San Francisco has established voluntary and involuntary seismic retrofit programs and is developing a similar program for urban flooding. Building code, planning code, and green building code are important regulatory tools that may be leveraged for developing climate and hazard resilience for housing.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Low income residents are particularly vulnerable to housing damage because they are more likely to rent, more likely to spend a high percentage of their income on housing, and they may not have the financial resources to find replacement housing. Structural racism and enduring impacts of exclusionary zoning make these vulnerabilities even more acute for communities of color who face displacement pressure under normal conditions. Displacement can result in longer commuters and separation from social connections and resources, affecting families and mental health. Without proactive strategies from the City, companies, foundations, and Community Based Organizations, natural disasters and/or climate change impacts could worsen this pressure and accelerate displacement. Below is more detail on specific housing challenges faced by San Francisco households as well as information on particular types of housing that are more likely to serve low and moderate income people and therefore have special social and equity importance. **Rent Controlled Housing:** According to data compiled for the Housing Needs and Trends Report an estimated 40% of San Francisco's total housing and nearly 70% of the rental stock are subject to rent control, an estimate of over 160,000 units. As of 2015, an estimated 68,000 low income renters and 24,000

moderate income renters lived in rent-controlled units and many were paying rents significantly below market. If tenants are forced to relocate after a disaster it could be difficult to find homes at an affordable price and they may be forced to leave the city. In addition, rent controlled housing is mostly multi-unit buildings which may require more time-consuming and costly repair than single family homes.

Cost burdened Renters: 2013-2017 ACS data shows over 87,000 renters in San Francisco who are cost burdened, spending more than 30% of income on rent. Of these, over 42,000 are severely cost burdened or paying more than 50% of income on rent. Renter cost burden is concentrated in low- and moderate-income households and severe cost burden is concentrated among extremely low and very low income households who earn up 30% and 50% of area median income, respectively. Many of these households are already taxed financially and dislocation from their housing could make it difficult to remain in the city during recovery and special focus and investment will be needed to help retain these households. Communities of color, including African Americans and Latinos along with seniors and people with disabilities are face higher rates of severe rent burden.

Cost Burdened Owners: 2013-2017 ACS data shows over 41,000 owner households are cost burdened spending more than 30% of income. Of these, over 18,000 are severely cost burdened spending more than 50% of income on housing costs. While homeowners have more security of tenure and are likely to have more wealth in home equity, lower income homeowners who are the majority of owners with severe cost burdens, are likely to be least equipped to recover from a disaster with less savings and less capacity to navigate bureaucracy to access recovery funds. Additional services and programs may be needed to reach vulnerable, low income homeowners.

Overcrowding: 2013-2017 ACS data shows 6% of all households or 22,000 households are overcrowded, meaning there are more than one person per habitable room and more than half of these households are severely overcrowded with more than 1.5 people per room. Overcrowding is problem overwhelmingly faced by families with children and is mostly a problem for low income households. It is also more pronounced among people of color especially Asians and Latinos. Many families with children who are overcrowding will struggle to find housing that can accommodate their families should they be displaced due to disaster. Services to help accommodate these households in the event of an emergency will help to retain them in the city.

	Subsidized affordable housing: There are approximately 33,000 housing units in San Francisco that have been built or preserved with public subsidy to be affordable to people with low and moderate incomes. This housing has been built and preserved with a range of local, state, and federal sources as well as inclusionary housing policies that require affordable units as part of market rate development. Some buildings that serve low income tenants may have maintenance and modernization needs that could affect recovery or resiliency after a disaster. Because affordable housing financing depends on many sources including tax credits, local public loans, private loans, and state funding, re-financing for repair or rebuilding could be more complex than average for a multifamily building. The need for relocation assistance could be particularly strong for affordable housing tenants during rebuilding or repair. Some publicly funded developments also house people with physical, mental, and developmental disabilities who need special attention. In the event of evacuation, these populations need additional oversight and assistance in the event of displacement. **SROs:** There are approximately 19,000 single room occupancy (SRO) units in hundreds of buildings around the city. According to San Francisco's Planning code, an SRO unit can be no more than 350 square feet. These small units tend to be more affordable than other housing and disproportionately serve lower income people including many seniors, people with disabilities, people of color, and immigrant families. Most SROs were built in the nine years following the 1906 earthquake and many are nearly 100 years old. As a result, many buildings may have significant maintenance needs, need adaptations for changing weather, and could need significant repairs following a disaster. San Francisco regulates SROs to preserve this housing stock through the Residential Hotel Unit Conversion Ordinance (HCO). Over 12,000 SRO units are privately owned while more 6,500 are nonprofit owned (and are included in the 33,000 affordable units described above). **Skilled Nursing Facilities (SNFs**), SNFS are often located in residential buildings and serve medically-vulnerable residents who need daily care. Any impacts to residential buildings that include SNFs would have severe impacts on residents who are unable to evacuate and need consistent access to medical care. **Geologic:** Seismic impacts would be the most widespread and therefore affect more people than other predicted hazards. Low income residents

	and renters may be disproportionately impacted because they may not have insurance or the financial means to seek alternative housing after a seismic event. **Flood:** Flood impacts to housing would be geographically limited, but historically have been most severe in low-income communities of color (Inner Mission and Cayuga). Flooding can result in mold conditions and adverse health impacts without appropriate cleanup and remediation. **Extreme Heat:** Heat impacts could disproportionately burden residents in overcrowded or substandard housing who have few resources for weatherproofing or retrofitting. **Fire:** Fire impacts could disproportionately burden residents in overcrowded or substandard housing. Poor air quality disproportionately affects the health of low-income communities concentrated in areas around freeways and those lacking the favorable prevailing winds (such as Bayview Hunter's Point). During prolonged fire seasons, residents have needed a safe haven from dangerous particulates, but in some neighborhoods, the interiors of residents' homes do not provide that safety. Households and owners in these neighborhoods often do not have the means to install HVAC systems or to seal their windows to mitigate the risks in the homes.
Economy	**All-hazards:** Depending on the scope of the hazard, impacts could range from individual households or neighborhoods to the region. Homeowners could lose equity in their homes. Both renters and owners would face direct costs like rent for alternative housing and repair/replacement of damage to the house itself and contents. Secondary economic impacts could include lost work time due to displacement and health impacts, and potential disinvestment in vulnerable neighborhoods if mortgage companies refuse loans or other market factors. Housing recovery post-disaster can take weeks to years depending on damage type and funding availability. Housing may or may not be habitable during recovery depending on the severity of the impact and what repairs are necessary. According to the 2018 Housing Needs and Trends Report, majority of lower wage workers in San Francisco also live in the city but the rate of lower wage workers living in the city has been declining and these workers may have higher vulnerability to displacement during

	a major disaster, given high market housing prices. San Francisco's post-disaster economic recovery could be hindered without plan to temporarily house and permanently re-house these workers. **Geologic:** Seismic hazards are the most widespread and could lead to regional impacts on housing supply in a large event with 68,900 residential buildings uninhabitable and 198,700 households potentially displaced across the Bay Area in a M7.8 San Andreas earthquake.[13] Most households do not carry earthquake insurance. **Flood:** Economic impacts from flood events on housing are likely to be limited to specific neighborhoods. FEMA flood insurance is not required in San Francisco which may lead to more severe economic impacts for homeowners and renters in the flood zone. **Extreme Heat:** Increased HVAC use can lead to higher operational costs for building owners. Recurring heat events could lead to increased medical costs and lost wages for outdoor workers. **Fire:** Fire events could result in direct economic impacts like damaged or destroyed homes and businesses. Without mitigations, poor air quality may result in extreme and costly health outcomes, with the attendant loss of economic vitality in the City. The key mitigation -- HVAC systems -- are costly for property owners.
Environment	**Geologic:** Reconstruction of damaged housing may be material and energy intensive and include emissions from equipment and impacts from trucks supplying construction materials. Temporary or interim housing may face challenges with management of wastewater and solid waste and may temporarily occupy open space. Displacement could cause longer commutes, which increases congestion and GHG emissions. Debris management and removal may have impacts, including truck traffic, and exposure to harmful chemicals. **Flood:** Floods could mobilize household hazardous waste that is improperly stored leading to water quality impacts. **Extreme Heat:**

[13] "Expected Housing Losses in an Earthquake," Association of Bay Area Governments Resilience Program, September 2018, http://resilience.abag.ca.gov/housing/losses/.

	Increased use of HVAC systems could increase GHG emissions if these are not efficient and using a clean energy source. **Fire:** Debris management and removal has the potential to expose humans and the environment to harmful chemicals if not properly managed. The use of HVAC systems to mitigate the hazard may have the unintended consequence of increased GHG emissions.

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Commercial Buildings

Introduction to Asset Class

For this assessment, commercial buildings are classified as office, retail, hotels, and mixed use property types. San Francisco has a high number of office properties, making up 55% of total commercial floor area (including hotels and industrial) and 37% of all commercial buildings in 2014. All other non-hospitality and warehouse properties (including retail) make up 27% of total commercial floor area and 43% of all commercial buildings.[14] There were 218 hotels counted in 2017, with more than 34,000 rooms.[15] San Francisco's commercial properties house the economic engine of San Francisco, supporting the City's tech and finance industries.

Commercial buildings are found throughout the city, but are densely concentrated in the northeast quadrant. Nearly 60% of hotel rooms in San Francisco are located within walking distance of the Moscone Center in the South of Market neighborhood.[16] The northeast quadrant features a variety of commercial building types, from small wood frame and masonry buildings to concrete and steel frame skyscrapers. Neighborhood commercial properties are prevalent throughout the city and concentrated along commercial corridors. These commercial buildings are smaller, usually 1-5 stories, and are often mixed use properties with retail use on the ground floor and residential or office use above. These properties are largely privately owned and managed.

Issue Statement

Commercial buildings are critical infrastructure for one of the largest job centers in the Bay Area. These buildings have a variety of built forms, and some have been identified as significantly vulnerable in a seismic and/or fire event. Pre-1978 wood frame buildings with residential units over commercial or retail spaces, known as soft-story buildings, are vulnerable to collapse in earthquakes. Older steel frame buildings constructed between the 1960s and 1990s have known deficiencies, including welded steel connections that have fractured in strong shaking during the 1994 Northridge

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[14] "San Francisco Existing Commercial Buildings Performance Report," SF Environment and ULI Greenprint Center for Building Performance, 2015, http://uli.org/wp-content/uploads/ULI-Documents/SFenergybenchmarkingreport.pdf.
[15] "2017 Lodging Statistics," San Francisco Travel, March 2018, https://sftravel.ent.box.com/s/qjchpspcuabqx400kp64yf4lqvtmbngw.
[16] "San Francisco Visitor Industry Statistics," San Francisco Travel, 2018, https://www.sftravel.com/san-francisco-visitor-industry-statistics-1.

earthquake. Older concrete buildings constructed before 1980 (a common building type in San Francisco) are likely to have non-ductile construction and other detailing that have led to collapse in past earthquakes. San Francisco's Earthquake Safety Implementation Program calls for older concrete buildings to be evaluated starting in 2020 and for older steel frame buildings to be evaluated starting in 2030. Soft-story buildings are required to be retrofitted by 2020.

Hotels are a unique asset in the commercial category, providing overnight housing for City visitors, who are particularly vulnerable in a hazard event. In the event of an evacuation due to earthquake or fire, the length of time necessary to evacuate large volumes of people who work in high rises coupled with the potentially short period of time available to safely evacuate makes populations who work in high rises particularly at risk, especially those with limited mobility or medical conditions. Many businesses in San Francisco handle highly sensitive data, information, or capital that could impact the national and global economy if operations are disrupted.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In Table A-11, on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data originates from datasets maintained by SF Planning.

Exposure Summary

Geologic: During a 7.8M earthquake on the San Andreas Fault, all commercial parcels are at risk of either Violent or Very Strong groundshaking. During a 7.0M earthquake on the Hayward fault, over 90% of office and commercial parcels are at risk of Very Strong or Strong groundshaking, retail parcels face slightly less risk citywide. Over 40% of office and hotel parcels are in the liquefaction zone, compared to 35% of mixed commercial parcels, and 22% of retail parcels.

Flood: Commercial asset exposure to flooding is minimal, but 13% of office parcels and 9% of mixed commercial parcels are in areas which may be exposed to 66 inches of future sea level rise, if protective measures are not taken.

Fire: Commercial assets not exposed

TABLE A-21: EXPOSURE

Hazard	Office Parcels 1300 Total		Mixed Commercial Parcels 1900 Total		Retail Parcels 2700 Total		Hotel Parcels 300 Total	
	#	%	#	%	#	%	#	%
Geologic								
San Andreas 7.8 - Violent	100	8%	300	13%	500	18%	-	3%
San Andreas 7.8 - Very Strong	1,200	92%	1,700	87%	2,200	82%	300	97%
Hayward 7.0 - Very Strong	200	16%	200	8%	100	5%	-	9%
Hayward 7.0 - Strong	1,000	76%	1,600	83%	2,200	80%	200	88%
Liquefaction Zone	600	44%	700	35%	600	22%	100	42%
Flooding								
100-Year Coastal Flood Zone	-	0%	-	0%	-	0%	-	0%
100-Year Storm + 24 inches SLR	100	5%	100	4%	-	2%	-	3%
100-Year Storm + 66 inches SLR	200	13%	200	9%	100	4%	-	7%
100-Year Stormwater Flood	100	5%	100	5%	100	4%	-	4%
Wildfire								
High	-	0%	-	0%	-	0%	-	0%
Moderate	-	0%	-	0%	-	0%	-	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

FIGURE A-31: COMMERCIAL USES AND LIQUEFACTION HAZARD

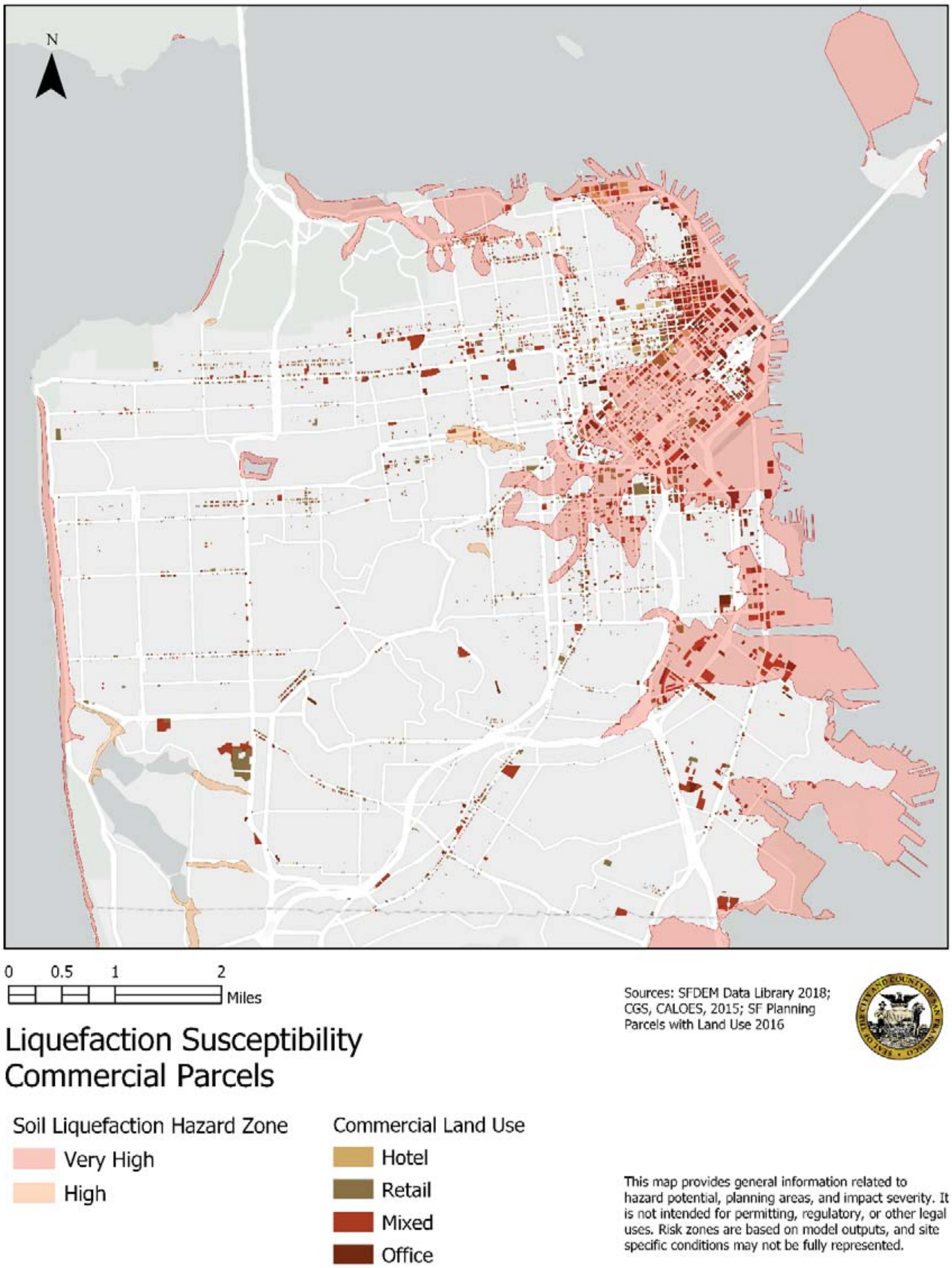
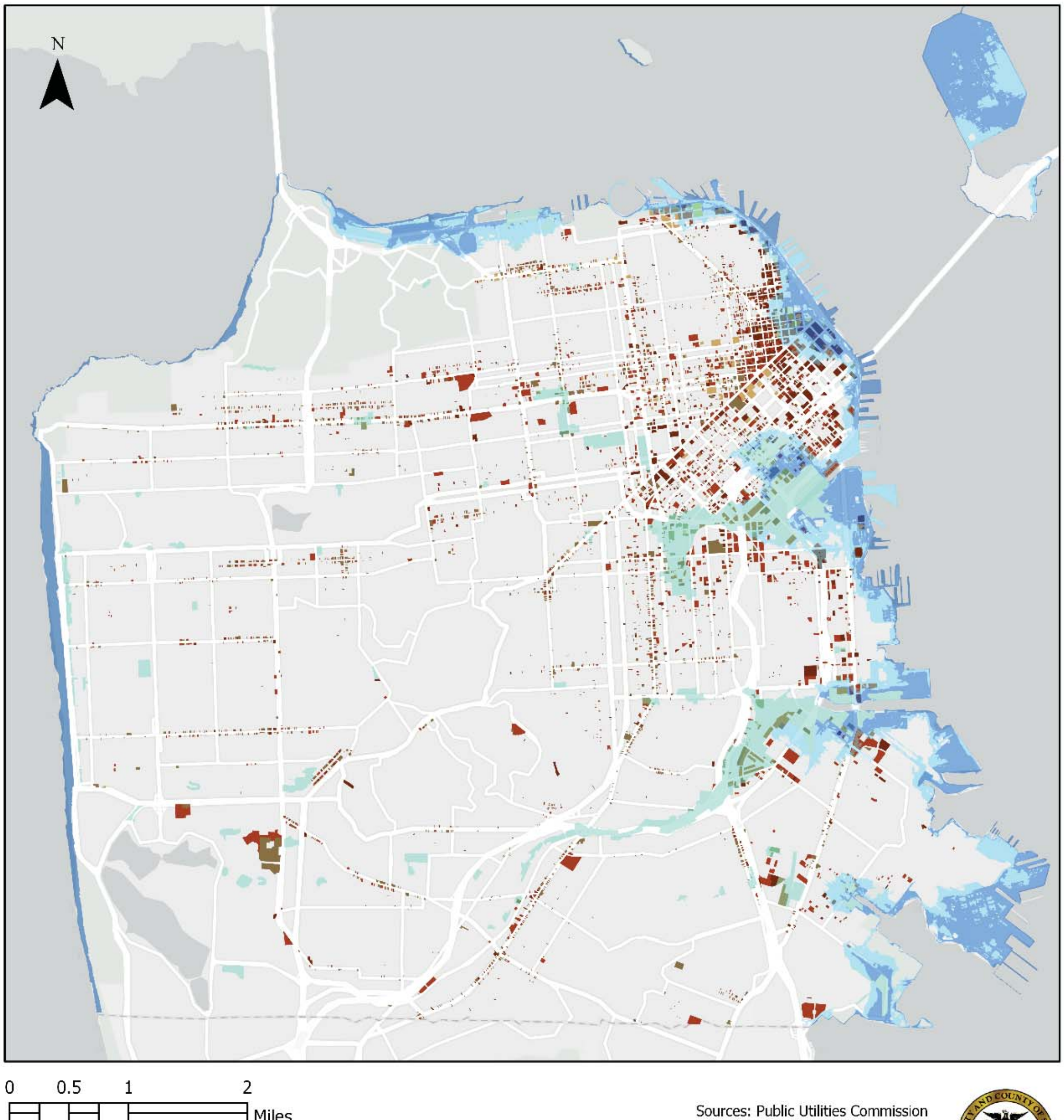


FIGURE A-32: COMMERCIAL USES AND FLOOD HAZARDS



Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps; SF Planning Parcels with Land Use 2016

Flood Risk and Commercial Parcels

Flood Hazards

- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Commercial Land Use

- Hotel
- Retail
- Mixed
- Office

This map is intended for planning-level analysis and should not be used for permitting, regulatory, or other legal uses. Flooding is possible in areas outside of those displayed on this map. The risk zones are based on model outputs and relied on LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and structures, site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Pre-1978 soft story buildings are vulnerable to extensive damage. This impacts commercial or retail spaces housed underneath multi-unit residential buildings or offices. Regulation requires these buildings (with 5+ units, and with 2+ stories over a soft story) to be retrofitted by 2020. Unreinforced masonry buildings that have not been retrofitted are also vulnerable to damage, but existing retrofit regulation should make these examples rare. Pre-1980 non-ductile concrete frame buildings are brittle and vulnerable to extensive damage with significant life safety risk.[17] Approximately 3,400 such buildings exist in San Francisco (residential and nonresidential), but it is not yet known which small percentage of these pose a collapse risk in an earthquake. Steel frame structures built between 1960 and 1994 are vulnerable to earthquakes if they use a welded steel construction method.[18] San Francisco's Earthquake Safety Implementation Program and Tall Buildings Safety Strategy recommend non-ductile concrete buildings and welded steel frame buildings be evaluated starting in 2020. **Flood:** Most commercial properties are not built to withstand any amount of flooding, as construction materials, siting and design standards do not require consideration of potential exposure to either water or salt. **Extreme Heat:** Older buildings that do not have adequate weatherization or HVAC may be more vulnerable to heat impacts. **Fire:** Buildings made with wood are highly susceptible to fire. Steel and concrete buildings are less vulnerable to fire damage and steel buildings contain fire proofing materials to resist fire damage. Older buildings that do not have adequate HVAC and filtration technology may be more vulnerable to air quality impacts.
Functional	**Networks:** Commercial buildings themselves are not networked, however, businesses may have important supply, information, or capital

[17] "Guide to Earthquake Vulnerable Commercial Building Types," Association of Bay Area Governments Resilience Program, September 2016, http://resilience.abag.ca.gov/commercial-building-types/
[18] Detweiler, S.T., and Wein, A.M., eds., 2018, The HayWired earthquake scenario—Engineering implications: U.S. Geological Survey Scientific Investigations Report 2017–5013–I–Q, 429 p., https://doi.org/10.3133/sir20175013v2

	networks between them. Businesses that handle highly sensitive data/capital may have detailed contingency plans if their operations are disrupted or shut down. **External Services:** Office and retail businesses rely on power, water, communications, and transportation access for full functioning. Buildings that have sensitive components (such as life and sciences commercial uses) may be more likely to have back up power. **Populations Served:** Commercial buildings house businesses that employ residents of SF and the greater Bay Area. These are typically those of working age, and include those who are physically disabled, low income, housing and transportation cost burdened, non-English speakers, renters, and those without cars. Hotels serve visiting populations overnight. Visitors may not speak English as a first language, have fewer back-up resources available to them, and may not know how to access important information or emergency service. Businesses and nonprofits that use commercial properties may be a part of the Neighborhood Emergency Response Team that aids in emergency response efforts. **Unique or Critical Function:** Commercial buildings in SF house one of the largest job centers in the Bay Area. These facilities are necessary for the Bay Area's primary industries to function. Many of these facilities house companies that could impact the global economy if their services are disrupted. Hotels house tens of thousands of visitors overnight daily.
Informational	**All-hazards:** ABAG has resources on seismic vulnerable commercial building types. The SF Department of Building Inspection maintains data on mandated seismic reporting and retrofitting. The SF Office of Resilience and Capital Planning published a report on tall buildings and their vulnerability in a seismic event, and strategies to reduce vulnerability. The USGS HayWired report also outlines SF high rise vulnerabilities during a seismic event. Additionally, a draft vulnerability and consequence assessment exists for sea level rise threat.
Governance	**All-hazards:** SF building code regulates commercial building safety requirements. This includes soft story and masonry retrofit requirements, as well as HVAC, filtration, and fire requirements. San Francisco's building code also contains requirements for post-earthquake repair and retrofit of earthquake damaged buildings (AB-098, AB-099, AB-100).

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** SF's commercial buildings provide places of work for San Franciscans and for a large proportion of Bay Area residents. Damage and disruption to these buildings can disrupt these residents' work, their workplace social networks, and can even prompt widespread short term unemployment. This is particularly impactful to the lives of those who are non-salaried, who are low-income, and who are transportation and housing burdened. Hotels also provide overnight housing for tens of thousands of San Francisco visitors daily. These guests may not speak English as a primary language, they will have fewer resources available to them, they may not know how to access important information or emergency services, and they are heavily reliant on hotel emergency procedures for their safety. Many commercial buildings are also important to the cultural identity of the surrounding neighborhood or city. These businesses can provide places for community members to gather and socialize, they can provide a unique neighborhood function, or they can serve as a community symbol. The destruction of these landmarks and nodes can have significant impacts to community identity and can disrupt local social networks. **Geologic:** Significant groundshaking can result in human casualties from building damage. In a large seismic event, populations in high rises are especially vulnerable in the event of an emergency evacuation, due to the short time available to safely evacuate, the large volume of people who need to evacuate, and the long distances many people will need to travel to evacuate. Populations with limited mobility or medical conditions are particularly at risk. Emergency plans and evacuation procedures are required by federal law. **Flood:** Significant stormwater flooding may result in human casualties if there is no 2nd story. Populations with limited mobility or medical conditions are particularly at risk. **Extreme Heat:** Heatwaves may cause closures in non-weatherized buildings without cooling capabilities. Heat waves increase health risk for

	medically sensitive populations, such as the elderly, pregnant women, and those with medical conditions. **Fire:** Significant fire can result in human death or injury, especially in high rises. Populations in high rises are especially vulnerable in the event of an emergency evacuation, due to the short time available to safely evacuate, the large volume of people who need to evacuate, and the long distances many people will need to travel to evacuate. Populations with limited mobility or medical conditions are particularly at risk. Emergency plans and evacuation procedures are required by federal law. The *San Francisco Building Code* requires many buildings to have an in-building secondary water supply to operate the sprinkler system for 30 minutes. The Tall Buildings Safety Strategy recommends a study to evaluate whether (1) the in-building secondary water supply for automatic fire suppression in tall buildings is sufficient to inhibit fire spread and allow safe evacuation, and (2) the building code provisions that rely on elevators for evacuation during a fire emergency will be effective following an earthquake. **Air Quality:** Reduced air quality from fire smoke in unfiltered buildings can result in increased rates of asthma attacks. This is especially true in under-resourced communities and communities of color, which have significantly higher rates of bronchial disease. Smoke impacts will not cause building damage or long term closure.
Economy	**All-hazards:** Any damage to the facility will require property owners to fund repairs or replacement. Businesses owners will have to bear the cost of relocating or otherwise accommodating its employees in the event of structural building damage. Each day of closure or limited facility use can reduce or eliminate daily revenue. In addition, non-salaried employees will lose wages for each day of closure. Hourly employees and small business employees/owners are most impacted by these events. Permanent closures will result in loss of employment. Many commercial building owners participate in DBI's Building Occupancy Resumption Program (BORP), which allows San Francisco building owners to pre-certify private post-earthquake inspection of their buildings by qualified engineers and specialty contractors to help speed re-occupancy of these buildings. **Geologic:** Depending on severity and building type, damage can lead to short to long term closure. The shutdown of many financial institutions

	and other global companies in the event of severe shaking and liquefaction may have economic impacts that are felt worldwide. Construction investment in the event of widespread destruction may have positive economic effects as well ("Creative Destruction" effect). **Flood:** Neighborhoods in coastal and storm water flood zones will see the most damage and economic impact. **Extreme Heat:** Depending on severity, health hazard can lead to short term closure in older buildings that do not have adequate HVAC. Those with adequate HVAC will increase power use and see associated financial impact. This hazard will not cause permanent or indefinite closure. **Fire:** Damage from fire can lead to short to long term closure. Air quality reduction from fire will not cause permanent or indefinite closure.
Environment	**Geologic:** Air quality could be temporarily impacted by the production of particulate matter from building damage. Reconstruction of damaged buildings may be material and energy intensive, including emissions from equipment and impacts from trucks supplying construction materials. Debris management and removal may have impacts, including truck traffic, and exposure to harmful chemicals. **Flood:** Flooding may cause debris from the building and soil from around the building to move into waterways. Floods could mobilize hazardous waste that is improperly stored leading to water quality impacts. **Extreme Heat:** Increased use of HVAC systems could increase GHG emissions if these are not efficient and using a clean energy source. **Fire:** Air quality would be reduced in the neighborhood, potentially regionally, if commercial buildings are directly impacted by fire. Debris management and removal has the potential to expose humans and the environment to harmful chemicals if not properly managed.

Industrial Buildings

Introduction to Asset Class

Industrial buildings are classified as production, distribution, repair (PDR) property types, housing industries such as construction, utilities, transportation, warehousing, fleet lots, wholesale, light manufacturing. Industrial buildings may also include more intensive uses, such as waste management or Port facilities. These properties house an important part of San Francisco's economy, with PDR jobs making up 13% of total employment and 8% of establishments in 2016.[19] PDR industries are especially important employers for low income families, with 70% of manufacturing employees coming from low income households.[20] The 2016 industrial inventory counts nearly 4,800 PDR establishments.[21] Around 2,100 parcels in San Francisco are for PDR use.

These buildings are densely concentrated in the east and southeast neighborhoods, including SOMA Showplace Square, Potrero Hill, Central Waterfront, and Bayview Hunters Point. PDR and waste management properties often take a warehouse building form (including tilt-up construction), but smaller industries may be found in a variety of commercial building types, such as masonry buildings and soft stories. These properties are largely privately owned and managed, though the City owns several maintenance and operations facilities, described in the Municipal Buildings section.

Issue Statement

Industrial buildings are critical infrastructure for job centers in the Bay Area that are especially important for low income households and for individuals without a post-secondary degree. These buildings often use old concrete, concrete tilt-up, and masonry construction, which are particularly vulnerable building types in a seismic event.[22] Smaller industrial companies may also use soft story building types. There is currently no mandatory retrofit regulation for tilt-up building forms. These buildings are

[19] "2016 San Francisco Commerce and Industry Inventory," San Francisco Planning Department, 2016, http://commissions.sfplanning.org/cpcpackets/2016CII.pdf.
[20] "Make to Manufacture: Advanced Manufacturing Playbook," Office of Economic and Workforce Development, 2016, https://oewd.org/sites/default/files/Documents/Make_to_Manufacture%20%282%29.pdf.
[21] "2016 San Francisco Commerce and Industry Inventory," San Francisco Planning Department, 2016, http://commissions.sfplanning.org/cpcpackets/2016CII.pdf.
[22] "San Francisco's Earthquake Risk," Department of Building Inspection, 2009,
https://sfdbi.org//sites/default/files/Documents/Boards_and_Commissions/Agenda_Attachments/Task_2_Report_apr8DRAFT.pdf

concentrated in low-lying neighborhoods with significant flood and liquefaction risks. Industrial buildings are important to maintain regional supply chains, distribution, and logistics, as well as citywide waste management.

TABLE A-22: EXPOSURE

Hazard	Industrial Parcels 2,100 Total	
	#	%
Geologic		
San Andreas 7.8 – Violent	200	7%
San Andreas 7.8 - Very Strong	1,900	93%
Hayward 7.0 - Very Strong	300	15%
Hayward 7.0 - Strong	1,700	81%
Liquefaction Zone	1,200	58%
Flooding		
100-Year Coastal Flood Zone	100	3%
100-Year Storm + 24 inches SLR	200	10%
100-Year Storm + 66 inches SLR	500	22%
100-Year Stormwater Flood	300	14%
Wildfire		
High	-	0%
Moderate	-	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

Exposure Summary

Geologic: All industrial parcels are within Violent or Very Strong groundshaking zones during a 7.8M earthquake on the San Andreas Fault. Ninety-six percent of industrial parcels are within Very Strong or Strong groundshaking zones during a 7.0M earthquake on the Hayward fault. Nearly sixty percent of industrial parcels are in a liquefaction risk zone.

Flood: Currently, three percent of industrial parcels have some portion in FEMA's 100-year coastal flood zone, and fourteen percent in the SFPUC's 100-year stormwater flood zone. In the future, ten percent of industrial parcels may be exposed to 24 inches of sea level rise, and 22% may be exposed to 66 inches.

Fire: Limited to no exposure.

FIGURE A-33: INDUSTRIAL USES AND LIQUEFACTION HAZARD

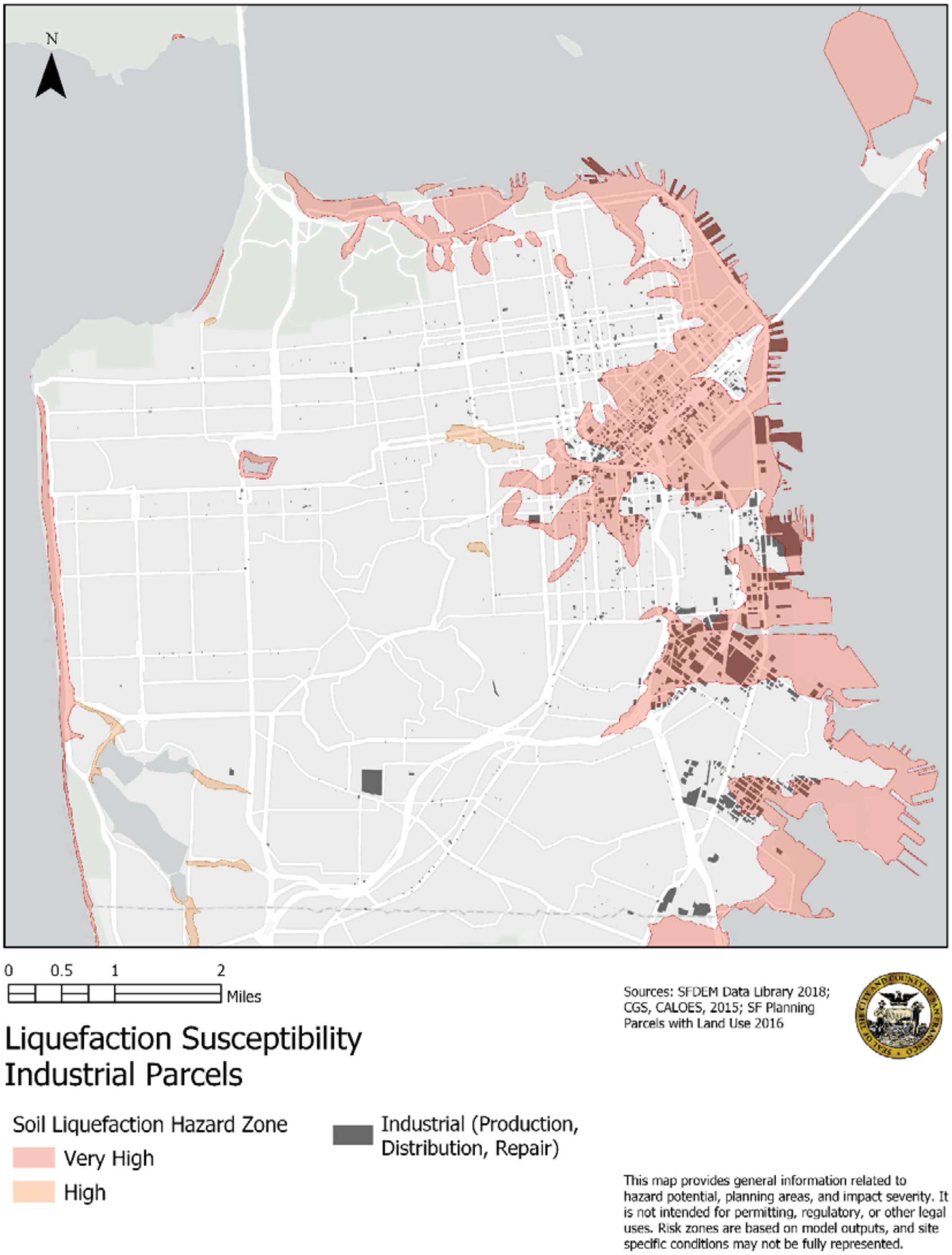
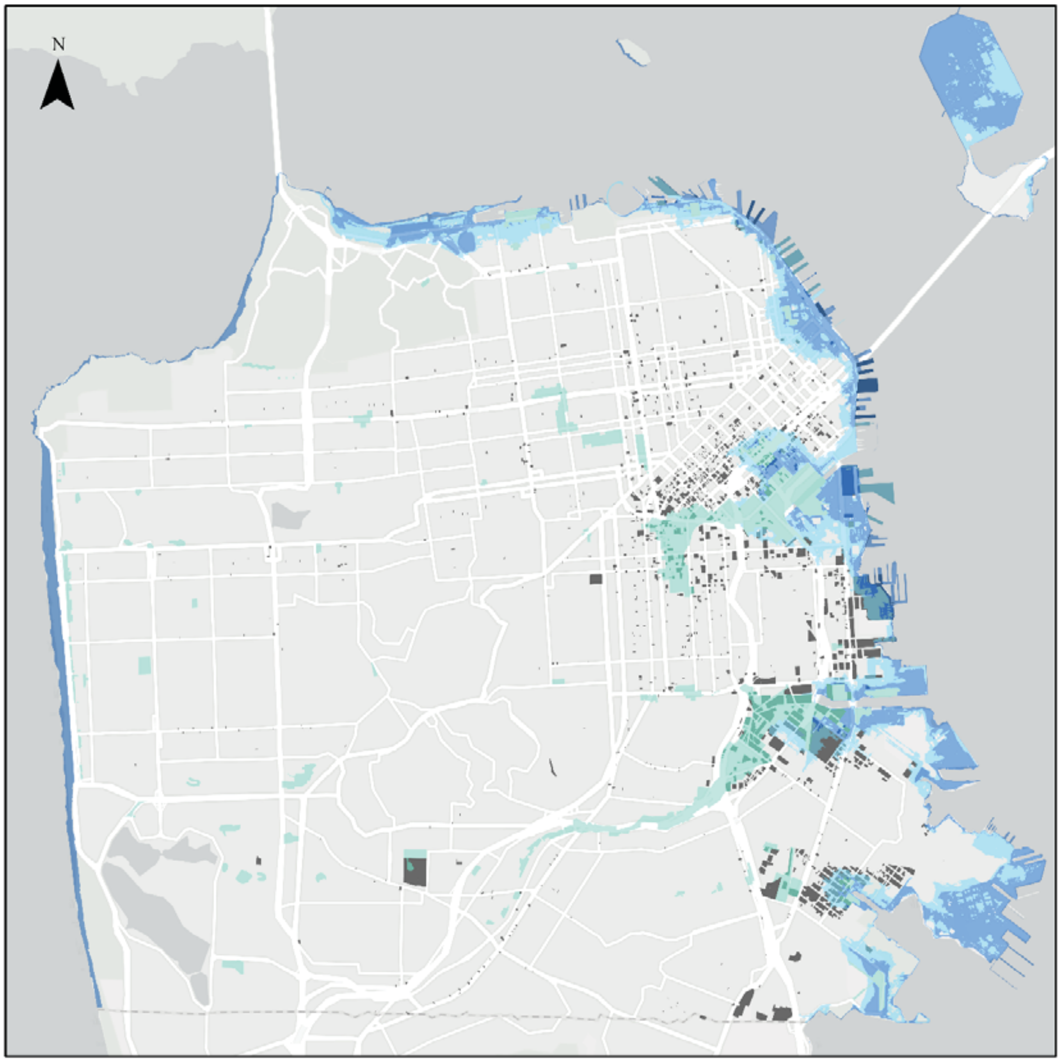


FIGURE A-34: INDUSTRIAL USES AND FLOOD HAZARDS



0 0.5 1 2
Miles

Flood Risk and Industrial Parcels

Flood Hazards

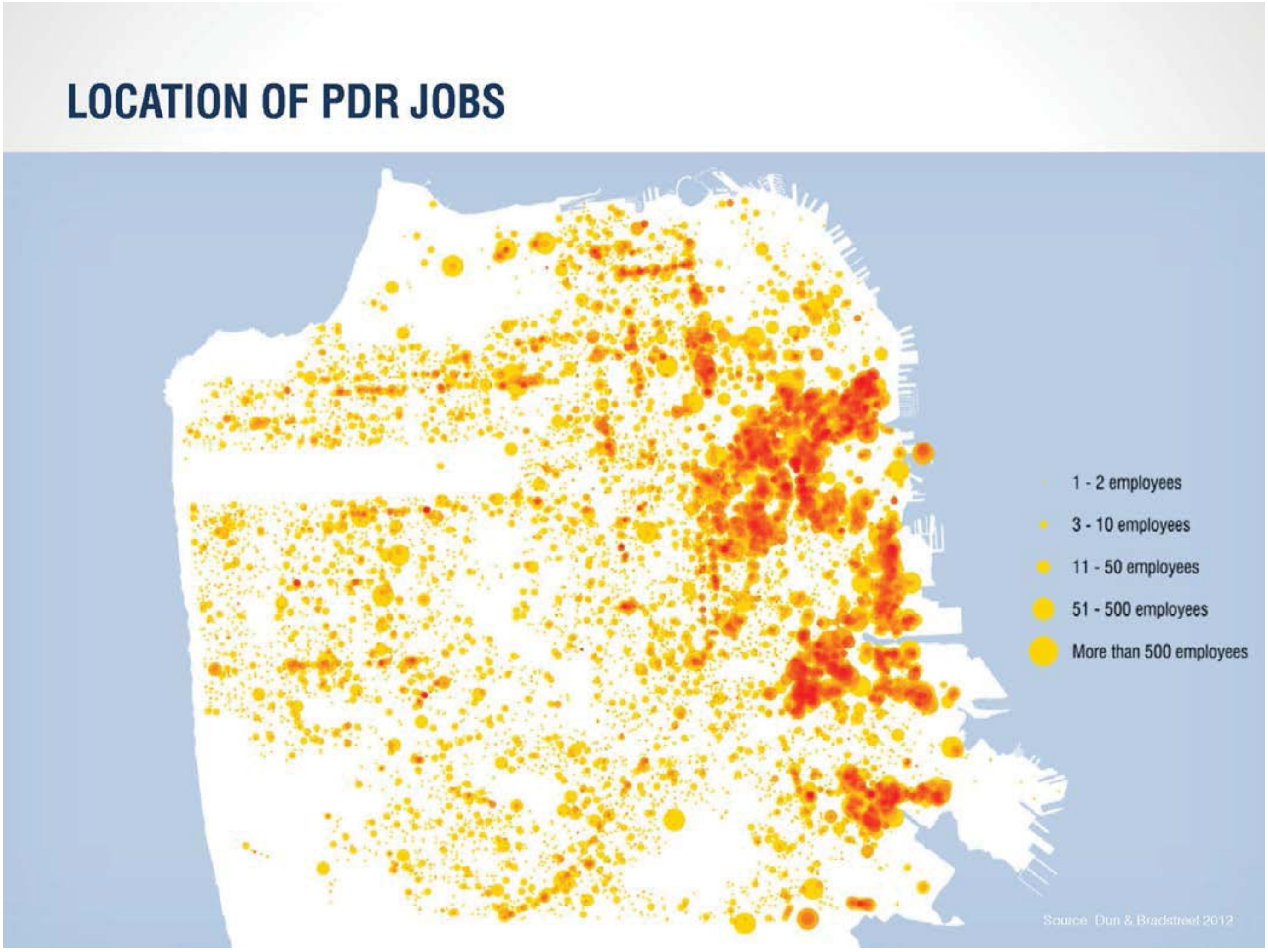
- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Industrial (Production, Distribution, Repair)

Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps; SF Planning Parcels with Land Use 2016

This map is intended for planning-level analysis and should not be used for permitting, regulatory, or other legal uses. Flooding is possible in areas outside of those displayed on this map. The risk zones are based on model outputs and relied on LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and structures, site specific conditions may not be fully represented.

FIGURE A-35: LOCATION OF PDR JOBS



VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Pre-1978 soft story buildings are vulnerable to extensive damage. This impacts small industrial businesses housed underneath multi-unit residential buildings or offices. Regulation requires these buildings (with 5+ units, and with 2+ stories over a soft story) to be retrofitted by 2020. Unreinforced masonry buildings that have not been retrofitted are also vulnerable to damage, but existing retrofit regulation should make these examples rare. Pre-1995 tilt-up buildings are vulnerable to extensive damage, but are not regulated. Tilt-up construction is a common industrial building type. In 2009 there were about 200 of these extant in San Francisco.[23] **Flood:** Most industrial properties were built before 1940 (40.3%) and in the decades immediately after World War II.[24] They were not built to withstand any amount of flooding, as construction materials, siting and design standards do not require consideration of potential exposure to either water or salt. These buildings are concentrated in low-lying neighborhoods with significant flood and liquefaction risks. **Extreme Heat:** Older buildings that do not have adequate HVAC may be more vulnerable to heat and air quality impacts. **Fire:** Older buildings that do not have adequate HVAC and filtration technology be more vulnerable to heat and air quality impacts.

[23] DBI (https://sfdbi.org//sites/default/files/Documents/Boards_and_Commissions/Agenda_Attachments/Task_2_Report_apr8DRAFT.pdf) Search "industrial"

[24] Bay Area Economics, 2018. "Port of San Francisco, Piers 90-94 Backlands Market Assessment: Draft Report." P.25

Functional	**<u>Networks:</u>** Industrial buildings themselves are not networked, however, many distribution yards or fleet lots have an office building that may be networked. These businesses have important supply, information, or capital networks between them. Industrial uses in particular are critical for business supply chains, construction, transportation (e.g. shuttles) and maintenance/operation of infrastructure equipment. **<u>External Services:</u>** Industrial businesses rely on power, fuel, water, communications, and transportation access for full function. Buildings that have sensitive operations may be more likely to have backup power. For example, operations that require temperature control (such as food processing facilities) may have generators. **<u>Populations Served:</u>** Industrial buildings house businesses that employ residents of SF and the greater Bay Area. These are typically those of working age, and include those who are low income, housing and transportation cost burdened, renters, and those without cars, as well as those who are ethnically and culturally diverse and/or have limited English speaking capacity. **<u>Unique or Critical Function:</u>** Industrial buildings in SF house many large employers in the Bay Area. Many of these facilities are necessary for the supply chain, distribution, and operation of Bay Area businesses and industries. For example, Recology's Recycle Central on Pier 96 is critical for SF waste management operations.
Informational	**<u>All-hazards:</u>** SF Department of Building Inspection put out an earthquake risk report in 2009 that provides an industrial building inventory, and outlines how these buildings would fare in different earthquake scenarios. Additionally, SF Planning published a 2016 Commercial and Industrial Inventory. A draft vulnerability and consequence assessment exists for sea level rise threat.
Governance	**<u>All-hazards:</u>** SF building code regulates commercial building safety requirements. This includes soft story and masonry retrofit requirements, as well as to HVAC, filtration, and fire requirements.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** SF's industrial buildings and facilities provide places of work for San Franciscans and for many Bay Area residents. Damage and disruption to these buildings can disrupt these residents' work, their workplace social networks, and can even prompt short term unemployment. This is particularly impactful to the lives of those who are non-salaried, who are low-income, and who are transportation and housing burdened. In manufacturing, 70% of employees come from low income households.[25] The destruction of industrial building landmarks might also have impacts to community identity in the surrounding neighborhood. **Geologic:** Significant groundshaking can result in human casualties from building damage. Populations with limited mobility or medical conditions are particularly at risk. **Flood:** Significant stormwater flooding may result in human casualties if there is no 2nd story. Populations with limited mobility or medical conditions are particularly at risk. Debris or contaminated soils could especially affect under-resourced communities and communities of color, many of which are adjacent to or mixed with industrial areas. **Extreme Heat:** Heatwaves may cause closures in non-weatherized buildings without cooling capabilities. Heat waves increase health risk for medically sensitive populations, such as the elderly, pregnant women, and those with medical conditions. **Fire:** Significant fire can result in human casualties. Populations with limited mobility or medical conditions are particularly at risk. Reduced air quality from fire smoke in unfiltered buildings can result in increased rates of asthma attacks. This is especially true in under-resourced communities and communities of color, many of which are adjacent to or mixed with industrial areas, and have significantly

[25] "Make to Manufacture: Advanced Manufacturing Playbook," Office of Economic and Workforce Development, 2016, https://oewd.org/sites/default/files/Documents/Make_to_Manufacture%20%282%29.pdf.

	higher rates of bronchial disease. Smoke impacts will not cause building damage or long term closure.
Economy	**All-hazards:** Any damage to the facility will require property owners to fund repairs or replacement. Businesses owners will have to bear the cost of relocating or otherwise accommodating its employees in the event of structural building damage. Each day of closure or limited facility use can reduce or eliminate daily revenue. In addition, non-salaried employees will lose wages for each day of closure. Hourly employees and small business employees/owners are most impacted by these events. Permanent closures will result in loss of employment. Industrial business slow-downs or closures can result in loss of revenue to upstream businesses (for example, supply shortages or logistics delays). **Geologic:** Depending on severity and building type, damage can lead to short to long term closure. The shutdown of many supply chain and logistics companies in the event of severe shaking and liquefaction may have regional economic impacts. Construction investment in the event of widespread destruction may cause positive economic effects ("Creative Destruction" effect). **Flood:** Neighborhoods in coastal and storm water flood zones will see the most damage and economic impact. The flooding of shuttle or other transportation facilities could also limit the ability of employees in all sectors of San Francisco to get to or from work. **Extreme Heat:** Depending on severity, health hazard can lead to short term closure in older buildings that do not have adequate HVAC. Those with adequate HVAC will increase power use and see associated financial impact. This hazard will not cause permanent or indefinite closure. **Fire:** Damage from fire can lead to short to long term closure. Air quality reduction from fire will not cause permanent or indefinite closure.
Environment	**Flood:** If commercial buildings are near to the coast, flooding may cause debris from the building and soil from around the building to move into waterways. This is especially a concern in older industrial areas

	where known or unknown contaminated soils from former uses could further pollute waterways and San Francisco Bay. **Fire:** Air quality would be reduced in the neighborhood, potentially regionally, if commercial buildings are directly impacted by fire.

Maritime

Introduction to Asset Class

The Port of San Francisco was created by the State of California to develop a Port within the State. Maritime uses depend on a waterfront location to operate. Since the 1960s, maritime needs have evolved and the demands for Port facilities and landside transportation changed with more focus on containerized cargo. In response, the Port has diversified its uses, including its maritime uses. The Port's maritime functions remain a critically important asset for the Port, the City, the region and the State. The importance of the Port's maritime functions is apparent from the range of activities that span its waterfront. These range from the fishing, police and recreational maritime uses in Fisherman's Wharf area, the cruise ship terminals, research vessel berths, Bar Pilots and fireboats in the Central Waterfront, and the cargo, ship repair and heavier industrial/maritime uses in the Southern Waterfront. Maintaining and enhancing the Ports maritime uses is important to the economy, safety, and job diversity of not only the Port itself but the rest of the City and County of San Francisco as well as the region.

There are unique physical characteristics of a number of Maritime assets that affect their vulnerability. All of the Port's maritime assets sit on or adjacent to the water and require shoreline access. The water dependency of the assets means that they were constructed to be durable given a certain amount of contact with water. However, Port facilities were constructed for lower water levels than those experienced today or those projected for the future. Additionally, many of the Port's maritime facilities are in need of additional maintenance and were constructed over 50 years ago. Many piers are served by utilities under them and this utility infrastructure are some of the Port's most vulnerable assets. The maritime assets at the Port also rely on shoreline transportation and utility network connections to function. The Port's maritime assets are constructed of a variety of materials including concrete, wood, covered asphalt, wood and steel piles, steel sheet piles and rely on piles, fendering, functioning aprons and floats. Many of the Port's assets, including its maritime assets are designated as historic and the Port is home to several historic districts-including the Embarcadero Historic District, the Northeast Waterfront Historic District and the Union Iron Works Historic District.

The Port holds the property within its jurisdiction in trust for the State of California. As a trustee, the Port must ensure that projects and leases within its jurisdiction are consistent with the public trust and the Port works closely with the other trustees (the

State Lands Commission and the Bay Conservation and Development Commission) to ensure that uses are advancing the trust. The Port is also an enterprise agency within the City and County of San Francisco and is governed by a Commission of five members appointed by the Mayor. The Port leases include over 550 ground, commercial, retail, office, industrial and maritime industrial leases including cargo shipping, ship repair, excursion boats, ferry boats, fishing and fish processing/distribution, tourism, filming, harbor services, and cruise-shipping. The in-water and shoreline work that the Port and its leases must conduct also requires a number of permits that are project-specific and must be obtained from agencies such as the Water Quality Control Board, NOAA Fisheries, the Bay Conservation and Development Commission, the Army Corps, the EPA and Fish and Wildlife.

Issue Statement

Maritime uses hold a unique and critical role in the city's economy and since they depend on water access, cannot be relocated or easily replaced. The facilities tend to be older and some are historic, which increases their vulnerability to earthquakes, flooding, and extreme heat. Many maritime uses are built on fill, which has higher susceptibility to liquefaction, which could cause significant damage to facilities and infrastructure. Piers are particularly vulnerable to flooding, especially where water-sensitive utilities are located under the piers. Damage and disruption of maritime uses would have far reaching consequences, but especially to the economy and workforce, given the diversity of well-paying and often unionized jobs in maritime businesses.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data originates from datasets maintained by SF Port (2018).

Exposure Summary

Geologic: All piers are in the Violent or Very Strong groundshaking zones during a 7.8M earthquake on the San Andreas Fault. Most piers are in the Very Strong groundshaking zone during a 7.0M earthquake on the Hayward fault. All piers are in the liquefaction zone.

Flood: All piers have some portion in the current 100-year coastal flood zone. Stormwater flooding analysis was not conducted in areas which are not served by the SFPUC's combined sewer and stormwater collection system, therefore the Port's property was not analyzed.

Fire: No piers with maritime assets are in a wildland-urban interface fire zone

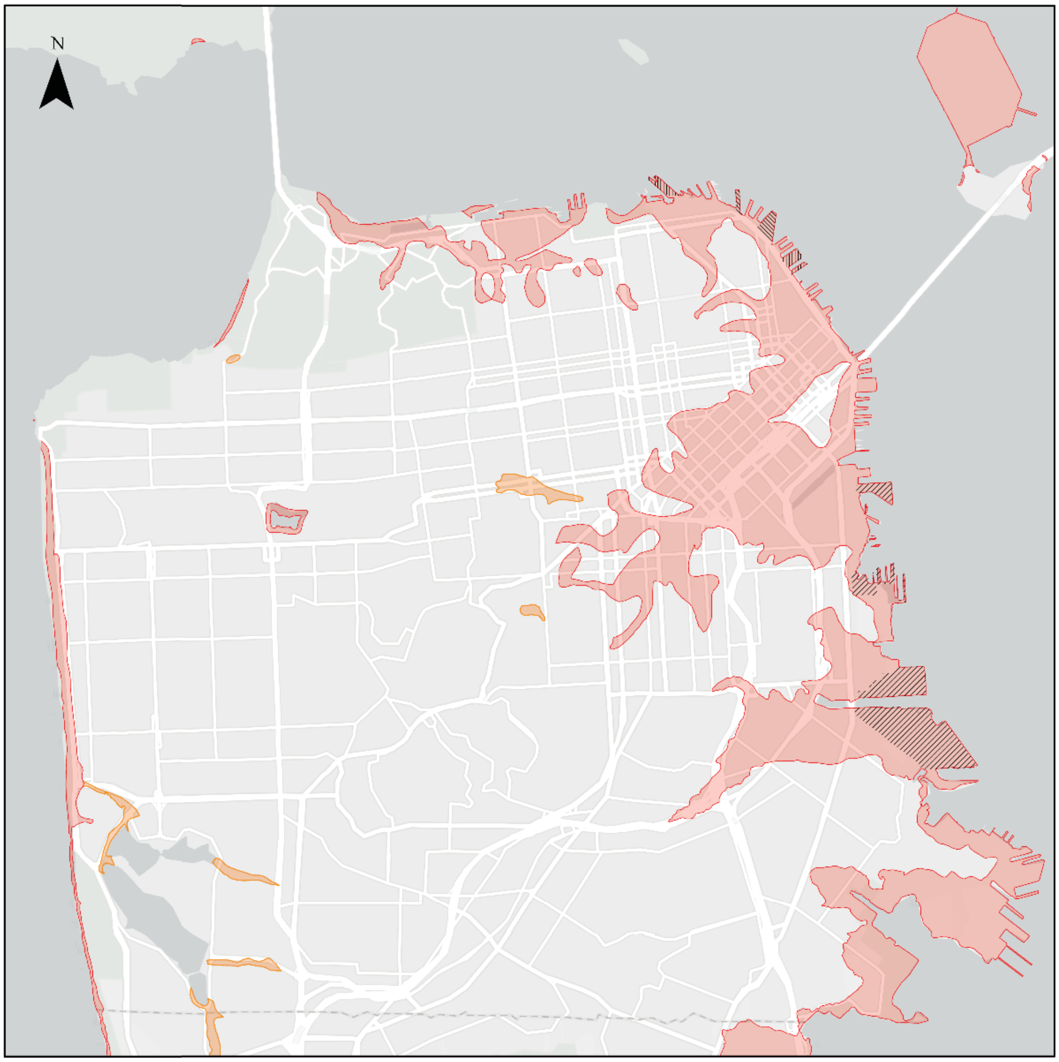
TABLE A-23: EXPOSURE

Hazard	Cruise Terminal Piers (27*, 29, 35*)		Heavier Industrial/ Maritime Piers (50*, 68, 70, 80*, 90*, 92*, 94*, 96*)		Other Maritime - Bar Pilots, Research Vessel Berths, Commercial Fishing (9, 15*, 17, 45)	
	#	%	#	%	#	%
Geologic						
San Andreas 7.8 - Violent	0	0%	4	50%	0	0%
San Andreas 7.8 - Very Strong	3	100%	4	50%	4	100%
Hayward 7.0 - Very Strong	3	100%	7	88%	4	100%
Hayward 7.0 - Strong	0	0%	1	13%	0	0%
Liquefaction Zone	3	100%	8	100%	4	100%
Flooding						
100-Year Coastal Flood Zone	3	100%	8	100%	4	100%
100-year storm + 24 inches SLR	3	100%	8	100%	4	100%
100-year storm + 66 inches SLR	3	100%	8	100%	4	100%
100-year stormwater flood	N/A	N/A	N/A	N/A	N/A	N/A
Wildfire						
High	0	0%	0	0%	0	0%
Moderate	0	0%	0	0%	0	0%

* Indicates active deep-water berths at the time of this publication

Note: For an exposure table with additional hazards, please see Chapter 5.

FIGURE A-36: MARITIME USES AND LIQUEFACTION HAZARD



0 0.5 1 2
Miles

Sources: SFDEM Data Library 2018; CGS, CALOES, 2015; SF Planning Parcels with Land Use 2018

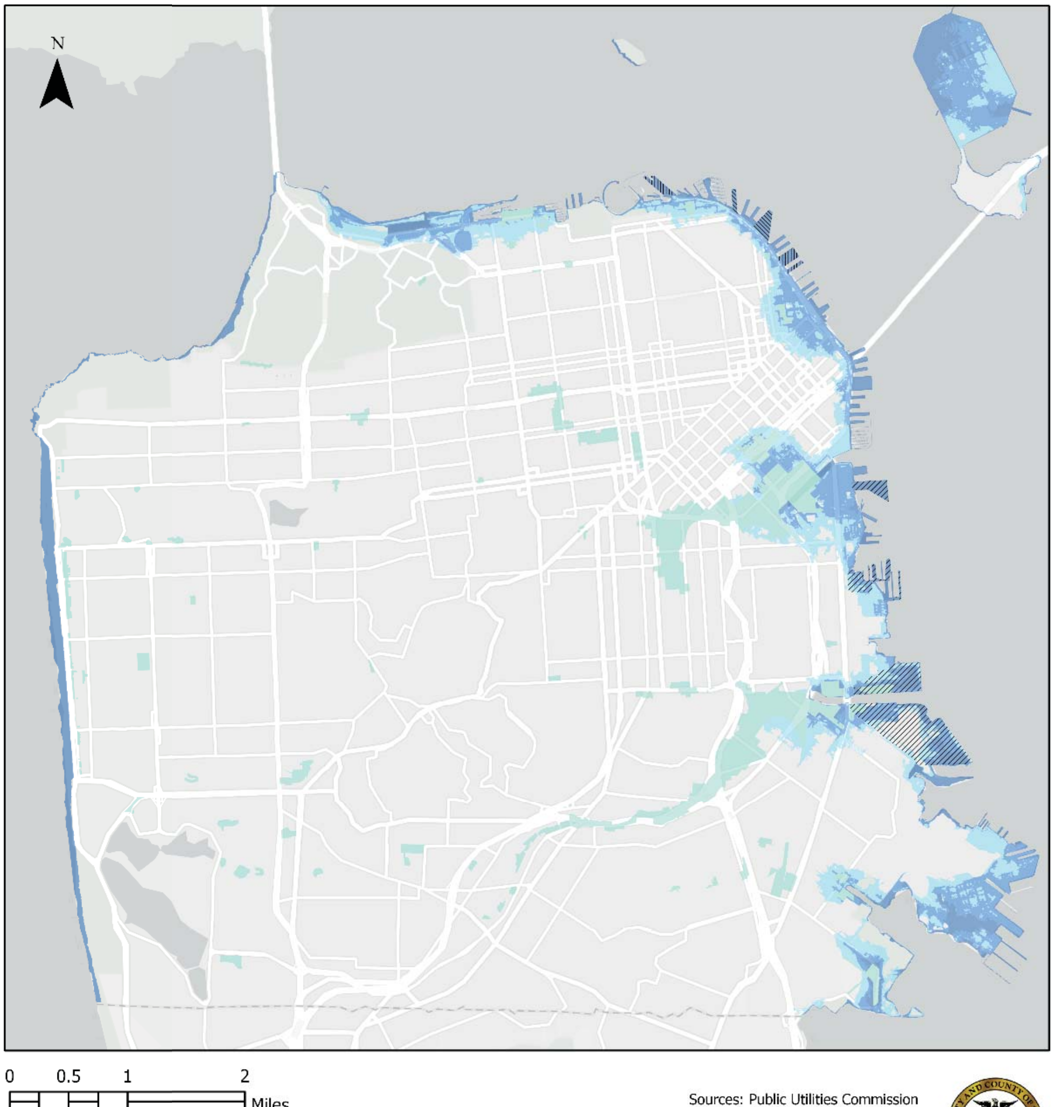
Liquefaction Susceptibility Maritime Parcels

Soil Liquefaction Hazard Zone
- Very High
- High

- Cruise Ships
- Heavy Maritime
- Other Maritime

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

FIGURE A-37: MARITIME USES AND FLOOD HAZARDS



Flood Risk
Maritime Parcels

Flood Hazards
- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

- Cruise Ships
- Heavy Maritime
- Other Maritime

Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps; SF Planning Parcels with Land Use 2018

This map is intended for planning-level analysis and should not be used for permitting, regulatory, or other legal uses. Flooding is possible in areas outside of those displayed on this map. The risk zones are based on model outputs and relied on LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and structures, site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Most of the Port's maritime facilities are vulnerable to seismic hazards due to both construction and location. The Port, and much of downtown San Francisco, was constructed on Bay fill, which is susceptible to liquefaction. In addition to location, the majority of the Port's facilities were constructed prior to current seismic safety standards and many have not been seismically retrofit. **Flood:** Piers have physical characteristics that make them more vulnerable to flooding, including where utilities exist under the piers, the need for space under the piers to maintain them, the condition of the pier aprons and fendering and the need for access connections between the water and the land. Some piers have utilities and infrastructure with salt sensitive components that would either need to be raised or made water proof. Hazardous materials that are stored on the piers will need to be secured to ensure there is no release into waterways or community spaces. The historic nature of many of the Port's assets also increases their vulnerability and could reduce adaptation options. **Extreme Heat:** A majority of the Port's buildings are in older, historic building stock and only a few of them have been weatherized. Additionally, the Port has a number of warehouse and industrial areas that are not easy to cool and employees in operations and maintenance who work outside. **Fire:** The majority of the Port's buildings lack air filtration and outside air quality has impacts on the quality of air inside of many of the Port's buildings. Additionally, many of the Port's buildings and assets are warehouses and industrial sites that are difficult to filtrate and a number of our employees work outside in maintenance and operations and are exposed to air quality conditions.
Functional	**Networks:** Redundant systems and services at the Port or elsewhere in the region could help ensure continuity of critical systems. **External Services:** Maritime uses depend on power, communications, fuel supplies and transportation access. Goods and materials are also important to some of the assets and services.

	The Port has backup power and pumping capacity at some of its facilities. Pier 1, the JOS Building, Illinois Street Bridge, AT&T Park, and Ferry terminals have standby power capabilities. All other port facilities lack backup power. An assessment of this capacity should be conducted to ensure that the measures are capable of maintaining critical operations regarding other facilities. **Populations Served:** The Port's maritime assets increase the diversity of employment in San Francisco and provide well paying, often unionized, jobs in the city. The assets and services are also important to the local economies where they are located, which includes Bayview-Hunter's Point, as well as small businesses in the northern waterfront that rely on the cruise industry. The fishing industry provides a cultural and economic connection to the Bay and aquatic resources that have been important to San Franciscans since the City's founding. **Unique or Critical Function:** The maritime assets and services provide recreational benefits, such as excursion trips to Alcratraz, whale watching, and tours to other destinations. The Port has a number of educational and interpretive materials throughout its jurisdiction (including the Bayside History Walk) which interpret and educate people on the history of maritime assets and the current maritime assets that can be found along the Port. Most of the Port's maritime assets are unique and would be difficult to replace in the region and impossible to replace in the City. The deep-water berthing sites for military and research ships is a unique asset and service found along the Port, the Cruise ship terminals are also unique to the region, the commercial fisheries facilities are unique and difficult to replace as well.
Informational	**All-hazards:** There are some existing studies including several flood risk studies conducted specifically for Port assets that were completed in 2016, a seismic vulnerability analysis that was conducted at a high level for the three mile seawall, a currently underway Multi-Hazard Risk Assessment for the three mile Seawall segment that assesses seismic and flood risk, a study of the flood risk at Mission Creek, a study of the flood risk (and a little seismic) at Islais Creek and a Citywide SLR study.
Governance	**All-hazards:** The Port must work with a number of regulatory and resource agencies to maintain, repair or improve maritime assets. These agencies include the Regional Water Quality Control Board, US Fish

	and Wildlife, California Fish and Wildlife, State Lands, Bay Conservation and Development Commission, State Historic Preservation Office and the Army Corps and their regulations and policies are numerous and depend upon the specifics of the project proposed. Anything associated with dredging and filling the Bay is heavily regulated. The Port currently has access to several funding sources to assess risks and vulnerabilities and improve resilience, including a San Francisco General Obligation Bond, City Capital Planning funding, a Caltrans resilience grant, Army Corps General Investigation, Port Capital Planning funding.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** The most significant impacts related to society and equity due to the disruption of the Port's Maritime assets would be related to a loss of industrial and maritime jobs, impacts to the safety of vessel travel on the Bay, reduced access to the Bay and its resources, local businesses would lose jobs that rely on, and provide service to, the Port's maritime assets and services, which include trucking, restaurants, etc. Disruption or loss of maritime uses would exacerbate existing inequities in the Port's southern waterfront area.
Economy	**Geologic:** The economic impact of groundshaking and liquefaction is currently being assessed from Fisherman's Wharf to Mission creek. The impacts of disruption of maritime assets due to a seismic event would range from citywide to regional to state-level. **Flood:** This is currently being assessed by two studies: the Multi-Hazard Risk Assessment for the Seawall Program and the Army Corps Flood Study. The impacts of disruption of Maritime assets due to flooding would range from citywide to regional to state-level.
Environment	**Geologic:** Seismic events that damage the Port's maritime facilities could result in contamination of the Bay, debris in the Bay, the need for in water construction repairs which would have ecological impacts, potential air quality impacts if facilities need to move further away, impacts to public access and parks that rely on or are enhanced by access to the water. **Flood:** Flood risks could release contamination into the Bay, could result in debris in the Bay, could reduce public access and could negatively impact habitats and species.

Contaminated Lands

Introduction to Asset Class

Historic land uses prior to the adoption of current environmental regulations left a legacy of contaminated land sites across San Francisco. Contaminated soil, groundwater, and soil vapor can negatively impact human health and environmental quality, and can limits future productive use of the land, unless proper cleanup and remediation actions have been taken. The City and County of San Francisco recognizes the importance of evaluating soil condition in advance of development. Sites requiring grading or building permit may be regulated under the Maher Ordinance, which covers areas with current or historical industrial use or zoning, areas within 100 feet of current or historical underground tanks, filled former Bay, marsh or creek areas and areas within 150 feet of a current or former elevated highway.[26] San Francisco Health Code Article 22a includes areas where UST were once leaking, resulting in potential for legacy contamination. Around 1800 Maher cases have been completed or are in progress. The San Francisco Department of Public Health's Local Oversight Program (LOP) oversees leaking underground storage tank remediation, over 3000 sites have been successfully remediated. Properties with known or potential chemical contamination outside the Maher area may be administratively added to the Maher Program or included in the Voluntary Remedial Action Program. Cleanups involve excavating contaminated source materials from the site to be stored in an engineered containment area. In some cases, contaminants cannot be removed and must be stabilized in place. Engineering techniques to prevent movement of contaminants include covers and vertical barriers made of clay or cement slurry.[27]

This assessment uses data from the Department of Toxic Substances Control (DTSC) to identify locations of ongoing cleanup activities. The mapping and analysis does not represent the location of every contaminated site in need of remediation; as demonstrated by the Maher map area,[28] potential to encounter contaminated soil exists across broad areas of the city. Nor does the DTSC data represent the full environmental burden that communities face. Four cleanup status categories were included:

- **Active**: investigation and/or remediation currently in progress

[26] https://data.sfgov.org/Energy-and-Environment/Maher/hqsk-4xmh
[27] https://www.epa.gov/sites/production/files/2018-08/documents/landfills_and_containment_as_an_element_of_site_remediation.pdf
[28] https://data.sfgov.org/Energy-and-Environment/Maher/hqsk-4xmh

- **Certified with land use restrictions**: the completed remedy resulted in hazardous substances remaining on site, and so future uses are restricted and long-term monitoring is required
- **Certified with ongoing operation and maintenance**: remedial activities (such as pumping and treating contaminated groundwater) must be continued for many years before completed cleanup will be achieved
- **Inactive with action required**: sites where DTSC has identified the need for a removal or remedial action, or extensive investigation

Federal Superfunds have a specific designation as heavily contaminated, underutilized and undeveloped land sites where hazardous waste is possibly affecting the health and safety of local communities and ecosystem. Superfunds are listed under the National Priorities List through the federal Superfund cleanup program. There is one Superfund site in San Francisco, located in the southeast area of the City in the Bayview Hunters Point neighborhood.

Issue Statement

It is in the interest of public health and safety to effectively and efficiently remediate contaminated land sites, and/or mitigate human health exposure, and/or mitigate human health exposure. Contaminated land sites are disproportionately located near low-income and communities of color, and any release of hazardous substances burdens communities which are already disproportionately burdened. Many sites undergoing remediation and/or mitigation have plans for new housing development. San Francisco is experiencing an affordable housing crisis, and there is a limited amount of undeveloped land to meet housing needs. Loss of land for new housing will have negative impacts citywide. Cleanup, remediation, and/or mitigation processes are extremely cost and time intensive, where encountering financial and/or regulatory obstacles can result in years-long delays. Sites that become exposed to flooding and rising groundwater in the future may not have been remediated to an aquatic standard, with potential negative impacts to health and the natural environment. Integrating adaptive site management into cleanup activities is a step towards equity and resilience.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault 7.8M and Hayward Fault 7.0M events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data originates from datasets maintained by the SF DEM (2018) and the California State Department of Toxic Substances Control (EnviroStor, 2018)

Exposure Summary

Geologic: Two thirds of parcels with ongoing cleanup activities are in a liquefaction zone. Ninety-eight percent of parcels are at risk of very strong or strong groundshaking during a 7.0M Hayward fault earthquake. All parcels are at risk of violent or very strong groundshaking during a 7.8M San Andreas Fault earthquake.

Flood: Fifteen percent of parcels with ongoing cleanup activities have a portion in the FEMA 100-year coastal flood zone, and one third of parcels are at risk of flooding from 66 inches of sea level rise. Two parcels are at risk of a 100-year stormwater flood.

Fire: There is moderate wildfire risk in four parcels.

TABLE A-24: EXPOSURE

Hazard	Parcels with DTSC Cleanup Activities 59 Total	
	#	%
Geologic		
San Andreas 7.8 - Violent	8	14%
San Andreas 7.8 - Very Strong	51	86%
Hayward 7.0 - Very Strong	15	25%
Hayward 7.0 - Strong	43	73%
Liquefaction Zone	39	66%
Flooding		
100-Year Coastal Flood Zone	8	14%
100-year storm + 24 inches SLR	11	19%
100-year storm + 66 inches SLR	19	32%
100-year Stormwater Flood	2	3%
Wildfire		
High	0	0%
Moderate	4	7%

Note: For an exposure table with additional hazards, please see Chapter 5.

FIGURE A-38: ACTIVE CLEANUP ACTIVITIES AND LIQUEFACTION HAZARD

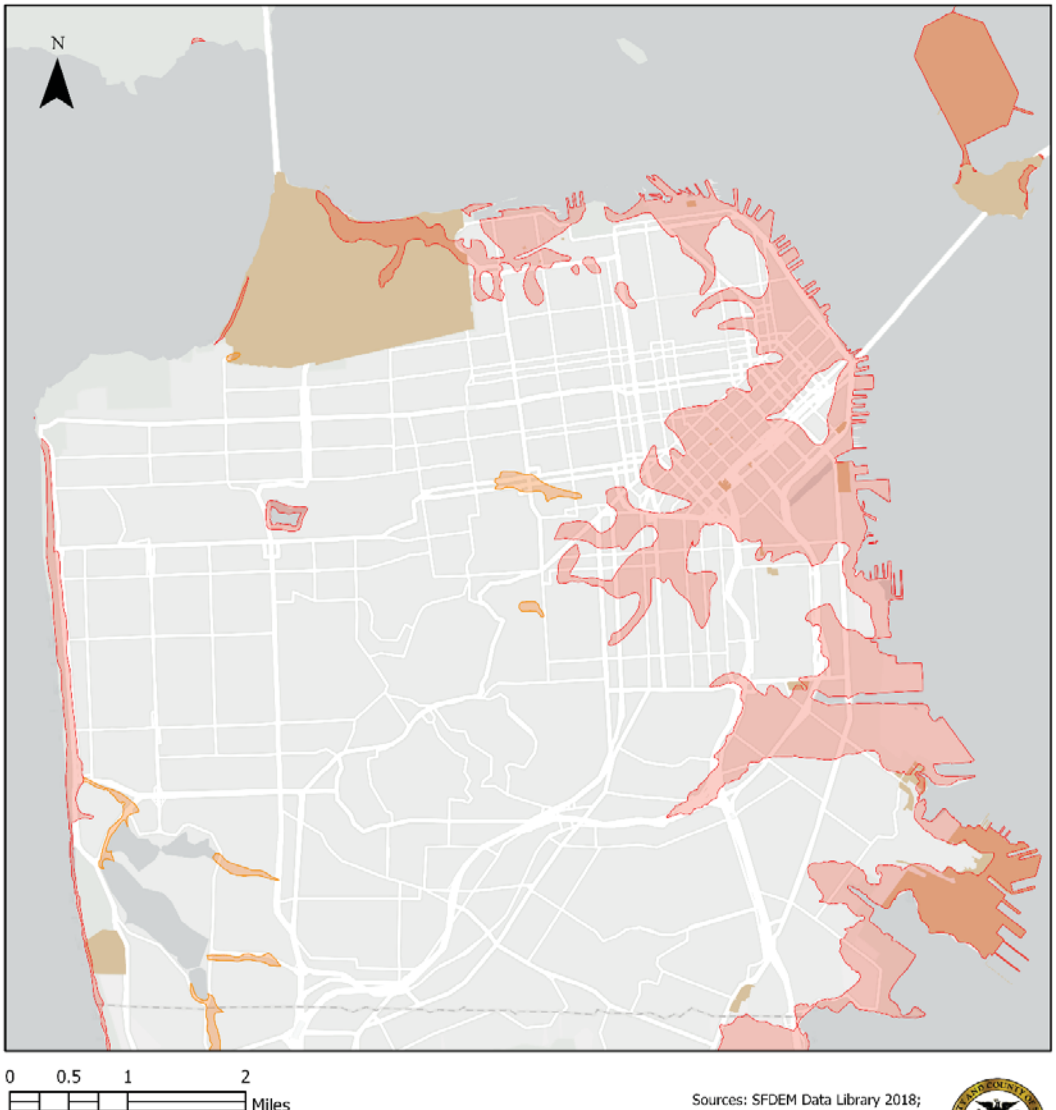
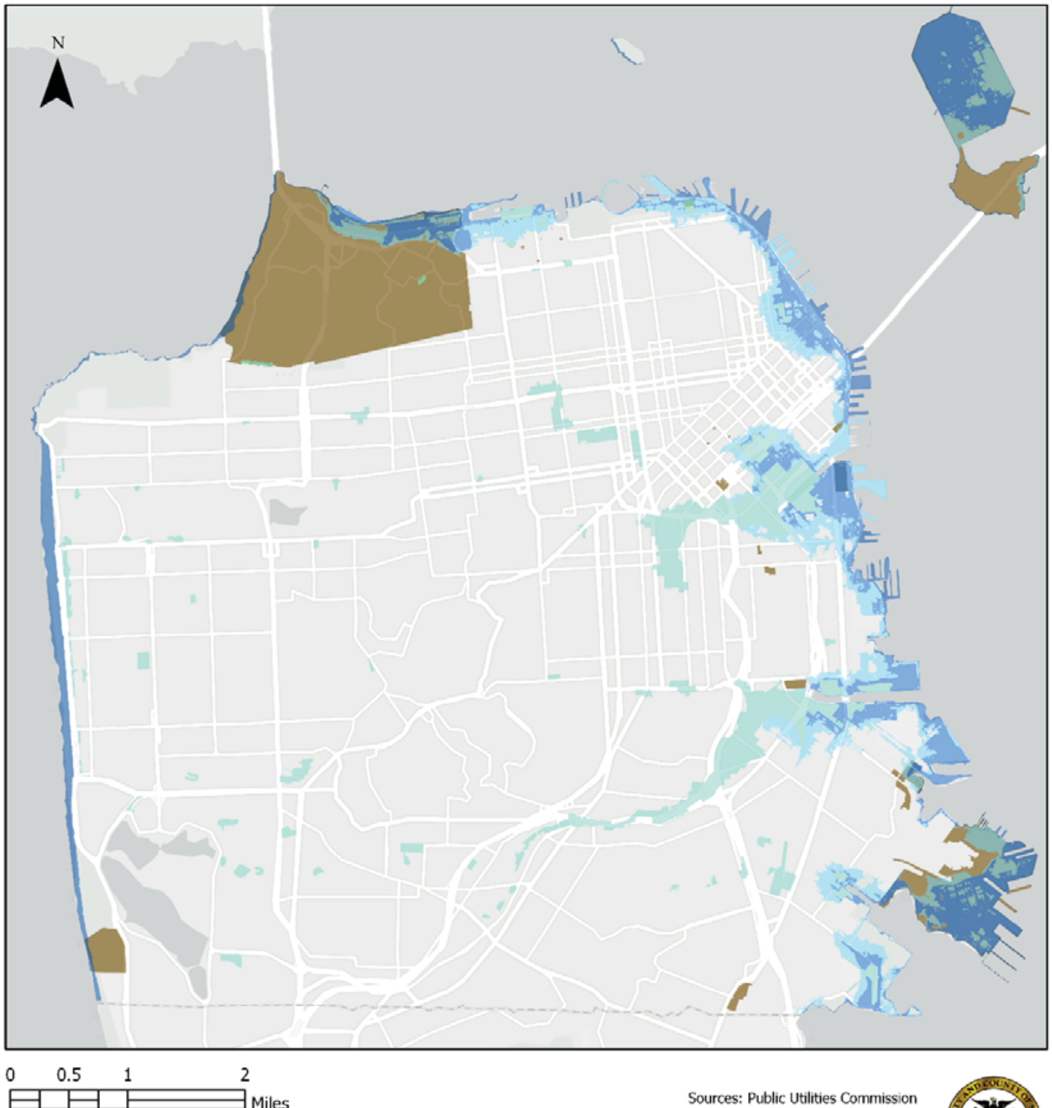


FIGURE A-39: ACTIVE CLEANUP ACTIVITIES AND FLOOD HAZARD



Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps; Department of Toxic Substances Control (DTSC) EnviroStor 2018

Flood Risk and Cleanup Sites

Flood Hazards

- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Parcel with ongoing DTSC cleanup activity

This map is intended for planning-level analysis and should not be used for permitting, regulatory, or other legal uses. Flooding is possible in areas outside of those displayed on this map. The risk zones are based on model outputs and relied on LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and structures, site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Ground shaking could compromise the integrity of caps and liners. Liquefaction could compromise the stability of waste containment facilities, such caps over remediated sites, and slurry walls that contain contaminants. **Flood:** The sensitivity varies by site and contaminant type, as well as the contaminant's mobilization pathways, and the degree of remediation. Contaminants that are bound to sediments are vulnerable to erosion and could be mobilized into the Bay. Other contaminants could dissolve in the water if exposed to rising groundwater during high tides or storms and contaminate soil and groundwater. Saltwater could also corrode cleanup equipment. Floodwater that remains for a long time period could infiltrate through the soil and become contaminated. Remediation standards for aquatic uses are more stringent than upland uses. Cleanups completed for upland standards may be unsatisfactory if sites become exposed to flooding. Residents in buildings located on remediated land rely on engineering control methodologies and technologies for protection, in particular where groundwater drives soil vapors up and into occupied spaces. These protective technologies may not be in place in areas newly exposed to flooding or groundwater changes.[29] Vapor barriers protect from fumes/contaminants. Cleanups in San Francisco receive a vapor barrier regardless of future use. Sites may need to mitigate exposure to vapor due to a variety of causes. For example, Mission Bay area has high methane soil vapor due to industry and bay muds, and uses a methane mitigation system – systems pull vapors from underneath and the building and release them through the roof (then need a permit from the Air Board). Many buildings operate groundwater pumping systems. **Extreme Heat:** Limited to none. Most cleanup sites are in different remediation stages and monitoring is done daily. In case of heatwave alerts, there is enough time available to take adaptive actions in advance. Extreme heat may lead to malfunction of equipment or communication

[29] 2017 Adapting to Rising Tides (ART) Contra Costa County: http://www.adaptingtorisingtides.org/wp-content/uploads/2017/03/Contra-Costa-ART-Project-Report_Final.pdf#page=42

	systems.[30] Extreme heat poses a risk to the health of remediation professionals on-site. SFDPH requires vapor systems, which can protect against increased vapor release during extreme heat. **Fire:** Closed permanent contaminated lands are generally capped by an impermeable or low permeability layer, such as clay, and underlain by the native geologic material. The damp clay is resistant to fire. However, surrounding areas that may be on fire, could pose fire hazard to cleanup site equipment and remediation systems, as well as any supporting structures.
Functional	**External Services:** Contaminated lands management relies on robust communication and emergency response channels, as well as a reliable power supply network for the timely execution of cleanup activities. Power outages may not cause immediate threats to public health, but will slow down cleanup activities and incur additional cleanup costs. **Populations Served:** The assets in this class do not serve vulnerable populations. However, contaminated sites are disproportionately located in or adjacent to low-income and communities or color. **Unique or Critical Function:** Cleanup activities are initiated on sites that are underutilized, and San Francisco has very limited undeveloped land area. Without proper cleanup, contaminated lands are left undeveloped which hinders the ability of the city to meet its pressing housing needs. Contaminated lands located in open space areas can be redesigned to provide recreational and habitat benefits. Closed landfills have to monitor methane for explosion hazard. Former landfill in presidio, hunter's point, treasure island. Capping is soil and other vegetative cap. There is a closed landfill by SF State. Required to monitor methane for explosion hazard.
Informational	**All-hazards:** Information on active cleanup activities and contaminated lands sites location is publicly available and updated regularly. Information on sites overseen by DTSC, Water Board and the City and County of San Francisco is available from the State's online CERS database. However, land remediation is a multi-stakeholder process and since

[30] https://www.nema.org/Standards/SecureDocuments/NEMA%20GD%202-2016%20Evaluating-Fire-and-Heat-Damaged-Electrical-Equipment-Guide.pdf

	most contaminated land sites are privately owned, the pace of cleanup depends on being able to locate property owners and discuss legal liability issues. Detailed research is needed to examine the risk of groundwater flooding of contaminated land sites for the City and County of San Francisco.
Governance	**All-hazards:** Cleanup activities are overseen by a number of agencies. US EPA is the lead regulatory agency for Superfund sites, along with the Navy, Department of Toxic Substances Control (DTSC), and the Regional Water Quality Control Boards (RWQCB); DPH-Environmental Health and City Planning Department. Site mitigation, the cleanup or management of chemical contaminants in soil, vapor, or groundwater is regulated per one or more programs within the San Francisco Department of Public Health's Hazardous Materials and Waste Program (HWMP), Local Oversight Program (LOP), and the Maher Program (SFHC Article 22a) and Voluntary Remedial Action Program (VRAP). Conducting a preliminary environmental assessment, carrying out a remedial investigation to determine the extent of contamination, and developing a cleanup plan is costly and timely process. Cleanup costs vary depending on contaminant type, and encountering unanticipated contaminants during cleanup can result in significant cost increases. The cleanup itself can take many years, depending on the nature and extent of the contamination, cooperation of site owner(s), and resources available. Property owners responsible for site cleanup, community groups, state and federal regulators, and technology developers may have different perspectives on how remediation technologies should be evaluated and selected. Reconciling the differing expectations of these stakeholders can add to delays in site remediation. Remediation and/or mitigation is addressed by the project proponent in the Site Mitigation Plan. While regulators have a different perspective than developers, the basis for remediation and/or mitigation activities is to protect the public's health during and after development. The State Water Resources Control Board (SWRCB) requires site owners to plan for sea level rise under the Waste Discharge Requirements (WDRs), which adds to adaptive capacity and may prioritize cleanup among the sites under their purview. While there are no WDR sites in San Francisco, this program demonstrates SWRCB's awareness of sea level rise risk. Infrastructure Plans for developments at Hunter's Point Shipyard and Candlestick point included sea level rise studies and design criteria for 100 year tide and future sea level rise.

	Cleanups can be led by local agencies, the Water Board, DTSC, or CalRecycle—although this last option is not common in San Francisco. Large cleanup projects can choose their regulatory lead; the lead will communicate with other agencies involved. Standards for cleanup are different if housing or park space. Regional Board, DTSC, SFDPH all environmental screening levels, must be below screening levels or mitigate exposure. The City and County of San Francisco and SFDPH requires a stamp of approval from licensed engineer or licensed geologists, can report abuses/violations of the professional with the potential to have their license revoked. The agency overseeing the cleanup has administrative oversight, and ability to deploy more inspectors if needed. The agency overseeing the cleanup has discretion. SFDPH knowledge of contractors with poor reputations will administer more frequent inspections. Shipyard has its own Article in the health code, Article 31. City accepts land from navy after it has been cleaned. Standards driven by federal requirements/numbers.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** The actual health consequences of a release of contaminants would depend on the substances released and the proximity of the sites to sensitive receptors, such as residential areas, schools, hospitals, and housing for the elderly. Radioactive contamination presents the greatest health threats. Site Mitigation Plans required by the Maher Ordinance address these potential health threats during and after development. Proximity to Nationwide, superfund sites has been associated with cancer, low infant birth weights, and liver disease.[31] The one Superfund site in San Francisco is located in the Bayview Hunters Point neighborhood. The percent of Bayview Hunters Point residents who are Black/African American is significantly higher than citywide rates—28% vs. 5%. Across the country, contaminated sites are disproportionately located in communities of color.[32]

[31] Ala A, Stanca CM, Bu-Ghanim M, Ahmado I, Branch AD, Schiano TD, et al. (2006). Increased prevalence of primary biliary cirrhosis near Superfund toxic waste sites. Hepatology 43(3):525-31
[32] Brown, P. Race, Class, and Environmental Health: A Review and Systematization of the Literature. Environmental Research
Volume 69, Issue 1, April 1995, Pages 15-30. https://doi.org/10.1006/enrs.1995.1021

	San Francisco has a significant shortage of housing, particularly affordable housing. The City plans to build new housing to address this shortage. Site remediation must be completed before housing development can begin, and delays in remediation impacting housing production. Additionally, delays in cleanup could result in longer endured health burdens for the surrounding community. A study which compared birth outcomes before and after Superfund site cleanups found an association of up to 25% increased risks of congenital abnormalities.[33] **Flood:** Contaminated substances, if suspended in the water column, can be consumed by fish and lead to food chain contamination that consequently affects human health. While San Francisco does not rely on groundwater for drinking water supply, contaminants that come into contact with groundwater would pose an additional threat to human health if the water were used for drinking.[34]
Economy	**All-hazards:** Direct consequences include the costs of remediation, mitigation, and/or cleanup of damaged property. Indirect consequences include economic losses to affected secondary industries. If human health is affected, productivity losses, increased health care costs, or liability claims could also occur. Human health effects may be acute or chronic. A longer-term economic impact could occur if contaminants are redistributed onto new sites, reducing the availability of productive, usable land and increasing the number of sites requiring cleanup. Cost is also a concern for the regulatory agencies, especially at the state level. If responsible parties are local industries, extraordinarily high remediation costs may result in a threat to shut down operations, resulting in loss of jobs and tax base, and delay in the usability of the site. State agencies can provide reimbursement for cleanup to developers if certain thresholds are met.
Environment	**All-hazards:** Contaminated land sites contain hazardous materials that pose risk to the environment and certain pollutants, such as polychlorinated biphenyls (PCBs), affect the health of wildlife as well as people.

[33] Currie, Janet, Michael Greenstone, and Enrico Moretti. 2011. "Superfund Cleanups and Infant Health." American Economic Review, 101 (3): 435-41. DOI: 10.1257/aer.101.3.435
[34] ART

	Flood: Contaminants released into the Bay could have significant adverse impacts on aquatic species, and potentially make their way into the food chain. **Fire:** Potential air pollution of surrounding urban areas and risk of toxic fumes that affect the local flora and fauna.

Hazardous Materials Facilities

Introduction to Asset Class

The San Francisco Department of Public Health (SFDPH) defines a hazardous material as any material that because of its quantity, concentration, or physical or chemical characteristics, poses a significant present or potential hazard to human health and safety, or to the environment. Hazardous materials include those which are radioactive, flammable, explosive, toxic, corrosive, or unsafe in other ways. Exposure to hazardous materials can occur through accidental release.

Hazardous materials facilities include businesses or institutional facilities that generate, store, transport or treat hazardous materials. Such facilities include research laboratories, manufacturing facilities, gas stations, dry cleaning services, paint supply stores, auto body shops, transportation maintenance facilities, among others. The types of facilities which use hazardous substances vary widely, providing community a wide range of services and employment and educational opportunities. Hazardous materials facilities provide unique functions and services, and support the business operations of other entities throughout the City and County of San Francisco. Hazardous materials facilities can be both publicly or privately owned.

Over the past decades, federal, state, and local regulations have been developed to protect human health and the environment from hazardous materials. The San Francisco Department of Public Health Hazardous Materials and Waste Program is the local enforcement agency which regulates hazardous materials facilities registered within the City and County of San Francisco. The program implements six state environmental mandates and two local mandates. Approximately 2,700 hazardous materials facilities operate in the City and County of San Francisco, the majority located in the east and southeast areas.

These facilities include:

- 2585 that store hazardous chemicals, 238 that store hazardous materials in underground storage tanks (USTs) and 156 that store petroleum in aboveground storage tanks (ASTs)
- 1341 that generate hazardous waste, 40 of which are classified as Large Quantity Generators (LQGs) by the USEPA's Resource Conservation and Recovery Act (RCRA) Program
- 1235 of these facilities both store hazardous chemicals and generate hazardous waste.

Issue Statement

Regulations and robust inspection practices work to prevent accidental release of hazardous materials. Technology improvements, such as alarms and automatic shutoff devices, also prevent releases. Even with existing precautionary measures, hazardous materials facilities may be vulnerable to climate-related hazards, due to their precarious physical and functional characteristics. Depending on the hazardous material present, facilities may be required to prepare emergency and/or risk reduction plans; however, preventing hazardous materials release ultimately depends on the day-to-day practices of each individual facility. Hazardous materials facilities are reliant on external services, including power, communications systems, emergency response systems, transportation routes, and the municipal sewer system.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data is from California Environmental Reporting System (CERS) as collected on the CalEPA Regulated Site Portal, 2019.

Exposure Summary

Geologic: All hazardous materials facilities are in the Violent or Very Strong groundshaking zones during a 7.8M San Andreas earthquake. Ninety percent of facilities that store hazardous chemicals and store hazardous are in the Very Strong or Strong groundshaking risk zones during a 7.0M Hayward earthquake. Nearly half of both facility types are in the liquefaction risk zone.

Flood: Two percent of chemical storage facilities and three percent of hazardous waste generators are in the FEMA 100-year coastal flood zone. Eleven percent of chemical storage facilities and twelve percent of hazardous waste generators are in the 100-year stormwater flood zone. Nearly twenty percent of both types of facilities are in the 66” sea level rise zone.

Fire: Wildfire risk is limited to 16 facilities that store hazardous chemicals in the moderate risk zone.

TABLE A-25: HAZARDOUS MATERIALS FACILITIES EXPOSURE

Hazard	Chemical Storage Facilities (2585 Total)		Hazardous Waste Generator (1341 Total)	
	#	%	#	%
Geologic				
San Andreas 7.8 - Violent	301	12%	143	11%
San Andreas 7.8 - Very Strong	2281	88%	1197	89%
Hayward 7.0 - Very Strong	443	17%	201	15%
Hayward 7.0 - Strong	1899	73%	1009	75%
Liquefaction Zone	1188	46%	642	48%
Flooding				
100-Year Coastal Flood Zone	64	2%	36	3%
100-year storm + 24 inches SLR	218	8%	112	8%
100-year storm + 66 inches SLR	500	19%	260	19%
100-year Stormwater Flood	274	11%	163	12%
Wildfire				
High	0	0%	0	0%
Moderate	16	1%	0	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

FIGURE A-40: HAZARDOUS MATERIALS FACILITIES AND LIQUEFACTION HAZARD

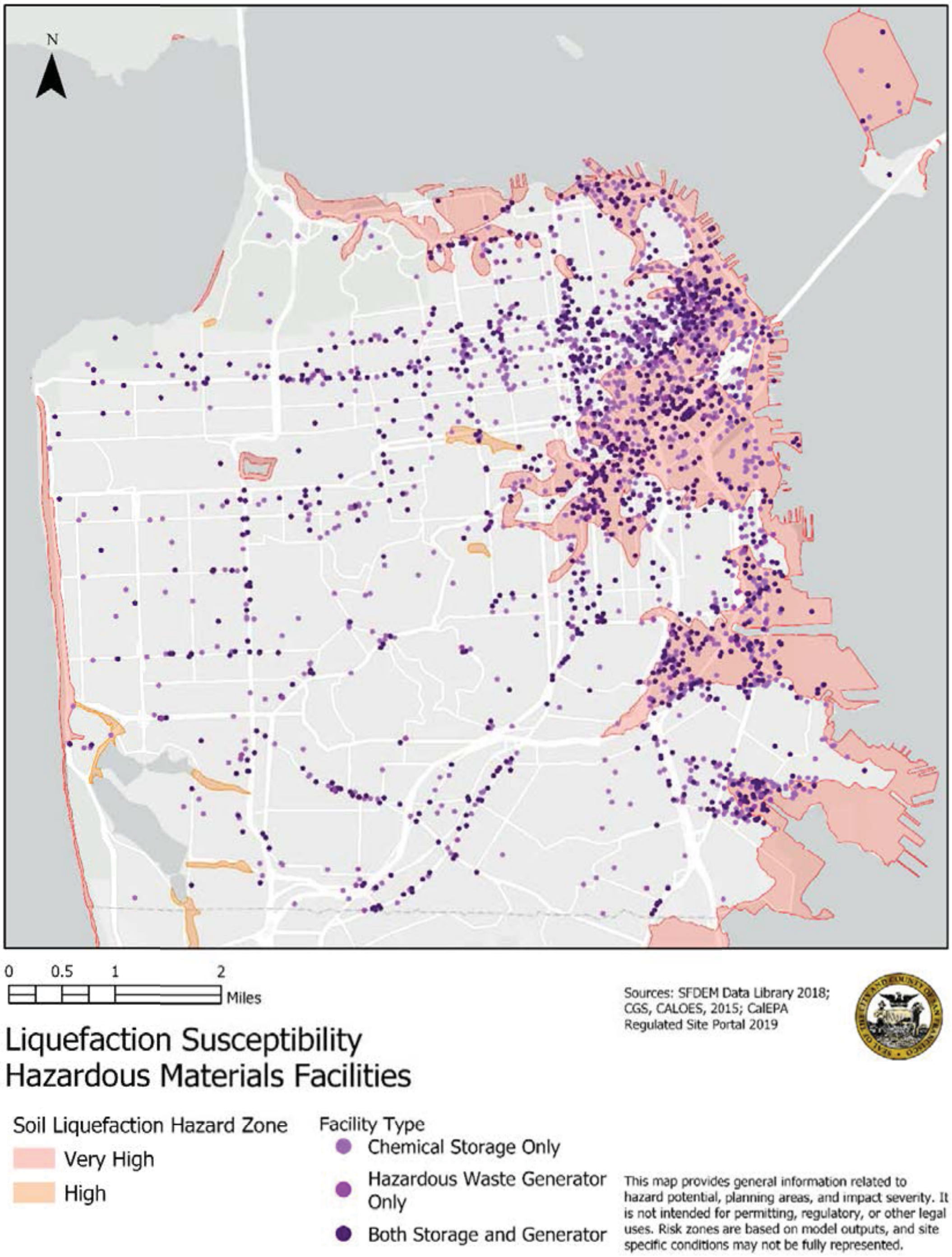
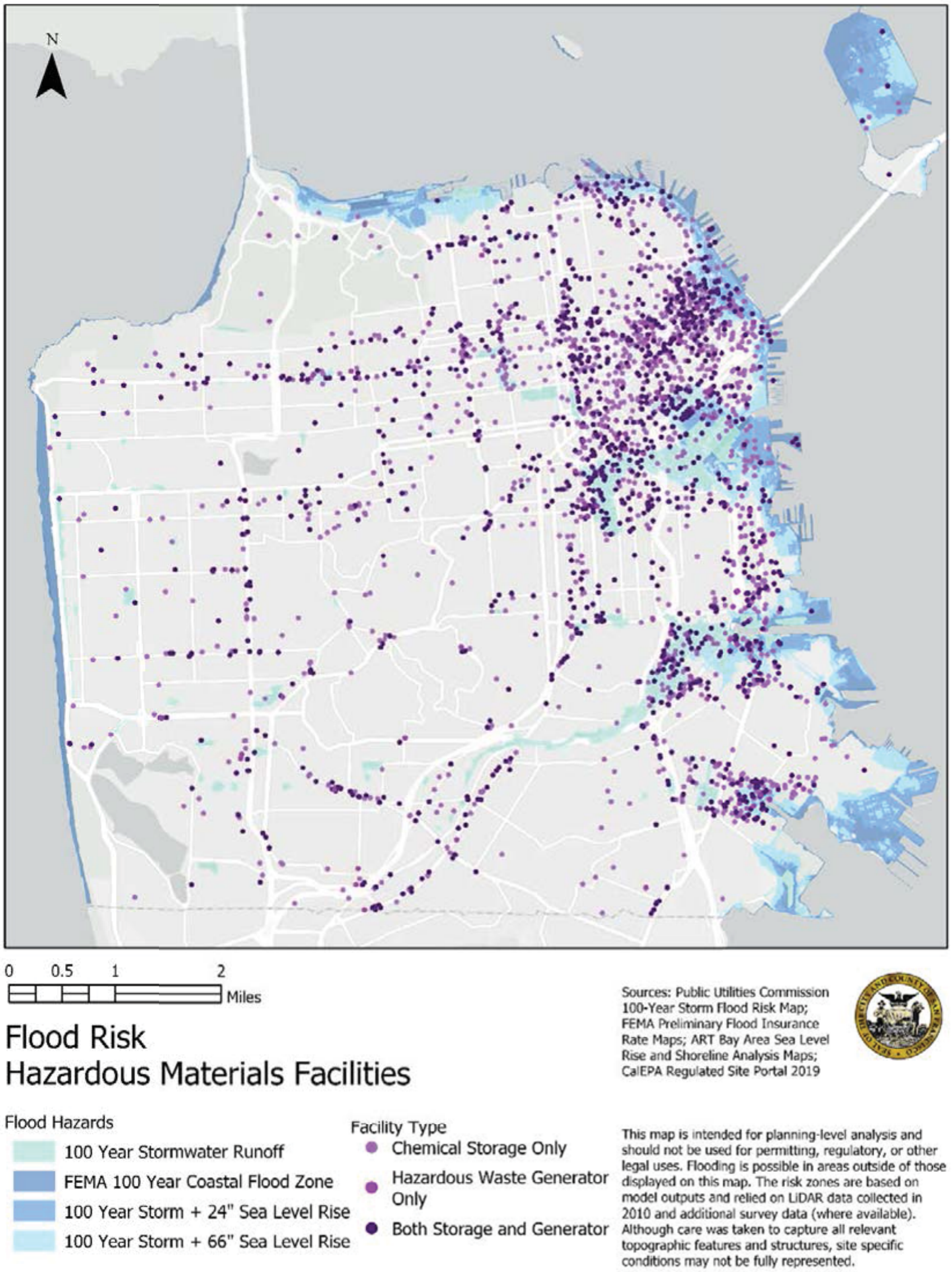


FIGURE A-41: HAZARDOUS MATERIALS FACILITIES AND FLOOD HAZARD



VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Hazardous materials facilities are vulnerable to seismic hazards, especially if stored underground. Historically dozens of hazardous materials releases have occurred as a result of seismic activity. Liquefaction can compromise the integrity of storage tanks and operating systems. Gaseous hazardous materials pose the greatest hazard during an earthquake due to their volatility and ease of spread. In facilities holding multiple hazardous material types, mixing upon release can result in secondary chemical reactions. Facilities located on hillsides generally perform worse during large-scale seismic activities. **Flood:** Facilities exposed to coastal flooding could result in hazardous materials release into the Bay. Industrial facilities containing hazardous materials are not generally designed to withstand flooding. If flooding damages electrical equipment, power disruption may lead to containment system failure and subsequent hazardous materials release. Secondary chemical reactions can also occur with highly soluble hazardous materials. Facilities with a history of improper storage or malfunction of containment systems or operations are at higher risk. Poor business practices can be prevented by the robust inspection frequency of SFDPH's Hazardous Materials and Waste Program. Vulnerability can be reduced by continued monitoring and maintenance of any on-site flood, erosion protection and lifeline infrastructures, as well as monitoring of storage tanks for potential leachates. In the long term, facilities located along the Bay may require intervention, mitigation, or relocation. **Extreme Heat:** Vulnerability to extreme heat depends on type of storage, cooling system capacity, and chemical characteristics impacting reactivity to extreme heat. Products with lower ignition points—such as gasoline and solvents—can be flammable if spilled to open air. Diesel and motor oil are combustible but have higher ignition points. Facilities that rely on cooling for operation face greatest risks, especially during a power outage. **Fire:** Hazardous materials can be highly flammable or unstable when mixed with other chemicals. SFDPH's Hazardous Materials and Waste Program inspections ensure that incompatible materials are segregated and secondarily contained. Fire could lead to depressurization of hazardous materials containment and increase the risk of explosions. Hazardous materials inventory statement and

	management plan required by the Fire Department includes addressing flammable storage risk. Deliberate fires and terrorism also pose a risk and it is difficult to predict such occurrences. Operational capabilities include employee training, evacuation plans, employee support system. Employees would be the first line of response to control any on-site fire before it damages hazardous materials containment tanks. Some businesses and institutions store hazardous materials in above ground storage tanks (ASTs) or underground storage tanks (USTs). ASTs and USTs may contain flammable liquids or other petroleum products. ASTs and USTs have alarms and automatic shutoff devices to prevent releases.
Functional	**Networks:** While hazardous waste facilities are not formally networked in an industrial system, they do rely on each other for continued operation. For example, a disruption in transporter service could result in storage overcapacity at generator facilities. Contingency plans are required of all certified hazardous materials businesses. **External Services:** Clear and reliable transportation routes, communication systems, and power are necessary to the operations of hazardous materials facilities. Transport of hazardous materials to San Francisco is predominantly via maritime or ground transportation. Some facilities are permitted to discharge waste to the sewer system. Hazardous materials facilities also rely on external response operations during an emergency. In the event of a hazardous materials release, facility operations must halt until emergency response and cleanup activities are completed. Additional regulatory requirements exist post-disaster before operations may continue. **Populations Served:** Hazardous materials facilities provide community a wide variety of services and employment and educational opportunities, with facility type ranging from vehicle repair to research institutions. Healthcare centers and hospitals, among other facility types, provide services to vulnerable populations. **Unique or Critical Function:** Permission to operate hazardous materials business is limited and facility-specific. The construction industry relies heavily on hazardous materials wholesalers, and other businesses may require certain hazardous materials in their industrial production processes. Gas stations are essential to certain vehicle operation, and support population mobility. There are a wide variety of entities that use hazardous materials, and some may be unexpected. For example,

	some restaurants are classified as hazardous materials facilities if they use compressed gas tanks for soda or frozen desserts.
Informational	**All-hazards:** Businesses that store, handle, or use hazardous materials must obtain and maintain a valid Hazardous Materials Certificate of Registration, and submit information to the California Environmental Reporting System (CERS). Facilities develop a site map, an emergency response and contingency plan, hazardous materials inventory and hazardous waste inventory statements, a training program for employees, and a hazardous materials reduction plan. The public has a right to review most of the information reported. However, the release of confidential and trade secret information to the public is regulated by state and federal law. SFDPH Hazardous Materials and Waste Program provides information, such as chemical inventory, to SFDPH Emergency Response teams to provide to the Fire Department for use during a hazardous material emergency. San Francisco residents can dispose of certain hazardous wastes—oil-based paints, solvents, cleaning products, pesticides, fertilizers, automotive products, photo chemicals, mercury thermometers and non-empty aerosols—at retail collection facilities or at through a free curbside pickup service. The pickup service is currently underutilized. If not disposed of properly, old containers of household chemicals can deteriorate and leak, causing fumes and fires, or polluting runoff. Improperly disposed chemicals can leach into the soil and groundwater, or pose risks to waste collection workers.
Governance	**All-hazards:** Under the Federal Code of Regulations, Title 13, the San Francisco Department of Public Health (SFDPH) Hazardous Materials and Waste Program (formerly known as the Hazardous Materials Unified Program Agency) is the local enforcement agency certified by the State's Department of Toxic Substances Control (DTSC) to regulate hazardous materials facilities registered within the City and County of San Francisco. SFDPH's Hazardous Materials and Waste Program implements six state environmental mandates and two local mandates.[35] Article 21 of the Health Code requires businesses that store, handle, or use hazardous materials must obtain and renew annually a Hazardous Materials Certificates of Registration (COR). While regulated facilities are inspected at least once every three years, preventing hazardous materials release ultimately depends on the practices of the

[35] Aboveground Petroleum Storage; California Accidental Release Prevention Program; Chlorofluorocarbon Recycling; Hazardous Materials Storage and Use; Hazardous Waste Generation; Hazardous Waste Treatment; Medical Waste Generation; Underground Storage Tanks

	individual facilities. The California Accidental Release Prevention (CalARP) Program is intended to reduce the likelihood and severity of consequences of extremely hazardous materials releases. CalARP requires that businesses handling more than a threshold quantity of a regulated substance develop a Risk Management Plan (RMP) with a detailed engineering analysis of the risks and mitigation actions needed to prevent an accidental release. RMPs must also consider external events such as natural disasters. Chemicals regulated under the CalARP are a subset of the hazardous materials which require a COR. The work of the SFDPH Hazardous Materials and Waste Program also includes regulating petroleum storage, hazardous wastes (Health Code Article 22), chlorofluorocarbon recycling (Health Code Article 24), medical waste (Health Code Article 25), and Underground Storage Tanks (USTs). The Fire Code regulates and governs the safeguarding of life and property from fire and explosion hazards arising from the storage, handling, and use of hazardous materials. The Stafford Act, as amended by the Disaster Management Act of 2000, does not require local hazard mitigation plans to cover human-caused hazards. LQGs are required to follow seismic and stormwater flooding compliance for management of above ground storage tanks (ASTs) and underground storage tanks (USTs), and secondary containment.[36] SQGs and VSQGs only have to comply with basic code requirements, reducing prevention of accidental release.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Serious health issues (acute, delayed, chronic) may occur, including skin damage or death. Vulnerable populations with pre-existing health conditions face greater impacts. Risk Management Plans must consider the proximity to sensitive populations such as schools, residential areas, general acute care hospitals, long-term health care facilities, and child day care facilities. Hazardous materials facilities located in or near communities of color and/or low-income neighborhoods pose a threat to already marginalized populations. Depending on the scale of a hazardous material release, communities may also be cut off from emergency response.

[36] Secondary containment is a means of surrounding one or more primary storage containers to collect any hazardous material spillage in the event of loss of integrity or container failure

	Geologic: Earthquakes can result in the release of hazardous dust, surface water runoff, or toxic vapors. The associated public health risk depends upon the materials released during an accident, the toxicity of the materials, and the wind or water direction that may carry the emissions from the release. In highly elevated areas and hill locations prone to mist, toxic fumes may persist longer in the air and cause health risks to local population. **Flood:** Hazardous materials can be released into the waterways and/or groundwater if they are improperly stored and carried by flood flows. Plumes can spread reaching areas remote to the release, contaminating the soil or sedimentation that remains once water levels return to normal. This poses a risk of direct contact to people, plants and animals, especially to workers involved in response and recovery. **Extreme Heat:** Hazardous material release into air can increase heat-related health issues. Contaminated air can infiltrate residential and commercial facilities and create additional indoor air quality issues. Facility overheating can result in heat-related health risks to hazardous materials facility employees. Failure of hazardous materials facility containment, transport, or cooling systems due to over exposure to heat could result in loss of life. **Fire:** Some hazardous materials upon burning may release highly poisonous byproduct gases and disperse in the air, causing inhalation problems and cascading health risks to the public.
Economy	**All-hazards:** Economic impacts vary depending on type of hazardous material released and the extent of response needed for cleanup. Release of hazardous materials will result in loss of facility raw materials and products, consequently increasing material and operational costs and loss of profits. There are additional costs associated with required cleanup activities and necessary actions to restore facility operations. Any hazardous material release will pose a strain on local agency resources to respond to the emergency. Cleanup operations may lead to lost wages and harm the economic health and livelihood of the surrounding community. Damages to surrounding private and public property (temporary, repairable, permanent), including essential support systems (water, food), and damages to employee health (acute, delayed, chronic) are to be expected.

	Flood: Depending on their location, hazardous materials facilities may need to be relocated as their main function would be difficult to maintain with periodic flooding or elevated groundwater. Release of contamination into the sewer system could pose long-term operational damage to wastewater treatment facilities, depending on the hazardous material reactivity and flammability. **Extreme Heat:** Failure of hazardous materials facility containment, transport, or cooling systems due to over exposure to heat could result in loss of life or asset damage. Heat can result in increased electricity costs for running cooling systems, and there are cost associated with weatherization of critical equipment, building envelope and lifeline equipment. **Fire:** Possible superficial damage to facility equipment and surrounding structures due to damage by toxic fumes. Risk of fire spreading out to surrounding areas and causing damage to property (temporary, repairable, permanent) and spread of contamination. A fire routinely follows an explosion, which may cause further damage to surrounding property/assets and inhibit emergency response.
Environment	**All-hazards:** Significant environmental impacts can result from the release of hazardous materials having long-lasting and far-reaching consequences on plants, wildlife, unique habitats, and water quality. Contamination of water supply is possible via damaged water supply pipe or damaged pipeline transporting natural gas. Leaking from industrial or commercial uses (including gas stations, car washes, etc.) may result in the release of toxic substances on or below the ground surface, contaminating soil and groundwater with long-lasting negative impacts to ecosystem health and biodiversity. **Geologic:** In highly elevated areas and hill location prone to mist, any fumes may persist longer in the air, settle on plants and animals impacting local habitat quality, as well as city parks and open spaces. **Flood:** Highly persistent hazardous materials can remain active within an ecosystem (e.g. organic compounds that bind to biomass, soluble chemicals, suspended solids). Highly mobile hazardous materials can spread for long distances from their release point and cause unforeseen consequences to habitat and local resources with a

	long-lasting, far-reaching effect on the environment (e.g. eutrophication or die-offs). **Extreme Heat:** Heat events that result in the release of toxic fumes or waterborne contaminants would be harmful to plants and wildlife and could result in long-term ecosystem damage and reduced habitat productivity. **Fire:** During a fire, volatile hazardous materials could exacerbate local fire intensity and cause additional complexities for emergency response.

Transportation Sector

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Roadways

Introduction to Asset Class

Roadways facilitate residents, workers, and visitors traveling within and through San Francisco, which supports economic activity, goods movement, and quality of life. The roadway 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. For this assessment, roadways include roadways, bicycle and pedestrian infrastructure, on-street parking, and bridges. Other elements found in the roadway not assessed in this profile include transit services (see public transit profile) underground utilities (see utilities and infrastructure profiles) street furnishings, planting strips, and lighting.

- **Roadways** are a system of interstates, freeways, major and minor streets that provide the main pathway for vehicle traffic throughout the city. Of San Francisco's, 1,088 miles of roadways, 946 miles are surface streets. Privately owned streets and park streets make up an additional 83 miles, and 59 miles are limited-access freeways.
- San Francisco's **bicycle network** is composed of 434 miles of bicycle facilities, 213 miles of which are signed bicycle routes that share right-of-way with motor vehicles, 125 miles are standard bikeways, and 13 miles are protected bikeways. The right-of-way also includes **sidewalks** that allow pedestrian travel and provide access to buildings, open space, roadways, and public transit. San Francisco sidewalks are typically 6-12 feet wide, elevated 6-8 inches above the roadway surface and have curb ramps that provide disability access in compliance with the Americans with Disabilities Act.
- **On-street parking** is also part of the roadway. SFMTA currently manages 23,000 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.
- **City-owned bridges**: Public Works inspects and maintains 98 bridges, including vehicular bridges, pedestrian bridges, movable bridges, overpasses over freeways/train tracks, and two tunnels. The City owns four drawbridges, including three bascule bridges that were constructed in the early-to mid-19th century and eligible for listing with the National Register of Historic Places.
- **State-owned bridges:** Caltrans owns and maintains state and federal highways, roads, and bridges in San Francisco, including US-101 (Van Ness Ave and

Lombard Street), CA Highway 1 (19th Ave, Cross Over Drive and Park Presidio Boulevard), CA Highway 35 (Skyline Blvd/Sloat Blvd), US-80, US-280, and CA 82 San Jose Avenue. The Bay Bridge is the primary connector between San Francisco and the East Bay. The Bay Bridge approach is a one-mile stretch of US-80 that leads to the Bay Bridge, supporting approximately 270,000 vehicles daily between San Francisco and the East Bay, and supporting commuter and goods movement for the region.

San Francisco's roadway network is overseen with shared responsibilities by the San Francisco Municipal Transportation Agency (SFMTA), San Francisco Public Works (Public Works), the San Francisco County Transportation Authority (SFCTA), California Department of Transportation (Caltrans) and, to a lesser extent, the Port of San Francisco and the Department of Recreation and Parks

Public Works inspects city-owned bridges on a bi-annual basis to note and address deficiencies and maintenance issues. A number of these bridges cross over freeways and are jointly inspected by Caltrans and Public Works. In addition, Caltrans also inspects a number of our local bridges including those over the Caltrain right-of-way. Because the drawbridges cross waterways that are designated as navigable waterways, the U.S. Coast Guard regulates the drawbridge operations and requires the drawbridges to remain in operational condition. Public Works operates and lifts the drawbridges as needed. Caltrans is responsible for inspection, maintenance and repairs for state and federal roadways and bridges, but has Delegated Maintenance Agreements with San Francisco Public Works to perform minor repairs of surface roadways.

Issue Statement

Roadways are integral to transportation, access, and connectivity throughout the City. There are a wide-range of users of the roadways, from drivers to bicyclists to public transportation riders. The roadway is vulnerable to significant damage and disruption from liquefaction, particularly if underground utilities rupture. The roadway has reduced accessibility and safety during flood events, but can usually be returned to functionality relatively quickly once waters recede. Roadways in San Francisco are already in high demand and key thoroughfares have little to no space capacity, particularly during commute times. The consequences of disrupted roadways can cascade to citywide or regional congestion especially if major arterials are disrupted, impacting access to homes and businesses, goods movement, and local air quality. Even the disruption of local streets can have profound impacts to residents and businesses in affected neighborhoods.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault 7.8M and Hayward Fault 7.0M events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

State bridges include their on and off ramps as part of their structures. Roadway and bikeway network data originates from the SF Open Data Portal (2018). Local and state bridges originate from the California Department of Transportation (Caltrans) GIS data library (2018).

Exposure Summary

Geologic: All roadway assets are exposed to violent or very violent shaking in a 7.9M earthquake on the San Andreas Fault. Most roadway assets are exposed to strong shaking in a 7.0M earthquake on the Hayward fault. 18% of roadways and 24% of bikeways are in the liquefaction zone. In addition, about a quarter of all bridges are located in the liquefaction zone.

Flood: Very limited roadway assets are exposed to the current 100-year coastal flood. However, with 66 inches of SLR, up to 8 percent of roadways and 11 percent of bikeways would be exposed to coastal flooding in a 100-year storm.

Fire: Five percent of roadways and 12% of bikeways are exposed to moderate wildland-urban interface fire risk, primarily in the Park Presidio.

TABLE A-26: EXPOSURE

Hazard	Roadways: 1,117 miles total		Bikeways: 233 miles total		Local Bridges: 53 total		State Bridges: 104 total	
	#	%	#	%	#	%	#	%
Geologic								
San Andreas 7.8 - Violent or Very Strong	321	29%	82	35%	6	11%	14	13%
San Andreas 7.8 - Very Strong	796	71%	151	65%	47	89%	90	87%
Hayward 7.0 - Very Strong	82	7%	19	8%	10	19%	11	11%
Hayward 7.0 - Strong	752	67%	164	70%	28	53%	62	60%
Liquefaction Zone	201	18%	56	24%	14	26%	23	22%
Flooding								
100-Year Coastal Flood Zone	12	1%	3	1%	1	2%	2	4%
100-year storm + 24 inches SLR	50	4%	14	6%	7	13%	2	4%
100-year storm + 66 inches SLR	92	8%	26	11%	7	13%	2	4%
100-year stormwater flood	38	3%	11	5%	11	21%	20	19%
Wildfire								
High	1	0%	0	0%	0	0%	0	0%
Moderate	56	5%	27	12%	0	0%	15	14%

Note: For an exposure table with additional hazards, please see Chapter 5.

FIGURE A-42: ROADWAYS AND LIQUEFACTION HAZARD

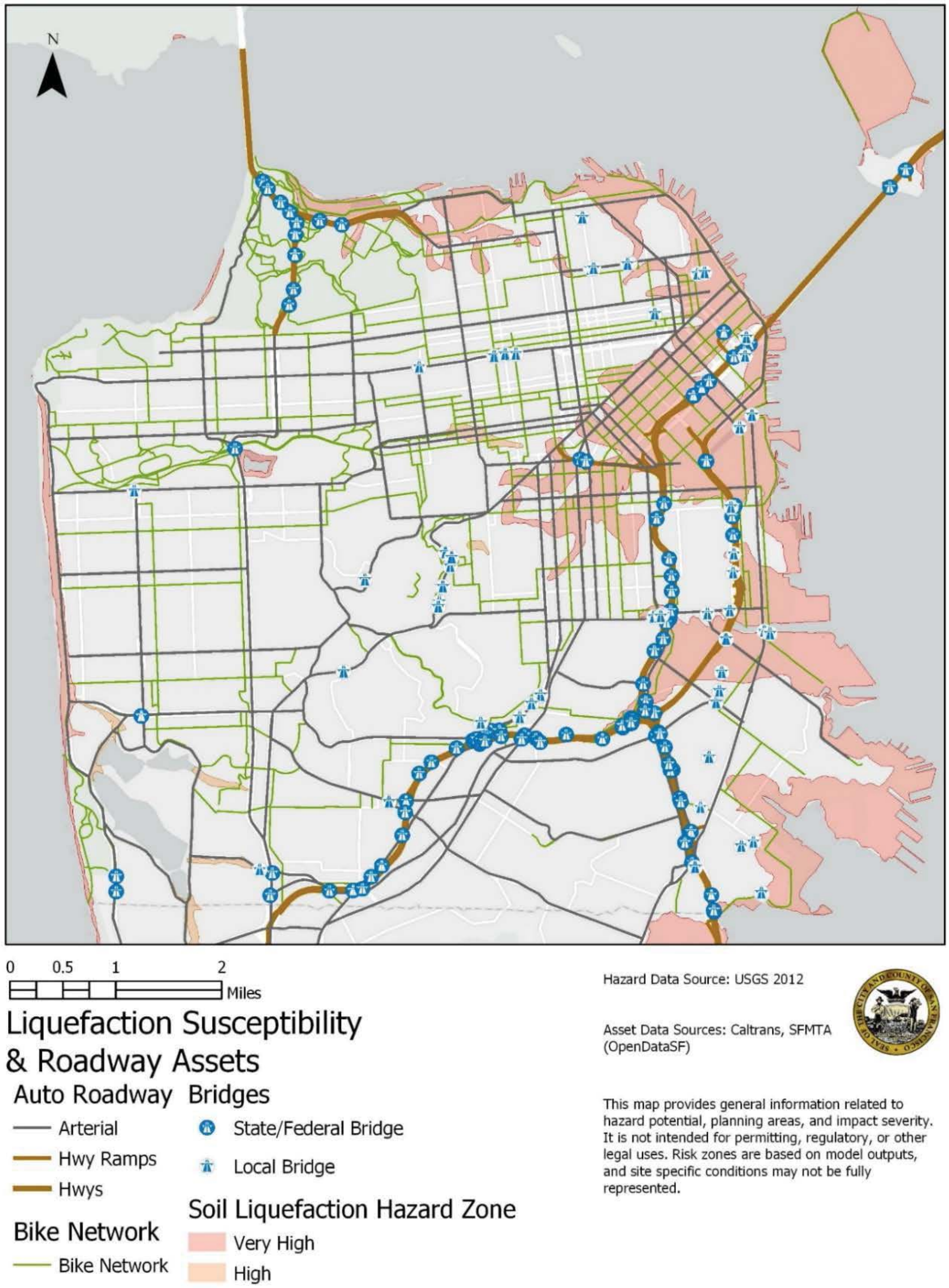
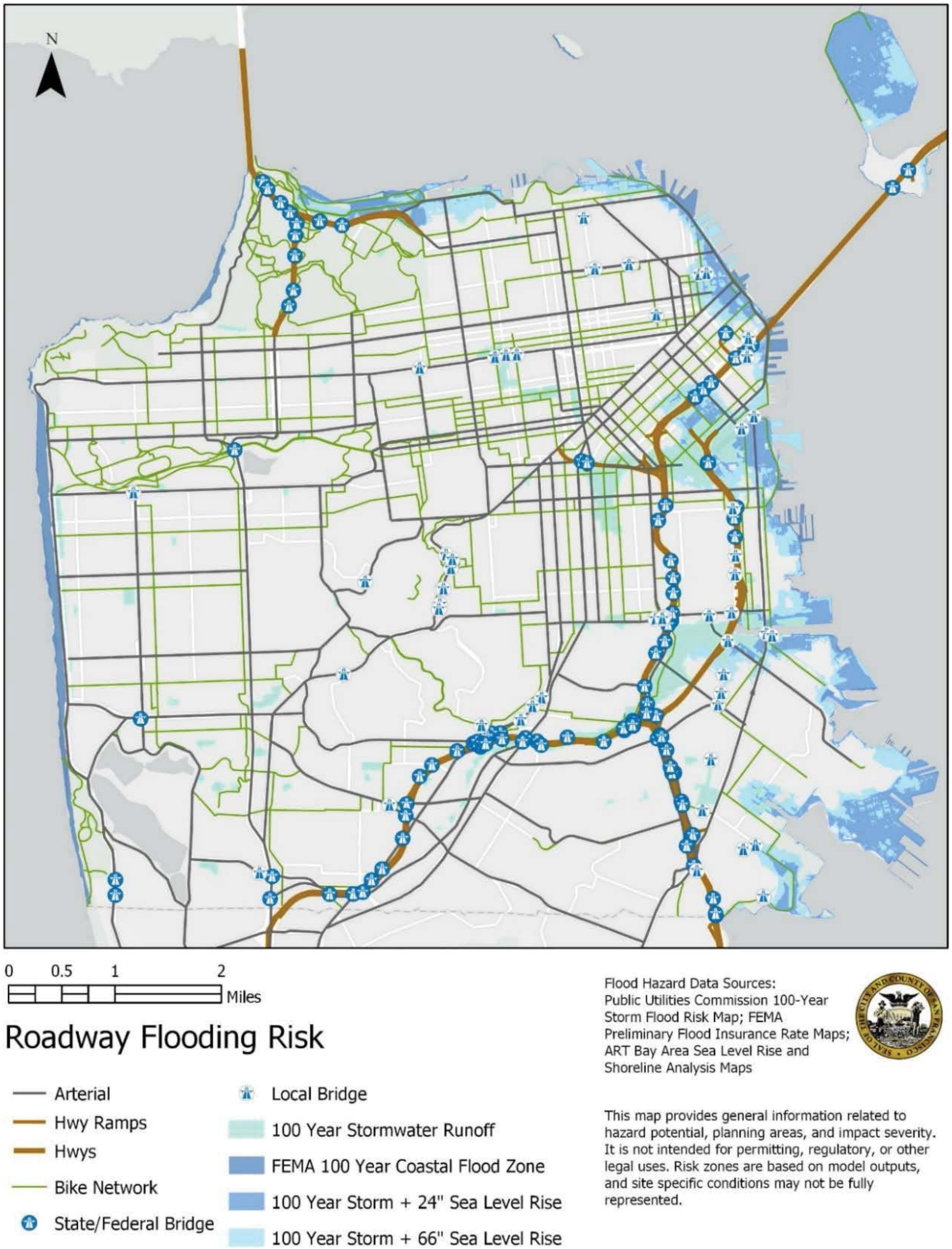


FIGURE A-43: ROADWAYS AND FLOOD HAZARDS



Flood Hazard Data Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Liquefaction may damage roadways, especially if underground pipes break. Most streets damaged during the Loma Prieta earthquake were damaged as a result of failing infrastructure – sewer, water, and gas breaks. Roadway damage impacts all uses of the roadway, including autos, public transit, bicycle facilities, and on-street parking. Liquefaction may also damage sidewalks, impacting pedestrian mobility.[37] Falling debris from buildings can temporarily disrupt roadways until cleared. Damaged buildings that have been cordoned may also disrupt access to the right-of -way.[38] In the 1990's following the Loma Prieta earthquake, City bridges were seismically analyzed and, if necessary, retrofitted to meet the standards of the era. Public Works is in the process of developing a plan to identify the most important bridges within the City and to perform a new seismic analysis to make sure that these structures meet modern code requirements. **Flood:** Although new roadways are designed to carry the 100-year flood event without flooding the adjacent sidewalk and structures, many roadways in San Francisco were constructed before this design criteria became mainstreamed, many roadways and sidewalks have subsided and impacted their drainage potential, and in some areas roadways repairs and re-grading efforts have reduced floodway capacity of the street.[39] Roadways that are exposed to more frequent flooding as sea level rises are likely to erode and subside.[40] When roadways are flooded, all users of the roadway (e.g., autos, public transit, bicycles, and on-street parking are affected by impacts to safety, accessibility, and increased congestion. Roadways can generally gain functionally shortly after floodwaters recede.[41]

[37] Lifelines Restoration Timeline Projection (forthcoming)
[38] Ibid.
[39] San Francisco Sea Level Rise Vulnerability & Consequences Assessment (forthcoming)
[40] Ibid.
[41] Ibid.

	Electrical components such as traffic signals, lighting, and control systems are particularly sensitive to any inundation and may take longer to regain functionality than roadways.[42] Interstate 80 and 280 are both elevated in areas of potential sea level rise exposure and thus less vulnerable to flooding. However, the footings of the elevated structures may be impacted by exposure to salt water (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.[43] Sidewalks are generally not sensitive to flooding and can resume their function once floodwaters recede; however, during flood events, accessibility and safety are issues. Sidewalks have minimal adaptive capacity for flooding as they cannot be easily raised and need to consider ADA accessibility and maximum slope restrictions when meeting the roadway. Although bridges are generally elevated structures, and vehicular 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 equipment room at the Islais Creek Bridge may be subject to flooding with sea level rise. **Extreme Heat:** Pavement exposed to high temperatures over long periods of time may deform (such as pavement heave).[8] However, high temperatures can be considered in pavement design to avoid deterioration. Given the relatively short lifespan of pavement (20-25 years) and the relatively low incidence of extreme heat given San Francisco's climate, the adaptive capacity is relatively high. Workers, such as construction and repair crews, spending considerable time in the roadway may be vulnerable to extreme heat. People, especially sensitive populations such as the elderly, young, and ill, that are waiting in the right-of-way for transit services may be impacted by extreme heat, especially if there is not shading from trees or protective transit facilities. Bridges are generally not sensitive to extreme heat, but they can expand in the heat and potentially face difficulty closing properly. The

[42] Ibid.
[43] Ibid.

	mechanical and electrical equipment for drawbridges could potentially be damaged by extreme heat conditions necessitating increased maintenance. **Fire:** While the roadway itself is not sensitive to fire, elements of the right-of-way can be damaged or destroyed including railings and electrical equipment. Fire can increase the risk of erosion and landslides which can damage roadways. Damaged or clogged drainage systems can also contribute to potential damage during rainfall events. Bridges are sensitive to fire as the extreme temperatures could reduce the performance of the bridge. Roadways and bridges are not sensitive to smoke.
Functional	**Networks:** Roadways function as a network. Disruption to the highest capacity roadways, such as interstates and arterials could affect the overall function of the network with substantial congestion because there are limited alternatives. Although alternative on and off ramps can be used to access the freeways, re-routing traffic increases traffic congestion on city streets. There is limited redundancy for bridges. Inland roadways can provide alternative routes for street traffic. However, Third Street, with two bascule bridges, is one of the primary north-south corridors on the southeast side of the city. **External Services:** The roadway depends on electric power for lights and signals and for the overhead power lines of the electric trolley system. If electric power is disrupted, then traffic control may be handled by SFPD officers and SFMTA parking control officers. Drawbridges also depend on electric power. Roadways depend on the combined sewer system to remove runoff and maintain accessibility during precipitation events. Roadway repair depends on two Granite Rock Asphalt plants located in Redwood City and South City which may be damaged after an earthquake and have high demand from other cities. **Populations Served:** Roadways serve all San Franciscans, commuters, and visitors. The transit, biking, and pedestrian facilities are especially important for

	those without a personal vehicle or not capable of driving, such as the elderly and disabled. **<u>Unique or Critical Function:</u>** Roadways in San Francisco are often very congested and there are competing demands for the space from different users. The roadway serves a critical function to provide access and mobility to all. Roadways are also critical for emergency responders to access those in need, and critical facilities, such as hospitals. Public Works has an Emergency Priority Routes Map to assist in conducting damage assessment and street clearance functions. More recently, a multi-agency work group has developed an Emergency Route Reopening Standard Operating Procedure to create tailored priority route maps following a disaster as pre-planned maps will not accurately reflect damage assessment information. Bridges are especially important for communities with limited access or communities in which freeways are a barrier to accessibility to the remainder of the City. The Bay Bridge plays an especially critical function providing connectivity to the East Bay.
Informational	**<u>All-hazards:</u>** Public Works is in the process of developing a plan to identify the most important bridges within the City and to perform a new seismic analysis to make sure that these structures meet modern code requirements.
Governance	**<u>All-hazards:</u>** Public Works is responsible for approximately 13,000 blocks within San Francisco. Approximately 1/3 of the streets are arterial or collector streets and approximately 2/3 are residential. Public Works is constantly resurfacing and repairing surface roads. Generally, six criteria (in no particular order) determine the priority for resurfacing in normal conditions: • Pavement Condition Index (scoring 0-100) • Geographic equity • Project readiness and coordination with private and public agencies • Inquiries • Mode(s) of transportation • Availability of funding

	The City has committed to Vision Zero with a goal of zero traffic fatalities and critical injuries in San Francisco by 2024. This has implications for the design and maintenance of streets, bicycle, and pedestrian infrastructure. SFMTA has its own capital program dedicated to the multimodal transportation system; however, the short-and long-term adaptation needs of the multimodal transportation system often require coordination with other agencies such as the SFCTA, the Port, and Public Works. The City is committed to safe and accessible travel for people with disabilities, making capital improvements and enhancing services across the City. Bridges in California are designed per the American Association of State Highway and Transportation Officials (AASHTO) Bridge Design Specifications with Caltrans Interims and Revisions. In addition, Caltrans has developed a Seismic Design Criteria document which defines the seismic design spectrum to be used. The Design Spectrum (DS) is defined as the greater of a probabilistic design spectrum based on a 5% probability of exceedance in 50 years or a deterministic spectrum based on the largest median response resulting from the maximum rupture of any fault in the vicinity of the bridge site. These design levels can also be increased in order to achieve a higher level of performance on important lifeline structures. The U.S. Coast Guard regulates drawbridge operations over navigable waterways and requires the drawbridges to remain in operational condition. Public Works lifts the bridges when notified by the U.S. Coast Guard.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Disruption to roadways during a hazard event could affect health and safety if people cannot access medical treatment or first responders cannot access an area. Nevertheless, priority lifeline routes are intended to maintain emergency access for first responders and critical medical care. Increased congestion and re-routing could increase collisions and related injuries/fatalities. Increased congestion and re-routing may be especially difficult for vulnerable populations, such as children and the elderly.

	Rerouting of traffic, especially truck traffic, could further impact communities that are already burdened by air pollution.
Economy	**All-hazards:** Increased congestion may result in the loss of economic productivity and the loss of economic activity if some businesses are not accessible. Many businesses rely on just-in-time goods movement deliveries that could be impacted by disrupted roadways. Small business are particularly vulnerable if access is comprised as they may have fewer resources to withstand a loss of business activity. This can impact the ability of community residents to purchase groceries, gas, and other necessities. If major arterials are disrupted, the impacts could quickly become citywide or regional. If local streets are disrupted the impacts may be neighborhood or citywide. If a major bridge were disrupted, such as the Bay Bridge, alternate routes would be extremely lengthy and heavily impacted with additional vehicles. The time-of-day and day-of-week of a hazard disruption can play a major role in the scale of consequences. A hazard event during working hours will likely result in greater congestion and disruption as hundreds of thousands of commuters would be trying to use the right of way. **Geologic:** The cost to repair roadways damaged by liquefaction would be significant. **Flood:** Increased coastal flooding could increase roadway maintenance costs. **Extreme Heat:** Increased extreme heat events could increase roadway maintenance costs and could reduce the lifespan of some electrical equipment. **Fire:** Exposure of roadways to fire can cause the closure of these routes with impacts for traffic circulation
Environment	**All-hazards:** Increased air pollution due to congestion. **Flood:** Abandoned vehicles may pose an environmental threat due to contamination from fuel and other chemicals.

Parking Garages

Introduction to Asset Class

City owned public parking garages are typically multi-story concrete parking structures. They are primarily concentrated in the Northeastern part of the city. They are a source of revenue for the City, offering short-term or monthly public parking for private vehicles. These assets are primarily owned and managed by SFMTA. If a parking facility is owned by Real Estate (RED), then a third party vendor is normally contracted to manage the garage. Some parking assets are owned by other city agencies, such as Recreation and Parks, and management varies from department to department.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault 7.8M and Hayward Fault 7.0M events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Data on public parking garage assets was sourced from the Facility System of Record map found on the SF Open Data Portal. This was then cross checked using the list of parking garages found on the SFMTA website.

TABLEA-27: EXPOSURE

Hazard	Parking Structures: 19 Total	
	#	%
Geologic		
San Andreas 7.8 - Violent or Very Strong	19	100%
San Andreas 7.8 - Very Strong	0	0%
Hayward 7.0 - Very Strong	1	5%
Hayward 7.0 - Strong	18	95%
Liquefaction Zone	6	32%
Flooding		
100-Year Coastal Flood Zone	0	0%
100-year storm + 24 inches SLR	1	5%
100-year storm + 66 inches SLR	1	5%
100-year Stormwater Flood	1	5%
Wildfire		
High	0	0%
Moderate	0	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

Dataset does not include: Japan Center Annex Garage

Exposure Summary

Geologic: All public parking structures will be exposed to violent or very strong shaking in a 7.8M earthquake on the San Andreas Fault. However, only one structure will be subject to violent or very strong shaking in a 7.0M earthquake on the Hayward fault.

Flood: Public parking assets are not expected to see significant exposure to flooding hazards. However, there is one facility (Golden Gateway Parking Garage) that will see exposure to flooding given both SLR scenarios as well as during 100-year storm water events.

Fire: Public parking assets do not see exposure to wildland-urban interface fire hazards

FIGURE A-44:PARKING ASSETS AND LIQUEFACTION HAZARD

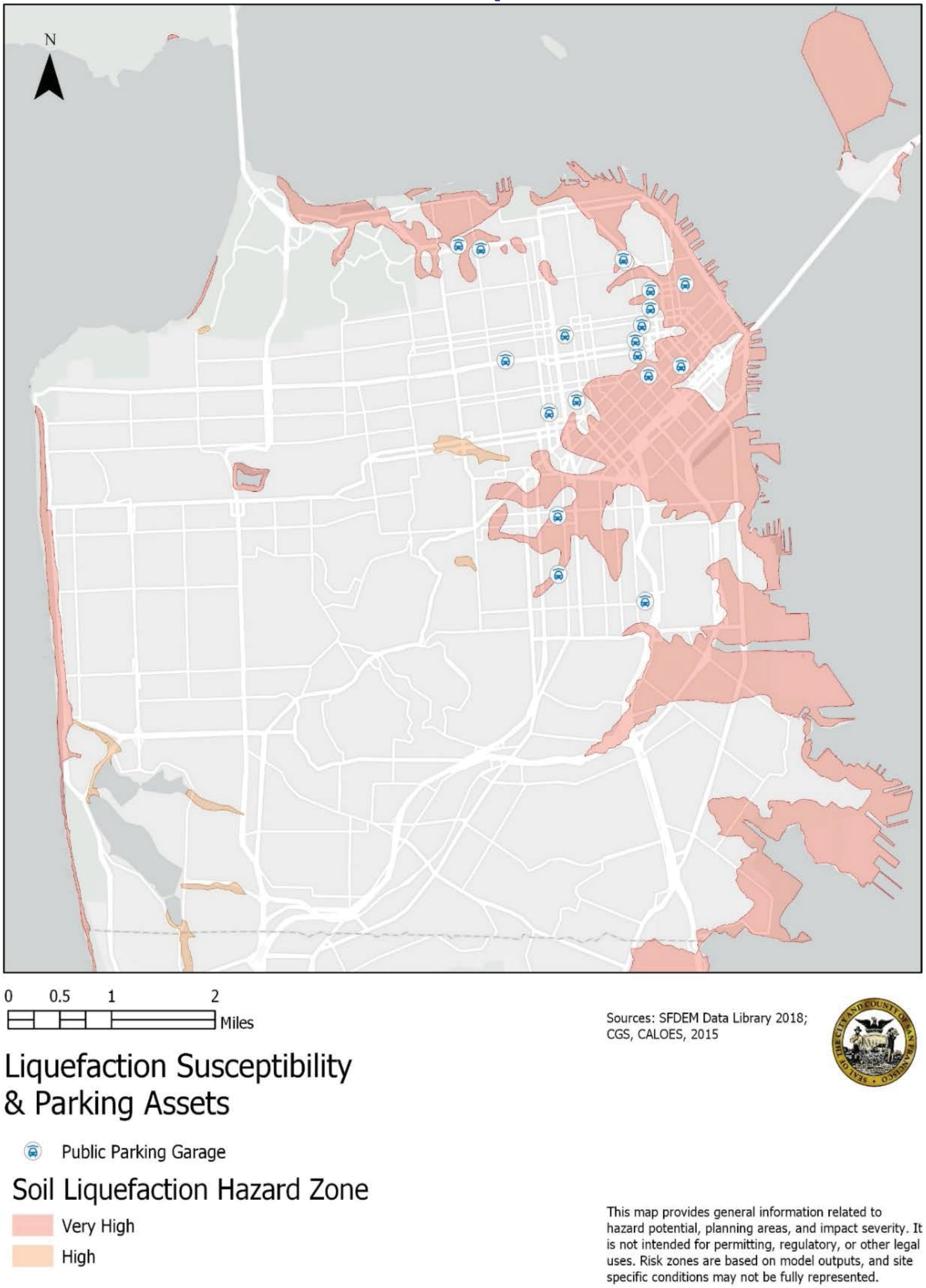
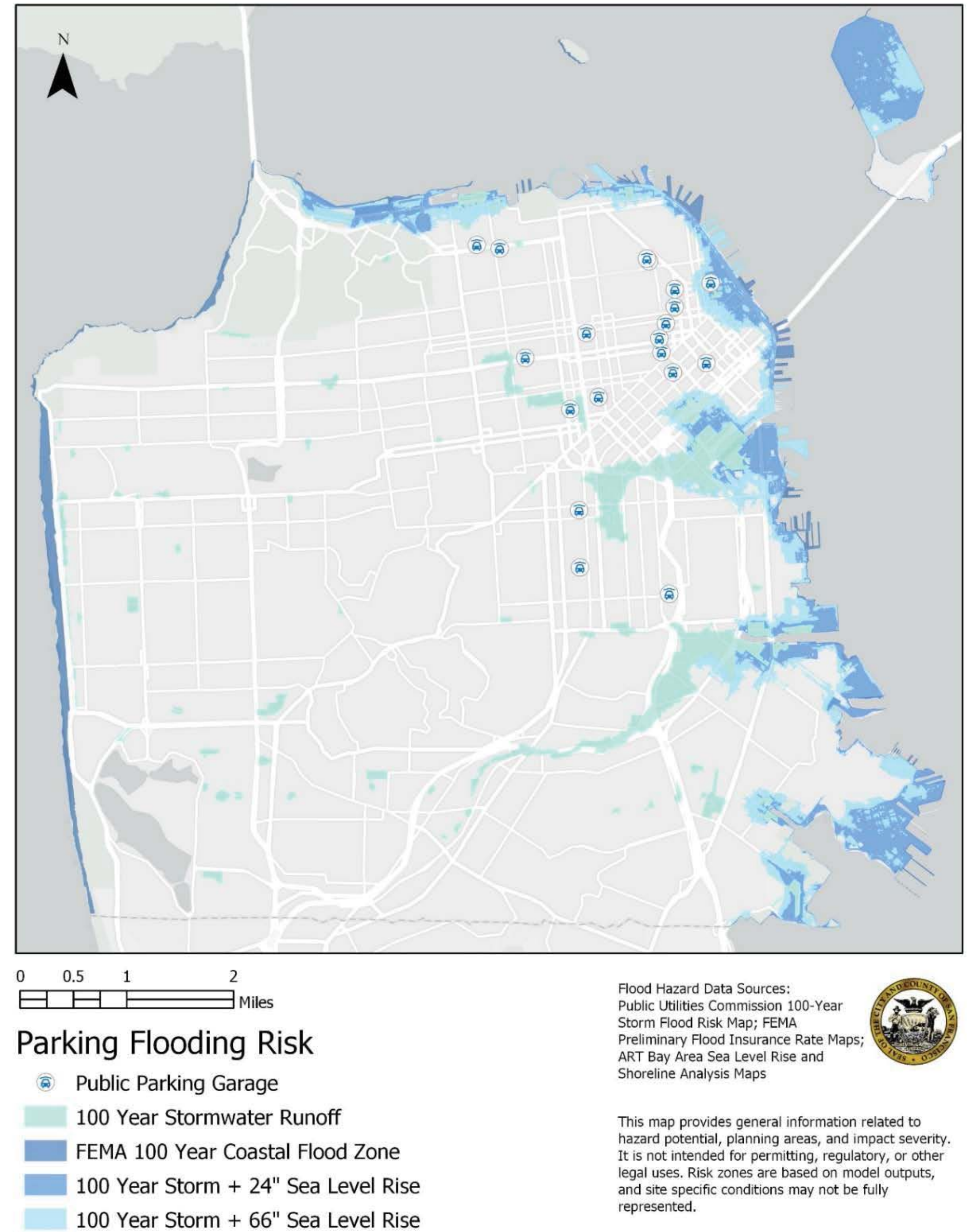


FIGURE A-45: PARKING ASSETS AND FLOOD HAZARDS



VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Many structures were constructed prior to 1975 and many have not been seismically retrofit. However, some of the oldest, most heavily used structures have received some manner of retrofitting **Flood:** Some garages have sub-basements that can be subject to flooding, impacting access to some of these facilities. **Extreme Heat:** Most structures are naturally ventilated and are not confined spaces.
Functional	**Networks:** Garages often operate independently and do not provide services that would require their connection to networks. If one or more garages is damaged, that may result in increased demand at other nearby garages. **External Services:** Garage structures rely on external power and communications infrastructure in order to operate. There are no backup resources or contingency plans in place if these services were to be disrupted. **Populations Served:** All structures are built to be ADA compliant, publicly available to all, and offer parking services at market or below market rates. **Unique or Critical Function:** This asset offers public parking in congested areas, thus reducing the number of vehicles on the street and contributing to traffic calming.
Informational	**All-hazards:** Relevant asset information can be found in SF Public Works 2013 Condition Assessment Report.
Governance	**All-hazards:** Improvement and management of this asset is dictated by the SFMTA Parking Facilities Restoration and Compliance Program which is tasked with assessing and restoring all assets in order to make them code compliant.

CONSEQUENCES

Category	Consequence
Society/Equity	**Geologic:** Asset services may be disrupted for years as repair/replacement processes are carried out. Depending on the severity of the event, this could lead to a shortage of market or below market rate parking in congested areas. This could lead to more congestion as a greater number of cars are forced to park on the street. **Flood:** Asset services may be disrupted by days following a significant flooding event. Depending on the severity of the event, this could lead to a shortage of market or below market rate parking in congested areas. This could lead to more congestion as a greater number of cars are forced to park on the street.
Economy	**Geologic:** Costs of repair or replacement of the asset can lead to a loss of fiscal revenue. Prolonged disruption from events can have an impact on economic success of nearby businesses. **Flood:** Interruption of economic activity to nearby buildings can occur if flooding were to effect access to certain facilities. Generally, loss of fiscal revenue would occur if significant disruption of this asset were to occur. Operational costs for this asset would also be impacted from repair expenses over time.
Environment	**All-hazards:** Any disruption that led to more congestion or cars circling, looking for parking, would lead to greater emission of pollution from vehicle exhaust.

Public Transit

Introduction to Asset Class

The public transit system facilitates the movement of residents, workers, and visitors traveling within and through San Francisco, which supports economic activity and quality of life. The transit system links people with services, jobs, family and friends, recreation, and other destinations within the city and throughout the Bay Area region. Public transit is regional in nature and offered by over 20 service providers in San Francisco. The transit system includes SFMTA's Muni (buses, electric trolley buses, metro light rail, cable cars, and historic street cars), BART, Caltrain commuter rail, as well as regional bus services provided by transit operators such as AC Transit, SamTrans, and Golden Gate Transit. (For ferry service, please see the Water Transportation profile.) Given the lower adaptive capacity of fixed rail (e.g. more capital intensive and difficult to re-locate and re-route), this profile focuses on agencies managing fixed rail public transit assets in San Francisco: Muni, BART, and Caltrain. This profile provides greater detail on Muni assets and services because it is owned and managed by the City and County of San Francisco and more information was readily available for this assessment. These transit systems are each described below:

Muni

- **Motor Coaches (Buses)** are fuel efficient vehicles that operate on routes throughout the city that can be re-routed if needed. They carry about 45% of MTA's public transportation system riders. The motor coach fleet consists of roughly 610 vehicles and includes 32-foot, 40-foot and 60-foot buses.
- **Metro light rail** includes 71.5 miles of standard-gauge track, seven light rail lines, three tunnels, 12 subway stations, 25 surface stations, and 87 surface stops. The system has an average weekly ridership of 173,500 passengers. As of 2016, Muni Metro consisted of 149 light rail vehicles (LRVs)[44].
- **Electric trolleys** operate on a fixed overhead line network that provides electric power. These 202 zero-emission vehicles carry about 30% of the public transportation system's riders and operate on local streets.

[44] SFMTA (2017) *'2017-2030 Short Range Transit Plan"*. Retrieved from: https://www.sfmta.com/reports/short-range-transit-plan-fy-2017-fy-2030

- **Cable cars** operate on fixed routes and are hauled by a continuously moving cable located just below street level. 40 cable cars make up Muni's cable car fleet.
- **Historic streetcars** operate on tracks along the roadway, with some track sections separated from regular auto traffic. Muni has 43 operational vehicles. Streetcars carry roughly, 21,000 passengers daily.

Bay Area Rapid Transit (BART)

Operates four regional commuter rail lines within San Francisco which are served by eight below grade subway stations (four shared with Muni Metro above). These stations are located along the Market Street corridor, Mission Street and interstate 280. Embarcadero and Montgomery stations are the busiest in the BART system. In Fiscal Year 2017, over 180,000 trips were made to or from these stations each weekday. BART has an estimated 679 fleet vehicles.[45]

Caltrain

operates three regional heavy rail commuter transit stations within San Francisco, providing connectivity to Peninsula. These stations are typically at grade and are found along the southeastern portion of the city.

Given the limitations of conducting an assessment at a citywide scale, not all transit sub-assets that are required for a functioning system were included in this assessment, such as telecommunications, signaling equipment, etc. Instead, Transit stations and the fixed guide-way more broadly were assessed for exposure as representative assets and therefore used as a proxy for potential impacts to other critical sub-assets. These two asset types are described in greater detail below. The overhead catenary system used by Muni buses and street car fixed-guideways, and related infrastructure were included in the exposure assessment to the extent possible and their vulnerabilities and consequences of disruption are discussed in the qualitative sections below. Cable cars we not included in the exposure analysis but their vulnerabilities and consequences of disruption are discussed below as well. Additional infrastructure and facility

[45] BART 2018 factsheet (2018). https://www.bart.gov/sites/default/files/docs/2018_BART%20Factsheet.pdf

vulnerabilities that may affect transit service are discussed in the Roadways Profile and Municipal Yards Profile.

Stations

In general, two types of transit stations can be found in San Francisco: below grade subway stations and at grade surface stations. Subway stations consist of surface entrances and typically have two levels: a mezzanine concourse containing ticketing and passenger fare gates, and a lower level consisting of boarding platforms and transit system operation. In SFMTA/BART shared stations, BART operates on a third sublevel. At the surface, stations include elevated platforms, boarding islands, bus bulbs and curbside bus zones.

SFMTA Transit stations, street level boarding islands, and curbside bus zones may be shared among regional transit service providers with shared governance structure and maintenance jurisdictions. For stations shared with BART, SFMTA is responsible to SFMTA service level, and assets related to Muni service on the passenger mezzanine (i.e. Fare gates/ticketing) BART is responsible to remainder of the station. SFMTA, BART and Caltrain are all individually responsible for stations discreet to their services. Other regional transit services providers (e.g. Golden Gate Transit, SamTrans, AC Transit) also have boarding islands and curbside bus zones within San Francisco that are either stand-alone or jointly operated with SFMTA.

Muni Fixed Guideway

Trackways consist of several critical functioning sub-assets such as the train control system, traction power system and switches. Trackways also include the track itself which is the rail equipment the LRVs and street cars run on. Trackways span over 70 miles and support seven light rail lines. The trackway runs below ground in the subway along the Market Street corridor and other tunnels along the system. In many instances the trackway runs at or above grade as the metro lines extend towards outer service areas.

Issue Statement

The public transit system plays a unique and critical function in San Francisco. Muni alone moves over 700,000 individuals daily, providing access to jobs, shopping, recreation, and other services. Embarcadero Station (Muni and BART) is particularly vulnerable to future coastal flooding events as sea level rises because it is below grade and has sensitive equipment. The Ferry and Central Subway portals and Caltrain and Muni T-Third line through Mission Bay may also be vulnerable to future coastal flooding as sea level rises. Both the Embarcadero area and Mission Bay are also susceptible to liquefaction in an earthquake, which could damage transit-related assets and infrastructure. Transit systems rely on electric power and do not have backup redundancies. Impairment of transit systems from flooding, earthquake, power loss, or other hazard events would have severe economic and equity consequences, potentially at a regional scale.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault 7.8M and Hayward Fault 7.0M events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Data originates from DEM Data Library (2018) and the SFMTA (2018). As discussed above, the exposure assessment focuses on fixed guideway assets given their lower adaptive capacity. Stations and trackways were assessed as representative assets, but do not reflect all assets that are necessary to run a functioning transit system. Additionally, exposure assessment does not explicitly include potential impacts from damage to the Transbay tunnel from these hazards. Surface flooding of some stations (such as embarcadero) can lead to miles of underground flooding underground, a fact not captured in this analysis.

TABLE A-28: EXPOSURE

Hazard	Muni Stations: 9 Total		Muni LRV Fixed Guideway: 42 miles total		BART Stations: 8 total (4 shared with Muni)		BART Right of Way: 8 miles total		Caltrain Stations: 3 total		Caltrain Right of Way: 18 miles total		Overhead Catenary System: 332 miles total		Central Subway: 2 miles total		Central Subway Stations: 4 total		Cable Car Lines: 7 miles total	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Geologic																				
San Andreas 7.8 - Violent	0	0%	10	23%	0	0%	8	100%	0	0%	4	25%	32	10%	0.0	1%	0	0%	0	0%
San Andreas 7.8 - Very Strong	9	100%	32	76%	8	100%	1	13%	3	100%	11	60%	296	89%	1.6	79%	4	100%	7	100%
Hayward 7.0 - Very Strong	6	67%	7	16%	1	13%	4	50%	0	0%	2	11%	32	10%	0.2	11%	1	25%	1	7%
Hayward 7.0 - Strong	1	11%	18	44%	5	63%	2	25%	3	100%	13	74%	296	89%	1.4	68%	3	75%	6	86%
Liquefaction Zone	3	33%	10	24%	3	38%	4	50%	2	67%	9	50%	169	51%	0.9	47%	2	50%	1	17%
Flooding																				
100-Year Coastal Flood Zone	0	0%	0	0%	0	0%	2	25%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%

100-year storm + 24 inches SLR	1	11%	5	11%	1	13%	0	2%	1	33%	6	33%	7	2%	0.192	33%	0	33%	0.116	2%
100-year storm + 66 inches SLR	1	11%	7	17%	1	13%	0	5%	1	33%	7	39%	13	4%	0.432	39%	1	39%	0.306	4%
100-year Stormwater Flood	2	22%	1	2%	0	0%	1	7%	1	33%	8	44%	10	3%	0	44%	0	44%	0	0%

Note: For an exposure table with additional hazards, please see Chapter 5.

Exposure Summary

Geologic: A significant amount of transit assets are exposed to violent or very strong shaking in a 7.8M earthquake on the San Andreas Fault. BART trackway and stations, Embarcadero Station is exposed to very strong shaking in a 7.0M earthquake on the Hayward fault. Three Muni and Bart stations are in the liquefaction hazard zone and two Caltrain stations and a significant share of Caltrain trackway are in the liquefaction zone. Fixed-guideway for light rail, streetcar, cable car and trolley coaches are all exposed. Specifically, the Muni T-Third and Caltrain lines traverses liquefaction hazard zones in Mission Bay and Islais Creek areas in addition to half of the central subway stops being located in a liquefaction zone

Flood: Embarcadero Station and the Ferry Portal at Folsom are susceptible to coastal flooding. Future Central Subway Stations may also be vulnerable at 4th Street and Harrison. Surface stations along the Embarcadero may also be exposed future coastal flooding as sea level rises, impacting both surface and subterranean fixed-guideway services. The Caltrain San Francisco Station and Caltrain trackway in Mission Bay may also be exposed to coastal flooding as sea level rises. The Muni T-Third line traverses flood hazard zones around Mission Creek and Islais Creek.

Fire: The limited public transit assets included in this assessment are not exposed to wildfire risk.

FIGURE A-46: TRANSIT AND LIQUEFACTION HAZARD

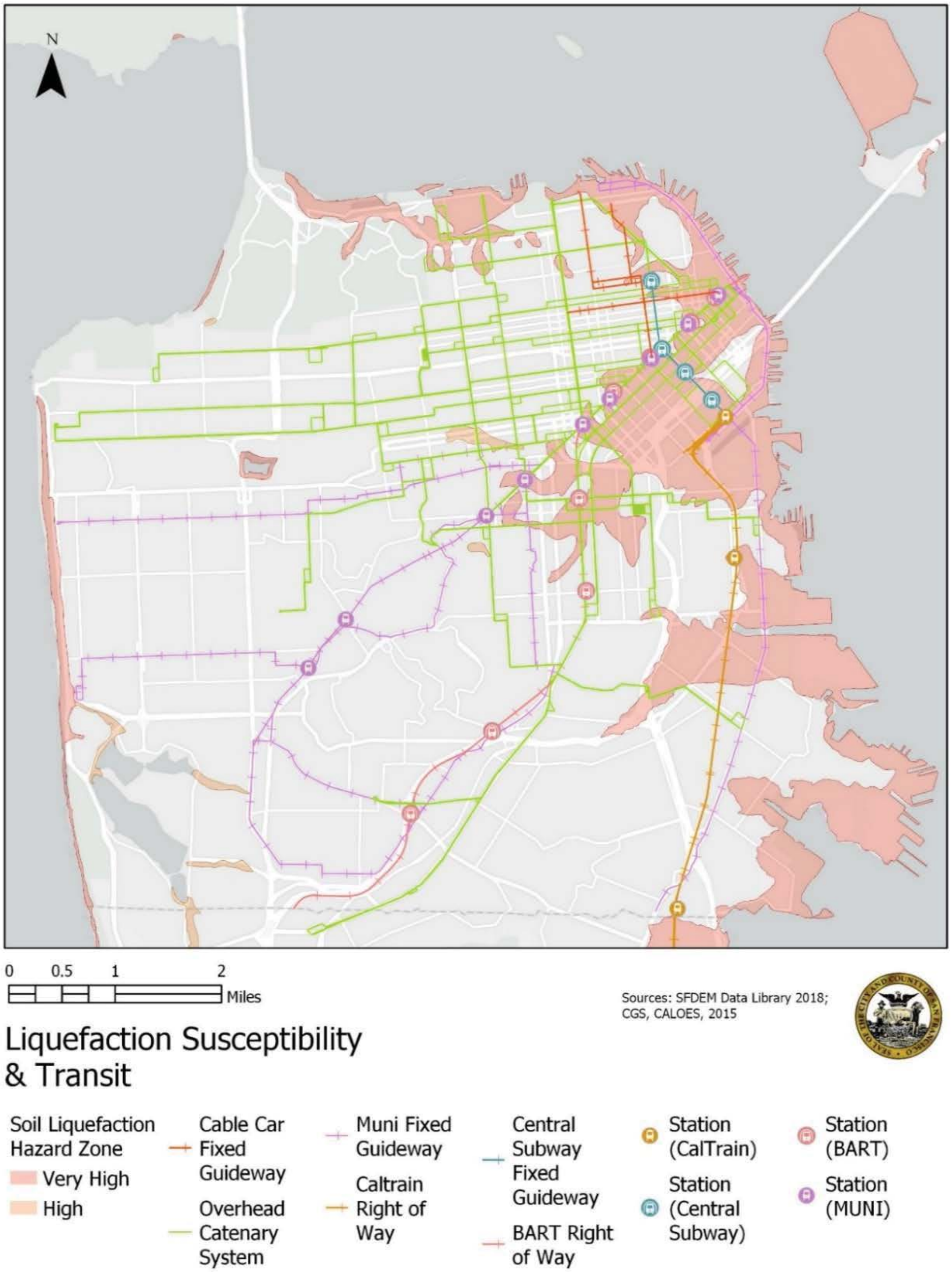
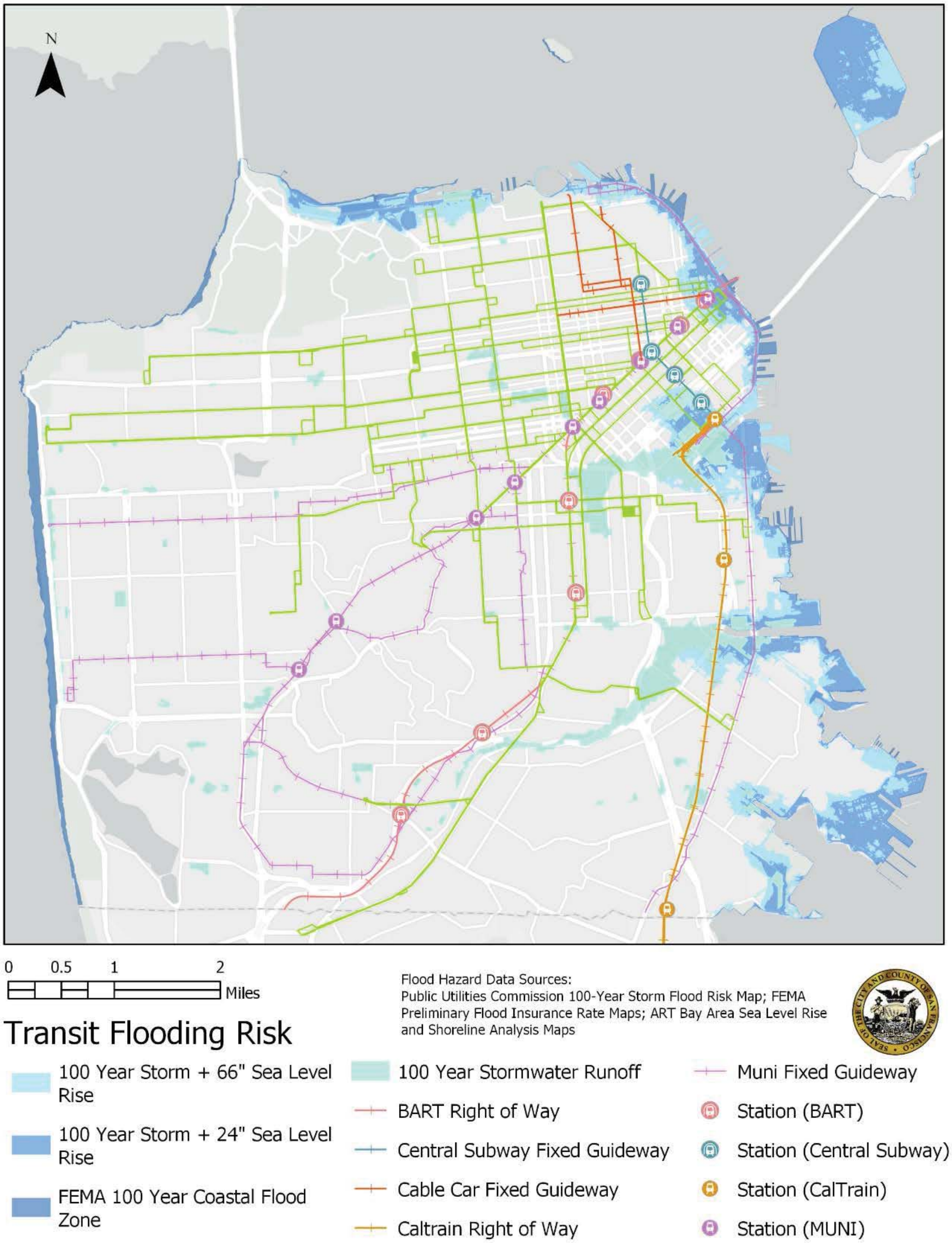


FIGURE A-47: TRANSIT AND FLOOD HAZARDS



VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Transit fixed guideway infrastructure, such as the overhead catenary system and track, is vulnerable to groundshaking and liquefaction hazards but the scale of disruption or potential failure is relatively uncertain. For example, rail assets have a certain level of tolerance through shifting. However, if the seismic event appreciably disrupts any sub-assets, transit service in the metro will suspend until the issue is addressed. These sub assets include the signal system, switch system, and train control system among others.[114] Damage to roadways may impact transit service (see Roadways profile). **Flood:** Stations along the waterfront and market street see exposure to coastal flooding under projected sea level rise inundation scenarios and they are particularly vulnerable because these station systems are below grade, have electrical equipment that is sensitive to water, and metal components (e.g. track) that are particularly sensitive to the corrosive nature of saltwater. Stations are less vulnerable to stormwater flooding due to the relatively short term nature and shallow depth of water, however this is dependent the sewers' capacity to shed water. Pumps currently exist throughout the system, but have a limited capacity and are dependent upon a functioning sewer system. Light rail tracks are sensitive to inundation and service would be suspended if the flood depth exceeds operator ability to judge safe passage. The rail system would require inspection before placing the system back in service. Exposure to salt water would accelerate corrosion. Exposure of streetcar cable lines would also likely accelerate corrosion. The cable cars can continue to operate during minimal flooding (as long as operator can visibly assess safe passage); however, operation would likely cease until floodwaters recede for safety reasons. Cable cars are currently not used during severe weather.[115] **Extreme Heat:** High heat is likely to affect electrical components across sub-asset systems, including the vehicles themselves. There have been

[114] Rewers J, (October 2018). *"MUNI Lifelines Restoration Interview"*. Interviewed by Mieler D.
[115] San Francisco Sea Level Rise Vulnerability & Consequences Assessment (forthcoming)

	instances of high heat affecting older light-rail vehicles (LRVs), however, there is uncertainty as to its effect on new LRVs. Pavement and track exposed to high temperatures over long periods of time may deform (such as pavement heave or track buckling),[116] affected rail lines and overhead catenary system poles. However, high temperatures can be considered in pavement design to avoid deterioration. Given the relatively short lifespan of pavement (20-25 years), the adaptive capacity is relatively high. The bus fleet may experience increased breakdowns and AC malfunction during extreme heat. BART's electrical and mechanical systems can potentially overheat during extreme heat events. This can impact delivery of power to the third rail used for the movement of vehicles as well as to BART stations. Additionally, essential air conditioning can fail from the strain of keeping other systems cool. **Fire:** All station and fixed guide-way sub-assets are vulnerable to fire. Even concrete assets (station platforms, tunnel walls, etc.) see reduced life expectancy if internal rebar is heated to (or near) the melting point. Failure in a single metro sub-asset halts or disrupts service until all sub-assets are functional. It is possible that service could continue at other points in the system if damage were isolated and the cause identified. Because cable cars are open air and without ventilation, they were removed from service during the severe air quality days in 2018 and replaced with bus service. Low visibility from wildland-urban interface fires may lead to service delays due to poor visibility of transit operators[117]
Functional	**Networks:** The transit systems are networked. The fixed guideway systems, including Muni metro, electric trolleys, cable cars, and historic street cars could experience widespread disruption even if a small portion of the network is damaged as it is difficult or impossible to re-route these services around impacted stretches. It is possible that subway stations along Market could be shut down with functional service remaining along the rest of the system unless system-wide electrical

[116] Caltrans, (2019). "*Caltrans Climate Change Vulnerability Assessment Summary Report District 4*"Retrieved From: http://www.dot.ca.gov/transplanning/ocp/docs/D4_Caltrans_Vulnerability_Assessment_v49.pdf
[117] SFMTA, (2018). *'San Francisco Commits to All-Electric Bus Fleet by 2035"* Retrieved from: https://www.sfmta.com/press-releases/san-francisco-commits-all-electric-bus-fleet-2035

	issues occur. In the case of BART stations affected by flooding, it is likely that all train connections to the East Bay would be disrupted until service could be restored. All MTA trolley coaches can run on batteries, which can help reroute the vehicle around a minor disruption. However, older vehicles have shorter battery range than newer models, especially in hilly conditions. Long-range plans to transition the electric trolley fleet to battery-powered busses that do not require overhead wires will increase the flexibility of the system.[118] If access or operations at a station is disrupted, redundancy and alternatives are very limited. It is possible that ground transit (motor coaches, electric trolley) could help to maintain continuity of services, but would still result in a net loss of services as vehicles would be diverted from other routes. Furthermore, ground transit reserve fleets are limited by federal law and available vehicles routinely replace broken down vehicles or vehicles scheduled for maintenance. This option is also dependent on the degree to which sub-assets associated with alternative service, such as the OCS, may also be impacted by hazard events. Motor coaches can be more easily be re-routed to avoid areas of flooding or other hazards. In addition, motor coaches can provide service along alternate routes during disruptions to electric trolley, cable car, and historic street car service if sufficient buses are readily available. However, there are limited buses available in the reserve fleet, therefore, serving alternative routes almost always necessarily reduces service on other existing bus routes. As BART is a regional service partner, disruptions from localized flooding can have an impact on other areas of the bay. **External Services:** Transit stations rely on electric power, communications systems, and the sewer system to operate. There are typically no redundancies in regards to external services, particularly electric power and networked communication systems. For example, If citywide power outages occur, the system will not be able to operate. If the power outage/interruption were isolated to a particular power supply/substation or transit station, it is possible that other elements/locations of the system could continue services. In regards to flooding, the ability to pump water is dependent on the sewer system.

[118] Ibid.

	As San Francisco transitions to an all-electric bus fleet by 2035, the system will be dependent upon electric power for battery charging. MTA motor coaches depend on fuel, which is stored in underground tanks and at all motor coach facilities. The transit system also relies heavily on water, for fire protection, and waste management services in order to maintain operations **Populations Served:** Muni service is critical to transit dependent residents including the elderly, very young, medically dependent or mobility challenged, low or very low income, housing or transportation cost burdened, renters, or those without a car. Service is critical to ethnically and culturally diverse populations with limited English-speaking capacity and non-English Speakers. SFMTA provides communications and critical information in languages prevalent in San Francisco. For people with disabilities who are unable to independently use public transit, SFMTA provides complementary Paratransit service via van and taxi services. **Unique or Critical Function:** Public transit is critical for movement of hundreds of thousands of commuter into and out of the city on a daily basis. Public transit provides access to San Francisco public parks and open spaces as well as state and regional recreational areas. Muni provides access to the local school system, cultural institutions such as museums and theaters and a critical in supporting access to neighborhood economic vitality.
Informational	**All-hazards:** Information related to vulnerabilities and consequences of this asset can be found through the San Francisco Vulnerability and Consequence Assessment, SFMTA Sea Level Rise Assessment, and the BART Local Hazard Mitigation Plan. Neither Samtrans or Caltrans have an Adaptation and Resilience plan formalized, Samtrans does have a plan underdevelopment. There is less information available on seismic and heat vulnerabilities.
Governance	**All-hazards:** Federal asset management and state of good repair reporting requirements assist in maintaining robust information on the status of our assets. This contributes to an understanding of asset useful life cycles and informs replacement/rehabilitation cycles based on maintenance and inspection activities. The diversity of funding sources (local, state and federal transportation funds) also informs governance of this asset class.

	Three different agencies own and operation transit station assets in San Francisco, including SFMTA, BART, and Caltrain.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Equity impacts have the potential to happen at the neighborhood, citywide and regional scales. Depending on the scale of damage/disruption, loss of access to transit system or loss of mobility across communities could persist. Similarly, as travel shifted to other modes/routes, disruptions could impact the safety of pedestrians or cyclists causing additional traffic congestion. Additionally, impacts that disrupt multiple elements of the transportation network can potentially exacerbate existing access/mobility inequities and cause further geographic isolation.
Economy	**All-hazards:** Economic impacts would disproportionately impact communities who rely on transit for mobility. For the SFMTA, substantial funds would be lost from fares if the transit system is impacted and the costs of repairs would be dependent on severity of damage. Depending on the severity of the damages and scale of the disruptions and associated system failures, economic disruptions could occur at the neighborhood, citywide and regional scales. Past disruptions include stormwater flooding in December 2014 which required temporary shutdown of the subway. **Geologic:** According to BART119, direct capital losses to overhead and at-grade trackways, the Transbay Tube, the Berkeley Hills tunnel, stations, buildings, systems and equipment due to faulting, shaking, liquefaction, and landslides will be around $1.1 Billion for a 7.0M Hayward Fault event and as much as $860 Million for a San Andreas Fault event **Flood:** Exposure of station sub-assets to water, especially salt water, may increase maintenance costs and reduce the useful lifespan of assets, thereby increasing replacement costs. In the near term, flooding of BART assets can lead to more frequent delays of service, impacting fare revenues.

[119] BART, (2017). '*Local Hazard Mitigation Plan: San Francisco Bay Area Rapid Transit District".*

	Extreme Heat: Exposure of station sub-assets to extreme heat may increase maintenance costs and reduce the useful lifespan of sub-assets.
Environment	All-hazards: In the event of a major disruption, existing air quality could change if congestion patterns shifted to remaining usable portions of the transportation network. Depending on the hazard/damage, release of hazardous materials could impact water quality with subsequent effects on various flora and fauna. Shifts in passenger loads at different transit locations can contribute to trash/debris accumulation.

Water Transportation

Introduction to Asset Class

Water transportation in San Francisco consists of ferries and water taxis, as well as facilities for private vessels and motorized and non-motorized boats. Ferry service was once the primary way people travelled over the Bay, but the California Legislature passed a law prohibiting other forms of transportation within 10 miles of the Bay Bridge upon its completion. It was not until the late 1960s and early 1970s that ferry service resumed on the Bay, albeit limited at the time. Only after several disasters, including a BART tube shutdown in 1979 and earthquake damage to the Bay Bridge in 1989, did ferry service substantively return as a regional transportation option. Since the early 2000s, ferry service and ridership has risen significantly and the region and San Francisco have been increasing the number of ferry landings to accommodate increased ridership and service. Approximately 5 million people travel between San Francisco and other locations by ferry each year, with the majority of those trips serving daily commuters travelling to and from work. San Francisco serves as the primary regional hub for ferry transportation and the major infrastructure for ferry service is located at the Ferry Building, as well as ferry and water taxi facilities that exist at AT&T Park, Pier 1 1/2, Hyde Street, Pier 43 /12, Pier 40 and a future ferry landing at 16th Street near Pier 54. Service is provided between San Francisco and Vallejo, Oakland, Alameda, Berkeley, Sausalito, Larkspur and with service planned between Richmond and San Francisco coming in 2019.

Physical characteristics unique to water transportation include the need to be at a waterside location, gates, gangways, floats and terminals and landside access by walking, biking, bus, scootering or car. In some cases, gangways and boats are designed in such a way as to make it impossible for certain boats to use particular ferry docks (this is true for Golden Gate and WETA ferries at the moment). Ferry terminals rely on several sub-assets to ensure that they can function to move passengers. These sub-assets include gangways, terminals, landside transportation, power and fuel supply, as well as sub assets that help run the system such as offices, maintenance, operations and repair facilities, fuel stations and the boats.

Ferry service is provided by several providers, including Water Emergency Transportation Authority (WETA), Golden Gate Ferry, Blue and Gold and smaller operators like SF Water Taxi and Tideline Marine Group. These providers either own or lease their ferry terminal, docks, gangways and staging areas. In San Francisco most of these facilities are leased from the Port of San Francisco. However, the new waterside infrastructure at the Downtown Ferry Terminal will be owned by WETA.

Issue Statement

Water transportation is a growing element of regional transportation and mostly serves commuters. Because water transportation assets are mostly found along the Embarcadero seawall, the landside facilities are vulnerable to damage in an earthquake. Ferry service is more sensitive to high winds than sea level rise or flooding, but landside access could be compromised in a flooding event. The most significant impact if water transportation was disrupted would be to emergency response as the system figures largely in the region's ability to transport people who are in San Francisco for work but who live in a different part of the region and as a means of getting emergency responders and supplies into San Francisco.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table on the following page, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Data on ferry landings and water taxi locations was provided by the SF Department of Emergency Management (DEM)

TABLE A-29: EXPOSURE

Hazard	Ferry Landing: 9 Total		Water Taxi Landings: 3 Total	
	#	%	#	%
Geologic				
San Andreas 7.8 - Violent	1	11%	3	100%
San Andreas 7.8 - Very Strong	7	78%	0	0%
Hayward 7.0 - Very Strong	6	67%	3	100%
Hayward 7.0 - Strong	3	33%	0	0%
Liquefaction Zone	9	100%	3	100%
Flooding				
100-Year Coastal Flood Zone	9	100%	3	100%
100-year storm + 24 inches SLR	9	100%	3	100%
100-year storm + 66 inches SLR	9	100%	3	100%
100-year Stormwater Flood	0	0%	0	0%
Wildfire				
High	0	0%	0	0%
Moderate	0	0%	0	0%

Note: For an exposure table with additional hazards, please see Appendix X.

Exposure Summary

Geologic: All water transportation assets are exposed to Violent or Very Strong shaking in a 7.8M earthquake on the San Andreas Fault. In addition, given the location on the east side of the city, they are nearly all exposed to violent or very strong shaking in a 7.0M on the Hayward fault.

Flood: Given the water-dependent nature of water transportation, all ferry and water taxi landings are exposed to current 100-year storm flooding and would continue to be as sea level rises. They are not exposed to 100-year stormwater flooding.

Fire: Water transportation assets are not exposed to wildfire risk.

FIGURE A-48: WATER TRANSPORTATION AND LIQUEFACTION HAZARD

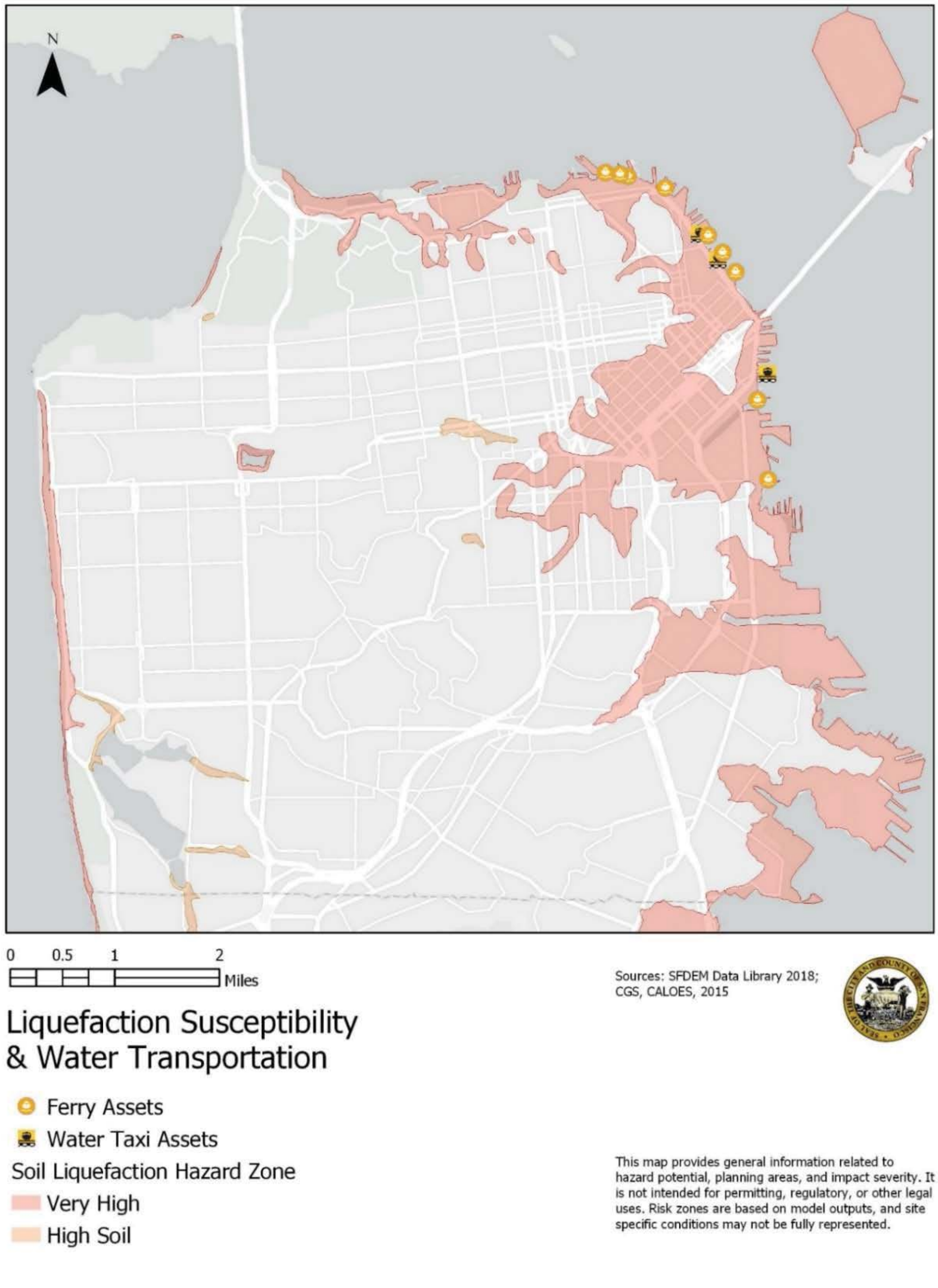
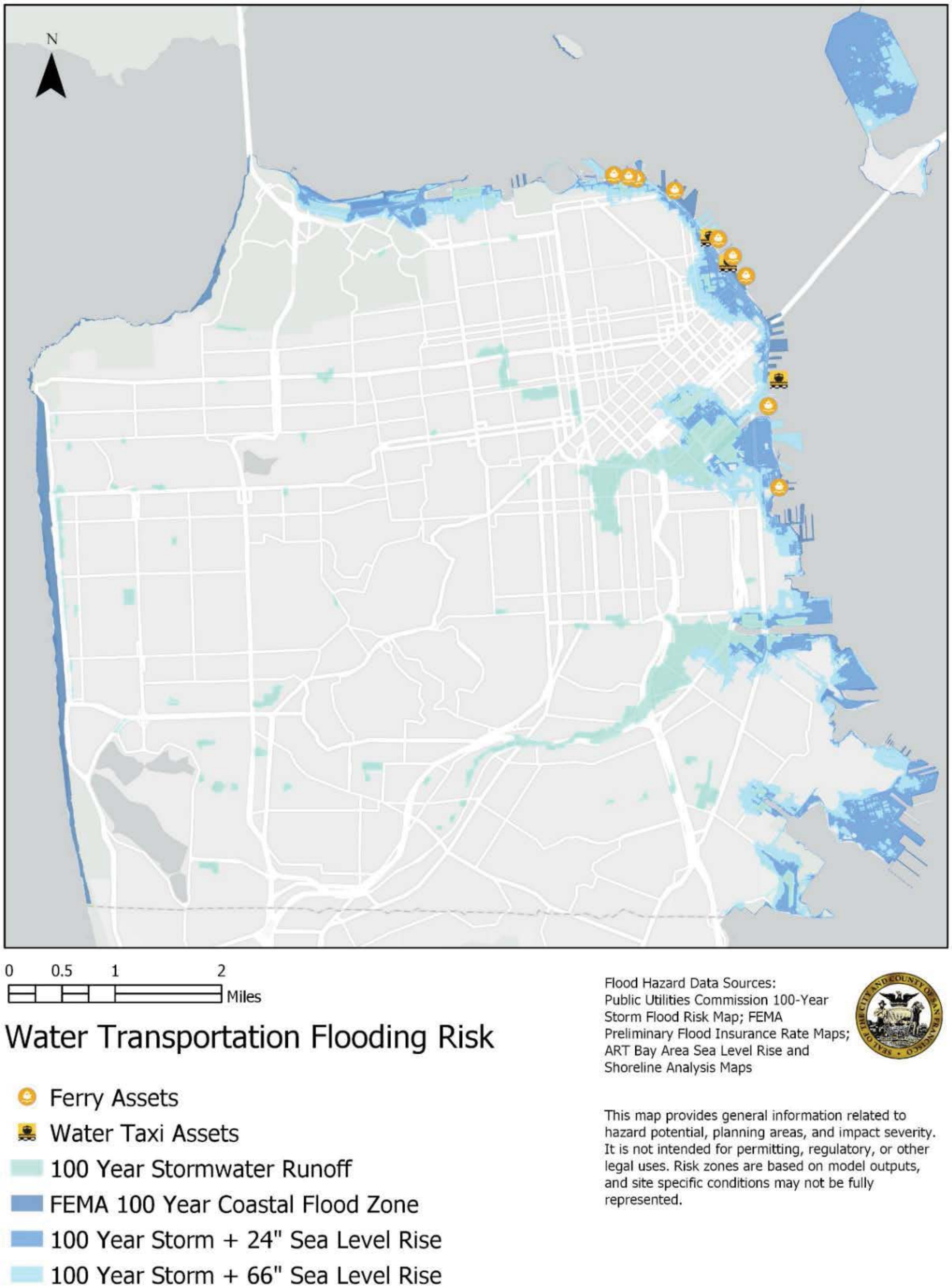


FIGURE A-49: WATER TRANSPORTATION AND FLOOD HAZARDS



VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** The water transportation assets in San Francisco are mostly found along the Embarcadero Seawall and on areas of fill. The landside facilities that the ferries rely on are at risk from a seismic event due to location on Bay fill, the age and construction of the Seawall and the age and construction of some of the buildings, such as the Ferry Building. The ferry assets themselves are less vulnerable to direct impact. A particular seismic related concern for WETA is potential failure of the Port of San Francisco seawall during a major earthquake. The seawall supports WETA's facilities at Pier 9 and the contract operator's facilities at Pier 41, the Ferry Building. The Downtown Ferry Terminal Expansion Project (FTX) upgrades water and landside terminal assets to Essential Facility Standards including design considerations of the seawall laterally shifting as much as 5 to 6 feet. **Flood:** When assessed as independent water side assets, floats, and gangways are not very sensitive to flooding and sea level rise because they are highly adaptable to the daily rise and fall of the tide. However, this is not necessarily true for the landside assets along the wharf. Additionally, many of the ferry piers appear not to be exposed directly to sea level rise because they are situated high enough above current Bay level and beyond the shoreline. Damage caused by storm events to the portions of the piers that are exposed to waves could be an issue for some of the ferry terminals. Ferry piers are sensitive to high winds because such events significantly affect the safe docking and operation of ferries. Even with today's sea level, ferry service has occasionally been suspended during storms. Landside access to the ferry terminals is also an important consideration and is vulnerable to flooding, making it difficult for people to travel to and from the terminals on whichever mode they use. Access roads are vulnerable to overtopping where they lie at lower elevations than the ferry docks and gangways. Their inundation would prohibit passengers from accessing the ferry piers. The Downtown Ferry Terminal Expansion Project (FTX) project is built to prevent exposure to 50-year sea-level rise is designed for adaptability to 100-year levels as well.

	Extreme Heat: Ferry service is open air and there is little ability to keep people cool while they wait in line for their ferries. There are some structures to shield people from the elements at the Ferry Building. **Fire:** There is no easy way to keep people who are queuing for a ferry out of smoke or poor air quality conditions.
Functional	**Networks:** Water transportation is part of the transportation network and disruption to these assets would result in affects to other modes in the system. If ferry service is disrupted, passengers may be able to use alternative transportation modes to cross the bay, such as BART, Transbay bus service, casual carpool, or personal auto. **External Services:** Water transportation relies on fuel supplies, landside transportation access, power and communications. Back up ferry service, back up docks and gangways, temporary facilities could be used in the event of failures due to earthquake or flooding. For high heat and poor air quality days, locations for queuing would need to be found to keep people safe while they wait for a ferry. The ferries are considered a critical component of the region's emergency response, particularly in the event of a large seismic event. WETA, MTC and the participating cities have emergency response plans and run drills to ensure a certain level of service. **Populations Served:** Water transportation may serve some people who are transit dependent. Additionally, ethnically diverse populations are served by this transit. Many riders live in isolated areas that are vulnerable to disruptions to the regional transportation system. **Unique or Critical Function:** Water transportation is a form of transit that keeps people out of their cars, provides a transportation alternative to driving alone and is increasingly switching to clean fuels. In addition, it provides relief capacity to other overburdened regional transit systems.

	Demand for water transportation options has been significantly increasing over the last decade and service is at capacity on most ferry lines. Water transportation will be critical during a significant hazard event, such as an earthquake or other disruption. It is an essential and critical back up service for moving people when other forms of travel are unavailable.
Informational	**All-hazards:** Currently, the most relevant publicly available information comes from the 2016 WETA Local Hazard Mitigation plan
Governance	**All-hazards:** WETA serves as a unique authority to alleviate transportation stress while securing emergency transportation. The WETA Emergency Response Plan (ERP) is designed to support the management of emergency water transportation after a catastrophic incident. When not serving in an emergency response capacity, WETA normally operates as a transportation agency with funding for operations derived from fares, bridge tolls, transportation sales taxes, local transportation funding, and state transit assistance. Federal, state and regional transportation funding has been used to assess the vulnerability of water transportation assets around the region.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** The most significant impact if water transportation was disrupted, damaged, or failed would be to emergency response. The water transportation system figures largely in the region's emergency response, particularly as a way to transport people who are in San Francisco for work but who live elsewhere in the region and as a way to get emergency responders and supplies into San Francisco. As a peninsula, water transportation is of particular importance to San Francisco during a hazard event. Additionally, any reduction in transit capacity could shift more people to drive their automobiles, increasing the impacts associated with that mode shift, such as congestion, longer commutes and air quality degradation associated with an increase in the number of automobiles idling on the region's roadways.
Economy	**All-hazards:** In addition to the direct cost to agencies to repair or replace damaged facilities and infrastructure, potential congestion on other

	modes and longer commutes could impact businesses and employees. **Geologic:** Would have temporary impacts as people shifted to other modes or services while the facilities were reconstructed. The scale of impact would be citywide or regional. **Flood:** Temporary impacts and closures. Flooding would likely cause people to shift to other modes while flooding was present and while damage to facilities, if any, was being repaired. **Extreme Heat:** Temporary and minor impacts. **Fire:** Temporary impact on service, displacing travelers to other modes or other facilities.
Environment	**All-hazards:** There could be air quality consequences depending upon which modes replaced water transportation trips. Public access could be impacted near the terminals and access to and on the Bay would be reduced.

Airport

Introduction to Asset Class

The San Francisco International Airport (SFO) provides commercial air transportation for the Bay Area. It is the largest of the three commercial airports in the region and offers non-stop service to more than 50 international cities on 44 international carriers as well as domestic non-stop service to more than 85 cities on 12 domestic airlines. SFO is located 11 miles outside of the City and County of San Francisco between the east side of highway US-101 and the San Francisco Bay, in San Bruno. There is some airport property located to the west of US-101 that is mostly habitat and some utilities. A large part of SFO was built on landfill including the critical runway infrastructure. The airport property covers 5,207 acres in total with over 100 supporting buildings, Federal Aviation Administration (FAA) tower and four intersecting runways. SFO is wholly owned by the City and County of San Francisco.

SFO is a complex campus with many different components. For the purposes of the assessment, SFO consists of the following sub-assets:

- **Airfield:** The SFO airfield consists of runways, taxiways, and service vehicle roadways. The airfield also has a storm drain and power distribution system, as well as telecommunications copper and fiber optic infrastructure. However, these systems are not essential to the function of the airport operations area. In addition, the FAA also operate their own power and telecommunications infrastructure for independent navigational aids and lighting systems. There is a shoreline protection system around 6 of 8 miles of the airport's bay front perimeter that consists of various ages and construction types.
- **Air Traffic Control Tower:** SFO's 221-foot air traffic control tower is located in the connector building between Terminal building 1 & 2. Construction of the new tower was completed in 2016 to replace the seismically unsafe tower built in 1983. Deconstruction of the former tower and two floors of the base structure below are scheduled to be completed in 2019. The bottom two levels of the space are being rebuilt to include a new public café and an outdoor observation deck along with an airline lounge and office space, and an additional gate at Terminal 2.
- **Terminal:** The airport consists of three domestic terminals and one international terminal. The terminal complex consists of multiple structures with varying ages.

Terminal 1 and Boarding Area B are currently being reconstructed and will open in phases between 2019 and 2023. Terminal 2 was reconstructed and reopened 2011. The eastern portion of Terminal 3 and Boarding Area E was reconstructed and opened in 2014

- **Parking facilities:** SFO has several parking structures on its campus. The central garages and north and south international parking structures are located near the terminals. A surface lot is located near north field.
- **Roadways**: Elevated structures and roadways owned by SFO connect vehicles exiting US-101 to the airport, and an elevated viaduct provides service to the departure level of the domestic terminals.
- **Utilities:** Two utility tunnels, one at the north end of the airport campus and the other at the south end traverse below highway US-101 to deliver electrical power, water, data and telecom services to the airport. Electrical power is fed to the terminal complex and across the campus through an underground distribution network to a series of substations that feed all building and facilities on the airport campus. The potable water feed is connected to a distribution system which services the airport campus. The telecommunications service from outside the Airport are delivered to the North and South Minimum Point of Entry (MPOE). From there the Airport distributes telecommunication services to the terminals and Airport tenants. There is a third utility tunnel under highway 101 that provides a third potable water feed to the airport campus just north of the terminal complex. Sewage from SFO facilities is treated in the Mel Leong Treatment Plant (MLTP) in the North Field.
- **Fuel**: Fuel is provided to SFO via a Kinder Morgan fuel pipeline that provides fuel from refineries located in the North Bay. In 2017, San Francisco Airport reached a milestone of 28 million gallons annually.

Issue Statement

As the largest commercial airport in the region, SFO is a major economic driver. While some of the structures may experience damage in a major earthquake, the airfield is susceptible to major damage due to liquefaction in a major earthquake. In addition, the airport is currently subject to flooding during a 100-year storm. With sea level rise, flooding may become more frequent and/or severe. Disruption to the airport for an extended period would have severe regional economic consequences.

Almost all of the terminal buildings, the boarding areas, the outlying buildings across the campus, and all of the supporting infrastructure, from here on to be referred to as the Facilities, were constructed over the last sixty years. The Facilities were all constructed to the relevant codes at the time of construction. In the intervening years, some of the Facilities have been renovated or upgraded, in these instances those renovations/upgrades were also done in accordance to the relevant construction codes at the time. The Airport Facilities that are relatively new or have been recently renovated will be more resilient to the effects of an earthquake while others may be susceptible to damage. In the event of a major earthquake, the Airport can expect to have damage to the Facilities. Some buildings could be damaged and be temporarily or maybe even permanently unusable. Some of the Airport's elevated roadways could be damaged and be temporarily or permanently unusable. Given the Airport's soil condition and the age of its underground infrastructure, it is likely there would be damage to underground piping systems and damage to its underground electrical and data distribution systems. The effects of liquefaction may also damage the taxiway and runway systems.

Flooding from storms is another possible area for a severe or even catastrophic disruption to the Airport. Flooding would not necessarily damage buildings, the airfield, or landside roadways and structures to the point of being unusable, but key electrical power distribution equipment could be severely damaged or destroyed. Catastrophic damage to the electrical power distribution system would render facilities unusable until the electrical equipment was replaced or facilities were provided with temporary sources of power.

Exposure

TABLE A-30: EXPOSURE

Hazard	Power Station 10 Stations Total		Pump Station 54 Stations Total		Power Ducts 34 miles Total		Industrial Pump Station 26 Stations Total		Water Pipelines 35 Miles Total		Aviation Fuel Pipelines 30 Miles Total		Natural Gas Pipelines 16 Miles Total	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Geologic														
San Andreas 7.8 - Violent or Very Strong	10	100%	54	100%	34	100%	26	100%	35	100%	30	100%	16	100%
San Andreas 7.8 - Violent or Very Strong	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Hayward 7.0 - Violent or Very Strong	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Hayward 7.0 - Violent or Very Strong	10	100%	54	100%	34	100%	26	100%	35	100%	30	100%	16	100%
Liquefaction Zone	8	80%	54	100%	33	97%	26	100%	33	94%	19	63%	15	94%
Flooding														

100-year storm + 24 inches SLR	10	100%	52	96%	33	97%	25	96%	34	97%	19	63%	15	94%
100-year storm + 66 inches SLR	10	100%	53	98%	33	97%	26	100%	34	97%	19	63%	15	94%

Hazard	Industrial Water Pipelines 12 Miles Total		Sanitary Sewer (Forced) Pipelines 16 Miles Total		Sanitary Sewer (Gravity) Pipelines 14 Miles Total		Stormwater Pipelines 92 Miles Total		Telecom Ducts 31 Miles Total		SFO Structures 697 Total		SFO Runways 7 Total Miles		SFO Storage Tanks 131 Total	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Geologic																
San Andreas 7.8 - Violent	12	100%	16	100%	14	100%	92	100%	31	100%	697	100%	7	100%	131	100%
San Andreas 7.8 - Very Strong	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Hayward 7.0 - Very Strong	0	0%	0	0%	0	0%	0	0%	0	0%	5	1%	0.3	5%	0	0%
Hayward 7.0 - Strong	12	100%	16	100%	14	100%	92	100%	31	100%	692	99%	0	0%	0	0%
Liquefaction Zone	12	100%	14	88%	13	93%	91	99%	30	97%	683	98%	7	100%	127	97%
Flooding																
100-year storm + 24 inches SLR	12	100%	14	88%	13	93%	91	99%	30	97%	661	95%	7	100%	123	94%
100-year storm + 66 inches SLR	12	100%	14	88%	13	93%	91	99%	30	97%	666	96%	7	100%	125	95%

Exposure Summary

Geologic: All airport transit assets are exposed to violent or very strong shaking in a 7.8M earthquake on the San Andreas Fault. Virtually no airport assets are subjecting to violent or very strong shaking given a 7.0M earthquake on the Hayward fault. A significant majority of all airport assets are exposed to liquefaction hazard zones.

Flood: Assuming no action is taken, a significant majority of all airport assets would be exposed to inundation from mid-century projections of SLR with coastal storms. This increases further in the end of century scenarios as well. Every sub asset sees exposure above 88% percent except for aviation fuel due to portions of the infrastructure running offsite under the Bay. GIS data on FEMA FIRM coastal 100-year flooding or 100-year stormwater flooding hazards were available for the airport study area. However, static maps show almost the entire SFO campus being subject to some level of flooding from the 1% chance flood (a.k.a. the 100 year flood) as defined by FEMA under the National Flood Insurance Program.

Fire: Hazard data regarding the risk from Wildfires displayed negligible risk.

FIGURE A-50: AIRPORT AND LIQUEFACTION HAZARD

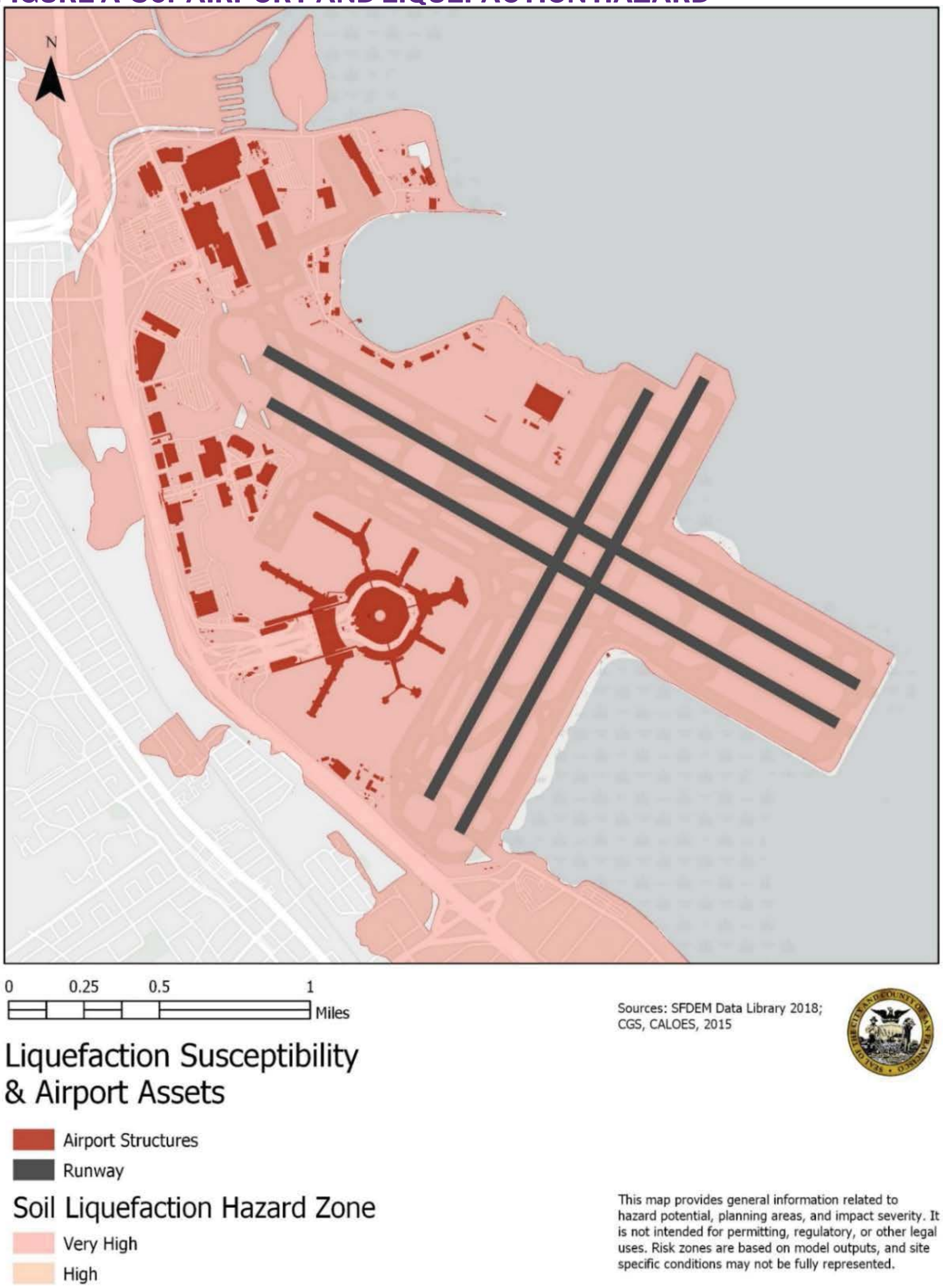
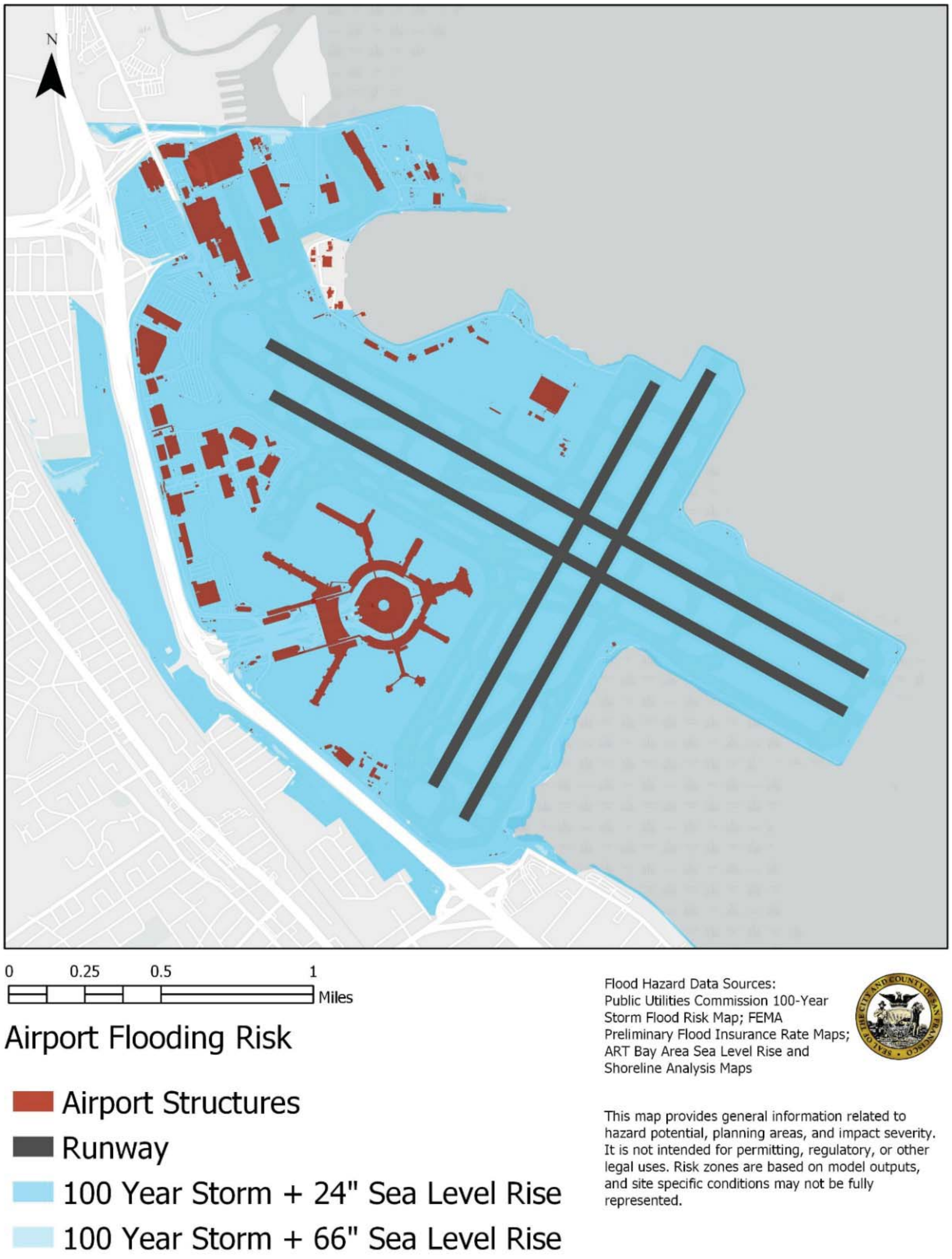


FIGURE A-51: AIRPORT AND FLOOD HAZARD

FIGURE A-52: AIRPORT AND FLOOD HAZARD WITH SEA LEVEL RISE



Flood Hazard Data Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** The terminal buildings consist of several different structures with varying ages that will perform differently in an earthquake. As structures are renovated or replaced, they are brought up to the current seismic standards of the time. The Air Traffic Control Tower and IT Building are expected to perform well. The airfield is vulnerable to severe damage from liquefaction. Underground utilities at the airport site are vulnerable to physical damage in an earthquake. External utilities such as power will also likely experience physical damage. The upper level viaduct which fronts the domestic terminals, T1, T2, and T3 has been seismically retrofit. The majority of the inbound outbound roadway structures from 101 were constructed in the late 1990's. These older ramps serving the Airport prior to the International Terminal Building development have been previously retrofitted The Central Garage consists of multiple buildings that employ two different design philosophies and construction methodologies. Each building type will perform differently in an earthquake, but neither one is up to current seismic requirements, and neither has been retrofit as of yet. The Central Garage also houses the airport's central heating and cooling plant and the main electrical substation which feeds all power to the terminal complex. The central plant's hot and chilled water distribution lines and as well as the electrical power distribution systems (PDS) are fed to the terminals via and underground utility tunnel and underground connectors to the individual terminal buildings. **Flood:** SFO was built in the late 1950's to early 1960's. The infrastructure has since been improved to meet the latest standards, but there are vulnerabilities. SFO has power substations located below sea level in the basement of the domestic garage which would be damaged by flooding. Depending on the scale of the damage, SFO could partially recover from a severe flood in as quickly as a week but full recovery could take months due to sensitive electrical field lighting and communications equipment distributed across the airfield. Almost the entire SFO campus is subject to some level of flooding from the 1% chance flood (a.k.a. the 100 year flood) as defined by FEMA under the National Flood Insurance Program. In the event of a 100 year flood, the airport campus would be flooded to various

	depths depending on local elevation. Critical infrastructure will be vulnerable to inundation and would be damaged in a 100 year flood. SFO has implemented a Shoreline Protection Program in order to address some of these flooding vulnerabilities this includes over \$383 million dollars of funding to plan, permit, design and construct comprehensive shoreline protection systems and storm drainage improvements. **Extreme Heat:** Heat causes fluctuations in aviation fuel weight and volume. Max aircraft weight capacity is greatly reduced during an extreme heat day, which reduces the number of people and cargo an aircraft can carry. This has a large economic impact to the airline (lost revenue) and impacts commerce as passengers and as cargo is left behind to satisfy weight issues. Heat can also cause issues with the Air Train Service. SFO is currently upgrading the system to address this issue. **Fire:** SFO vulnerable to wildfire or wildfire given its location. However, SFO has a large underground fuel network that can be ignited under the wrong conditions. Natural gas distribution and transmission lines also pose a fire risk. However, the airport does not allow wood construction and requires all buildings to have fire suppression systems and fire alarms. **Air Quality:** Indirect smoke while a concern for employees who work outdoors does not have a major impact to SFO's ability to operate. Visibility issues from smoke might cause flight delays but the airport would continue to operate at some level.
Functional	**Networks:** While not part of a formal network, if SFO were disrupted, some air traffic could potentially be re-routed to other airports in the region, including Oakland International Airport (OAK) and San Jose International Airport (SJC). Nevertheless, these airport have constraints in terms of air traffic volume and aircraft size, such that they could not accommodate all of SFO's traffic. The Airport has the ability to isolate segments of the local fuel distribution network. However, transmission from East Bay refineries and Brisbane tank farm are not under airport control and fuel supply would be disrupted by damage to these transmission lines. The water and gas supply is also built on a closed loop design that can isolate damage and continue service, but if the damage is from the

	input lines that service the airport (outside the closed loop) service would be disrupted. The airport is designed with continuity in mind and could operate with limited capacity if parts of the critical infrastructure were undamaged. Following a major disaster, supporting emergency response will be the focus of restoration efforts, followed by a focus on business continuity. **External Services:** SFO relies on electric power, water, aviation, vehicle fuel, telecommunications services, and natural gas. Fixed and external generators can supply enough power for critical needs and emergency lighting. However, this would not be enough to maintain normal operations across the airports terminals. Passengers and staff also rely on the ground transportation network to access the airport. SFO is dependent on fuel delivery to the Fuel Farm for its operations. If the fuel pipelines are damaged, fuel can be shipped to Brisbane or Port of San Francisco via barge, but there is currently no infrastructure to transport the fuel from the barges to SFO. Given the volume of fuel needing, fuel truck delivery is not a viable alternative. As SFO nears the capacity of the current pipeline, it is looking for alternative fuel delivery sources that will also increase the reliability of fuel delivery in an earthquake. **Populations Served:** The airport supports the needs of all of travelers (families, access and functional needs (AFN), business, low income). The buildings and offerings are compliant with all standards for AFN passengers and visitors. The airport supports low cost carriers and premier business carriers with a variety of options and offerings that meets the diverse needs of the community we serve. Signage is compliant with International Air Transport Association standards for international airports. Additionally we have translation services if needed at all of our customer service centers. Airlines employee bilingual staff to assist their customers as well. **Unique or Critical Function:** SFO is a critical air transportation hub serving San Francisco and the Bay Area. Wide body aircraft require long runways for takeoff and landing. This requirement makes SFO critical for air carriers in that OAK and SJC are limited and cannot support large aircraft appropriately.

	SFO maintains a season wetland across from U.S. Highway101. SFO also maintains a fully accredited on site museum.
Informational	**<u>All-hazards:</u>** SFO has conducted numerous studies that assess the many components of our infrastructure. These have included targeted structural assessments of key facilities, an airfield seismic stability study, contaminated soils studies, shoreline protection system assessments, and an ongoing master utility infrastructure assessment
Governance	**<u>All-hazards:</u>** Airports are highly regulated by several federal agencies including the FAA, CBP, TSA. The City and County Of San Francisco is the owner of SFO so all city standards apply, but SFO physically resides in the County of San Mateo which creates some political sensitivities and compromise. SFO primarily uses airport revenue bonds for funding projects to improve resilience. SFO also explore the use grants from CalOES and FEMA when appropriate.

CONSEQUENCES

Category	Consequence
Society/Equity	**<u>All-hazards:</u>** Disruption of SFO could result in separated families (if traveling members return trips are delayed). If SFO is damaged, SFO's workforce may experience fewer shifts and lost wages. SFO employs a diverse workforce with a range of skill types and levels. **<u>Geologic:</u>** In the event of a major earthquake, multiple airports in the region may be damaged. Medivac flights may need to be supported out of military airports and would be balanced with relief flights bringing in large amounts of life sustaining commodities (food, water, medical supplies, shelter, etc.). **<u>Flood:</u>** Should a flood event over take the airport grounds it would result in the immediately closure of SFO resulting in thousands of flight cancellations until the water recede. **<u>Fire:</u>**

	1-2 depending on where a fire breaks out the impacts to SFO and commercial aviation are not expected to be as dire. While flights my indeed be impacted the airport should still be able to operate at some level of managed capacity.
Economy	**All-hazards:** Depending on the level of damage, costs to repair airport infrastructure would be in the hundreds of millions to billions of dollars. Disruption to SFO would have a substantial economic impact both locally and regionally due to the significant economic footprint SFO has. The direct/indirect jobs it creates, and the multiplier effect this has on the regional economy, means that SFO generates as much as $62.5 billion dollars in business sales and supports 300,000 jobs across the Bay Area. **Geologic:** The ability for the greater Bay Area to recover from a major earthquake would be greatly hampered if SFO were damaged and not functioning for an extended period. **Flood:** Airlines and other airport tenants may lose revenue from a temporary loss in service due to flooding. **Fire:** Airlines and other airport tenants may lose revenue from a temporary loss in service.
Environment	**Geologic:** A ruptured fuel line would create a large pool of fuel that could contaminate the ground, estuary or bay. **Flood:** Flooding could release hazardous materials into the Bay. **Air Quality:** Smoke from a fire could temporarily impact local air quality.

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Power

Introduction to Asset Class

The electric power asset class generates, stores, manages, and delivers electricity to end-users, such as homes and businesses. For the purpose of this assessment we divided the asset class into four sub-asset types: Generation, Substations, Transmission and Distribution.

a) *Generation* refers to the process of electricity production from diverse sources of primary energy such as natural gas, hydropower, coal, wind, nuclear power, solar, geothermal, steam, agricultural waste products and more. CCSF electricity supply comes from both centralized and distributed generation.[121] All of the centralized generation assets (i.e. Hetch Hetchy Generation and industrial power plants) are located outside of the assessment area, therefore this sub-asset type is not assessed for vulnerability and consequences in this profile, but it is a critical piece of the overall resilience of the power system. Distributed generation assets include small, local, grid-connected devices (e.g. microgrids, combined heat and power systems, rooftop solar installations, backup power generators, and battery storage systems), referred to as distributed energy resources (DER).[122,123] Large DER providers are non-utility parties that own or operate onsite electric and thermal loads and participate in the wholesale market.[124]

b) *Substations* connect the electric power lines between the transmission and distribution systems. The main purpose of substations is to transform the energy to a lower voltage to safely deliver electricity to residences and businesses.[125] Substations have expensive and potentially dangerous equipment such as large

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[121] SPUR. (2001) "*San Francisco's Utilities in 21st Century"*. Retrieved from: https://www.spur.org/publications/urbanist-article/2001-11-01/san-francisco-s-utilities-21st-century
[122] Virginia Tech. (2007) "*Introduction to Distributed Generation*. Retrieved from: http://www.dg.history.vt.edu/ch1/introduction.html
[123] C2ES. (2018). "*Resilience Strategies for Power Outages"*. Retrieved from: https://www.c2es.org/site/assets/uploads/2018/08/resilience-strategies-power-outages.pdf
[124] CAISO "*Distributed Energy Providers. Retrieved from:* http://www.caiso.com/participate/Pages/DistributedEnergyResourceProvider/Default.aspx
[125] ART. (2014). "*Chapter 16. Energy, Pipeline and Telecommunications Infrastructure*". Retrieved from: http://www.adaptingtorisingtides.org/wp-content/uploads/2014/12/Energy_Pipes_Telecom_VR.pdf

power transformers (LPT), which change the voltage of electrical current[126]; capacitors, which store energy in an electric field; voltage regulators, which maintain a constant voltage; and switchgears, which control, protect and isolate electrical equipment[127] - components critical to the substations operation. The service areas of substations are distributed and local, but substations function as a networked system, as they are connected through high-voltage transmission lines. Typically, substations are located aboveground in fenced enclosures or are in underground vaults within special-purpose buildings.

c) *Transmission* includes all electrical power lines that run underground and overhead and carry electricity from generators to substations. Transmission lines typically run through tall structures, usually steel lattice towers.[128] There are no aboveground high-voltage transmission towers within CCSF, as these have been previously undergrounded. The assessment area is served by an underground transmission lines network[129], as well as a 3.5-mile-long submarine transmission line under the San Francisco Bay.[130]

d) *Distribution* connects the transmission system with end customers. The system is comprised of main lines and lower voltage lines that supply power, and distribution transformers that lower voltage to usage levels.[131] We include the physical power poles, as well as street lights and supporting infrastructure in the vulnerability assessment, but do not include in the exposure assessment due to the ubiquitous locations of these assets across the city.

Pacific Gas and Electric (PG&E) and San Francisco Public Utilities Commission (SFPUC) are the two main electricity providers. PG&E predominantly services city residents and businesses. PG&E operates nine substations within CCSF.

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[126] CA Energy Commission. (2012). "*Large Power Transformers and the U.S. Electric Grid*". Retrieved from: https://www.energy.gov/sites/prod/files/Large%20Power%20Transformer%20Study%20-%20June%202012_0.pdf

[127] IEEE. (2001). "Standard Definitions for Power Switchgear". Retrieved from: https://ieeexplore.ieee.org/document/182886

[128,9] Ibid.

[129] CPUC. (1999). '*PG&E Divestiture of 4 Power Plants A.98-01-008, Chapter 4.12.1*". Retrieved from: http://www.cpuc.ca.gov/Environment/info/esa/divest-pge-two/eir/chapters/04-12utl.htm

[130] T&D World. (2015). "*System Upgrades Boost Disaster Resiliency"*. Retrieved from: https://www.tdworld.com/features/system-upgrades-boost-disaster-resiliency

[131 5] ART (2017). '*Adapting to Rising Tides: Contra Costa County Assessment and Adaptation Project"* Retrieved from: http://www.adaptingtorisingtides.org/wp-content/uploads/2017/03/Contra-Costa-ART-Project-Report_Final.pdf#page=2

SFPUC operates its own municipal power network that supplies energy from several facilities in the Hetch Hetchy system to all municipal facilities, streetlights, customers in Hunters Point and Treasure Island, redevelopment areas and other critical facilities, such as the airport, San Francisco General Hospital, Muni, and the Police and Fire Departments. SFPUC transmits the power from Hetch Hetchy to a substation in Newark, where it is then distributed via PG&E's grid to end users. SFPUC is connected to a substation in the Port of Oakland, from which power is transmitted via a submarine cable under the Bay Bridge to Treasure Island and Yerba Buena Island. SFPUC is the exclusive power provider for TI/YBI and the redeveloped Hunters Point Shipyard. SFPUC owns intervening facilities (connections between SFPUC and PG&E) in the TransBay terminal, Laguna Honda, and Hunters Point. Three substations at SFO provide power to the airport, which is SFPUC's largest retail customer (please see Airport Profile for additional information). SFPUC is responsible for about 60% of the street lights in the city but is reliant on PG&E to actually supply the power to the lights (PG&E is responsible for the remaining 40% of street lights).

California's Investor-Owned Utilities (IOU), such as PG&E, are subject to regulation by the California Public Utilities Commission (CPUC) with respect to retail electricity distribution, and the Federal Energy Regulatory Commission (FERC) with respect to applicable wholesale electricity transmission.[132] The California Independent System Operator (CAISO) oversees the operation of California's bulk electric power system, transmission lines, and electricity market generated and transmitted by electricity providers. While PG&E still owns transmission assets, CAISO controls the power routing, maximizing transmission system efficiency and supervises the maintenance of the lines. CAISO is regulated by FERC.[133]

The vulnerability and consequences assessment focuses on in-county assets only, but recognizes our dependence on a broader system of generation and transmission located outside of the county.

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[132] San Francisco Chronicle (2017). "*San Francisco Seeks Oversight for PG&E Transmission Spending*" Retrieved from: https://www.sfchronicle.com/business/article/California-SF-seek-oversight-for-PG-E-11095829.php
[133] CAISO (2018). *Understanding the ISO*. Retrieved from: http://www.caiso.com/about/Pages/OurBusiness/Default.aspx

Issue Statement

Electric power assets are vulnerable to seismic hazards. Electrical substations are the most vulnerable components of an electric power system.[134] Transmission lines are generally not impacted by earthquakes, except in areas of extreme ground failure.[135] Distribution power poles do not have robust foundation structure and are more vulnerable to ground shaking and liquefaction than transmission lines, while underground power lines may be damaged due to liquefaction induced lateral spreading.[136] Above ground distribution and transmissions lines are relatively easy to restore after an earthquake. However, underground distribution systems and substations can be difficult to replace in the event of a catastrophic failure and may require very expensive specialized parts making them more difficult to restore. Given data limitations, the extent of exposure of the electric power system in San Francisco to flooding is unknown. However, if exposed, flooding can damage electrical system components, potentially resulting in outages. Extreme heat may also strain the power system, as cooling demand increases, making the system more prone to brownouts and blackouts. Interruption to electric power would have severe and cascading economic, social and environmental consequences.

Assumptions and Limitations

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table below, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

[134] Cagnan, Z., Davidson, R., Guikema, S., (2006). Post-Earthquake Restoration Planning for Los Angeles Electric Power, *Earthquake Spectra* 22 (3), 589-608.
[135] ABAG (2014). "*Cascading Failures"* Retrieved from: http://resilience.abag.ca.gov/projects/transportation_utilities_2014/
[136] Kongar, I., Giovinazzi, S., Rossetto, T., (2017). Seismic performance of buried electrical cables: evidence-based repair rates and fragility functions. *Bulletin of Earthquake Engineering* 15 (7) 3151–3181.

Asset Data Assumptions

Asset data is sourced from the California Energy Commission open data portal, last updated in 2018. The sources used for the exposure analysis come from the California Energy Commission GIS Open Data Portal. It includes transmission line data, substation locations, and centralized electric generation within the city limits. While this does include some information on PG&E assets, it is not comprehensive. This is important to note, as without complete asset data, it is not possible to fully characterize the full extent of potential exposure of power assets to hazards in San Francisco.

Exposure Summary

Seismic: All power assets are exposed to violent or very strong shaking in a 7.8 earthquake on the San Andreas Fault. Based on the limited data available, two substations, four power generation sources, and six miles of transmission lines are subjected to violent or very strong shaking in a 7.0 earthquake on the Hayward fault. Seven substations, five generation sources, and 18 miles of transmission lines are in areas with high or very high liquefaction susceptibility.

Flood: Given the data limitations, the extent of power asset exposure to flooding hazards is unknown. Based on the limited data available, a single substation and three power generation sources are potentially exposed to coastal flooding by sixty-six inches of projected sea level rise. Additionally, underground distribution transformers inside vaults may be exposed.

Fire: Based on the limited data available, local power assets see no exposure to wildfire hazard within the City and County of San Francisco.

TABLE A-32: EXPOSURE

Hazard	Substations (9 Total)		Power Generation (11 Total)		Transmission Lines (47 Miles Total)	
	#	%	#	%	#	%
Seismic						
San Andreas 7.8 - Violent or Very Strong	9	100%	11	100%	47	100%
Hayward 7.0 - Violent or Very Strong	2	22%	4	36%	6	13%
Liquefaction Zone	3	33%	4	36%	18	38%
Flooding						
100-Year Coastal Flood Zone	0	0%	1	9%	0.13	0%
100-year storm + 24 inches SLR	0	0%	0	0%	1	2%
100-year storm + 66 inches SLR	1	11%	3	27%	5	11%
100-year Stormwater Flood	0	0%	0	0%	4	9%
Wildfire						
High	0	0%	0	0%	0	0%
Moderate	0	0%	0	0%	0	0%

Note: For an exposure table with additional hazards, please see Chapter 05.

FIGURE A-53: POWER AND LIQUEFACTION HAZARD

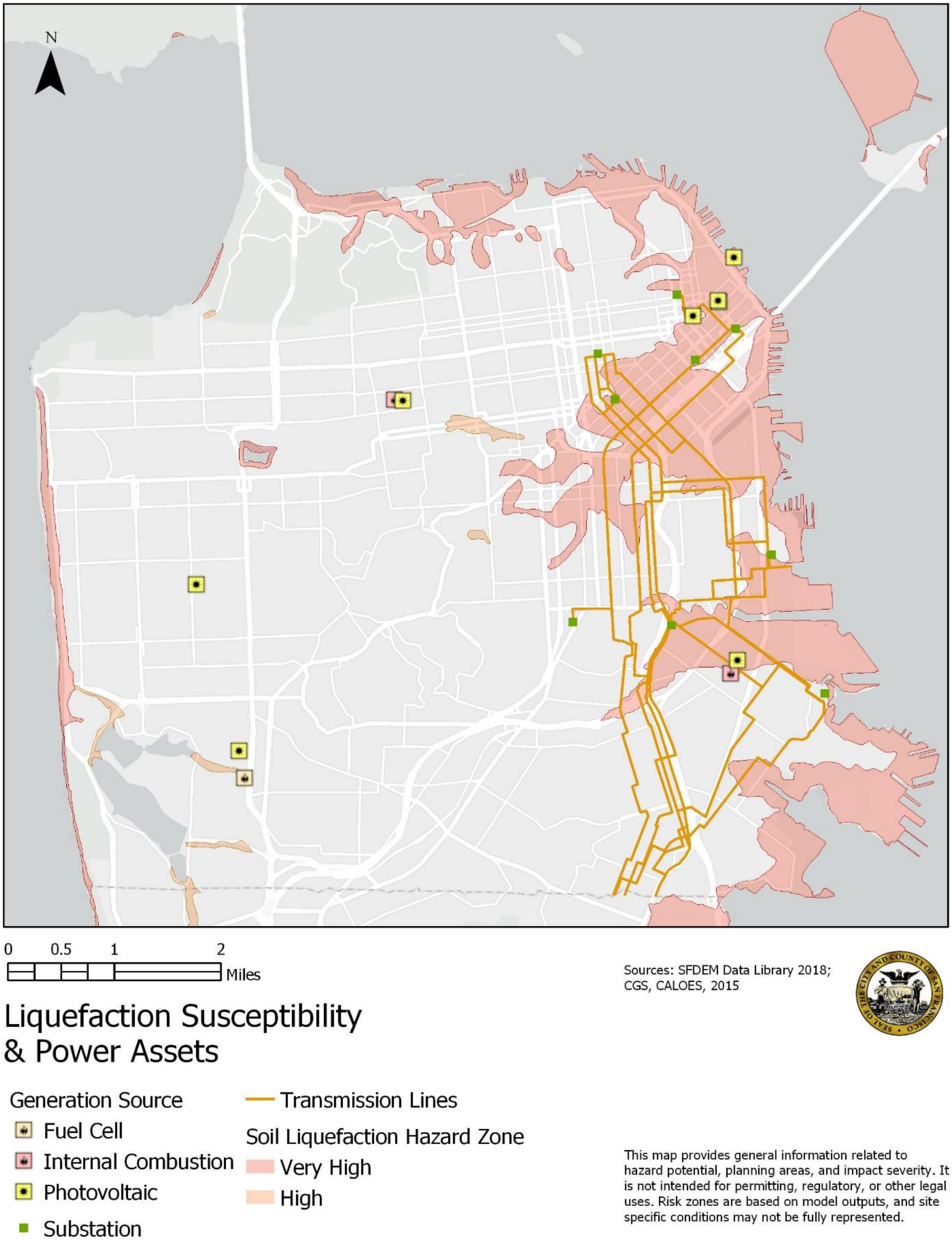
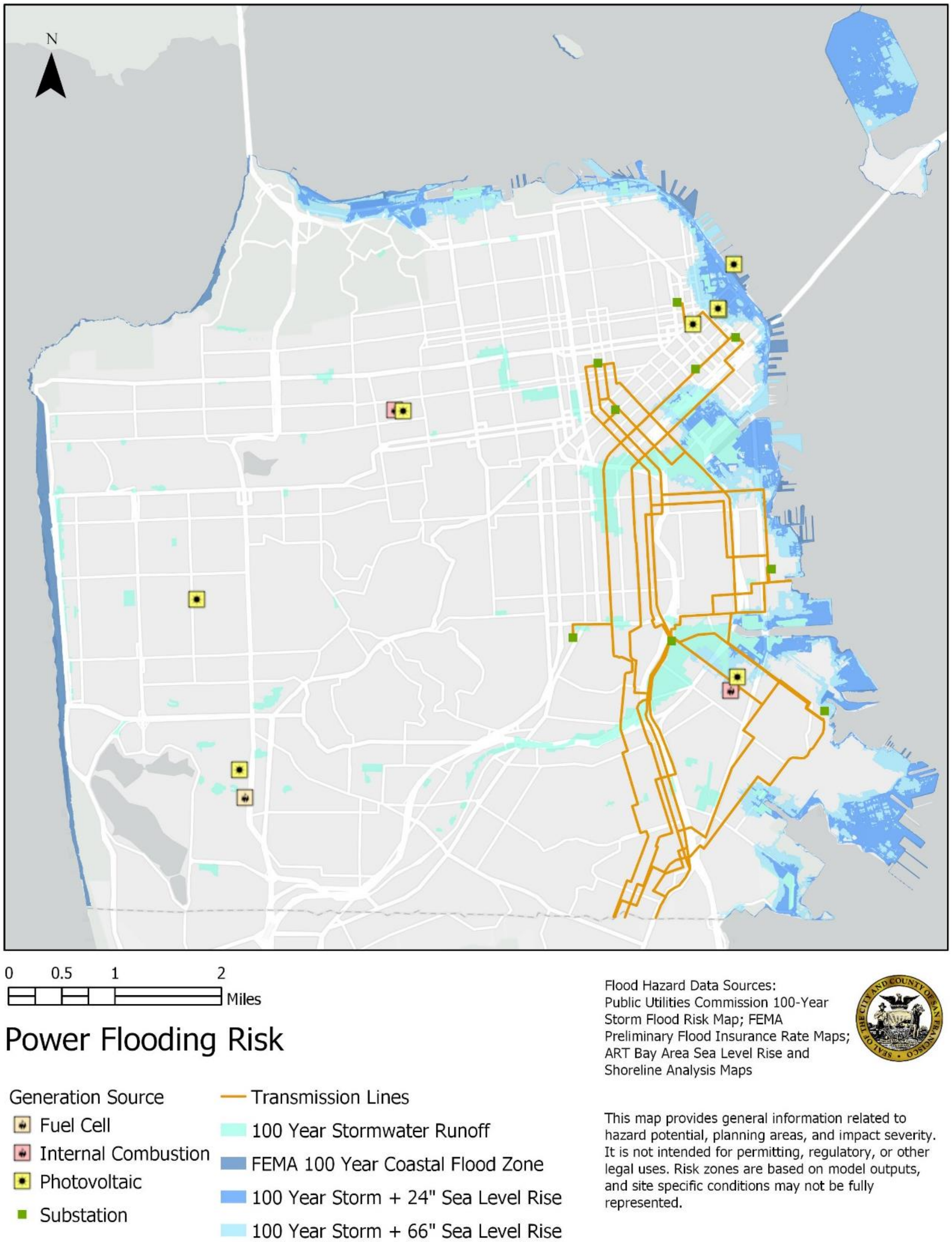


FIGURE A-54: POWER AND FLOOD HAZARDS



VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Transmission and distribution systems include generation sources, transmission lines, substations, transformers and distributions lines that could be damaged from earthquake shaking or liquefaction. Estimates of duration of power outages following a major seismic event range from few hours to 1-14 days in San Francisco.[137] Damage to this asset may be also exacerbated by the following vulnerabilities: • Transmission power lines are well engineered but are vulnerable to damage in areas of extreme ground failure. • Distribution power poles have no foundations and their stability is reliant upon soil conditions. • Above ground power lines are vulnerable to damage by falling debris. • Underground power lines are vulnerable to lateral spreading damage and may take longer to repair due to more difficult access. • Substation structures and supporting equipment are fragile and may be damaged during a seismic event, especially in areas of high ground shaking. However, there have been efforts to increase the resiliency of the system to date, including: • PG&E investing in advanced meters, automated switches technology[138] and testing commercial-grade earthquake early warning (EEW) system for substations.[139]

[137] Range estimated based on past outages events. Sources include various news articles and PG&E press releases.
[138] San Francisco Chronicle (2017). "*Despite Recent Blackout, PG&E Upgrading Its Substations"*. Retrieved from: https://www.sfchronicle.com/opinion/openforum/article/Despite-recent-blackout-PG-E-upgrading-its-11109701.php
[139] PG&E (2016). '*Climate Change Vulnerability Assessment"*. Retrieved from: http://www.pgecurrents.com/wp-content/uploads/2016/02/PGE_climate_resilience.pdf

- PG&E upgrading the power transmission system, especially in the high liquefaction susceptibility zone
- PG&E adding redundant transmission paths between its substations and adding redundancy within the substations.
- PG&E increasing its power restoration capability through the Greater ay Restoration Project.
- The submarine transmission line is located in trench designed to allow the cable to flex during ground shaking.[140]

Flood:

- Substations have electrical components that are both water and saltwater sensitive, if located at- or below grade.
- Transformers and switches in Hunters Point and TransBay Center, located below ground in subsurface vaults, are somewhat flood resilient and can operate for extended periods of time under water.[141]
- Underground transmission and distribution lines are unlikely to be affected by coastal flooding unless flooding results in erosion and scouring.
- Switchgears are extremely vulnerable to flooding and need to be shutdown to avoid explosions. If switchgears are not operational, the downstream distribution system will fail.
- Any electrical equipment at sidewalk grade is not water tight. Standing water within street light boxes can enter conduits that protect electrical wiring.[142]
- High winds associated with storm events could down power lines and poles.[143]

Extreme Heat:

Heatwaves generally lead to higher energy demand for cooling, as air conditioning loads rise in the afternoon and remain high until late at

[140] [10] T&D World, Resiliency
[141] [10] SFPUC, Vulnerability Assessment
[142] Ibid.
[143] [3] C2ES, Resilience

	night. There have been incidents where extreme heat has caused demand to exceed supply resulting in blackouts in San Francisco and other cities in the region and the risk is increasing as extreme heat events are becoming more frequent and severe.[144] Prolonged and extreme heat can degrade the operational lifetime of large power transformers (LPTs) and increase the risk of their premature failure by reducing the structural integrity of insulation.[145] **Fire:** If exposed, assets are directly vulnerable to fire. Substations are generally located in open-air urban areas with no fire-resistant perimeter fences or enclosures. Overhead electric power assets can ignite if vegetation or other combustible objects come into contact during high winds events[146]. PG&E's Wildfire Safety Operations Center monitors extreme weather and fire threats in real time.[147] PG&E also has extensive vegetation management program to protect overhead electric lines and reduce the likelihood of an ignition associated with vegetation contact.[148]
Functional	**Networks:** All sub-assets are connected through the transmission and distribution system as part of the power grid, such that if an asset fails, it may result in operation failure in its service area. If damage is limited, it may be possible to contain the service disruption and reroute electricity around the damaged assets. However, if several critical assets, such as substations, are damaged, service interruption may be more widespread. Even if the substations themselves do not fail, its status can be off because of connectivity, power imbalance, or abnormal voltage level.[149] CAISO implemented emergency technology and energy conservation programs to mitigate the risk of outages and blackouts and reduce distribution bottlenecks by rotating blackouts among customers to

[144] California National Resources Agency (2018). "*Safeguarding California Plan: 2018 Update – California's Climate Adaptation Plan".* Retrieved from: http://resources.ca.gov/docs/climate/safeguarding/update2018/safeguarding-california-plan-2018-update.pdf

[145] MIT (2017). "*Preventing the Next Blackout*" Retrieved from: https://phys.org/news/2017-12-blackout.html

[146] PG&E (2016). "Climate Change Vulnerability Assessment". Retrieved from: http://www.pgecurrents.com/wp-content/uploads/2016/02/PGE_climate_resilience.pdf

[147] San Francisco Chronicle (2018). "*Utility Plans 24/7 Prediction and Response Center in CA*" Retrieved from: http://www.govtech.com/public-safety/Facing-Blame-for-Fires-Utility-Plans-247-Prediction-and-Response-Center-in-California.html

[148] [19] PG&E, Climate

[149] Cagnan, Z., Davidson, R., Guikema, S., (2006). Post-Earthquake Restoration Planning for Los Angeles Electric Power, Earthquake Spectra 22 (3), 589-608.

	reduce load demands, but this varies by neighborhood substation grid design. Certain City entities also own and operate their own on-site backup generators and/or have installed solar PV panels and storage, which decreases their vulnerability. There are backup generators on Treasure Island that are sufficient to meet the needs of both islands, if sufficient fuel is available. **External Services:** The power asset class relies on transportation access for vehicles and personnel in order to maintain and repair assets. Maintenance and repair vehicles also rely on fuel. Backup power generators also rely on fuel. **Populations Served:** Power serves all residents and businesses in the city. Electric power is especially critical for those dependent on 24/7 life supporting medical equipment, as well as to mobility-impaired and all elderly residents. Electric power is also critical for the continued operation of public services, such as public transport, sewage, water and waste management. **Unique or Critical Function:** Power is critical for a functioning city, from transportation to business to healthcare to households. Service providers of electric power are limited, and the city depends on their ability to manage and operate a secure and reliable electric power grid. Since energy storage technology solutions are not yet cost-effective and accessible to regular consumers it is vital that power supply is not interrupted.
Informational	**All-hazards:** Electrical single line drawings are available for the location of both SFPUC and PG&E owned substations and PG&E transmission lines.[150] However, information is not publicly available about the age, expected remaining service life and condition of substations, as well as their operational capacity and load sharing possibilities due to security concerns. The Lifelines Restoration Performance Project (report forthcoming) has assessed restoration timelines for the power sector in the event of a seismic event.

[150] CA Energy Commission (2017). "*California Transmission Lines and Substations Map*". Retrieved from: http://www.energy.ca.gov/maps/infrastructure/3P_Enlg.pdf

	In past events, there have been delays in utilities signaling substation fires to public service authorities.[151] Emergency response authorities and utilities are already collaborating to increase oversight and training.[152]
Governance	**All-hazards:** CPUC approval is needed for any resilience improvement projects and the CAISO determines whether or not new transmission lines and substations are needed to meet the grid's future demands. There is continued investment in renewable energy and community choice aggregation (CCA) programs, which would allow for redundancies and a more diversified and localized energy supply system,[153] but solutions remain reliant on the integrity of the transmission and distribution systems. There is a lack of clarity on exactly where PG&E service ends and SFPUC service begins, which results in some challenges regarding ownership and repair of some assets.[154]

[151] San Francisco Chronicle (2017). "Fires at PG&E's Substations a Recurring Problem". Retrieved from: https://www.sfchronicle.com/bayarea/article/Fires-at-PG-E-s-SF-substations-a-recurring-11119604.php
[152] [19] PG&E, Climate
[153] CPUC (2018). "California Customer Choice" Retrieved from: http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/Cal%20Customer%20Choice%20Report%208-7-18%20rm.pdf
[154] Lifelines Restoration Performance Study (forthcoming)

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Power outages are generally short-term, but any prolonged widespread service interruption will pose health risk to people dependent on medical equipment if no backup or alternatives are available. Potable water systems are also affected by power outages, potentially leading to public health impacts. Mobility would be affected if transit and street lights are not operational. Communications networks could be affected posing risk to public safety. Low-income residents relaying on day paychecks and small businesses would be more affected due to halt of activities. Elderly and/or mobility-impaired residents in multi-story buildings may be unable to access critical daily needs if elevators are not functioning. **Geologic:** Health, public safety and mobility would be affected (see all hazards). Depending on the magnitude of the earthquake, disruption of the power grid could be regional in nature. **Flood:** Health, public safety and mobility would be affected (see all hazards) if there were localized power outages due to a flooding event. Substation equipment contain insulating oil that could contaminate if released into floodwaters. **Extreme Heat:** Health, public safety and mobility would be affected if there were widespread power outages due to a heat event. **Fire:** Health, public safety and mobility would be affected if there were localized power outages due to a fire.
Economy	**All-hazards:** A power outage may have severe economic consequences as it interrupts business operations across all industries. In the digital age, business operations are more dependent on reliable power than ever. The scale of the disruption will depend on the type and extent of the hazard event. Substations that are damaged or need to be shut down will not be able to provide power to the neighborhoods in their service area. **Geologic:** In the event of an earthquake, electric power would likely be affected at a regional scale. The economic consequences would include the cost to repair damaged infrastructure and the loss of

	economic activity during the power outage, including municipal operations. **Flood:** In the event of a flood the impacts would likely be localized. The impacts could become regional in nature if the outage affects regionally critical assets, such as BART or a wastewater treatment plant. The economic consequences would include the cost to repair damaged infrastructure, loss of economic activity and municipal revenue. **Extreme Heat:** In the event of a heatwave, the effects are most likely widespread power outages that could be regional in scale or at neighborhood level. The costs would include the loss of economic activity during the outage. **Fire:** In the event of a fire the impacts would likely be localized. The impacts could become regional in nature if transmission lines are affected or the outage affects regionally critical assets, such as BART or wastewater treatment. The economic consequences would include the cost to repair damaged infrastructure and the loss of economic activity.
Environment	**All-hazards:** Many facilities within the city maintain backup supply generators. However, if they are widely used for an extended period, air quality may be affected. If wastewater systems are unable to operate due to a power outage, then water quality may be impacted.

Natural Gas

Introduction to Asset Class

The natural gas asset class generates, stores, manages, and delivers natural gas to end-users, such as homes and businesses. For the purpose of this assessment we divided the asset class into five sub-asset types: production, interstate transmission, intrastate and local transmission, distribution and service lines.

a) *Production:* Most of the natural gas used in California comes from out-of-state natural gas basins. In 2012, California customers received 35% of their natural gas supply from basins located in the Southwest, 16% from Canada, 40% from the Rocky Mountains, and 9% from basins located within California.[155] The main source of natural gas for San Francisco is Canada and the Rockies.[156] Natural gas processing plants separate hydrocarbon gas liquids, nonhydrocarbon gases, and water from the natural gas to make it safe for delivery into the interstate transmission system. PG&E does not own any natural gas production facilities. Production facilities are not included in the exposure assessment given the focus on assets within the City and County of San Francisco.

b) *Interstate Transmission:* Transmission pipelines carry natural gas across long distances, usually to and from compressors or to a distribution center or storage facility. Transmission lines are large steel pipes (10" to 42" in diameter) that are federally-regulated. They carry unodorized gas at a pressure of approximately 60-900 psi. Natural gas is delivered into California from producing and processing areas via the interstate natural gas pipeline system to storage facilities and distribution centers where natural gas is delivered to local distribution companies, such as PG&E. The major interstate pipelines that deliver out-of-state natural gas to California are the Gas Transmission Northwest Pipeline, Kern River Pipeline, Transwestern Pipeline, El Paso Pipeline, the Ruby Pipeline, Questar Southern Trails and Mojave Pipelines.[157] Interstate transmission facilities are not included in the exposure assessment given the focus on assets within the City and County of San Francisco.

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[155] http://www.cpuc.ca.gov/natural_gas/
[156] https://www.quora.com/Where-does-PG-E-source-their-gas-and-electricity-to-provide-consumers-homes-in-San-Francisco
[157] http://www.cpuc.ca.gov/natural_gas/

c) *Intrastate Transmission:* PG&E delivers natural gas across its service area through high pressure transmission lines, often called the backbone system. Natural gas on the backbone pipeline system is then delivered into the distribution pipeline systems, to natural gas storage fields and directly to some large customers, such as power plants. There are no gas storage facilities or power plants located in San Francisco. Three 19-30 inch diameter PG&E transmission lines deliver natural gas up the Peninsula into the City of San Francisco. A fourth transmission line delivers natural gas from Oakland to Treasure Island via submarine pipeline. Local transmission is included in the exposure assessment below.

d) Distribution: Smaller diameter, lower pressure pipelines are the middle step between high pressure transmission lines and low-pressure service lines. These small to medium sized pipelines (2-24 inches in diameter) are generally located beneath all surface streets in San Francisco and carry odorized gas at intermediate pressure levels. Distribution pipelines are not included in the exposure assessment below as the City and County of San Francisco does not have access to that data.

e) Service Lines: Service lines connect distribution lines to meters at homes and businesses and carry odorized gases at low pressures. Most natural gas customers are in residences and small commercial businesses that use natural gas for heating and cooking. Some fleet vehicle owners rely on compressed natural gas delivered by PG&E for their vehicles.

PG&E is regulated by the California Public Utilities Commission (CPUC) and the Federal Energy Regulatory Commission (FERC). CPUC regulates natural gas rates and services including in-state transportation of natural gas over transmission and distribution pipeline systems as well as the storage, procurement, metering and billing of natural gas.[158] FERC is an independent agency that regulates interstate natural gas transmission.

Issue Statement

Natural gas pipelines are vulnerable to seismic hazards, particularly liquefaction. Damage in two or three transmission lines could result in a pressure loss and gas service would be curtailed throughout the city.[159] Since 2014, all seismically vulnerable cast iron

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158 http://www.cpuc.ca.gov/natural_gas/
159 [2014 SF Lifelines Council Interdependency Study]

transmission pipe have been replaced in the City and PG&E plans to upgrade some of its seismically vulnerable distribution pipes. Any gas leaks on the transmission system would be controlled through 2,200 manual, remote, or automatic shut-off valves located throughout the system. Gas leaks on the distribution system are primarily controlled by manual shut-off valves that need to be located by field personnel below the street. Restoration of the gas system can take several weeks due to the time needed to inspect, repair, test, and re-pressurize the system. Relighting individual pilot lights at each service location would also require coordinating a large number of personnel to achieve. The consequences of impairment of natural gas service would have health impacts due to the lack of building heating, which would especially impact vulnerable populations during winter months. Damage to the natural gas system due to an earthquake or other hazard event also has the potential to result in an explosion and fire, potentially leading to deaths, injuries, and/or property damage.

Assumptions and Limitations

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table below, shaking intensity is represented for two earthquake scenarios: San Andreas Fault 7.8 and Hayward Fault 7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data is sourced from the California Energy Commission open data portal, last updated in 2018.

TABLE A-33: EXPOSURE

Hazard	Natural Gas Transmission Pipelines 19 Miles Total		Natural Gas Stations 3 Total	
	#	%	#	%
Geologic				
San Andreas 7.8 - Violent	2	11%	0	0%
San Andreas 7.8 - Very Strong	17	91%	3	100%
Hayward 7.0 - Very Strong	2	13%	1	33%
Hayward 7.0 - Strong	13	68%	2	67%
Liquefaction Zone	5	26%	3	100%
Flooding				
100-Year Coastal Flood Zone	0	0%	0	0%
100-year storm + 24 inches SLR	1	5%	0	0%
100-year storm + 66 inches SLR	2	11%	2	67%
100-year Stormwater Flood	2	11%	0	0%
Wildfire				
High	0	0%	0	0%
Moderate	0	0%	0	0%

Note: For an exposure table with additional hazards, please see Chapter 05.

Exposure Summary

Geologic: All natural gas stations and one quarter of transmission pipelines are located in areas with liquefaction risk. 91% percent of natural gas transmission line assets are in very strong ground shaking risk areas assuming a M7.8 San Andreas earthquake. Every natural gas station is subjected to very strong shaking in this scenario as well. A significant proportion (greater than 60% percent) of all natural gas assets are subjected to strong shaking from a M7.0 Hayward earthquake.

Flood: One mile of transmission pipelines are in a 24" sea level rise risk area, and an additional mile of pipelines are in a 66" risk area. Two natural gas stations are in a 66" sea level rise risk area. Two miles of pipelines are in a 100-year stormwater flood area.

Fire: Natural gas transmission pipelines and stations are not in a wildland-urban interface risk zone. Natural gas valves are not included in the exposure analysis.

FIGURE A-55: NATURAL GAS AND LIQUEFACTION HAZARD

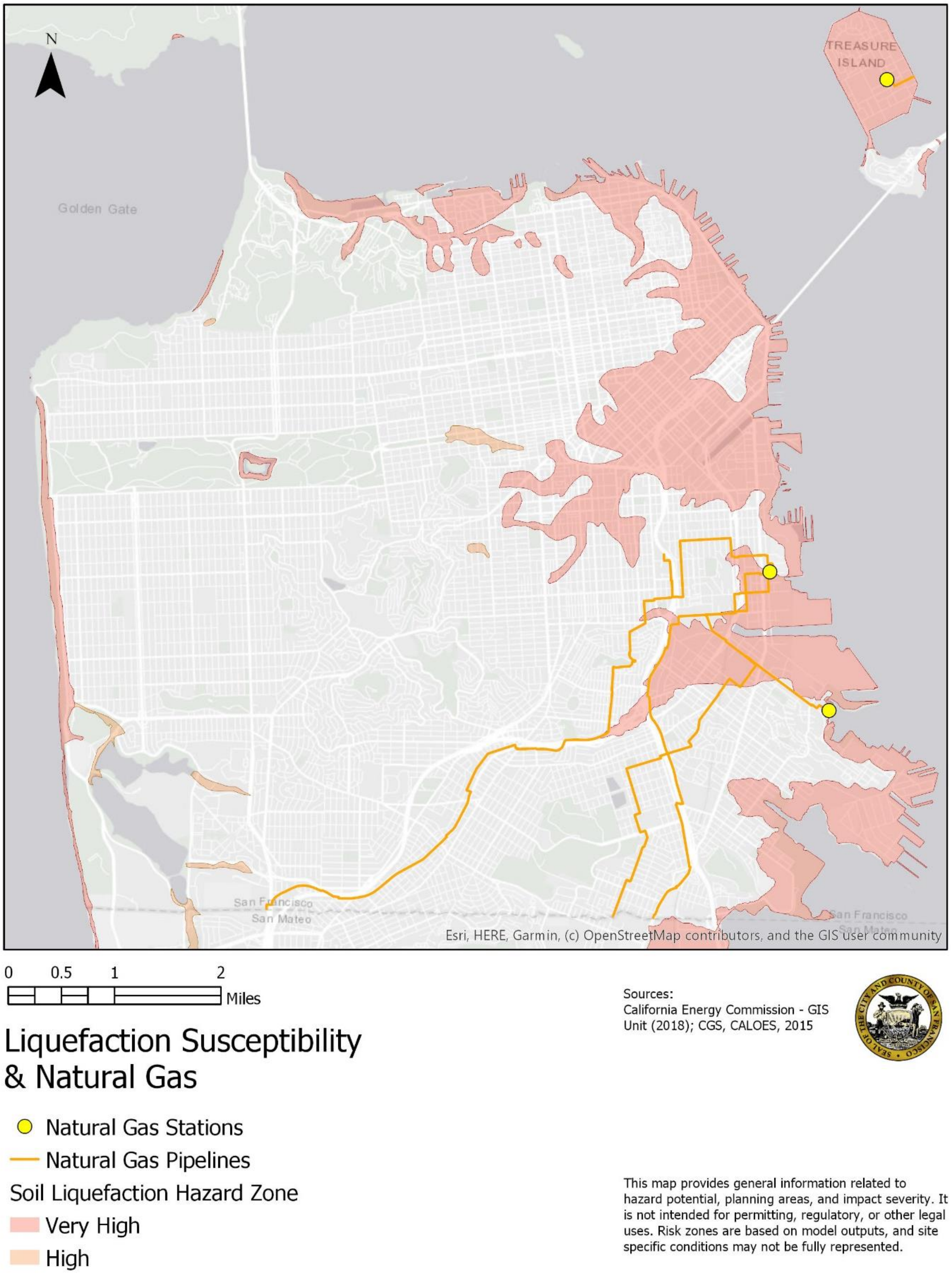
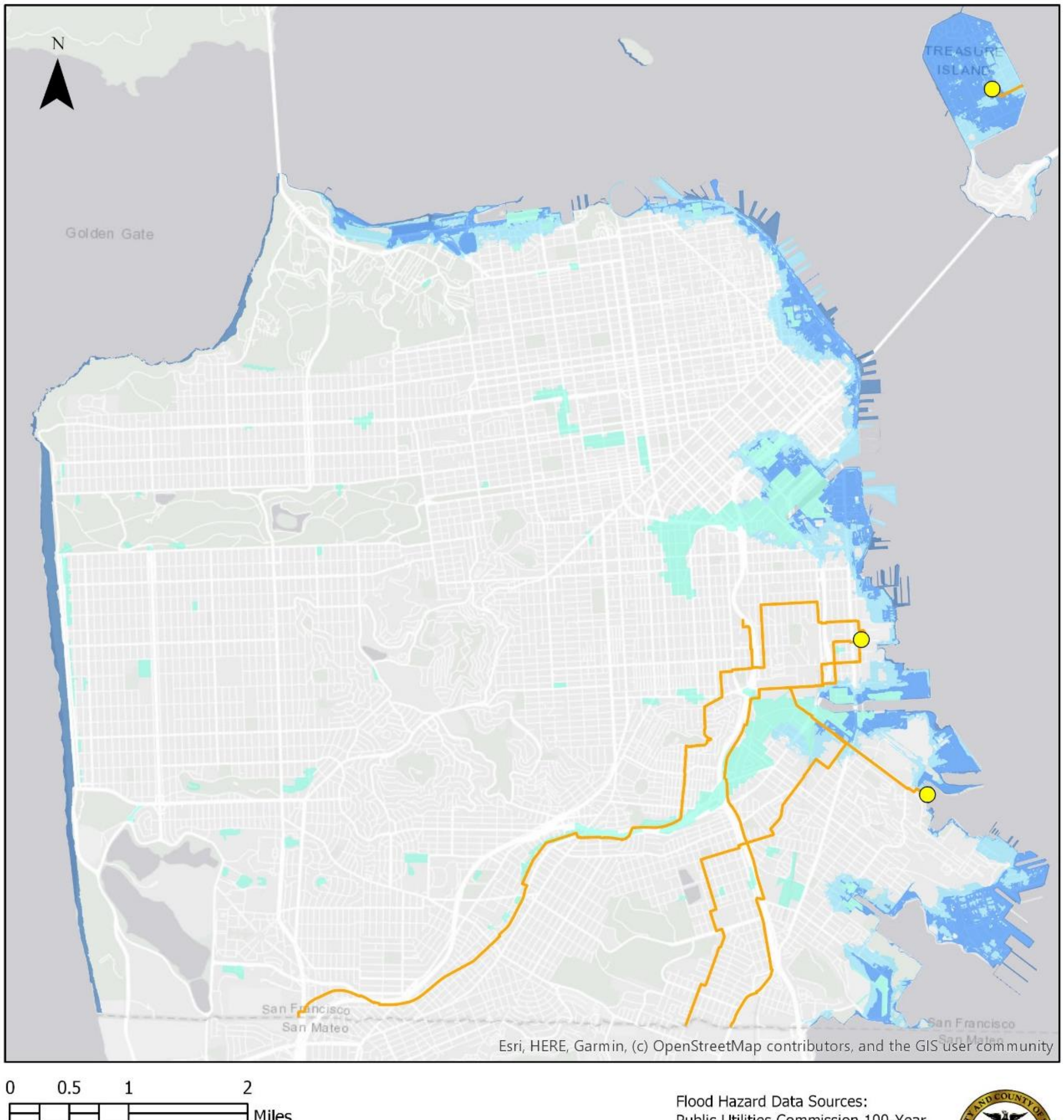


FIGURE A-56: NATURAL GAS AND FLOOD HAZARDS



Natural Gas Flooding Risk

- Natural Gas Stations
- Natural Gas Pipelines
- 100 Year Stormwater Runoff
- FEMA 100 Year Coastal Flood Zone
- 100 Year Storm + 24" Sea Level Rise
- 100 Year Storm + 66" Sea Level Rise

Flood Hazard Data Sources: Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps

Asset Data Sources: California Energy Commission - GIS Unit (2018)

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Since 2005, all seismically vulnerable cast iron transmission pipe have been replaced in the City. Any gas leaks on the transmission system would be controlled through 2,200 remote and automatic shut-off valves located throughout the city. Remote shut off valves can be controlled from the new Gas Control Center in San Ramon when significant drops in pressure are detected. Automatic gas shut off valves have been installed in densely populated areas and where transmission lines cross major faults. The shutoff valves have been designed to close automatically when local sensors at the valve site detect a possible pipe rupture. PG&E has plans to upgrade brittle cast iron distribution pipes. These pipes will likely be damaged in areas of high liquefaction. Shut off valves on the distribution system are manually and automatically operated. Natural gas valves are frequently collocated with streets, and damage to streets impedes operators' ability to access manual valves. Restoration of the gas system can take several weeks due to the time to inspect, repair, test, re-pressurize the system and relight pilot lights at each service location, requiring a large number of personnel. PG&E has a prioritization of customers for restoration with hospitals and other critical customer's first and residential customers later. **Flood:** While most pipelines are cathodically protected, those constructed with older seam types are susceptible to corrosion from saltwater intrusion.[160] The rates of unprotected pipes are low statewide (0.5%), but information on the specific conditions in San Francisco is not available. Depending on the intensity of storm energy, pipelines may be damaged due to increased hydrostatic pressures. Burial depth and covering material also affect vulnerability. **Extreme Heat:** Natural gas systems have low vulnerability to extreme heat. Natural gas production from hydraulic fracturing (fracking), however is very water intensive. Extreme heat and related drought conditions

[160] 2017 California Energy Commission Climate Change Center, Assessment of California's Natural Gas Pipeline Vulnerability to Climate Change

	projected to increase in California under climate change make this source of fuel less adaptive under climate change.[161] **Fire:** Aboveground components are vulnerable to fire. If meters are melted away during a fire, gas can ignite.[162]
Functional	**Networks:** San Francisco receives natural gas from three transmission lines running up the peninsula and into the city with a fourth submarine transmission line supplying gas to treasure island from Oakland. PG&E manages gas infrastructure for contingencies, but damage to two or three of these transmission lines could result in a pressure loss which would limit gas service to the city. PG&E estimates that following a 7.8M earthquake on the San Andreas Fault, it could take up to 6 months for full restoration of service if gas transmission is lost.[163] **External Services:** The collocation of natural gas infrastructure with San Francisco streets increases vulnerabilities for both assets. Following Loma Prieta, most street damage was due to sewer, water, gas breaks. Before street repair can begin, underground utility breakage will need to be repaired. Operators may need to manually control natural gas valves, an ability that may be hindered if streets are closed, damaged, or obstructed.[164] **Populations Served:** Natural gas is primarily used by residences and small businesses for cooking, space heating and water heating. Hospitals and some other large entities also rely on natural. Loss of natural gas service would have a significant impact on vulnerable populations, especially during winter months. **Unique or Critical Function:** Natural gas is important for a functioning city, especially for household cooking, water heating and space heating. There is only one provider of natural gas, and the city depends on their ability to manage and operate a secure and reliable pipe network. Disruption to

[161] Moran, M. D., N. T. Taylor, T. F. Mullins, S. S. Sardar, and M. R. McClung, 2017: Land-use and ecosystem services costs of unconventional US oil and gas development. Frontiers in Ecology and the Environment, 15 (5), 237–242. doi:10.1002/fee.1492
[162] Case Studies of Natural Gas Sector Resilience Following Four Climate-Related Disasters in 2017
[163] 2014 SF Lifelines Council Interdependency Study
[164] 2018 Interview for Lifeline Restoration Performance Project

	the gas system has the likelihood to ignite fires and pilot lights must be manually relighted at each individual residence or business, which is extremely time and labor intensive.
Informational	**All-hazards:** The locations of natural gas transmission pipelines and facilities are made publicly available by PG&E and the California Energy Commission, however distribution pipe locations are not known, though it is generally co-located with roads in residential areas.
Governance	**All-hazards:** Natural gas is privately managed by PG&E. Natural gas infrastructure is collocated with roads, and requires coordination among multiple managers, both public and private. The PUC's Fuel Switching Project is working to replace natural gas heating systems with electric systems for public schools and small commercial properties.[165] Department of Environment also identifies fuel switching as a prioritized action to reduced greenhouse gas emissions. A hazard event such as an earthquake that damages natural gas pipelines could provide an opportunity to switch other facilities from natural gas to electric cooking and heating systems.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Gas leaks or explosions pose risks to public health and safety. Homes and businesses without natural gas can still be occupied, however they might not be able to cook or heat their homes or water if those appliances rely on natural gas. Most restaurants rely on natural gas for cooking and would be particularly affected by an outage. Loss of natural gas over an extended period of time can impact the ability of communities to shelter in place, impacting the long-term neighborhood stability and cohesion.
Economy	**All-hazards:** The economic consequences of disruption of the natural gas system include the cost to repair damaged infrastructure and the loss of business activity during the outage. **Geologic:** In the event of an earthquake, natural gas would likely be affected at a regional scale.

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Environment	**<u>All-hazards:</u>** Gas leaks or explosion pose risks to air quality and natural area habitats and sensitive species. Loss of natural gas supply could increase electricity use, especially in winter. This could have a positive or negative effect on emissions depending on the source of electricity.

Potable Water

Introduction to Asset Class

The potable water system delivers roughly 60 million gallons per day to meet the needs of San Francisco residents and businesses. The local water supply system is made up of over 1,250 miles of distribution pipelines (also known as distribution mains), 17 storage reservoirs and tanks, and 4 groundwater well sites. Recently, SFPUC has expanded the local supply to include groundwater sourced from the 45-square mile Westside Basin located under Golden Gate Park. This new source is explicitly developed to provide emergency water in the case of system disruptions. Currently, 17 pumping stations move water across the city, spanning a range of elevations and serving a wide range of users including users via the Treasure Island/Yerba Buena distribution system. In order to maintain this service, 24 pressure zones are created throughout the system based on user elevation, available pumping capacity, and water supply.

SFPUC's Water Enterprise is responsible for managing the transmission, treatment, storage and distribution of potable water to San Franciscans and 27 water agencies in three Bay Area counties – San Mateo, Santa Clara and Alameda.[166] While the majority of San Francisco's potable water resources come from outside the county, and we are committed to their resilience, this vulnerability and consequence assessment focuses on local water supply assets within the city and county boundaries. The system has seen extensive improvements over the last decade as a result of the Water System Improvement Program (WSIP) which has included local and regional improvements replacing outdated/worn infrastructure as well as the installation of seismic improvements to reservoirs, pumping stations, reservoirs and other critical facilities.

Issue Statement

The potable water system provides a vital lifeline service to the residents and businesses of San Francisco and there are limited alternatives should the system be impaired. Some distribution mains are old and made of less resilient materials such as cast iron, and pipelines traverse seismic hazard zones, which could result in damage in an earthquake. The system heavily relies on pumping stations with some containing

[166] SFPUC. "About US: Water". Retrieved from: https://www.sfwater.org/index.aspx?page=6

below grade electrical components. This may be an issue for the Bay Bridge Pumping Station which would be exposed to flooding from a 100-year storm with 66 inches of sea level rise and is the only connection for potable water into the Treasure Island/Yerba Buena distribution system. Water storage is centralized in reservoirs that may face contamination issues if damaged.

TABLE A-34: EXPOSURE

Hazard	Pump Stations: 17 Total		Water Transmission Lines: 24 Miles Total		Water Reservoirs 15 Total	
	#	%	#	%	#	%
Geologic						
San Andreas 7.8 - Violent	4	24%	11	46%	3	20%
San Andreas 7.8 - Very Strong	13	76%	13	54%	12	80%
Hayward 7.0 - Very Strong	1	6%	0.1	0%	0	0%
Hayward 7.0 - Strong	6	21%	0.1	0%	9	60%
Liquefaction Zone	0	0%	0.4	2%	0	0%
Flooding						
100-Year Coastal Flood Zone	0	0%	0	0%	0	0%
100-year storm + 24 inches SLR	0	0%	0	0%	0	0%
100-year storm + 66 inches SLR	1	3%	0	0%	0	0%
100-year Stormwater Flood	0	0%	0	0%	0	0%
Wildfire						
High	0	0%	0	0%	0	0%
Moderate	1	6%	2	8%	0	0%

Note: For an exposure table with additional hazards, please see Chapter 05.

Exposure Summary

Geologic: All potable water assets are exposed to violent or very strong groundshaking in a 7.8 earthquake on the San Andreas Fault. Potable water assets have limited exposure to violent or very strong shaking in a 7.0 earthquake on the Hayward fault and the liquefaction hazard.

Flood: Only one pump station is exposed to flooding in a 100-year storm with 66 inches of sea level rise. This is the pump stations that provides potable water service to Yerba Buena Island.

Fire: four pump stations are exposed to moderate wildfire risk.

FIGURE A-57: POTABLE WATER ASSETS AND LIQUEFACTION HAZARD

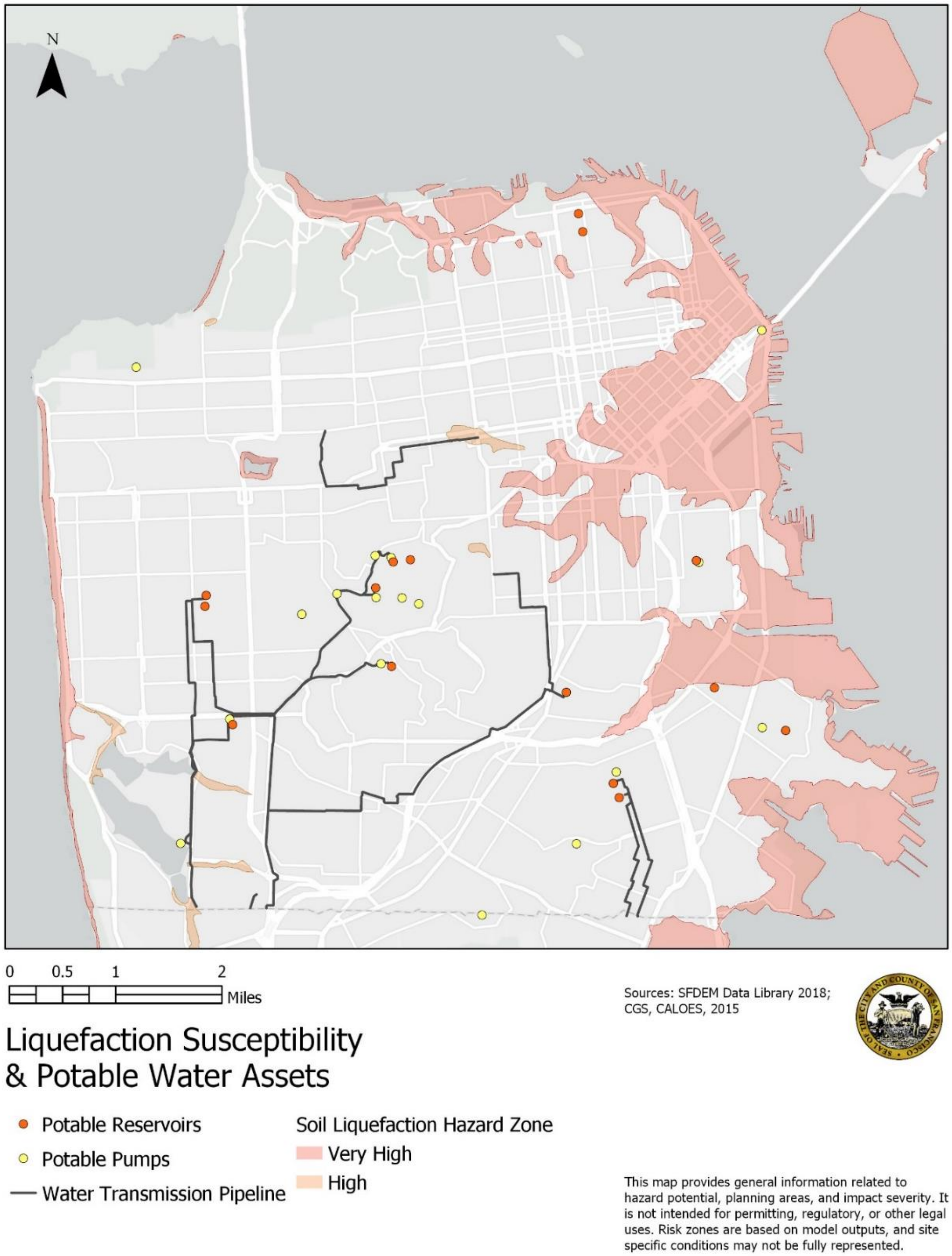
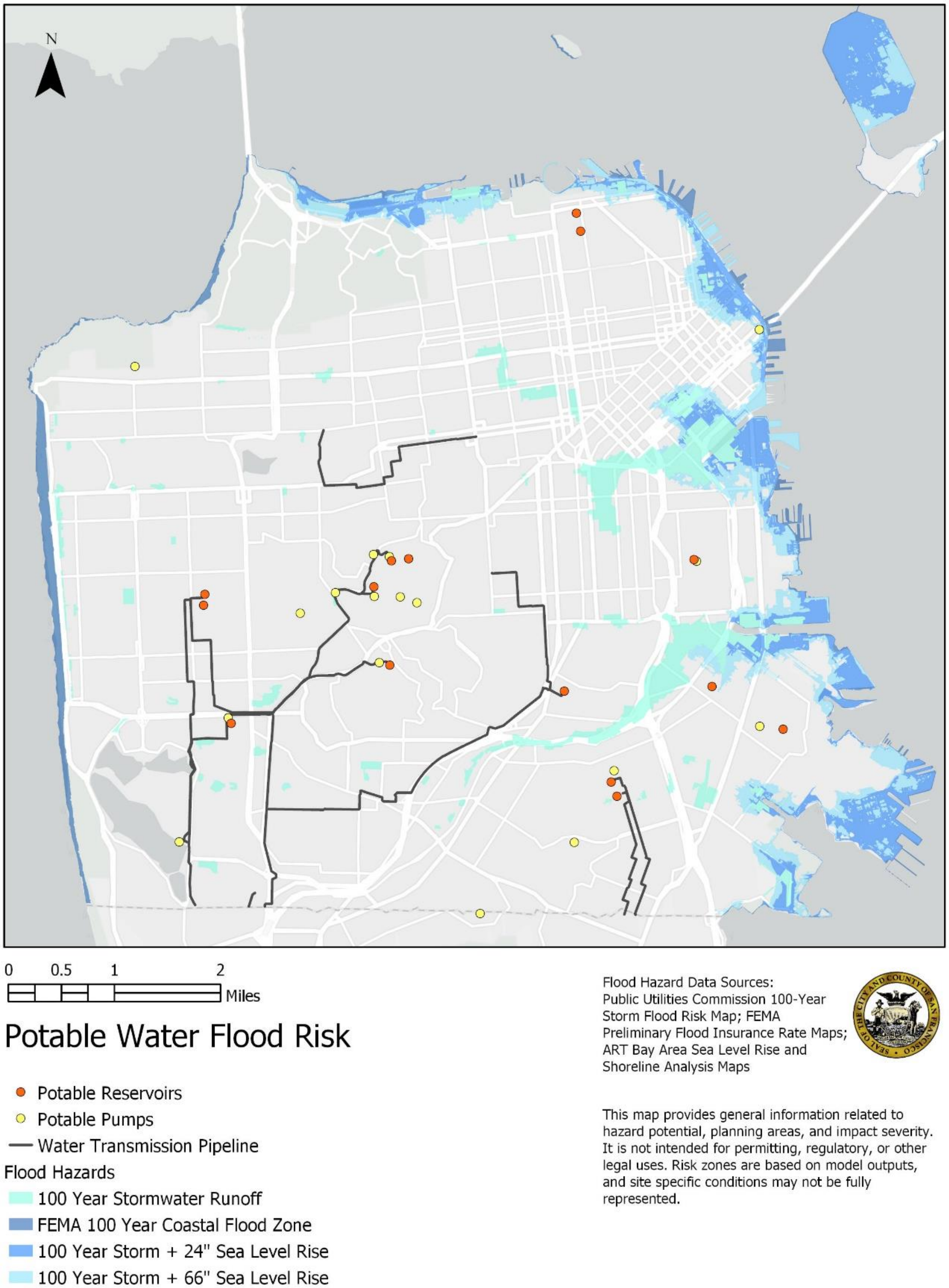


FIGURE A-58: POTABLE WATER ASSETS AND LIQUEFACTION HAZARD



VULNERABILITIES

Category	Vulnerability[167][168]
Physical	**Geologic:** Previous experience has shown that transmission mains in liquefaction zones can experience some damage, particularly if they are cast iron construction. This damage can leave some users without access to water if they are located at higher elevations. Damage to reservoirs can lead to the contamination of potable water resources. However, most reservoirs have been seismically retrofitted and can be expected to perform well in the case of a major earthquake. **Flood:** Pumping stations have below grade electrical components that are sensitive to inundation. Additionally, some pumping stations have numerous flood vulnerable entryways and may lack comprehensive flood proofing. Most notable is the Bay Bridge Pumping Station that is in the sea level rise hazard zone and functions as the sole entry point for water into the Treasure Island/Yerba Buena Water Distribution System. Many local water control systems used to maintain reservoir levels and control water flows are dependent on below grade electrical components that face inundations risks. Repeated, increasingly frequent saltwater inundation of transmission mains can lead to corrosion damage to these sub-assets. The overall system relies on valves for isolation and distribution routing of water throughout the city. Under sea level rise scenarios carried out by the PUC, these valves will not be accessible or will be located under water, potentially impacting the function of the system in the inundation areas. **Extreme Heat:** None. **Fire:** None.
Functional	**Networks:**

[167] Miller K, Bechelli A, Young S, Teahan B, Gonzalez R, Conci B, Gabriel B, Lampe D. "SFPUC Water Lifelines Interview" Interview by Mieler D. 8/16/18
[168] SF Planning (2019) "*SLR Vulnerability and Consequences Assessment*"

	This system is networked and depends on the maintenance of pressure zones for transportation of water across the city to customers at different elevations. The networked nature of the system means that assessments can be made to identify breakages in the system and water can be rerouted around these breakages to maintain service. There is redundancy in the distribution network that can assist in rerouting water around areas that have been damaged. Lower pressure water hydrants may serve as water distribution points in the community, with support from trained volunteers with NERT. However, this is reliant on hydrants which may also be damaged in an earthquake event. Taken together, reservoirs can hold about 500 million gallons (4-5 day's supply) of potable water when full which can siphoned off and transported in water trucks if the distribution network were disrupted. **External Services:** The system has reliance on external power to operate pumping stations. While there are backup generators, these are reliant on diesel fuel availability. The system relies heavily on pumping capability to function and loss of power can impact the ability to move water or maintain operational pressure in the system. Telecommunications are vital to coordinate actions over the wide geographic extent of the system. These function to coordinate reservoir levels to maintain pressure as well as remotely operate pumping stations. Transportation access is essential to facilitating repair employees to access the city from their housing outside the county and is also essential for accessing broken pipe sections around the city as sections are repaired. **Populations Served:** This system is essential for providing potable water to all residents and businesses in the city and county of San Francisco. As the system spans the entire city, it serves numerous community members that are ethnically/culturally diverse and may have limited English proficiency and access or functional needs. **Unique or Critical Function:** This asset functions as the primary source of potable drinking water for everyday use by residents as well as businesses operating in the city.

	In addition, potable water is critical following a significant earthquake event for the general public, mass care facilities, and fire-fighting needs.
Informational	**All-hazards:** Generally, there is information available regarding the flood and seismic risks to the system but significantly less information regarding potential impacts to the system from extreme heat events or direct fire events. The primary fire risk to the system would most likely occur outside of the city/county boundary, and therefore outside the scope of this effort.
Governance	**All-hazards:** The WSIP program is the primary policy/funding initiative guiding the maintenance, repair, and improvement of the system. Additionally, this program strives to specifically identify seismic resilience improvements for implementation. SFPUC also plans the system based on its Level of Service (LOS) goals. In the case of a large disruptive event, such as an earthquake, repair work would have to compete with other priorities such as the EFWS system or the wastewater collection system, which could potentially delay restoration of any of these services without proper coordination.

CONSEQUENCES[169]

Category	Consequence
Society/Equity	**All-hazards:** Delays to water supply restoration following an event could impact restoration of wastewater, telecommunications equipment cooling, refueling services, and even the provision of basic services for the city's lifelines systems. This would be disruptive across numerous aspects of society.[170] In the case of major disruption over a protracted period, the mobility challenged may find it difficult to access locations with alternative

[169] Miller K, Bechelli A, Young S, Teahan B, Gonzalez R, Conci B, Gabriel B, Lampe D. "SFPUC Water Lifelines Interview" Interview by Mieler D. 8/16/18

[170] SF Lifelines Council (2014). "Lifelines Interdependency Study I Report" Retrieved from: https://sfgov.org/orr/sites/default/files/documents/Lifelines%20Council%20Interdependency%20Study.pdf

	water resources, be they water distribution points in the form of low pressure hydrants or community centers distributing water bottles. **Geologic:** Significant breakage of mains and distribution infrastructure could lead to an extended period without potable water, with detrimental health and safety implications for community residents
Economy	**All-hazards:** Disruption to this asset would have significant citywide consequences across numerous sectors **Geologic:** Damage to transmission mains and pipelines can lead to water leaks and damage to co-located assets. For example, burst water mains that haven't had their flow rerouted can create sinkholes or cause surface flooding, potentially damaging roadways and buildings. This can necessitate costly repairs by public and private entities. Damage to transmission mains can also lead businesses to lose potable water access and have to shut down temporarily, losing revenue. **Flood:** Saltwater corrosion could shorten the life expectancy of buried pipe infrastructure. This could lead to increased replacement costs for the system as the frequency of inundation increases over time. This would be most pronounced for assets in coastal inundation zones. **Extreme Heat:** Warmer temperatures can lead to increased demand by both water utility customers and competing users, with demand peaking when supplies are most restricted. This can lead to increases in water pricing, putting pressure on local businesses and low income individuals.[171]
Environment	**All-hazards:** If the potable water system were disrupted, alternative source of potable water could have environmental impacts such as waste management issues from disposable plastic water bottles or emissions from water distribution trucks.

[171] AWWA Research Foundation (2008) "Effects of Climate Change on Public Water Suppliers"

Emergency Firefighting Water System

Introduction to Asset Class

The Emergency Firefighting Water System (EFWS) is a high-pressure firefighting water system constructed shortly after the 1906 earthquake to safeguard lives and property in the case of future earthquakes. The system is routinely tapped to fight multi alarm fire events even in the absence of an earthquake and can be called on as much as 30 times in a single year.[172] The primary function of the system is to provide large volumes of high pressure water for firefighting purposes and numerous types of equipment are used to achieve this goal. Although the eastside is reliably and extensively covered by the system, the Westside has lower reliability due to its more recent development in the city's history. Currently, agencies are identifying extension alternatives in partnership with the public to increase Westside reliability.[173,174]

The primary water supply for the system comes from the Twin Peaks reservoir, with a storage capacity of 10.5 million gallons. This is bolstered by the Ashbury and Jones Tanks. In addition, the EFWS system has a secondary water source, the San Francisco Bay, which can be accessed via two pump stations, five manifolds connections, and drafting points that allow saltwater to be drawn into the system with the assistance of three fireboats and pumping engines. Approximately 210 underground cisterns located around the system can also provide water for the system. 131 miles of pipelines and motorized/manual valves facilitate transportation of this water across the city to the high pressure fire hydrants used by SFFD.

Originally, the EFWS was constructed by Public Works and managed by SFFD. However, ownership transferred to SFPUC in 2010 and a full assessment of all existing facilities commenced through a comprehensive planning study. The analysis showed that the 2010 EFWS would be about 47% reliable in terms of providing EFWS water citywide

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[172] METCALF AND EDDY/AECOM (2009) "*Auxiliary Water Supply System Study: Final Report*. Retrieved from: https://s3-us-west-2.amazonaws.com/ucldc-nuxeo-ref-media/b2754026-dded-4ee6-b24c-2cf837f3bc00
[173] AECOM/AGS (2014). *"CS-199 Planning Support Services for Auxiliary Water Supply System (AWSS): Project Report"*. Retrieved from: https://sfwater.org/Modules/ShowDocument.aspx?documentid=5055
[174] San Francisco Public Utilities Commission. (2012) *'Assessment of Fire Suppression Options for Westside"*. Public Presentation. Retrieved from: https://sf-fire.org/sites/default/files/COMMISSION/Fire%20Commission%20Support%20Documents%20 2015/AWSS%20Presentation%20for%20SFFD%20Commission.pdf

following a 7.8M earthquake. It also identified combined projects to be completed using the 2010 and 2014 Earthquake Safety and Emergency Response (ESER) bonds authorized by voters to increase average reliability from 47% to 87% with additional projects raising it to 96%.

Issue Statement

The EFWS provides a critical emergency response function, supporting firefighting efforts both in the event of a major earthquake and on a more regular basis. The ability of the EFWS system to provide high pressure water for firefighting may be disrupted by hazard events, particularly as it is a networked system that relies on interconnected system components. Using ESER bond funds, the SFPUC has increased average citywide reliability to 87% once the ESER 2010 and 2014 projects are completed and additional projects will bring it to 96% reliability following a 7.8 earthquake. With regarding to flooding impacts, below grade valve and pumping station components are vulnerable to damage from flooding. Access to hydrants, drafting points, or manifolds may also be compromised by flooding. If functionality of the EFWS is disrupted, firefighting capabilities may be compromised, increasing the risk of fire damage and potentially injury or loss of life.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table below, shaking intensity is represented for two earthquake scenarios: San Andreas Fault 7.8 and Hayward Fault 7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

EFWS pipeline data contains proposed EFWS pipes, existing EFWS pipes, and existing potable water pipes that are used in the system. The dataset containing valves only contained information for 18 of the 30 valves used in the system. Additionally, a 32 foot buffer was applied to the pump stations due to a lack of redundancy and proximity to coastal flood zones.

Asset data is originates from datasets maintained by SFPUC, SF Planning, and SF DEM (2018).

Exposure Summary

Geologic: All of the EFWS system is exposed to violent or very strong shaking in a 7.8 earthquake on the San Andreas Fault. A much smaller share of the system is exposed to violent or very strong shaking in a 7.0 earthquake on the Hayward fault. Almost a third of the EFWS systems pipelines are in the liquefaction hazard zone.

Flood: The EFWS systems pipelines have very little exposure to the current 100-year flood zone. With sea level rise, more of the EFWS will be exposed. For example, with 66 inches of sea level rise 17% percent of valves and 14% percent of pipelines may be exposed to flooding during a 100-year storm.

Fire: Only a very limited amount of the system is exposed to moderate wildfire risk.

TABLE A-35: EXPOSURE

Hazard	Valves: 3326 Total		Cisterns: 210 Total		Pipelines: 131 Miles Total		High Pressure Hydrants: 1,644 Total		Pump Stations: 2 Total	
	#	%	#	%	#	%	#	%	#	%
Geologic										
San Andreas 7.8 - Violent	176	5%	30	14%	10	8%	102	6%	0	0%
San Andreas 7.8 - Very Strong	3148	95%	180	86%	120	92%	1542	94%	2	100%
Hayward 7.0 - Very Strong	483	15%	6	3%	16	12%	218	13%	2	100%
Hayward 7.0 - Strong	2584	78%	172	82%	101	77%	1257	76%	0	0%
Liquefaction Zone	1262	38%	45	21%	45	34%	602	37%	1	50%
Flooding										
100-Year Coastal Flood Zone	21	1%	0	0%	1	1%	12	1%	1	50%
100-year storm + 24 inches SLR	308	9%	3	1%	10	8%	138	8%	0	0%
100-year storm + 66 inches SLR	545	16%	11	5%	19	15%	253	15%	1	50%
100-year Stormwater Flood	154	5%	8	4%	7	5%	84	5%	0	0%
Wildfire										
High	0	0%	0	0%	0	0%	0	0%	0	0%
Moderate	10	1%	2	1%	0.7	0%	6	0%	1	50%

Note: For an exposure table with additional hazards, please see Chapter 05.

FIGURE A-59: EFWS ASSETS AND LIQUEFACTION HAZARD

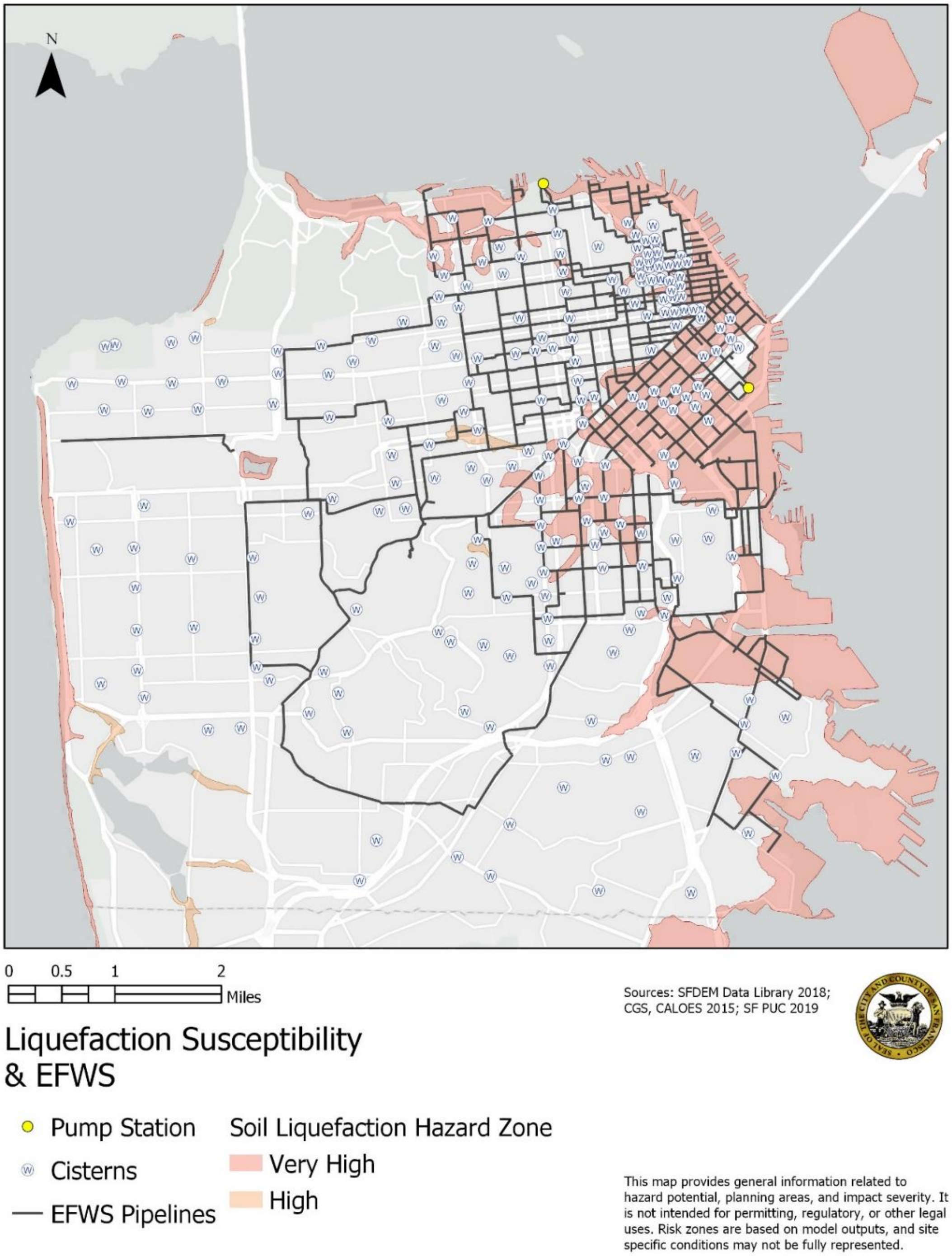
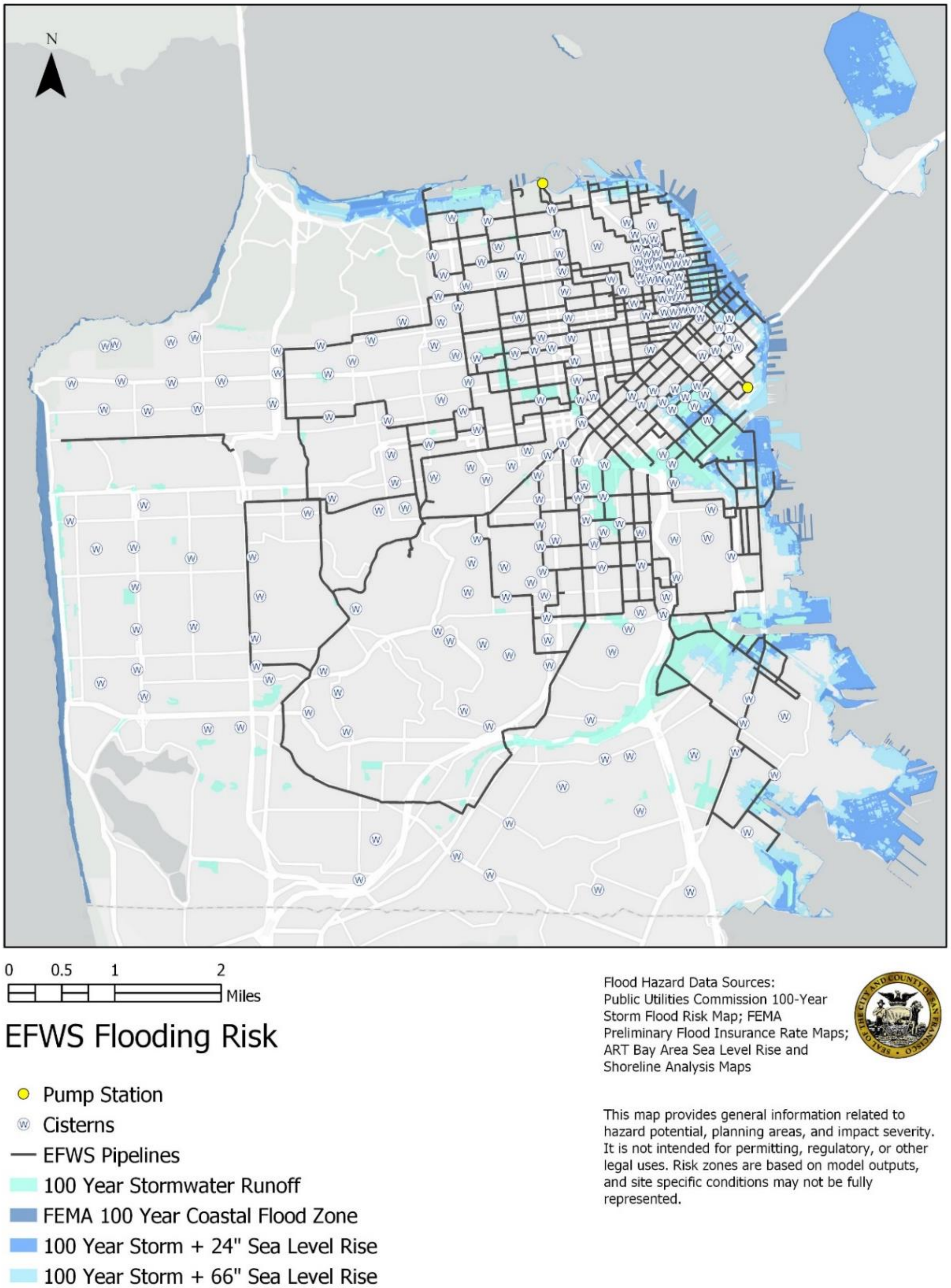


FIGURE A-60: EFWS ASSETS AND FLOOD HAZARDS



VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** EFWS pipelines are vulnerable to damage from bending or pipe joint extension/ compression, particularly where they pass through liquefaction zones. The SFPUC has performed pipe assessment analysis and EFWS pipelines will see some degree of breakage or failure, however, the system is expected to meet level of service goals in the case of a disaster. The SFPUC and SFFD utilize earthquake resistant pipe for new pipeline projects. The rigid pipes in the EFWS system are being replaced with Kaboda, flexible pipe systems that are substantially less prone to damage. Physical damage to valves or loss of power to areas that rely on motorized valves can compromise the ability to immediately isolate damaged sections of the system. However, all motorized valves have the ability to be closed manually. Damage to reservoir or storage tanks could reduce available water supply to fight large fires as well as disrupting operational pressure levels. Twin Peaks Reservoir, Jones Street Tank, and Ashbury Heights Tank have all completed seismic upgrades. Pumping stations may be subject to damage during a large seismic event because the age of the facility as well as the aged status of their mechanical/electrical systems. Pump Station No.1 was recently upgraded and Pump Station No. 2 is receiving seismic retrofits to be completed in 2020. High pressure hydrants have been designed to withstand large earthquake events. **Flood:** Contact with seawater from coastal flooding can increase hydrant corrosion damage. Increasingly frequent contact with seawater can lead to increased corrosion of distribution pipelines. Below grade battery vaults powering motorized valves can become inoperable if exposed to water. These would require repair and replacement in order to be operational again. Additionally, exposure to saltwater can increase valve corrosion damage. Both pumping stations have below ground electrical components that are sensitive to inundation. Additionally, Pump Station No. 2 only has 1 to 2 feet of freeboard in its seawater tunnel during king tides, which is expected to reduce even further as sea levels rise. Upgrades to the

	Pump Station No.2 tunnel is a potential project that SFPUC and SFFD are analyzing. Drafting connection points can become unusable if they are fully inundated by flood waters. **Extreme Heat:** None.
Functional	**Networks:** The system Is heavily networked and disruptions to one area can negatively impact the pressure and performance of the whole system, rendering some areas of the system completely inoperable. Valves can be used to isolate compromised or damaged sections of pipeline so that other areas can remain fully operational. Currently, seismically triggered valves will automatically isolate certain areas prone to liquefaction following any 6.8Mw earthquake or higher. This increases reliability of the whole system until pressure can be verified and valves re-opened. Recent efforts have focused on remotely motorizing valves to shorten response time to pipe breaks and reduce potential loss of stored water. However, their use is circumstantial and not always included as normal operational practice. **External Services:** The EFWS system relies on access to water to operate. The EFWS' primary source of water is the Hetch Hetchy Regional Water System, which feeds the reservoir and tanks that fill the system. A secondary source of water for the EFWS is the San Francisco Bay. Finally, there are approximately 210 cisterns throughout the city that hold water specifically for firefighting. EFWS pumping stations rely on electric power. Both pumping stations have backup diesel generators in the event of a power outage. The EFWS system relies on firefighting apparatus to utilize the water it supplies for firefighting purposes. A two-stage turbine pump can be used to fill Twin Peaks Reservoir from Ashbury tank and can run on an emergency diesel engine in the event of a power outage. Additionally, using ESER Bond funds, the SFPUC added a larger pipe to increase the speed of re-filling the Twin Peaks reservoir from the 11 Million gallon Summit Reservoir. **Populations Served:**

	Generally, the EFWS serves the whole city's population. This is a particularly essential service for individuals with access or functional needs. These individuals may not be able to quickly exit structures during urban conflagration events. **Unique or Critical Function:** The EFWS is one tool that the city can use to avoid urban conflagrations following a severe earthquake. Additionally, it provides year-round assistance fighting multi-alarm fires.
Informational	**All-hazards:** Information regarding seismic and flooding impacts to the EFWS are available from the following publications: Auxiliary Water Supply System [EFWS] (2009),[175] Earthquake Safety Implementation Program (2017), CS-199 Planning Support Services for Auxiliary Water Supply System [EFWS} Project Report (2014),[176] 2019 Sea Level Rise Vulnerability and Consequence (2019)[177]. As new developments and population growth occur in San Francisco, the water required for firefighting to address post-earthquake fires may change. SFPUC is modelling the effects of new developments on EFWS capacity requirements, both within the new developments and in the City as a whole. The SFPUC and SFFD are working together to specify new EFWS piping and hydrants required within the new developments. Additionally, developers are required to contribute financing towards, or construct, EFWS facilities such as pipelines or pump stations, for additional firefighting needs. These requirements are specified in the Development Agreements approved by the Board of Supervisors for new, large development projects.
Governance	**All-hazards:** Analysis showed that the 2010 EFWS was 47% reliable, and thus only able to provide about half of the water needed for city-wide firefighting following a 7.8 earthquake. Utilizing this information, the SFPUC, SFFD, and SFPW identified projects that would increase system reliability and could be funded by the 2010 and 2014 Earthquake Safety and Emergency Response (ESER) Bonds authorized by San Francisco voters. Decisions on which projects to implement utilizing bond funds are based on a given project's ability to improve the reliability score for the Fire Response Area that the

[175] METCALF AND EDDY/AECOM (2009) "Auxiliary Water Supply System Study: Final Report. Retrieved from: https://s3-us-west-2.amazonaws.com/ucldc-nuxeo-ref-media/b2754026-dded-4ee6-b24c-2cf837f3bc00
[176] AECOM/AGS (2014). "CS-199 Planning Support Services for Auxiliary Water Supply System (AWSS): Project Report". Retrieved from: https://sfwater.org/Modules/ShowDocument.aspx?documentid=5055
[177] SF Planning (2019) "SLR Vulnerability and Consequences Assessment"

	given project serves and its ability to increase the likelihood of delivering water after an earthquake. Bond-funded projects make seismic upgrades to the system and repair, replace, and extend system components to increase the ability to provide adequate water for firefighting. Funding is allocated to repair, replace, and extend system components to improve the ability to provide adequate water for firefighting purposes following a major earthquake and during multiple-alarm fires from other causes. This includes repairs and upgrades to core facilities, pipelines, and tunnels, and construction of new cisterns. Once fully completed, the projects implemented with the ESER 2010 bond funds will increase the citywide reliability score from 47% to 67%. The full completion of the projects implemented with the ESER 2014 bond funds will increase the citywide reliability score from 67% to 87%. Construction of additional recommended future projects will increase the citywide reliability score to 96%. Overseeing the selection and implementation of EFWS projects is the Management Oversight Committee consisting of the SFPUC General Manager, SFFD Chief, SFPW Director, and SFPUC Assistant General Manager of the Water Enterprise. The San Francisco Capital Planning Committee, consisting of the City Administrator and including the President of the Board of Supervisors, the Mayor's Budget Director, the Controller, the City Planning Director, the Director of Public Works, the Airport Director, the Executive Director of the Municipal Transportation Agency, the General Manager of the Public Utilities System, the General Manager of the Recreation and Parks Department, and the Executive Director of the Port of San Francisco, reviews the progress and implementation of EFWS capital projects. Capital Planning Committee meetings are open to the public.

Consequences

Category	Consequence
Society/Equity	**Geologic:** If the EFWS were disrupted, firefighting abilities may be compromised, thereby increasing the likelihood of urban conflagrations that threaten life safety and property. Fires may cause health impacts, including death or injury as well as illness due to exposure to smoke and toxic substances. Community members with access and functional needs and the elderly are more likely to experience health impacts from fires due to potential reduced ability

	to evacuate a building. Increased fire damage would cause displacement and disrupt community and social networks. Damage to businesses may impact jobs and workers. **Flood:** Disruption of the EFWS may compromise firefighting capabilities during the flood event. However, it is possible that the portion of the EFWS network impacted by flooding would not have its performance affected by the flooding. If its performance was impacted, the impacted portion could be isolated from the rest of the system, limiting the level of disruption.
Economy	**Geologic:** If the system were to be significantly disrupted during a major earthquake event, the risk of building damage due to fires and resultant loss of economic activity could increase. Depending on the scale of fire damage, the consequences could be at the scale of the neighborhood, citywide, or regional. Additionally, there would be replacement costs for damaged pipes or other components. **Flood:** Shortened repair and replacement cycles from increased corrosion due to exposure to seawater can increase the costs of maintaining the distribution pipeline system. This is particularly notable in the bay shore area that is most prone to damage from liquefaction, which could become more likely in corrosion-weakened distribution pipelines. There may also be repair and replacement costs of below grade valve system/pump station components from flood damage. This could particularly effect critical electrical components as well as underground battery vaults.
Environment	**All-hazards:** Disruption of the system could lead to more severe fires, increasing contamination of air, soil, and water from toxic materials commonly found in urban areas, such as asbestos and household chemicals. **Geologic:** Decreased ability to fight urban conflagrations would have a temporary impact on the air quality following a seismically induced urban conflagration event. This would have implications at the citywide scale.

Combined Sewer System

Introduction to Asset Class

San Francisco's combined sewer system treats over 70 million gallons of combined wastewater during dry conditions and peaking to as much as 575 million gallons during wet weather conditions. The collection system is largely gravity driven, using an interconnected web of combined sewers, tunnels, and transport/storage boxes to intercept, store, and convey combined sewer flows throughout the City. Where gravity isn't sufficient to move this water around the system, or where weather conditions require the use of different facilities, force mains and pumping stations move wastewater to its eventual destination at one of three treatment facilities. Following treatment to nationally permitted standards, effluent is either discharged to the Pacific Ocean through one of eight combined sewer discharge outfalls on the Western/Pacific shoreline or discharged to the Bay through one of the twenty-nine outfalls located along the Bayshore.

For the purposes of this assessment, the combined sewer system is composed of seven sub-assets that are spread across the city with different patterns based on their function.

- **Combined sewer pipes and tunnels** convey sewage from buildings and runoff from streets and are spread widely throughout the City. This infrastructure has a wide inland extent as there are countless points of combined wastewater generation across the city.
- **Pumping stations** are predominantly located along the Pacific coast or Bayshore with a few exceptions, and connected to the force main infrastructure.
- **Force mains** are typically buried conduits used when gravity flow is not sufficient to move combined sewer flows through a sewer. They link pump stations to other part of the collections system or deliver combined wastewater to treatment facilities.
- **Outfalls and transport/storage boxes** ring the City's coastal area and transport flows from the collection system to the treatment facilities, and storage of combined sewer in wet weather events.
- **Treatment facilities** receive combined sewer flows from the system for treatment before being discharged into the San Francisco Bay or Pacific Ocean. Two of the three treatment facilities that make up the system are considered

aged and the City has been investing heavily in improvements in recent years. The North Point Wet Weather facility (Constructed in 1951) only operates in wet weather conditions and is found close to the Bayshore near Fisherman's Wharf. The Southeast Treatment Plant (Constructed in 1952) is located in Bayview/Hunters Point, is San Francisco's largest wastewater facility, and serves the eastside of the City. The Oceanside facility is the youngest in the system (Constructed in 1993), is located near the Pacific Ocean and the San Francisco Zoo, and serves the westside of the City. The Southeast Treatment Plant and the Oceanside Treatment Plant operate 24 hours a day, every day of the year with the North Point Treatment Facility brought online during large rain events.[178]

Every resident, worker, public/private organization, or tourist relies on the combined sewer system to manage wastewater generated in the city. SFPUC's Wastewater Enterprise is responsible for operation, maintenance, and capital improvement of all the combined sewer system assets and facilities.

Issue Statement

The combined sewer system provides a vital service by treating wastewater and stormwater before it is discharged into the Bay or ocean. While the combined sewer system has a high exposure to seismic hazards, significant investment has been made to improve the seismic performance of the system, mainly at the treatment facilities. Coastal flooding will become increasingly become an issue as sea level rises, particularly for sensitive assets in low-lying coastal areas, including outfalls, pump stations, and force mains. While specific consequences of disruption in San Francisco have not been studied, generally negative impacts to environmental health can be expected from the discharge of untreated wastewater into ecosystems. Impacts to economic activity and human health can also potentially occur from the inability to remove waste from homes and business. This document is intended to conceptually describe the various assets and potential effects of service disruption.

[178] SF PUC, San Francisco's Wastewater Treatment Facilities (2014). Retrieved from: https://sfwater.org/modules/showdocument.aspx?documentid=5801

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table below, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault 7.8M and Hayward Fault 7.0M events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data originates from datasets maintained by SFPUC, SF Planning, and SF DEM (2019).

Exposure Summary

Geologic: All combined sewer assets would be exposed to violent or very strong shaking in a 7.8 earthquake on the San Andreas Fault. A smaller share of infrastructure would be exposed to violent or very strong shaking in a 7.0 on the Hayward fault, but this does include almost half of pump stations and Southeast Treatment Plant. A large share of pump stations, force mains, and transport/storage boxes, and outfalls are located in the liquefaction hazard zone.

Flood: Pump stations and outfalls have greater exposure to coastal flooding than other asset types. With 66 inches of sea level rise and a 100-year coastal storm event, nearly half of all outfalls and 75% of pumps may be exposed to flooding.

Fire: Only a small amount of combined sewer system assets are exposed to moderate wildfire risk.

TABLE A-36: EXPOSURE

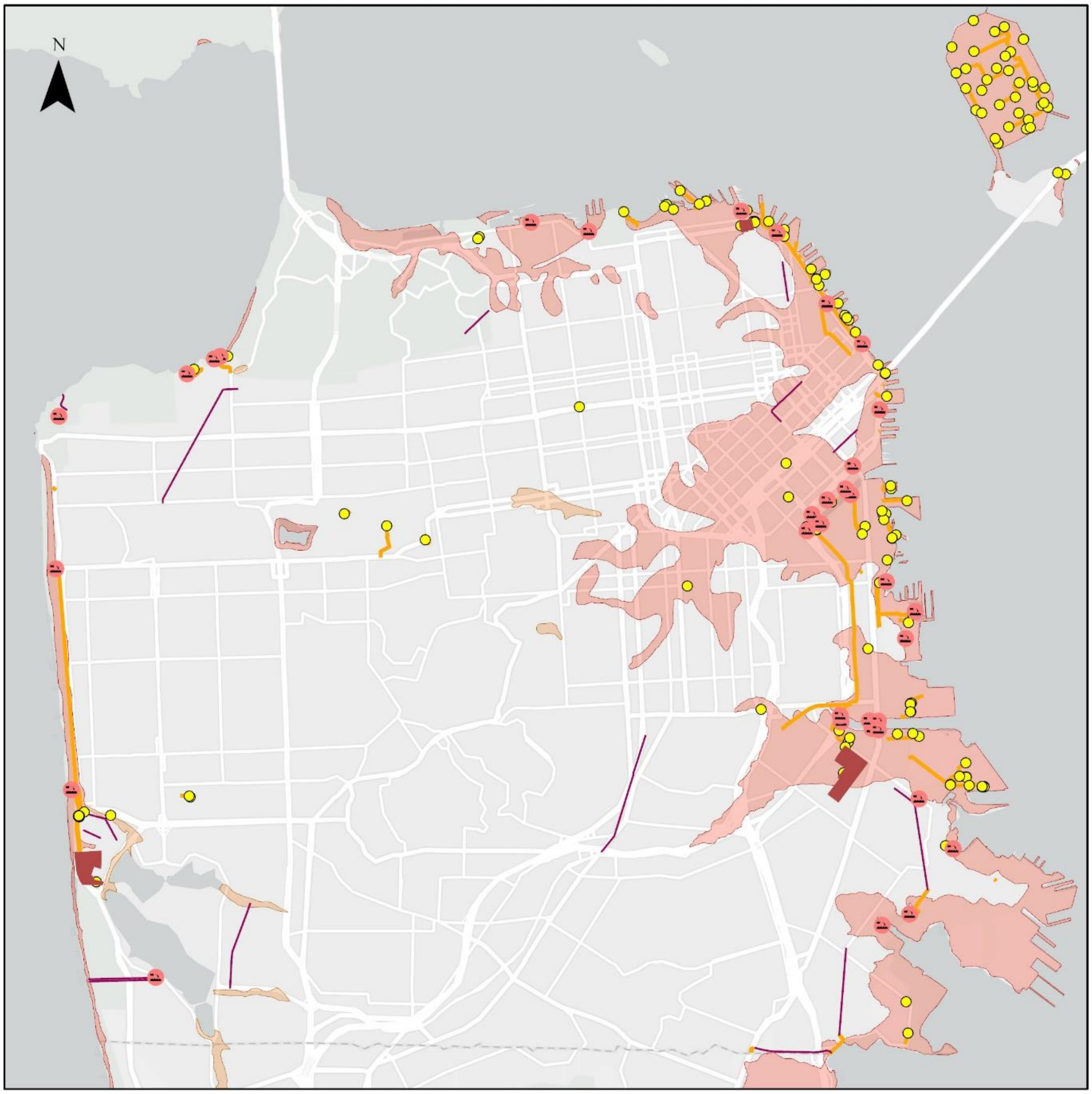
Hazard	Combined Sewers 1,058 Miles Total		Tunnels 8 Miles Total		Pump Stations 181 Pumps in 32 Pump Stations Total [(a)]		Force Mains 23 Miles Total		Transport and Storage Boxes 16 Miles Total		Outfalls 34 of 37 Total [(b)]		Treatment Plants 3 Total	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Geologic														
San Andreas 7.8 - Violent	303	29%	4	47%	74	41%	8	100%	9	57%	17	50%	1	33%
San Andreas 7.8 - Very Strong	755	71%	5	57%	107	59%	15	66%	7	46%	17	50%	2	67%
Hayward 7.0 - Very Strong	88	8%	1	13%	93	51%	11	48%	5	32%	12	35%	2	67%
Hayward 7.0 - Strong	681	64%	5	57%	87	48%	12	52%	5	31%	21	62%	1	33%
Liquefaction Zone	200	19%	1	13%	160	88%	20	87%	11	69%	24	71%	2	67%
Flooding														

100-Year Coastal Flood Zone	15	1%	0	0%	61	34%	3	13%	1	6%	7	21%	1	33%
100-Year Storm + 24 inches SLR	63	6%	0	0%	78	43%	9	39%	4	25%	8	24%	2	67%
100-Year Storm + 66 inches SLR	107	10%	0	0%	135	75%	14	61%	7	44%	16	47%	2	67%
100-Year Stormwater Flood Risk	39	4%	0	1%	21	12%	1	4%	3	19%	10	29%	1	33%
Wildfire														
High	1	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Moderate	21	2%	1	13%	5	3%	0.4	2%	2	13%	2	6%	0	0%

(a) Data was available for 181 individual pumps, some of which are redundant. Numerous pumps are located at 32 pump stations around the city.

(b) Data was only available for 34 out of 37 outfall locations. Eight outfalls are located on the Westside and 29 on the Bayside

FIGURE A-61: COMBINED SEWER ASSETS AND LIQUEFACTION HAZARD



0 0.5 1 2 Miles

Sources: SFDEM Data Library 2018; CGS, CALOES, 2015

Liquefaction Susceptibility & Shoreline Protection Assets

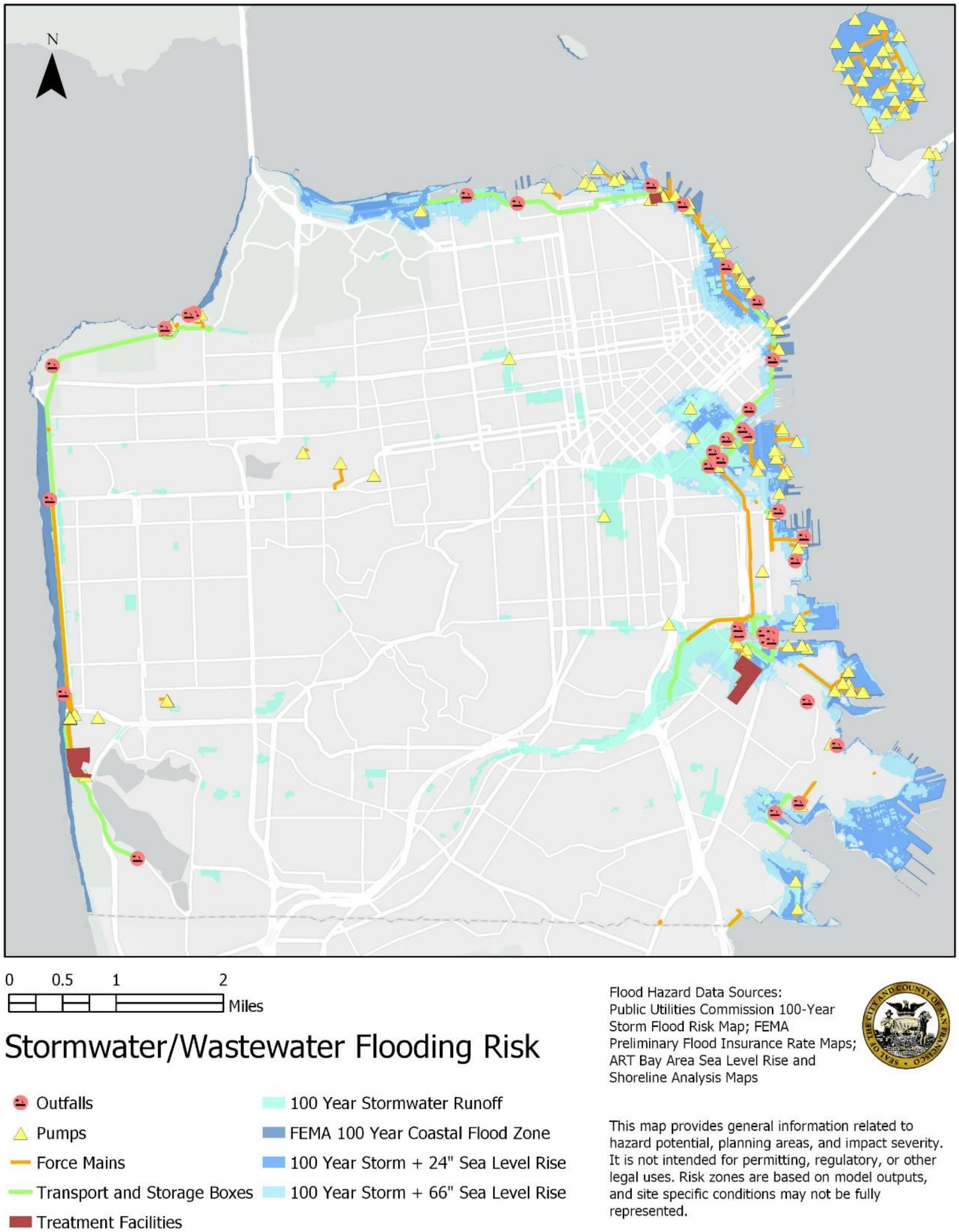
- Outfalls
- Pumps
- Force Mains
- Treatment Facilities
- Tunnels

Soil Liquefaction Hazard Zone

- Very High
- High

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

FIGURE A-62: COMBINED SEWER ASSETS AND FLOOD HAZARDS



VULNERABILITIES

Category	Vulnerability[179 180]
Physical	**Geologic:** Pump stations are vulnerable to damage during significant ground shaking events due to land movement and liquefaction. Areas of all three treatment plants are seismic hazard zones based on their development on Bay fill material or in areas vulnerable to landslides Aspects of the older treatment plants were not constructed to modern seismic building codes, although improvements are underway to retrofit them. For example, all three plants have undergone seismic reliability and condition assessments and seismic retrofits are underway. Underground infrastructure (force mains, tunnels, combined sewers, and transport/storage boxes) may be susceptible to damage due to their linear nature and their potential placement in liquefaction prone soils. Some of the larger infrastructure, such as tunnels and T/S boxes, are constructed on piles or are in bedrock. An asset-specific analysis of the underground infrastructure is beyond the scope of this document. **Flood:** Pump stations are vulnerable to structural damage from direct wave action, coastal erosion, and potential storm surge/stormwater inundation from numerous non-flood proofed entryways in their structures. Many pump station control components are located below grade, making them particularly vulnerable. The Southeast Treatment Plant and North Point Wet Weather Facility are vulnerable to future storm surge events based on projected SLR. Many treatment plant components, such as electrical components, may be salt-sensitive so exposure to coastal flooding can render a facility inoperable for an extended time. Combined sewer discharges during wet weather may be interrupted when outfalls are exposed to flooding for an extended period of time and this disrupts the ability of the system to discharge combined sewer flows if the treatment and storage capacity of the entire system is maximized. Presently, many outfalls are below current 100-year storm surge elevations and may see saltwater intrusion during this severity of storm today. Sensitivity to flooding is largely dependent on whether an outfall as backflow prevention. SFPUC has

[179] San Francisco Public Utilities Commission (2019) "*Climate Vulnerability and Adaptation Assessment, Sewer System Improvement Program*"
[180] SF Planning (2019) "*SLR Vulnerability and Consequences Assessment*"

	a plan to install backflow prevention at the outfall structures over time as part of the capital improvement plan. Underground infrastructure is vulnerable to the corrosive effects of saltwater which can occur from permanent inundation or from compounded temporary events. SLR induced saltwater intrusion can also potentially physically damage these components or result in a loss of storage capacity. Interdependent vulnerabilities are also a concern. For example, storm surge can impact the function of outfall infrastructure and because the sub-assets are connected, water can backflow through outfalls all the way to the treatment plant, impacting the effectiveness of treatment plant processes. **Extreme Heat:** Generally, warmer temperatures correlate with drought and heatwaves which can cause odor management or conveyance issues in the collection system. Biological treatment processes are temperature sensitive. In the long term, by the end of the century, elevated summer temperatures and prolonged heat waves may begin to impact biological wastewater treatment processes, leading to increased difficulty meeting effluent discharge standards. The potential effects of warmer temperatures on San Francisco's biological treatment plant processes have not been studied.
Functional	**Networks:** The system is heavily networked to introduce flexibility in moving sewage from one part of the system to another as available capacity or treatment volume demands change. The system is also networked to route combined stormwater from numerous collection points around the city to just three centralized treatment plants. While the network provides flexibility, it also poses some risks. For example, outfalls have been identified as a network vulnerability because they are directly connected to transport/storage boxes, often without backflow preventers, and some may be prone to flooding during a 100-year storm event. Additionally, disruption of particular sub-assets can impact a large portion of the network. Due to the location of treatment plants at the terminus of the collection system, their disruption would have significantly more wide felt impacts than sub-assets further upstream. There are no viable alternatives if the entire networked system was severely disrupted. If certain elements were to fail, there is spare capacity in the system that can be utilized to collect wastewater and wait out the disruption. However, this is dependent on dry weather conditions as wet weather conditions would quickly exceed the

	storage capacity that transport/storage boxes normally have when they convey wastewater to treatment plants. **External Services:** The combined sewer system is dependent on electric power. Some pump stations have backup power to continue flowing sewage to treatment plants, however, the electrical capacity needed to power the treatment process exceeds the energy that can be provided by backup power systems.[181] If power supply were disrupted, pumping and aeration would be impacted. Prolonged disruption can interrupt biological treatment process, which can take days/weeks to recover. The system depends on the transportation network for delivery of necessary chemicals via truck from Southern California and Richmond. In addition, effective operation of the system requires coordinated efforts of numerous staff who rely on a secure transportation network to reach system infrastructure.[182] Coordinating efforts between system components also requires external telecommunication services. **Populations Served:** Combined sewer systems serve all community members and businesses. **Unique/Critical function:** Wastewater treatment is critical to maintaining a healthy Bay ecosystem, a function that is nearly impossible to replace. SFPUC integrates green infrastructure in their urban water management approach and focus on increasing on-site stormwater retention. This provides a variety of co-benefits for city residents as well as replenishing groundwater beneficial to urban habitats.
Informational	**All-hazards:** General information on impacts of coastal/stormwater flooding and extreme heat hazards are available through the following SFPUC publications: Draft Climate Vulnerability and Adaptation Assessment (forthcoming, 2019), Urban Watershed Assessment, Collection System Capital Needs Report, and the Flood Resilience Study. However, site specific characteristics of sub-asset vulnerability are not readily available for analysis (i.e., where flood vulnerable

[181] Andrew C, Henderson B, Harris M, Harrison L, McDaniels C, Prather J, Norby G, Koehler-Downie "SFPUC Sewer Lifelines Interview" Interview by Mieler D. 8/14/18
[182] Andrew C, Henderson B, Harris M, Harrison L, McDaniels C, Prather J, Norby G, Koehler-Downie "SFPUC Sewer Lifelines Interview" Interview by Mieler D. 8/14/18

	components are located on site, where non-flood proofed entryways are in relation to flood prone areas). Another notable information source is the Lifelines Restoration Timelines Project currently being pursued by ORCP which identifies interconnected points between wastewater and other lifeline systems in order to propose potential interventions to improve resiliency.
Governance	**All-hazards:** Notable policies governing system maintenance, repair, or improvement of assets in this class are the SSIP Program and Level of Service Goals which are based on M7.8 San Andreas Fault and M7.1 Hayward Fault events. This policy works to ensure that the system can treat flows within 72 hours of a major earthquake or catastrophic event. Additionally, the Capital Planning Committee SLR guidance ensures that any new facilities are planned and designed to consider SLR projections in their development. Repair policies include contractual obligations with private contractors that perform roughly 75% of repairs as well as contractual obligations with DPW for the remaining 25% of repairs. The duties of these parties in times of disaster remains unclear.[183] Currently, the most appropriate funding source for improvements to these assets comes from the $2.9 Billion dollars allocated for Phase One of the SSIP Program. Additional funding will likely be available during subsequent phases, pending approval from the SFPUC Commission. A variety of state and federal grants have been identified for projects improving, protecting, or enhancing water quality. Many improvements to the combined sewer system would also satisfy this criteria.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** There are potentially significant impacts to health and human safety in the event of a disruption to the combined sewer systems. Collapse of combined sewer pipes can allow sewage to back up into streets or in home systems that aren't outfitted with a backflow preventer, increasing the risk of community member contact with human waste and related pathogens. In the case of disruption during wet weather conditions, stormwater flooding on streets can also put

[183] Ibid.

	the community in contact with pathogens found in combined sewage water. Flooding can also presents challenges for vulnerable populations with mobility impairments. **Geologic:** Loss of the ability to dispose of waste from homes can increase community members contact with human waste and attendant pathogens unless proper procedure is followed. **Flood:** Disruption of the system during wet weather conditions can increase stormwater flooding, particularly in low-lying areas, which can disrupt the ability of community members to safely access their own neighborhoods, jobs, or participate in their regular community social events. If disruption of the system leads to the temporary closing of businesses, the lost income could impact the ability of community members to pay their bills. This impact would be more pronounced for low-income families, which may even extend to their ability to purchase essential goods.
Economy	**All-hazards:** If businesses lose the ability to flush their toilets or dispose of waste, they may have to temporarily shut down, losing revenue. Disruptions that lead to more untreated sewage reaching the Bay and Pacific Ocean can have impacts on tourism due to increased prevalence of litter or odor management issues. If effluent from required hazard induced discharges into The Bay or Pacific Ocean exceed water based effluent limits for any given pollutant, it is expected that operational costs would increase due to the structure of the permit based National Pollutant Discharge Elimination System (NPDES)[184]. **Geologic:** In the case of severe shaking, such as a 7.8M San Andreas Fault or 7.0M Hayward Fault seismic event, the treatment system will be automatically shut down in order for an immediate condition assessment on broken pipelines and other infrastructure. At a minimum the system would be down for at least 24 hours before primary treatment could begin. However, the duration of system disruption would be comparatively short if system components are not severely damaged. However, damage from seismic events to treatment plant assets can damage expensive, unique equipment that can compromise secondary treatment that is costly to replace.

[184] WERF (2009) "*Implications for Climate Change for Adaptation by Wastewater and Stormwater Agencies*" Retrieved from: http://www.climatestrategies.us/library/library/download/960

	Flood: If collection is disrupted leading to backups and flooding, businesses may temporarily close. **Extreme Heat:** If increased heatwave events reduce the efficiency of the treatment process, it can become more costly to treat combined wastewater up to effluent standards or result in more permit violations and subsequent payments.[185]
Environment	**All-hazards:** Disruption of the system may result in water quality permit violations and impact the ecosystems and habitats of San Francisco Bay and the Pacific Ocean from the release of minimally treated sewage. Coastal waters may see microbiological contamination, oxygen depletion from high concentrations of fecal matter, or potentially, eutrophication from excess nutrients. These impacts would depend heavily on the volume of combined sewage released and the duration of the disruption. Without the treatment of sewage before release, many industrial pollutants can make their way to surrounding ecosystems in The Bay and Pacific Ocean as well. This would have a strong impact on regional environmental conditions.

[185] Ibid.

Shoreline Protection

Introduction to Asset Class

Shoreline infrastructure provides a critical function to much of the city, including flood protection during storms and extreme tide events, habitat, recreation opportunities, and public access. It also supports key utility and transportation infrastructure, including BART, Muni, the Port maritime facilities and ferry transportation. During an emergency it supports emergency response and recovery operations. Shoreline protection around San Francisco is made up of a variety of shoreline types and conditions, including beaches and bluffs along the western and northern shoreline of San Francisco, which fronts the Pacific Ocean and structural protection in many forms along the eastern and southern shorelines of the city along the San Francisco Bay.[186] The elevation of the shoreline also varies, with some of the lowest areas between the Bay Bridge and Pier 9 and in the southern waterfront. Some of the highest shoreline elevations can be found near Fort Mason and along the northern edge. The risks to shoreline protection infrastructure are related to several factors, including age, maintenance schedule, construction materials and methods, soil/substructure composition, elevation and near-shore conditions. Shoreline infrastructure in San Francisco is not able to provide the level of service that it has in the past, given its current elevation, age and condition.

The majority of San Francisco's shoreline protection infrastructure is owned by public agencies, including the Port of San Francisco and the Department of Parks and Recreation; and the National Park Service. Although the majority of the owners and managers of the city's shoreline protection are public entities, none of these agencies have flood management as a primary role or have dedicated funding or mandates to focus significant resources on flood management. However, the City is prioritizing action to improve the Embarcadero Seawall to reduce risks to the City from earthquakes and flooding, with the Port leading the effort.

[186] Regional resource and research agencies and organizations have been working together to classify the types of shorelines that make up the region's current Bayfront. These eight shoreline types are identified as engineered levee, berm, shoreline protection structure, embankment, transportation structure- major road, transportation structure-railroad, natural shoreline and wetlands. Further information about this analysis can be found here: https://www.sfei.org/content/flood-infrastructure-mapping-and-communication-project#sthash.Kj0plZxL.dpbs.

Issue Statement

Shoreline infrastructure provides a critical function to much of the City, including during an emergency. In most locations, failure of the infrastructure due to flooding, erosion, settlement or seismic event would cause significant impacts to community, economic and environmental resources. Areas of shoreline protection infrastructure serve as essential transportation, maritime and utility connection points while being seismically vulnerable. Future sea level rise and storm events can be expected to contribute to overtopping and flooding impacts across a wide geographic range of this asset and this flooding will potentially span multiple neighborhoods.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table below, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault 7.8M and Hayward Fault 7.0M events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data is sourced from the SF Bay Shore inventory GIS data created by the San Francisco Shoreline Estuary Institute in 2016. To convey overtopping for 100-year storm events with different sea level rise scenarios, each map displays color where overtopping would likely occur. The color displayed shows the type of shoreline found at the site of likely overtopping as well.

Exposure Summary

Geologic: All shoreline protection infrastructure is exposed to violent or very violent shaking in a 7.8 earthquake on the San Andreas Fault. Notable amounts of shoreline protection infrastructure are subjected to violent or very strong shaking in a 7.0 earthquake on the Hayward fault. As much as 70% of shoreline protection structures and 80% of embankments are subjected to liquefaction hazard zones.

Flood: Flooding exposure is described as the amount of overtopping seen by each shoreline type based on the two sea level rise scenarios. With 24 inches of SLR, significant overtopping can be expected in the north, in down town, and to the south but many pier structures remain protected. However, with 66 inches of SLR, virtually all shoreline protection assets can expect to see some degree of overtopping without intervention.

TABLE A-37: EXPOSURE

Hazard	Berm 1 Miles Total		Embankment 6 Miles Total		Natural Shoreline 5 Miles Total		Shoreline Protection Structure 37 Miles Total		Transportation Structure .11 Miles Total		Wetland .32 Miles Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Geologic												
San Andreas 7.8 - Violent	0.41	100%	3	44%	4	100%	16	42%	0	0%	0	0%
San Andreas 7.8 - Very Strong	0.57	57%	3	54%	1	19%	19	52%	0.1	100%	0.32	100%
Hayward 7.0 - Very Strong	0.28	28%	4	67%	0.6	12%	24	65%	0.05	53%	0	0%
Hayward 7.0 - Strong	0.70	70%	0.5	8%	4	86%	11	29%	0.05	54%	0.32	100%
Liquefaction Zone	0.9	90%	5	83%	3	60%	26	70%	0.1	100%	0.32	100%
Flooding												
100-year storm + 24 inches SLR	0.8	80%	5	83%	2	40%	19	51%	0.06	55%	0.32	100%
100-year storm + 66 inches SLR	0.9	90%	6	100%	3	60%	34	92%	0.07	64%	0.32	100%

Note: For an exposure table with additional hazards, please see Chapter 05.

FIGURE A-63: SHORELINE PROTECTION AND LIQUEFACTION HAZARD

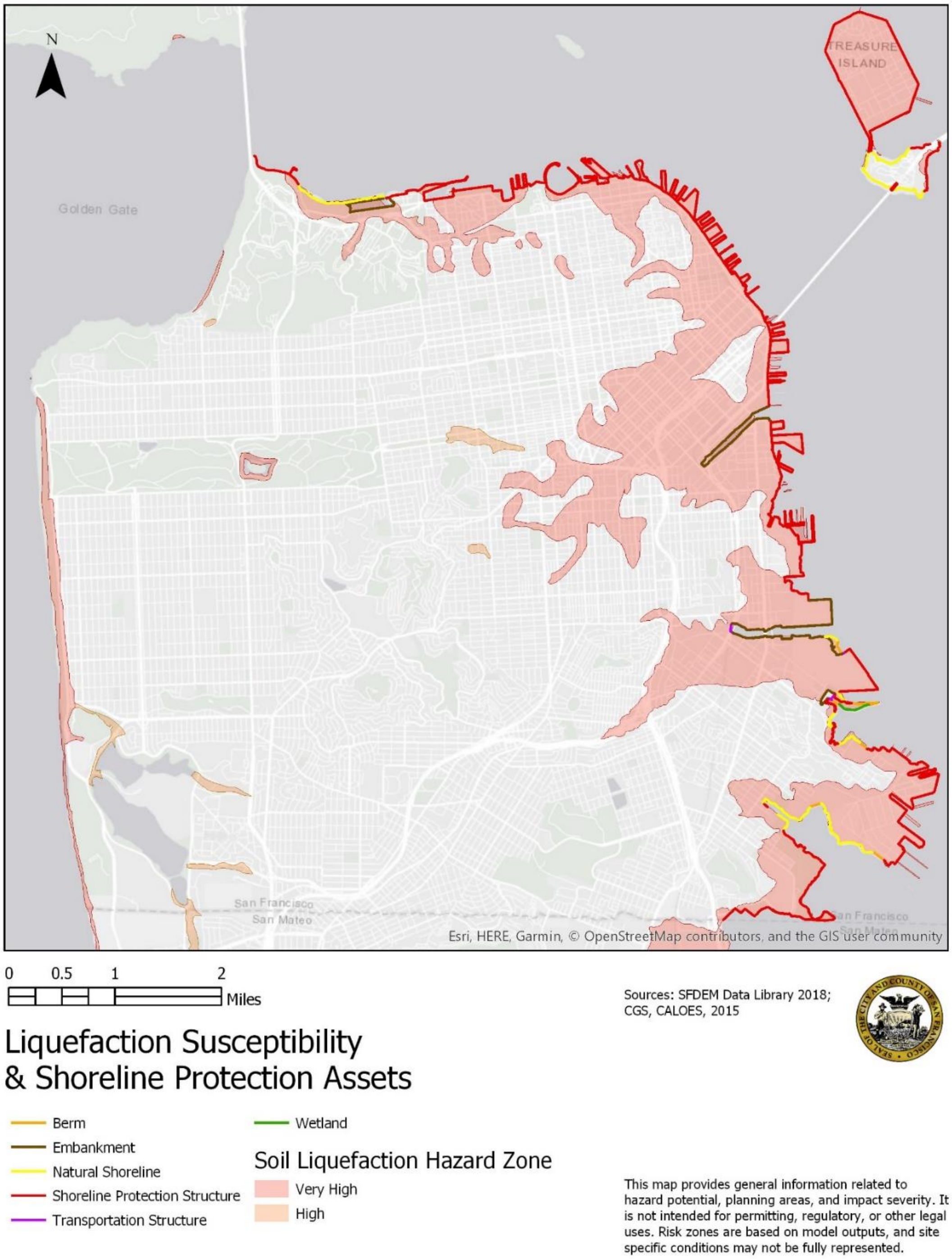
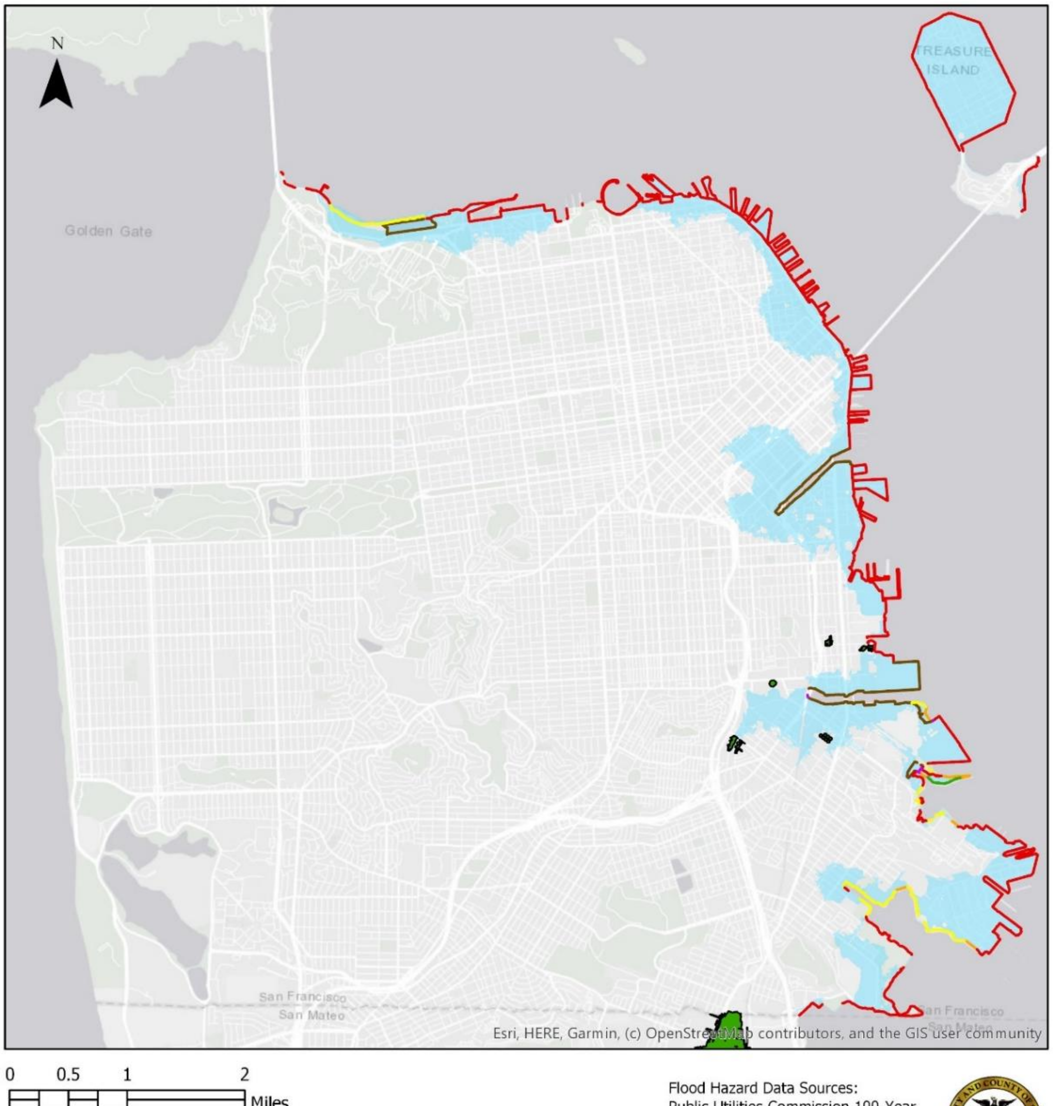


FIGURE A-64: SHORELINE PROTECTION AND FLOOD HAZARD (100 YEAR STORM + 24" SEA LEVEL RISE

FIGURE A-65: SHORELINE PROTECTION AND FLOOD HAZARD (100 YEAR STORM + 66" SEA LEVEL RISE)



Shoreline Protection Flooding Risk

Shoreline Protection Type
- Berm
- Embankment
- Natural Shoreline
- Shoreline Protection Structure
- Transportation Structure
- Wetland
- Low Lying Disconnected Areas Subject to Flooding
- 100 Year Storm + 66" Sea Level Rise

Flood Hazard Data Sources:
Public Utilities Commission 100-Year Storm Flood Risk Map; FEMA Preliminary Flood Insurance Rate Maps; ART Bay Area Sea Level Rise and Shoreline Analysis Maps

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** The shoreline is made up of fill along most of the Bay shoreline along the eastern and southern parts of the shoreline, making settlement and liquefaction risks more significant for these areas. Many of the shoreline structures, including the Embarcadero Seawall, were constructed prior to current seismic standards and have not been retrofit. **Flood:** Shoreline infrastructure has characteristics that make it vulnerable to flooding, including the elevation of the infrastructure, the age of the infrastructure, the soils and foundation that supports the infrastructure, the nearshore environment, the maintenance schedule and the materials used to construct the infrastructure. San Francisco's shoreline infrastructure was designed for lower water levels and without consideration of sea level rise. Much of the shoreline currently consists of ad hoc flood protection and was not intended to protect against higher water levels. Much of the shoreline infrastructure is beyond its expected project life and has not been significantly maintained or rehabilitated. **Extreme Heat:** Not vulnerable to extreme heat. **Fire:** Not vulnerable to fire.
Functional	**Networks:** If one segment of the shoreline infrastructure along the City's shoreline were to be overtopped by a flood event or damaged in an earthquake, the damage would extend beyond the segment and cause water to inundate the areas around the damaged segment. If parts of the shoreline are damaged, temporary flood management (such as deployables, pumps, etc.) could be used to keep water out of as many areas as possible. However, it is uncertain whether there is sufficient equipment available to deal with a shoreline failure. **External Services:**

	Power and fuel are important if pumps are used as a back-up in the case of shoreline infrastructure failure. **Populations Served:** Shoreline infrastructure that protects the neighborhoods, services, and jobs of those with access or functional needs includes areas where there is a large population of people, such as the Embarcadero Seawall segment and Mission Bay and areas with shoreline protection that serve significant geographic area, including those locations as well as Ocean Beach and Islais Creek. **Unique or Critical Function:** Much of San Francisco's shoreline infrastructure serves as, or is directly adjacent to, recreational and habitat areas, as well as interpretive and educational sites. Examples include Heron's Head Park and the Ecocenter in the Southern Waterfront: the Embarcadero Seawall which includes Rincon Park, the Embarcadero Promenade, Piers 7 and 14, Brannan Street Wharf and the Exploratorium along the Northeastern Waterfront and a significant amount of open space along the Northern and Western shorelines including Marina Green, Crissy Field and other open spaces and natural areas. Emergency responders rely on the stability of the shoreline infrastructure, particularly along the eastern portion San Francisco's shoreline. After a significant event, the shoreline will be used to move people who work in the City but live elsewhere out of the City and move supplies and emergency responders into the City. Additionally, after a significant event, emergency responders will need to deal with the direct impacts of the event and limiting secondary events, such as flooding caused by the failure of shoreline infrastructure or damage to utilities and transportation due to the failure of shoreline infrastructure, will make it much more challenging to respond to an event. The Port’s maritime industries and historic resources also serve unique and critical functions in the city’s economy. Maritime industries include cargo, cruise, fishing, ship repair, ferries, and recreation. All of these industries rely heavily on the Port waterfront, and associated shoreline protections, to operate effectively. Shoreline protections assets are also responsible for preserving the three National Register historic districts along our waterfront: Central Embarcadero Piers Historic District, Embarcadero Historic District, Union Irons Works Historic District
Informational	**All-hazards:** There have been a number of recent studies for some segments of the City's shoreline infrastructure. The Citywide SLR work has

	included mapping of the entire City shoreline. The regional shoreline typology work provides some understanding of the shoreline type and elevation. The Ocean Beach Master Plan provides information on the western shoreline. The earthquake and flood studies for the Embarcadero Seawall provide an overview of the risks in that segment. The Seawall Program's Multi-Hazard Risk Assessment will provide a more refined understand of the vulnerabilities and consequences of seismic and flooding along those three miles. There is a lack of analysis related to the seismic risks to other parts of the shoreline infrastructure outside of the Embarcadero Seawall. Additionally, the risks of combined coastal and riverine flooding in the areas where creeks enter the Bay is also a gap in knowledge. There is some information available on shoreline conditions from the agencies, such as the Port of San Francisco, Parks and Recreation and Public Works, that manage the shoreline, but it is not in one dataset.
Governance	**All-hazards:** There are planning and analysis efforts in place, such as the Lifelines and Hazard Mitigation Planning where City priorities are identified in order to take action. For example, the Embarcadero Seawall was identified as a priority in the Lifelines Interdependency Study of 2014. Capital Planning funding, SB1 Funding, Port capital funding. It is important to note that the funding available for assessment and taking action is significantly less than what is needed.

CONSEQUENCES

Category	Consequence
Society/Equity	**Geologic:** If a significant earthquake were to damage the shoreline infrastructure along the San Francisco shoreline it could have significant impacts on society and equity- disrupting the ability of those who are transit dependent to travel; the ability to get to work, school, other critical trips; small businesses; may result in difficulties to respond to an earthquake and to recover from it which would impact the neighborhoods closest to the failed infrastructure and those who lack redundant networks and assets. Damage to utilities would have widespread impacts on a large number of neighborhoods. Existing issues such as housing and transportation costs, transportation access, access to jobs, income and health disparities could be exacerbated by a significant earthquake that damages shoreline infrastructure and results in disruption or temporary displacement of homes, businesses or other services. Damage to the shoreline infrastructure due to an earthquake would also have significant impacts on historic, cultural and recreation resources along the shoreline, including the Embarcadero Historic District, the Ferry Building, the Embarcadero Promenade and many shoreline open spaces. **Flood:** If a significant flood event were to temporarily overtop the shoreline protection along the San Francisco waterfront it could disrupt transportation and utility services, affect people's ability to travel to work or make other trips, disrupt small and local businesses and damage homes and neighborhoods, as well as damage the cultural, historic and recreational resources along the shoreline. Additional issues related to flood damage including mold and the possible mobilization of contaminants which could result in larger impacts to community members with underlying health conditions such as asthma.
Economy	**Geologic:** Significant damage to Port facilities, the Embarcadero, the transportation and utilities in the Embarcadero, recreation and natural areas, historic and cultural resources, jobs, maritime uses, and other roadways and utilities adjacent to the shoreline. The scale of impact could range from the neighborhood to the region and state. **Flood:**

	Currently there are portions of the San Francisco shoreline that are within the 100 year flood zone. As sea level rises, the area that is at risk from flood events will increase. These areas include significant sections of downtown San Francisco, regional and Citywide transportation infrastructure including BART, MUNI and ferry service; Citywide utilities are also at risk from coastal flood events, some of the City's last maritime and industrial land. Even temporary disruption of some of these sections of the city could have significant economic impacts. The scale of impact could range from the neighborhood to the region and state.
Environment	**Geologic:** If a significant earthquake were to damage the shoreline infrastructure there would also likely be damage to water and soil quality from the debris that would result from such a failure, habitat and species could be affected by the mobilization of debris and contaminants, a significant amount of public access and open space could be disrupted and damaged and flood risk would increase as the shoreline infrastructure failed and water overtopped the damaged, lower shoreline. The liquefaction risk at the shoreline significantly increases the risk to shoreline infrastructure. It is possible that a significant seismic event could cause soils to liquefy at the shoreline, the infrastructure to fail and slide into the Bay. This would mobilize debris and contaminants into the water and sediment, have impacts to habitat and species and result in a shoreline that loses elevation and provides flooding pathways suddenly inundating public access and open spaces along the shoreline. **Flood:** Flooding that overtopped the current shoreline infrastructure could result in damage to water and soil quality by mobilizing contaminants and toxics and increasing stormwater runoff, such flooding could drown habitats and impact the species that rely on the transition zone for habitat, toxics and contaminants mobilized by the flooding could also damage habitats and species. Flooding would disrupt and damage public access and open spaces.

Communications

Introduction to Asset Class

The City's communications asset class transmits voice, video and data communications by fiber infrastructure, cellular and radio communications, and inside wired infrastructure. San Francisco Department of Technology manages a wide array of communications systems including radio, TV, internet, City internal data network, public warning sirens, emergency call boxes, communication path for traffic signals and the Mayor's Emergency Telephone Systems (METS). In some instances, these communication channels leverage, private communications operators fiber networks and internet service

Key City owned systems assessed for this assessment, include the municipal fiber optics network, data centers, and an 800Mhz radio system.

a) Fiber optics network: Hundreds of miles of fiber optic cable connects every municipal building in San Francisco. This fiber network provides internet access, email and VoIP communications.

b) Data centers: The primary data centers store, manage, and transmits the information for the City's communications systems. A back up data center out of the area, is used as a disaster recovery site for City information systems.. Between the primary and DR data center there are two separate and redundant network paths.. In addition to the City owned data centers, the City manages and uses a distributed number of cloud service providers for compute and storage infrastructure.

c) 800 MHz radio: The City is transitioning to a new 800MHz radio system for emergency communications. The system relies on 11 antennas placed on buildings or high locations throughout the city, with two antennas located outside of San Francisco in Daly City and on San Bruno jail. Most antennas are located on shared radio tower sites on buildings or high ground. The towers are not owned by the City of San Francisco. They are built to the highest seismic standards, but the performance of the buildings on which they are placed is generally not known. Loss of one or more antennas in the network will degrade communications, but the system is designed so it can remain operational despite loss of several antennas.

The antennas are connected to each other by fiber cables and microwave paths. Radio towers have back up power.

Private communications systems are owned by a wide range of operators, including Verizon, AT&T, T-Mobile, also Comcast and these are used for redundant access to the Internet. Primarily these private fiber networks are used when City fiber is unavailable.

Issue Statement

City owned communications assets are vulnerable to damage in earthquakes, especially where there is ground failure or buildings that support antennas are damaged. The communication system is highly redundant, so loss of a few antennas, data centers or a portion of the fiber cables, may not result in outage of the system. Long term inundation and exposure to heat can also damage the communication system.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table below, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault 7.8 and Hayward Fault 7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Some of the assessed fiber assets are located within buildings, underground, or overhead. Distinctions between these location options were not assessed, as that relates to the infrastructures adaptive capacity rather than the exposure. Data was sourced from the SF Department of Technology (SF DT, 2019).

Exposure Summary

Geologic: All communications assets are exposed to very strong or violent shaking in the 7.8 earthquake on the San Andreas Fault. In the 7.0 scenario earthquake on the Hayward Fault, 30 miles of fiber, one data center and one radio antenna are exposed to very strong or violent shaking. Seventy miles of fiber, one data center and 3 radio antennas are located in areas with high or very high liquefaction susceptibility.

Flood: Fiber is not significantly exposed to flooding. With 66 inches of sea level rise and a 100-year coastal storm event, 33 miles of fiber will be exposed to flooding. In this scenario, one data center and two radio antenna are within the flood zone, however the radio antenna may not get wet depending on if they are on top of buildings. Ten miles of fiber, two data centers and two radio antennas may be exposed to stormwater flooding, depending on their elevation above ground.

Fire: Less than one percent of the fiber network, radio antenna and data centers are exposed to wildland-urban interface fire risk.

TABLE A-38: EXPOSURE

Hazard	Fiber Network: 203 Miles Total		Data Centers: 3 In County Total		Radio Antenna: 12 Total	
	#	%	#	%	#	%
Geologic						
San Andreas 7.8 - Violent	33	16%	0	0%	6	50%
San Andreas 7.8 - Very Strong	167	82%	3	100%	6	50%
Hayward 7.0 - Very Strong	30	15%	1	33%	1	8%
Hayward 7.0 - Strong	138	68%	2	67%	7	58%
Liquefaction Zone	70	34%	1	33%	3	25%
Flooding						
100-Year Coastal Flood Zone	4	2%	0	0%	0	0%
100-year storm + 24 inches SLR	18	9%	1	33%	1	8%
100-year storm + 66 inches SLR	33	16%	1	33%	2	17%
100-year Stormwater Flood	10	5%	2	33%	2	17%
Wildfire						
High	0	0%	0	0%	0	0%
Moderate	1	0%	0	0%	1	8%

Note: For an exposure table with additional hazards, please see Chapter 05.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Fiber cables are contained in below ground conduit, primarily made of flexible PVC. Shaking will likely not damage the conduit, but significant ground movement, such as in liquefaction or landslide could cause the conduit to break. Some fiber is located on above ground lines that would break if the poles fail, most likely in liquefaction areas. Data centers are built to a high seismic standard with seismic bracing for components and are not likely to experience significant earthquake damage, however data centers contain significant sensitive components which are sensitive to shaking and if fire sprinklers are activated the electronic equipment will be damaged. Radio antennas are also built to high seismic standards, but may be located on buildings that are not. Radio antennas have back up power with redundant microwave and fiber connections. **Flood:** Fiber conduit is not sensitive to short-term flooding, but permanent inundation would damage the conduit over time. Antennas are located on high ground or on top of buildings and will not likely be damaged by flooding. Flood inundation will damage data centers. **Extreme Heat:** Telecommunications systems are extremely sensitive to heat. Data centers rely on cooling technology to keep the equipment cool and high temperatures can stress those systems. Extended exposure to high temperatures will result in failure of electronics. Increased temperatures can also decrease the life span of telecommunications infrastructure as well[187]. When fiber cables get hot, they lengthen and soften and can result in weaker connectivity. Buried cables are less affected by high air temperatures. **Fire:** Recent wildfires have damaged buried and above ground fiber optic cables.[188] Buildings that house datacenters or support antennas can be damaged in fires.
Functional	**Networks:**

[187] GSA (2014). "Climate Risks Study for Telecommunications and Data Center Services". Retrieved from: https://sftool.gov/Content/attachments/GSA%20Climate%20Risks%20Study%20for%20Telecommunications%20and%20Data%20Center%20Services%20-%20FINAL%20October%202014.pdf
[188] https://www.geo-tel.com/california-camp-fire-threatens-fiber-optics/

	Communications systems have significant redundancy. Redundant fiber paths means that loss of some fiber cables may not result in loss of system functionality. Similarly, the loss of a few radio antennas will not impact communications functionality. Most networks have back up communication paths to provide redundancy if one is lost. San Francisco has an out of city back up data center to provide this redundancy. It is noted that not all City business and information systems are located and tested for disaster recovery at the Disaster Recovery data center. **External Services:** Communications systems are primarily reliant on power to operate. Some components have battery backup that will provide continued service for up to 8 hours. Fuel will then become critical for continued operations of backup generators. **Populations Served:** All San Francisco residents, business, as well as City Government rely on communications services. The City owned communications systems analyzed in this assessment provide service for the 911 system, MUNI signals and trains, emergency radio services, City email, phone and internet, City payroll, and SCADA systems. **Unique or Critical Function:** Communication systems are critical for emergency responders to communicate with one another through the 800mHz radio and for the citywide 911 system to function.
Informational	**All-hazards:** Because of the critical services provided by City owned communications infrastructure, the location of these assets cannot be shared with the public.
Governance	**All-hazards:** The City not the only provider of communications in San Francisco. Multiple private owners also operate internet, and cell networks throughout the City. The City, as well as the public, relies on these networks for many forms of communication.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Loss of the City owned communication system has significant consequences on public health and safety due to the loss of 911 system, emergency radio system for fire and police, traffic signals

	and operations of the SCADA system to run water and wastewater. Loss of citywide communication in a disaster will hamper emergency response and recovery efforts.
Economy	**All-hazards:** The economic costs of disruption to the City owned communication system in a natural disaster include the cost to repair the system and the cost of business interruption during the outage.
Environment	**All-hazards:** Disruption to the City owned communication system will not have environmental consequences.

Open Space Sector

Parks and Open Space 360

Parks and Open Space

Introduction to Asset Class

Recreation and open space are critical components of any community's quality of life; for San Franciscans they are defining elements of the City itself. The City's open space system provides places for recreation, activity and engagement, for peace and enjoyment, and for freedom and relief from the built world. Many of these open spaces also include natural areas, native species and habitat spaces, as well as serving the social and environmental health of the City, providing additional ecosystem services like reducing the urban heat island effect and filtering stormwater. Open space includes recreation centers, playgrounds, playing fields, un-programmed open areas, trails and natural areas, cultural arts and recreation centers, and sports facilities.

San Francisco has around 3,400 acres of recreation and open space owned and managed by the Recreation and Park Department (SFRPD[189]). San Francisco has over 800 acres of open space owned and managed by the State of California, and another 2100 acres of federally owned open space in the Golden Gate National Recreation Area including Ocean Beach, the Presidio, Lands End, Sutro Heights, and Fort Mason.[1] The Port of San Francisco manages additional 88 acres of public open space along the City's Bay shoreline, as well as heavily used pedestrian bicycle networks along the waterfront, such as the Embarcadero Promenade. The federal, state and Port open space includes more natural areas and fewer recreation facilities compared to the City Parks. These publicly owned open spaces make up almost 20% of the City's total land area.

Issue Statement

Parks and open space contribute to San Franciscan's quality of life by providing access to nature, recreation, and respite. Parks and open space can also help mitigate urban heat island effects and provide refuge for residents during heat events. While open space has low to moderate vulnerability to most natural hazards, the buildings that support open space use and recreation can be damaged by seismic, flooding, or other hazards. Shoreline habitat will be lost to erosion and sea level rise if sufficient space is not provided for it to move inland. Recreation Centers that serve as shelters are doubly

[189]San Francisco Planning Department. SF Open Space Dataset, 12/13/18

important after disaster events and they may not be resilient to seismic or flood events depending on their age and construction type.

Exposure

Hazard Data Assumptions

This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table below, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

Asset Data Assumptions

Asset data was collected from contacts within the SF Planning Department, which keeps an updated database of park assets in order to assist their planning processes.

Exposure Summary

Geologic: All open space assets experience Violent or Very Strong shaking conditions in a 7.8M earthquake on the San Andreas Fault. Given the Port's location on the eastern shoreline, under the Hayward 7.0M scenario, the Port has the highest share of open space assets exposed to Violent or Very Strong shaking even though they represent less in total acreage compared to the assets managed by SFRPD, State, or Federal entities. 904 acres of open space are located in the liquefaction zone, comprising 15% of open space citywide.

Flood: 45 acres of SFRPD parks are currently exposed coastal flooding in a 100-year storm. However, with 66 inches of sea level rise, up to 128 acres could be exposed. 59 acres of SFRPD parks are exposed to the 100-year stormwater flood. While the Port open space will see similar exposure in acres, that exposure represents a greater share of the Port's open space. With 66 inches of SLR, up to 77 acres or 88% of Port parks could be exposed to coastal flooding. Federal open spaces located on the north and west side of the city are also exposed to coastal flooding with 246 acres of Federal open space exposed to coastal flooding with 66 inches of sea level rise, which comprises 10% of total state/federal acreage in the city.

Fire: Exposure of open space to wildland-urban-interface fire risk within the city is limited to moderate risk. Exposure to wildland-urban interface fire is pronounced for a significant share of State/Federal open space in the city (1,549 acres, 65%), particularly in Presidio Park and Mount Sutro open space. Exposure of SFRPD open space is 565 acres (17%) and concentrates in the Glen Canyon and Mount Davidson Parks.

TABLE A-39: EXPOSURE

Hazard	SFRPD Parks 3,398 Acres Total		Port Open Space 88 Acres Total		State/Federal Open Space 2,388 Acres Total	
	#	%	#	%	#	%
Geologic						
San Andreas 7.8 - Violent	2,004	59%	9	11%	1,333	56%
San Andreas 7.8 - Very Strong	1,394	41%	79	90%	1,055	44%
Hayward 7.0 - Very Strong	137	4%	59	67%	116	5%
Hayward 7.0 - Strong	2,123	36%	29	33%	2,023	85%
Liquefaction Zone	347	10%	83	93%	474	14%
Flood						
100-Year Coastal Flood Zone	45	1%	43	49%	310	13%
100-Year Storm + 24 Inches SLR	87	3%	45	51%	123	5%
100-Year Storm + 66 Inches SLR	128	4%	77	88%	246	10%
100-Year Stormwater Flood	59	2%	5	5%	11	0.4%
Wildfire						
High	0	0%	0	0%	0	0%
Moderate	565	17%	0	0%	1,549	65%

Note: For an exposure table with additional hazards, please see Chapter 05.

FIGURE A-66: OPEN SPACE AND LIQUEFACTION HAZARD

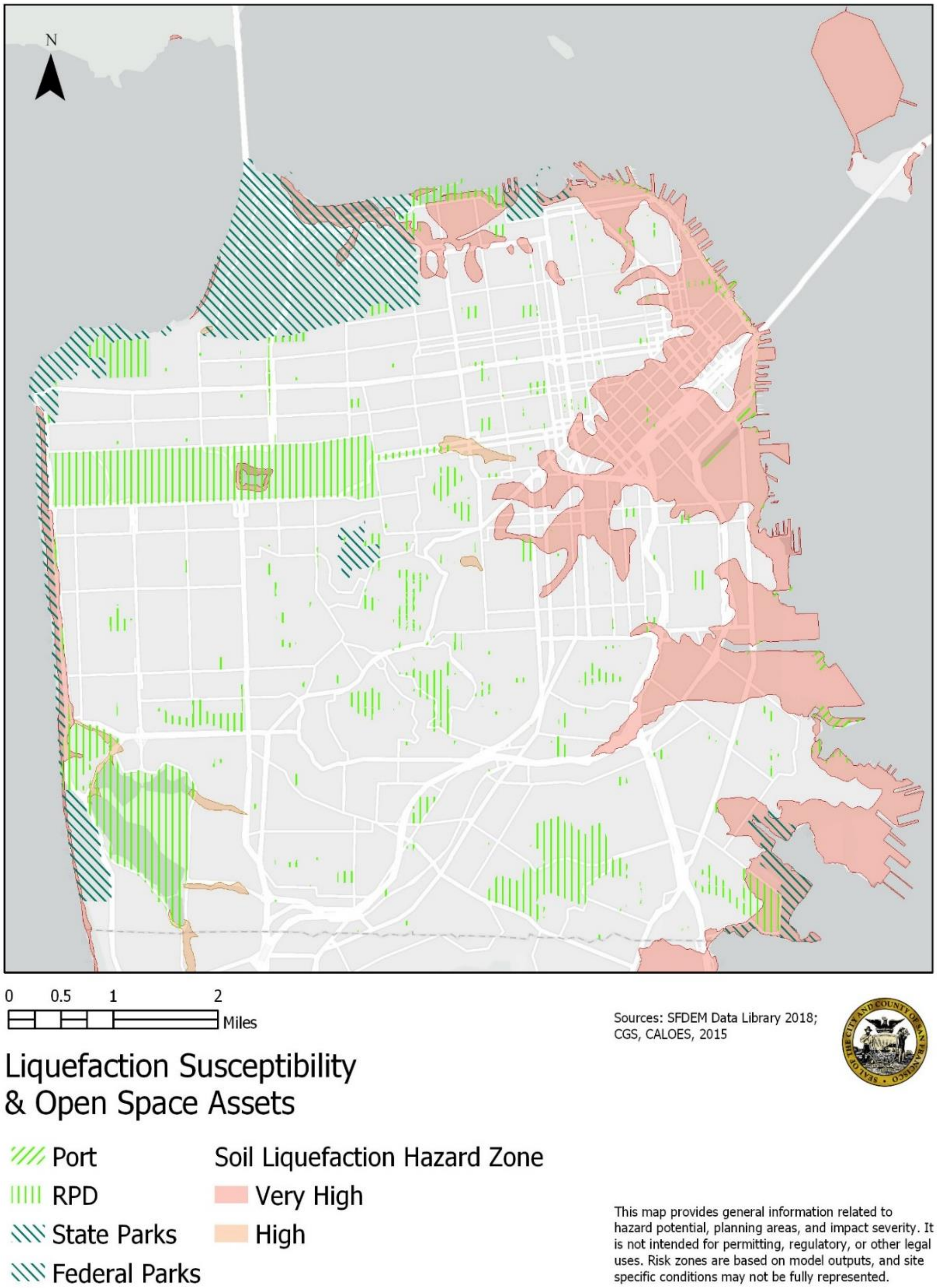


FIGURE A-67: OPEN SPACE AND FLOOD HAZARDS

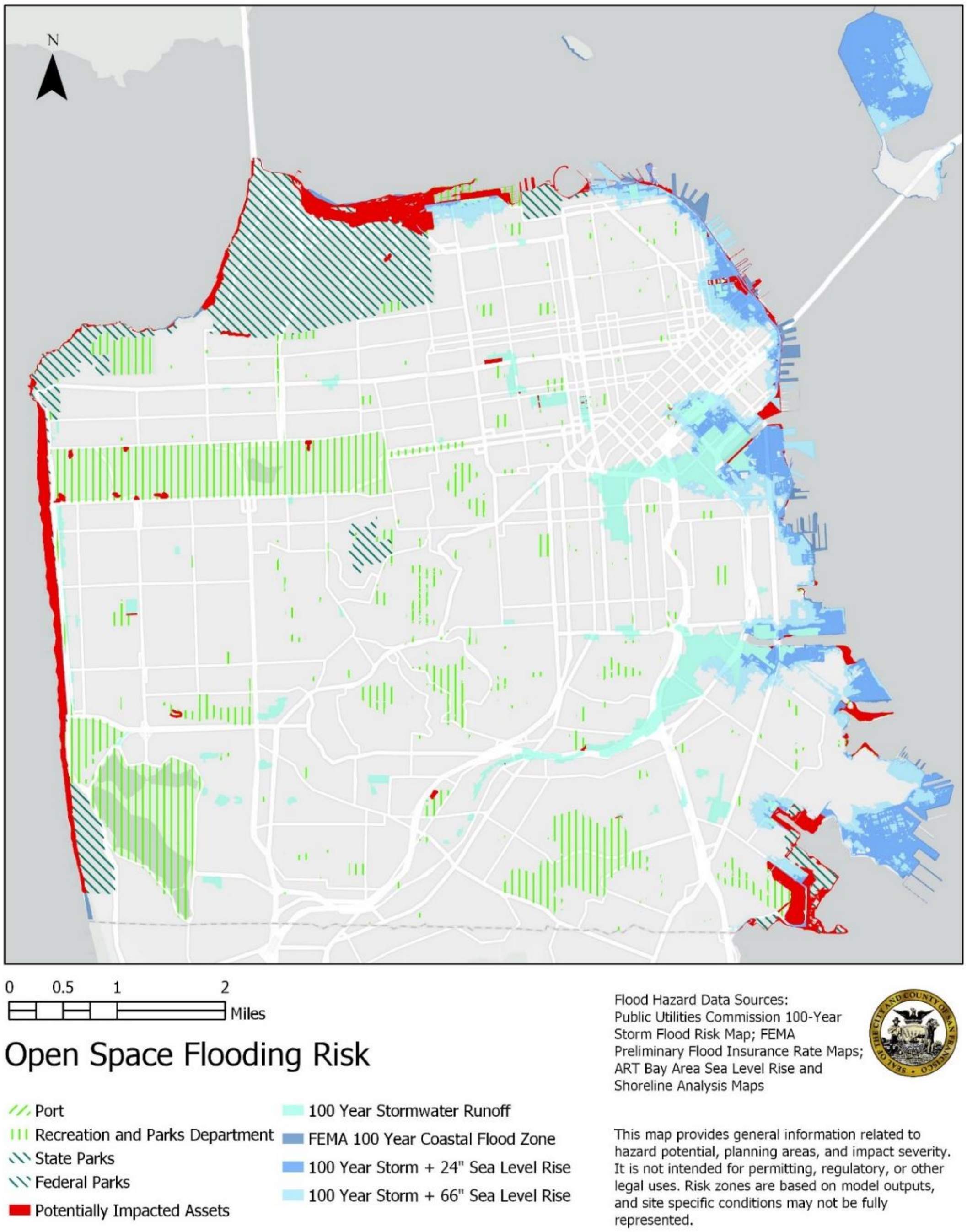
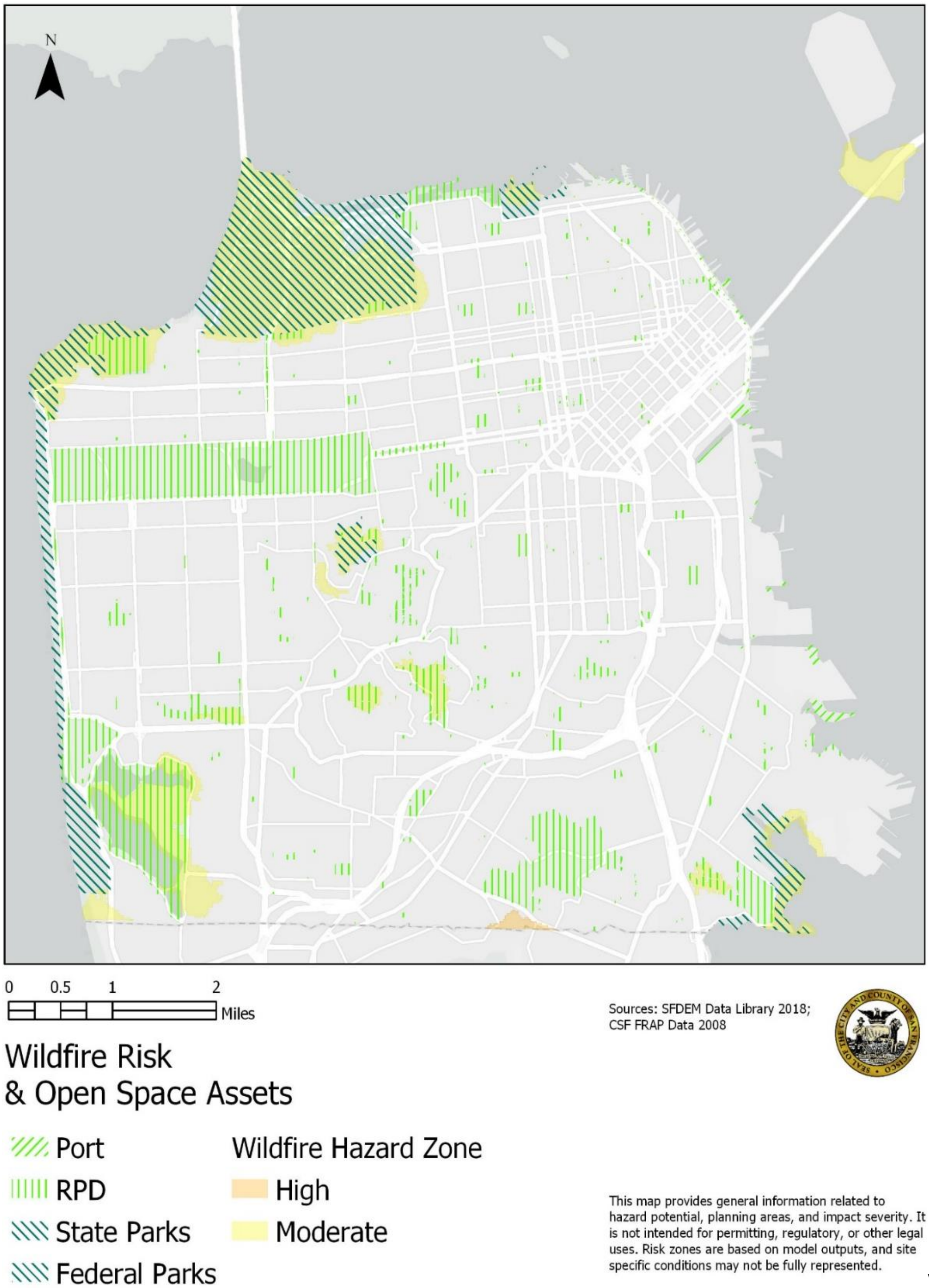


FIGURE A-68: OPEN SPACE AND WILDFIRE HAZARD



Sources: SFDEM Data Library 2018;
CSF FRAP Data 2008

This map provides general information related to hazard potential, planning areas, and impact severity. It is not intended for permitting, regulatory, or other legal uses. Risk zones are based on model outputs, and site specific conditions may not be fully represented.

VULNERABILITIES

Category	Vulnerability
Physical	**Geologic:** Park buildings may be damaged by seismic hazards depending on their construction type. Park buildings are generally low rise and have various construction methods. **Flood:** Park buildings like offices, maintenance facilities, and restrooms may be sensitive to flooding. Planted areas and sports fields are sensitive to flooding and extremely sensitive to saltwater flooding. Damage due to flooding will increase operations and maintenance costs. **Extreme Heat:** Park buildings without sufficient AC may be impacted during high heat days. This is even more important if they provide community shelter during heat days like rec centers and community centers. Although there can be concerns regarding air quality during high heat days, dependent on geographic and health disparity considerations, parks and open space can provide refuge from extreme heat to residents and visitors. **Fire:** Recreation centers, especially older facilities that have not been remodeled, may not have sufficient HVAC for fire events in the region. This may be even more critical if these facilities provide shelter during events. Wildland open space, particularly Glen Canyon, Presidio, and other grassland open space, are vulnerable to direct fire
Functional	**Networks:** SF has many parks and open space facilities although some neighborhoods have more access than others. For inland parks, if one park is closed due to a hazard, other parks may be used as an alternative. SFRPD has identified Equity Zones where parks are less available and residents may be unable to access alternative parks. Closure of a park may also put additional use strain on nearby parks. Additionally, redundancy does not apply to our waterfront parks,

	which often have no viable alternative nearby when disrupted by hazards. **External Services:** Park buildings rely on power, water, wastewater, and often staff access. Open space itself is not reliant on any of these systems in the short term. In the long term, parks may not be able to provide high quality recreation without irrigation and transit access. **Populations Served:** Parks and open space serve all community members but access may be limited in underserved areas, especially for specific types of open space and recreation like water access, rec centers, athletic fields or others. SFRPD has identified equity zones where improving access and open space quality is a priority. Open space is especially important for people who live in multifamily housing without private outdoor space and those without air conditioning. During heat events, open space and air-conditioned recreation centers provide respite for residents. **Unique or Critical Function:** 1. Recreation and habitat are core goals of SFRPD open space. Although CCSF has many parks, they are heavily used and could not be easily replaced. This is particularly true for shoreline habitat, waterfront parks and open spaces, water access, and athletic fields.
Informational	Information on the location and condition of open space is available through SFRPD and SF Planning efforts. Little information is available on the number of visitors or who uses various open space facilities citywide. Crissy Field and Ocean Beach have assessed their sea level rise vulnerability and identified some resilience strategies through the Rise Up[190] and Ocean Beach Master Plan projects[191].
Governance	Regional and state funds (SB 68) are available for park and habitat improvement related to climate change impacts.

[190] "Crissy Field Rise Up" Golden Gate National Parks Conservancy, October 2016, https://issuu.com/parks-conservancy/docs/crissy_field_sea_level_rise_analysi

[191] "Ocean Beach Master Plan" SPUR, June 26th, 2012, https://www.spur.org/featured-project/ocean-beach-master-plan

	Open space, particularly shoreline habitat, is subject to extensive regional, state and federal regulations that may make adaptation difficult to implement. This includes coastal management regulations from the Coastal Commission and the Bay Conservation and Development Commission, the Regional Water Quality Control Board, the Endangered Species Act, and others.

CONSEQUENCES

Category	Consequence
Society/Equity	**All-hazards:** Open space is used by all residents and many visitors to SF. This would be particularly important in SFPRD's identified equity zones where park access is limited. Parks and open space are especially critical for residents without private outdoor space and those without air-conditioning. The distribution of, and access to, parks and open spaces is not equal in the City and damage and/or disruption to any of these facilities could have significant consequences for communities with fewer park spaces and/or lack the ability to access other parks.
Economy	**All-hazards:** Depending on the scope of the hazard, impacts could range from the loss of SFRPD revenue to major citywide capital costs for habitat restoration and building reconstruction. Damage and disruption to parks and open spaces will increase the operations and maintenance costs for these facilities and functions. Some parks and open space in San Francisco are significant tourist attractions. Even temporary closures at these sites could lead to reduced tourism and spending, which would affect San Francisco's economy.
Environment	**All-hazards:** None. **Geologic:** None. **Flood:** Coastal flooding due to sea level rise could eventually drown shoreline habitats resulting in the loss of critical ecosystem services

	and biodiversity. Flooding can negatively impact planted areas and trees and saltwater flooding is especially damaging to both planted areas and electrical and mechanical equipment in parks like irrigation systems and lights. **Extreme Heat:** Extreme heat can damage vegetation over extended periods, impacting the function of ecosystems found within them and thereby reducing the efficacy of the ecosystem services that they provide. **Fire:** Fires can damage natural areas and require long term recovery.